



HYDROGEN
Emergency Response
Training Resources

First Responder Training: Supporting Commercialization of Hydrogen and Fuel Cell Technologies

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PNNL's Hydrogen Safety Resources



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 Tools

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



HYDROGEN Emergency Response Training Resources

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

Identifying the Need

Why focus on first responder training?

- A suitably trained emergency response force is essential to a viable infrastructure
 - emergency response personnel need to understand how to respond to a hydrogen incident
 - 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.
- Resources that provide accurate information and current knowledge are essential to effective hydrogen and fuel cell related first responder training programs



Credit: KTLA



H2USA identified first responder training as a key barrier to ensuring a safe transition to fuel cell vehicles and hydrogen infrastructure and paving the way for broader public acceptance.

First Responder Hydrogen Safety Training

▶ National Goal

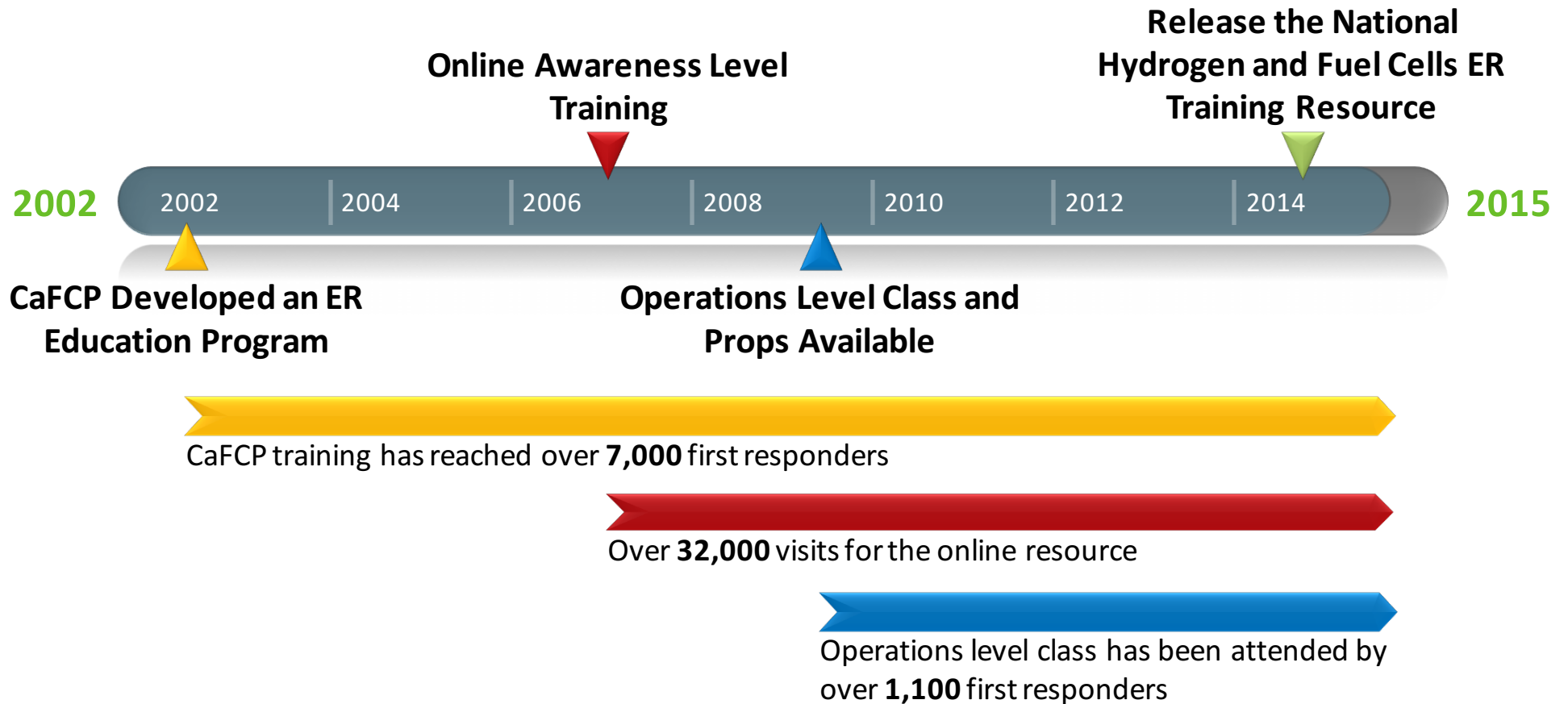
- Support the successful implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders

