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

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**Hydrogen Safety Panel and Resources Project**

Hydrogen Program Annual Merit Review and Peer Evaluation Meeting

Washington, DC

June 15, 2018

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

## HYDROGEN SAFETY PANEL AND RESOURCES

### Project Timeline

- ▶ Project Start Date: March 2003
- ▶ Project End Date: September 2018<sup>1</sup>

### Budget

- ▶ FY17 DOE Funding: \$1,218K
- ▶ Planned FY18 DOE Funding: \$40K
  - ▶ Hydrogen Safety Panel (HSP): \$0K
  - ▶ Safety Knowledge Tools: \$40K
  - ▶ First Responder (FR) Training: \$0K

### Barriers Addressed<sup>2</sup>

- A. Safety data and information — limited access and availability
- C. Safety is not always treated as a continuous process
- D. Lack of hydrogen knowledge by authorities having jurisdiction (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)
- ▶ Sandia National Laboratories (SNL)
- ▶ California Energy Commission (CEC)

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<sup>1</sup> Project continuation and direction determined annually by DOE.

<sup>2</sup> Technical Plan – Hydrogen Safety, Codes and Standards, Section 3.7, Multi-Year Research, Development and Demonstration Plan, 2015, pp. 21-22 (updated June 2015) - [https://www.energy.gov/sites/prod/files/2015/06/f23/fcto\\_myrd\\_d\\_safety\\_codes.pdf](https://www.energy.gov/sites/prod/files/2015/06/f23/fcto_myrd_d_safety_codes.pdf).



## 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 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

**Primary Objective:** Enable the safe and timely transition to hydrogen and fuel cell technologies through unique and highly impactful safety resources

Barrier from SCS MYRDD	PNNL Objectives (impacts are provided on later slides)
<p>C. Safety is not always treated as a continuous process</p> <p>G. Insufficient technical data to revise standards</p>	<p>Provide expertise and recommendations to DOE and assist with identifying safety-related technical data gaps, best practices, and lessons learned</p> <p>Help integrate safety planning into funded projects to ensure that all projects address and incorporate hydrogen and related safety practices</p>
<p>A. Safety data and information — limited access and availability</p> <p>D. Lack of hydrogen knowledge by authorities having jurisdiction (AHJs)</p>	<p>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</p> <p>Capture vast and growing knowledge base of hydrogen experience and make it publicly available to the hydrogen community</p> <p>Participate in key outreach opportunities to share HSP learnings and safety information with AHJs and code officials</p>
<p>E. Lack of hydrogen training materials and facilities for emergency responders</p>	<p>Implement a national hydrogen emergency response training resource program with downloadable materials that are adaptable to the specific needs of FRs and training organizations</p> <p>Identify enhancements to FR training content, techniques, and delivery</p>