▶ Integrated Activities

- Online, awareness-level training
(<http://hydrogen.pnl.gov/FirstResponders/>)
- Classroom and hands-on operations-level training
- National training resource (enabling trainers)
(<http://h2tools.org/fr/nt>)



Training Resources - Timeline and Accomplishments



Online Awareness-level Training

Address <http://www.ehammertraining.us/energy/hydrogen/controller.cfm>

Introduction to Hydrogen Safety for First Responders

U.S. Department of Energy
Hydrogen Program
www.hydrogen.energy.gov

COURSE MATERIALS LIBRARY EXIT ▶

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

INCREASE YOUR
H₂ IQ
www.hydrogen.energy.gov

The Course Materials cover the following topics:

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

You can view the topic modules in sequence or select them in random order using the top navigation bar.

A short quiz follows at the end of the course. User responses will be collected but will not be attributed to you as an individual.

Begin the Course ▶

- 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.

Typical users:

- fire prevention and protection community
- fire fighters
- fire department education coordinators
- fire marshals
- fire plan examiners/inspectors
- code officials
- law enforcement officials
- representatives from industry, universities, and the military and non-profit organizations.

Enhancing the Impact of Online Training

- PNNL will be working with the National Fire Academy (U.S. Fire Administration) 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.



The screenshot shows a web page titled "Introduction to Hydrogen Safety for First Responders". At the top right, it says "U.S. Department of Energy Hydrogen Program" and "www.hydrogen.energy.gov/firstresponders". Below the title is a navigation bar with "COURSE MATERIALS", "LIBRARY", and "EXIT" buttons. Underneath is a list of course topics: "Hydrogen Basics", "Transport & Storage", "Hydrogen Vehicles", "Hydrogen Dispensing", "Stationary Facilities", "Codes & Standards", "Emergency Response", and "Summary & Quiz". The main content area is titled "Hydrogen Safety Course Contents" and features a graphic on the left that says "INCREASE YOUR H2 IQ www.hydrogen.energy.gov". To the right, it lists the topics covered: "Hydrogen Basics", "Hydrogen Vehicles", "Stationary Facilities", "Emergency Response", "Transport & Storage", "Hydrogen Dispensing", and "Codes & Standards". Below this list, there are instructions: "You can view the topic modules in sequence or select them in random order using the top navigation bar.", "A short quiz follows at the end of the course.", and "You can mute the narration by clicking on the mute button in the navigation bar." At the bottom right, there is a "Begin the Course" button with a play icon. At the bottom left, it says "Slide 1 of 1" and "Submit Comment".

Classroom and Hands-on Training

► Classroom Content

- 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

CaFCP Activities and Collaboration

The California Fuel Cell Partnership (CaFCP) and its members are playing a central role in the realization of fuel cell electric vehicles and the supporting infrastructure required in California. “A California Road Map” identifies the challenges ahead and provides the analysis to determine the appropriate number of hydrogen stations required for pre-commercial activities as well as launching early market communities.



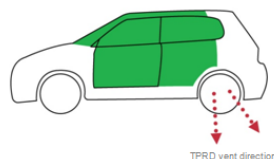
- Initiated outreach and first responder training in 2002
- Training efforts were intended to address problems with early hybrid vehicles where first responders were met with high voltage in vehicles they had never had to deal with previously
- The first version of the emergency response guide, developed in collaboration with member organizations, the California State Fire Marshal and the fire departments of West Sacramento, CA and Richmond, CA, has served as the principal basis for these outreach efforts
- Over 114 outreach events for nearly 8,000 first responders and permitting officials since 2004
- Future work → Train the trainer

National Training Template

National First Responder Training Resource

Hydrogen Vehicle Safety Systems

- When a leak is detected by hydrogen sensors, solenoid valves close, shutting off the flow of hydrogen, and the vehicle safely shuts down
- When collision sensors activate:
 - Tank solenoid valves close so that hydrogen remains locked in the tank.
 - In FCVs, high-voltage relays open so that the high-voltage battery/capacitors are isolated from the system
- Tank solenoid valves also close when the vehicle is turned off or the power is disrupted
- Tanks have thermally activated pressure relief devices (TPRDs)



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A TEMPLATE for TRAINING

NATIONAL HYDROGEN AND FUEL CELLS EMERGENCY RESPONSE TRAINING

Slide #1: *What and Why*
Slide #2: *National Hydrogen and Fuel Cells Emergency Response Training*

Example Uses of Training Slides

| L1 Overview | L2 Short Course | L3 Full Course |
|-------------|-----------------|----------------|
| | | |

1. Introduction and Background Slide #3

| | | | |
|--|---|---|---|
| Slide #4: <i>Fuel Cells Overview and Benefits</i> | ✓ | ✓ | ✓ |
| Slide #5/6/7: <i>Fuel Cells – Where are We Today?</i> | | | ✓ |
| Slide #8: <i>Diverse Fuel Cell Transportation Applications</i> | | | ✓ |

2. Hydrogen and Fuel Cell Basics Slide #9

2.1 Hydrogen – Where does it come from and how do we use it now?

| | | | |
|---|---|---|---|
| Slide #10: <i>Why Hydrogen?</i> | ✓ | ✓ | ✓ |
| Slide #11: <i>Where Do We Get Hydrogen?</i> | ✓ | ✓ | ✓ |
| Slide #12: <i>Hydrogen Uses</i> | ✓ | ✓ | ✓ |
| Slide #13: <i>Hydrogen Distribution</i> | | | ✓ |
| Slide #14: <i>Transporting Hydrogen Today</i> | | | ✓ |

2.2 Properties of hydrogen and its safe use

| | | | |
|---|---|---|---|
| Slide #15: <i>Hydrogen Properties and Behaviors</i> | ✓ | | ✓ |
| Slide #16: <i>Hydrogen Properties: A Comparison</i> | ✓ | ✓ | ✓ |
| Slide #17: <i>Relative Vapor Density</i> | | | ✓ |
| Slide #18: <i>Auto-Ignition Temperature</i> | | | ✓ |
| Slide #19: <i>Comparison of Flammability</i> | ✓ | ✓ | ✓ |
| Slide #20: <i>Flammability Range</i> | | | ✓ |
| Slide #21: <i>Explosive Range</i> | | | ✓ |
| Slide #22: <i>Comparison of Fuel Odorants and Toxicity</i> | | | ✓ |
| Slide #23/24/25: <i>Designing Safe Systems – Gaseous Hydrogen</i> | | | ✓ |
| Slide #26: <i>Designing Safe Systems – Liquid Hydrogen</i> | | | ✓ |

Revision Date: September 30, 2014

2

Can be downloaded at <http://h2tools.org/fr/nt>

What and Why – National Hydrogen and Fuel Cell Emergency Response Training Resource

- ▶ Hydrogen and fuel cell-related first responder training utilizing a national emergency response education program as a **consistent source of accurate information and current knowledge**.
- ▶ A resource **adaptable to the specific needs** of first responders and presentation styles of training organizations and meant to complement extensive training programs already in place.
- ▶ The nationally-focused training template intended to serve as a resource and guide for the delivery of a variety of training regimens to various audiences.

National Training Resource - History of Development

- ▶ Used existing materials from DOE and CaFCP programs
 - Approved, vetted information
 - Made updates as necessary
- ▶ Three 'levels' of information in 130 slides
 - Accompanying template document with guidance on use
 - Slides suggested for three levels of information:
 - Introductory course
 - Short course
 - Extended course
- ▶ Not prescriptive; trainer can select any/all of the slides that are appropriate for the audience

Hierarchy of the Training Template Approach

An outline was developed to topically to cover the following:

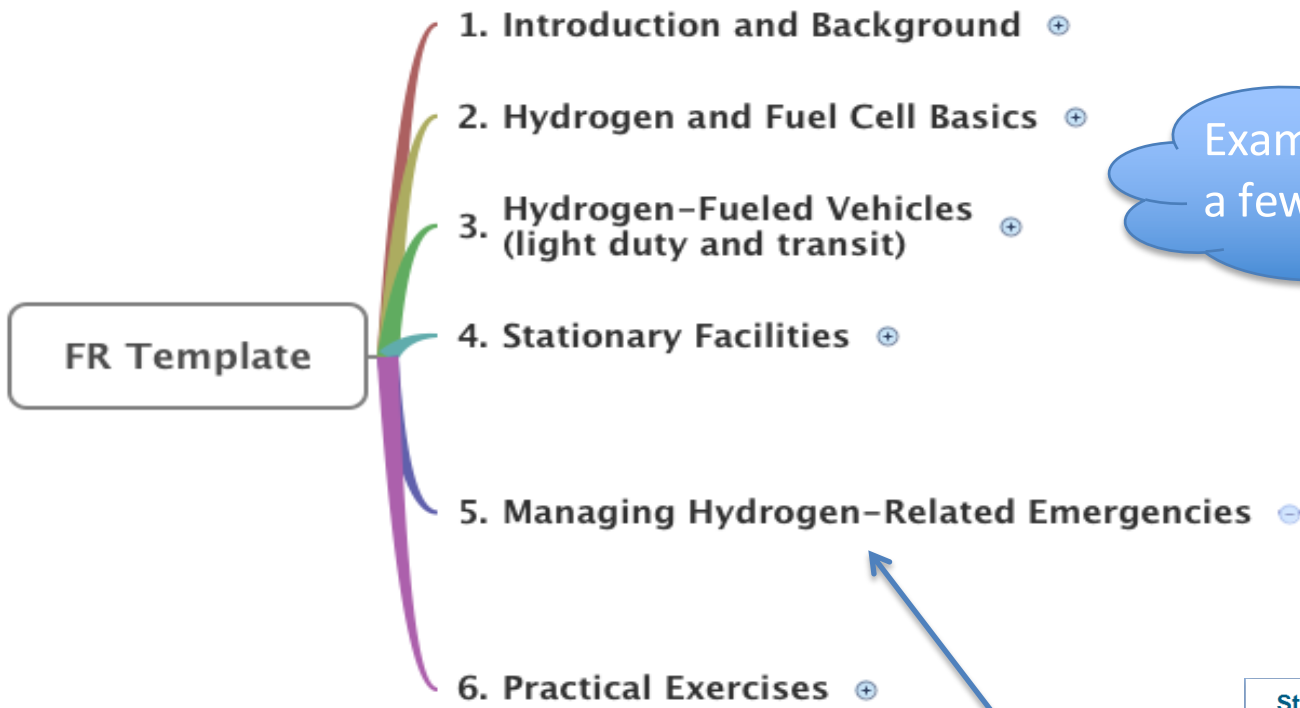


National Hydrogen Emergency Response Education Program

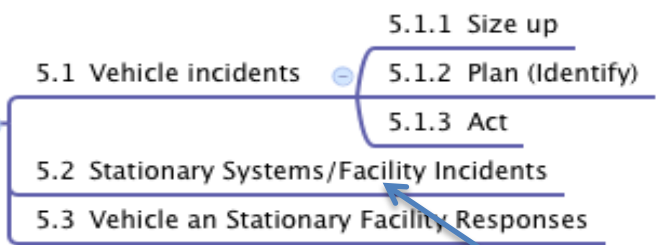
Collaboration with the



Managing Hydrogen-related Emergencies



Examples of slides covering a few topics/subtopics



National Fire Academy (NFA) Command Sequence

1. Size Up (Think) **SIZE UP**
2. Identify Strategy/Tactics **PLAN**
3. Assign Tasks **ACT**
4. Review Results of Actions/Critique **EVALUATE**




Photo: Volpertest-HAMMER Training and Education Center

Follow SOPs for vehicle response, paying particular attention to unique systems and characteristics for hydrogen-powered fuel cell vehicles

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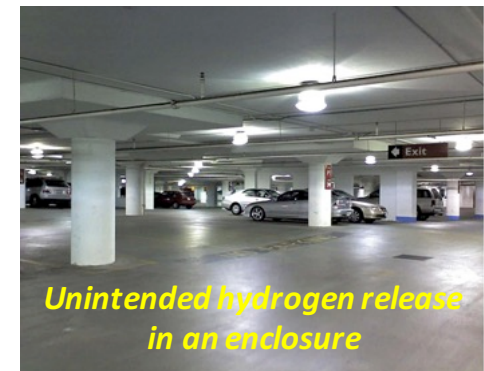
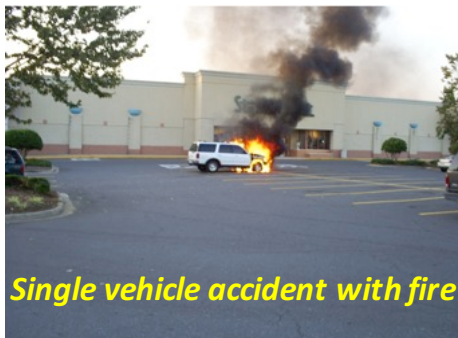
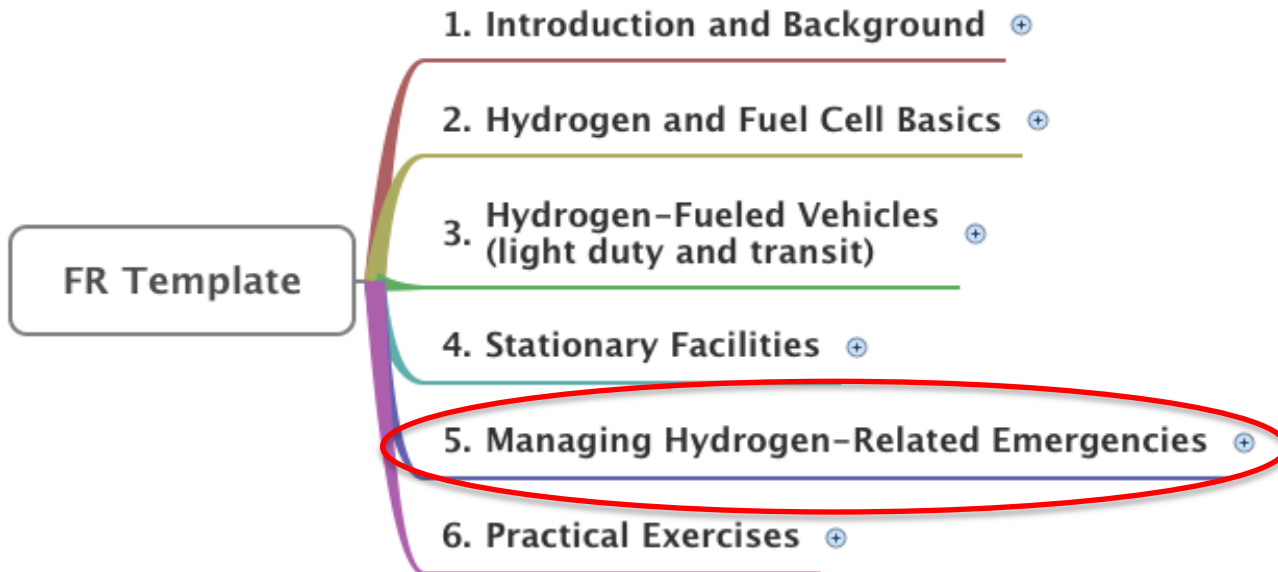
Stationary facilities **SIZE UP**

Stationary hydrogen facilities will have hazards similar to facilities with other compressed and/or cryogenic gas processing or storage systems

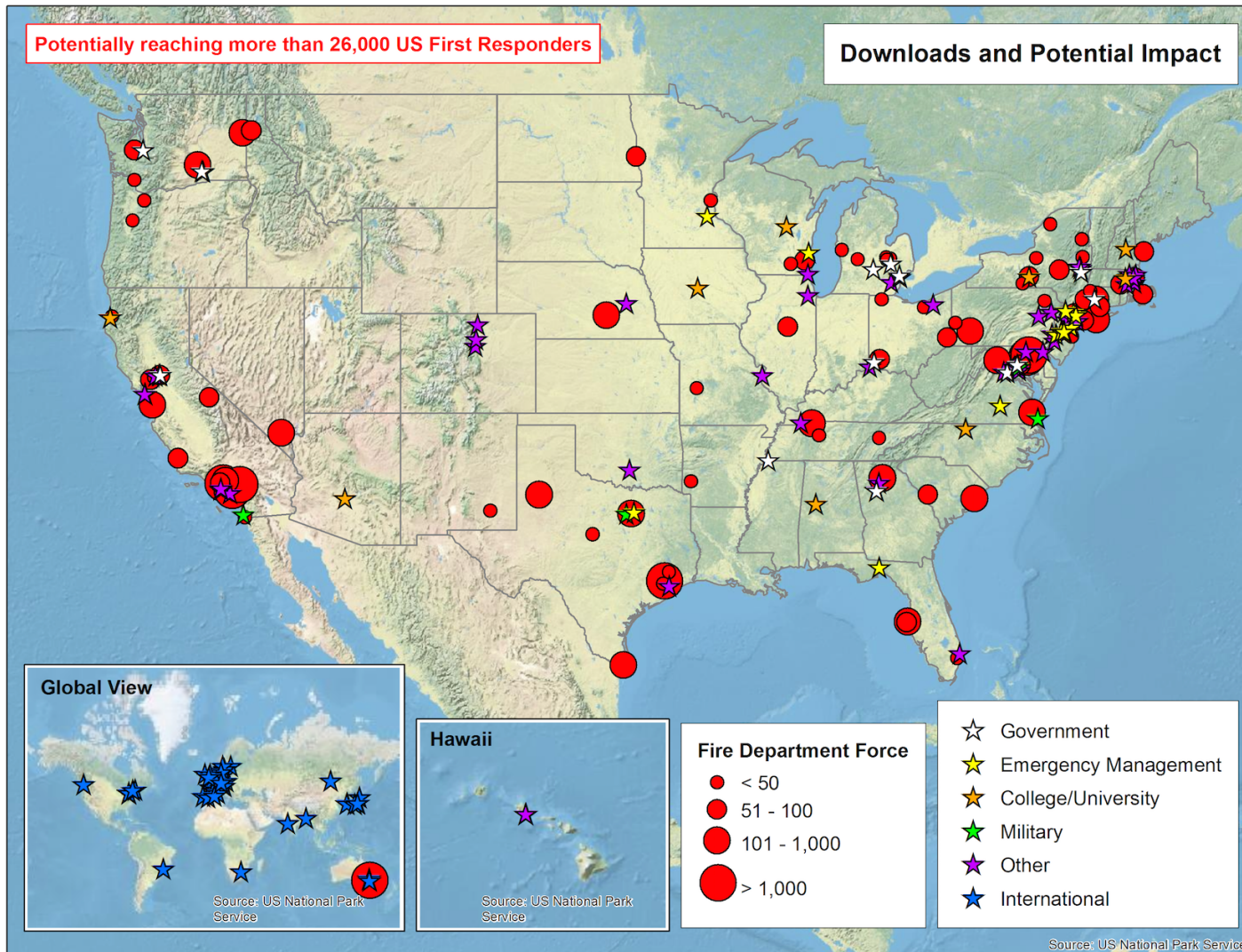
- Gas or liquid storage?
 - High-pressure cylinder storage
 - Cryogenic liquid storage
- Is there a leak or flame present?
 - Gaseous hydrogen: use CGI/hydrogen detector and thermal-imaging cameras
 - Liquid hydrogen: look for ice crystals/frozen water vapor
- Is the leak confined by a structure? Ventilation adequate?
- Onsite reforming? Is a methane source present?
- Presence of other fuels (e.g., CNG, propane, gasoline)
- Identify potential ignition sources

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Accident Scenarios Provided for Group Discussion



National Training Resource Metrics



Since October 2014

- >300 downloads
- in 6 Continents
- and 35 of 50 states
- 250 participants in March 2015 announcement webinar
- translated into Japanese in support of Japanese fuel cell initiatives

New Resources and Approaches

Planning for the Future

- New approaches can help meet the specific needs of first responders and presentation styles of training organizations and can complement existing training programs
- 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.

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.

What We Learned from the Planning Team

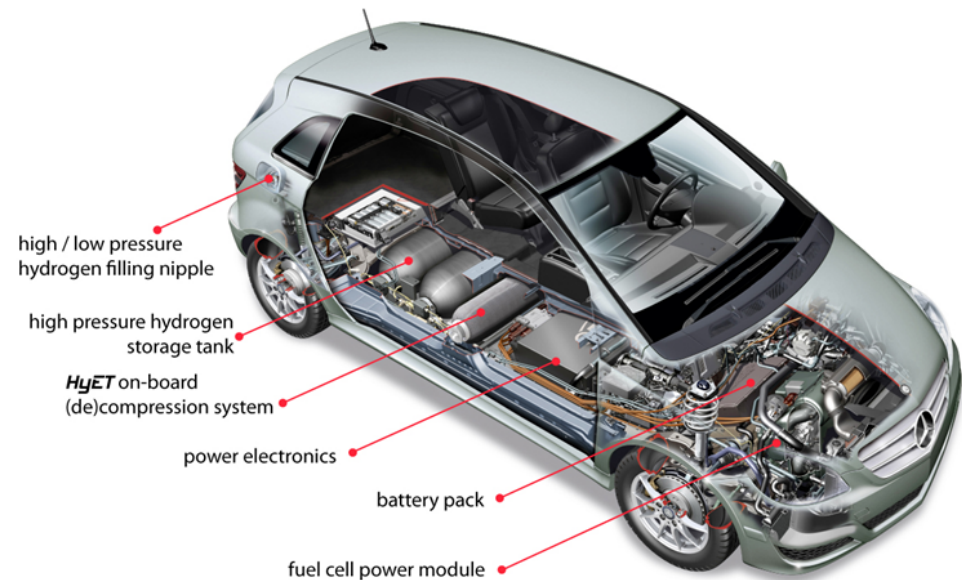
- ▶ Results from the planning activities suggested that:
 - Training tools focused in one area alone (online, classroom, etc.) will not be broadly beneficial. Different training organizations may use different tools to accomplish their purposes. Focusing on one resource is not a recommended approach.
 - Utilizing different media (images, video, virtual reality, etc.) and different presentation formats (classroom, online, etc.) offers the greatest opportunity to address the diverse needs of first responder training organizations and reach a broader audience.
 - Consideration should be given to developing and/or integrating training resources with other alternative fuels first responder training programs.



Enhancing Existing Tools and New Props

The planning activities identified opportunities for improving the instructional quality and potential reach of first responder hydrogen safety training resources in a cost-effective manner. Implementation of the recommendations will make it easier for trainers to present the material and students to learn. Specific areas for improving the impact include:

- ▶ updated videos
- ▶ new and enhanced images
- ▶ new smaller table-top props
- ▶ virtual reality tools



Using Technology to Enhance FR Safety

Concept: A Wi-Fi broadcast triggered automatically on accident detection that transmits critical vehicle status (airbag deployed, PRD opened, electrical system deenergized, etc.) and an emergency response guide.

- Approximately 300' of access point range
- Using standard wireless protocols and data structure to support the development of mobile apps
- Vehicle description and stock photo for quick and accurate recognition
- Contact number for live help in answering questions when responding to an incident



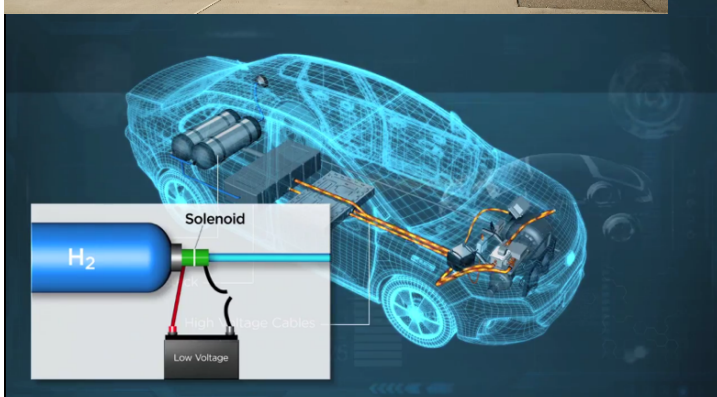
Additional Resources



**ALTERNATIVE
FUEL VEHICLES**
SAFETY TRAINING PROGRAM

NFPA Classroom & Online AFV Safety Courses

Please visit: EVSafetyTraining.org



Classroom

- **Comprehensive instructor led 8 hour classroom course includes responder safety instruction, a pre/post test, group exercises, PowerPoint slides, videos, and 3-D animations.**
- **Entire section has been devoted to hydrogen fuel cell vehicles and their refueling station responder safety training**

Online (Self-Paced)

- **Interactive, high quality graphics, 3-D animations, videos & simulations.**
- **Includes Learning Management System that will track, record and report on student completions.**

Hydrogen Tools

A Transformative Step Towards Hydrogen Adoption

CENTRALIZED LOCATION

organizes current H₂ 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 H₂ user groups

CUSTOMIZABLE INTERFACE

allows content to display based on the H₂ user's role or interests

RESPONSIVE DESIGN

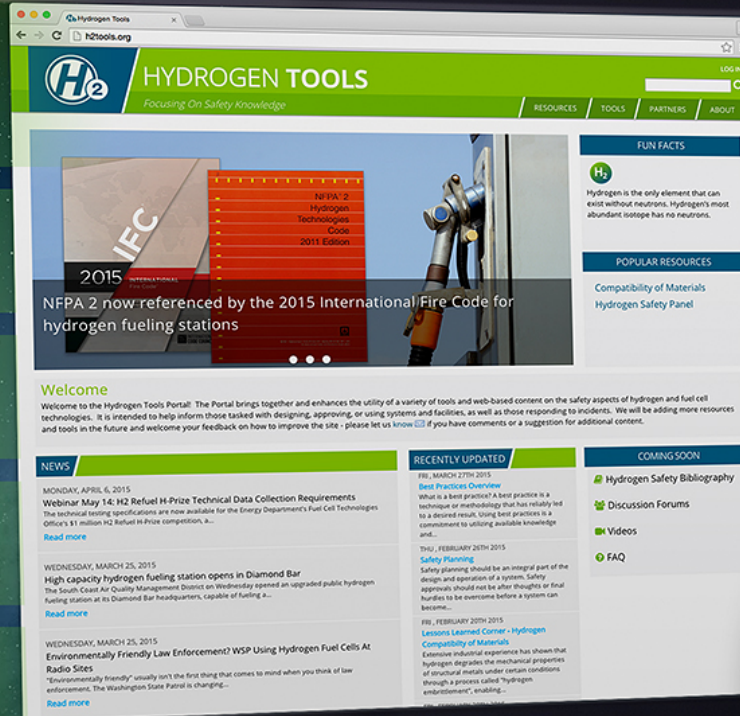
enables H₂ safety work across both desktop and mobile devices

TRUSTED COMMUNITIES

fostered through social networking around H₂ subject matter expertise

EXPANDABLE FORMAT

built with frequently requested future feature sets in mind



Now Available

+ Mobile Friendly



<http://h2tools.org>

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

Collaborative Opportunities Taking Hold

- ▶ The HyResponse project aims “to facilitate safer deployment of FCH systems and infrastructure.”
 - Project team visits PNNL (Richland, WA) to discuss our respective projects (April 2014)
 - PNNL and DOE contribute to the First International Workshop on Hydrogen Safety Training for First Responders, ENSOSP, Aix-en-Provence (September 2014)
 - Planning underway for participation in HyResponse training sessions.

“The authors believe that mutual benefits can be achieved by such collaborations that build upon the goals, objectives and successes achieved by national programs on first responder training.”

Conclusion

- ▶ **Training of emergency response personnel should be a high priority** to ensure that these personnel understand how to properly respond to a hydrogen incident. As hydrogen and fuel cell-related technologies and systems are being developed, deployed and commercialized, the role played by first responders becomes increasingly important to the success of these worldwide efforts.
- ▶ **Collaborative efforts, both nationally and internationally, are key to first responder training products and experiences.** Such efforts have been an important aspect of the work that has been discussed in this paper and opportunities for valuable collaboration on a global basis are starting to take hold.



Photo: Volpentest HAMMER Federal Training Center

Thank You for Your Attention!

The authors wish to thank the U.S. Department of Energy's Fuel Cell Technologies Office (Sunita Satyapal, Director and Charles James, Safety, Codes and Standards Lead), and the California Fuel Cell Partnership for their support of this work.

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