# Approach

*Priority attention to safety and enhanced visibility*

## Hydrogen Safety Panel

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

## Safety Knowledge Tools and Dissemination

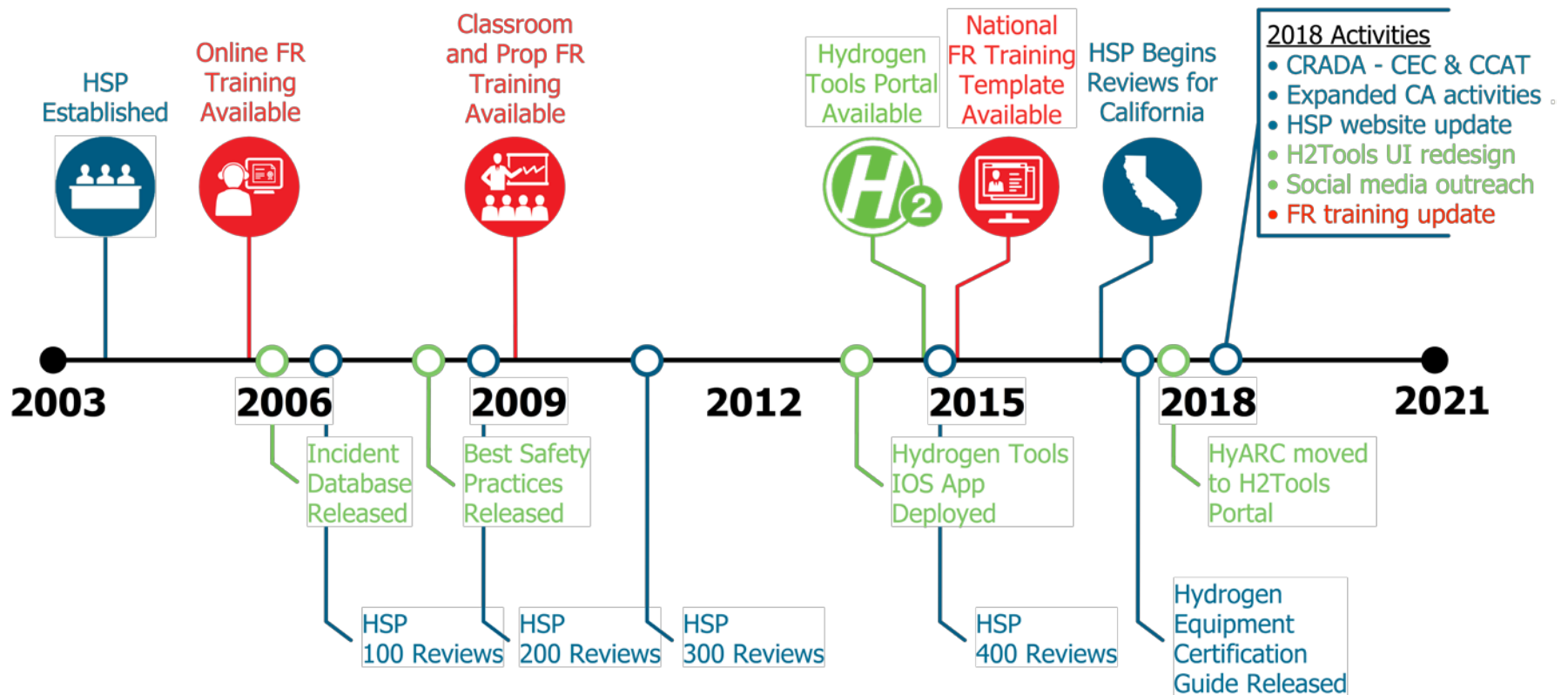
- ▶ Identify and develop new tools and methods to support hydrogen and fuel cell commercialization and disseminate hydrogen safety knowledge through the Hydrogen Tools Portal
- ▶ Bring greater visibility to hydrogen safety and the project's safety knowledge tools through presentations to relevant audiences not familiar with fuel cell technologies

## First Responder Training

- ▶ Engage organizations and outreach opportunities to share online and classroom training for FRs and bring visibility to the program's safety resources

# PNNL Hydrogen Safety Program Timeline

- Hydrogen Safety Panel
- Safety Knowledge Tools
- First Responder Training





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# Hydrogen Safety Panel

# Hydrogen Safety Panel Membership



The HSP is a multidisciplinary team of engineers, code officials, safety professionals, equipment providers, and testing and certification experts. The Panel provides guidance for hydrogen projects and facilities, including design and process safety reviews, support/review of risk analyses, onsite safety presentations, and training.

Name	Affiliation
Nick Barilo, Manager	Pacific Northwest National Laboratory
Richard Kallman, Chair	City of Santa Fe Springs Fire Dept.
Eric Binder	Santa Monica Fire Department
Ken Boyce	UL
David Farese	Air Products and Chemicals
Donald Frikken	Becht Engineering
Livio Gambone	CSA Group
Aaron Harris	Air Liquide
Chris LaFleur	Sandia National Laboratories
Miguel Maes	NASA-JSC White Sands Test Facility
Steve Mathison	Honda Motor Company
Larry Moulthrop	Proton OnSite (retired)
Glenn Scheffler	GWS Solutions of Tolland
Tom Witte	Witte Engineered Gases
Robert Zalosh	Firexplo



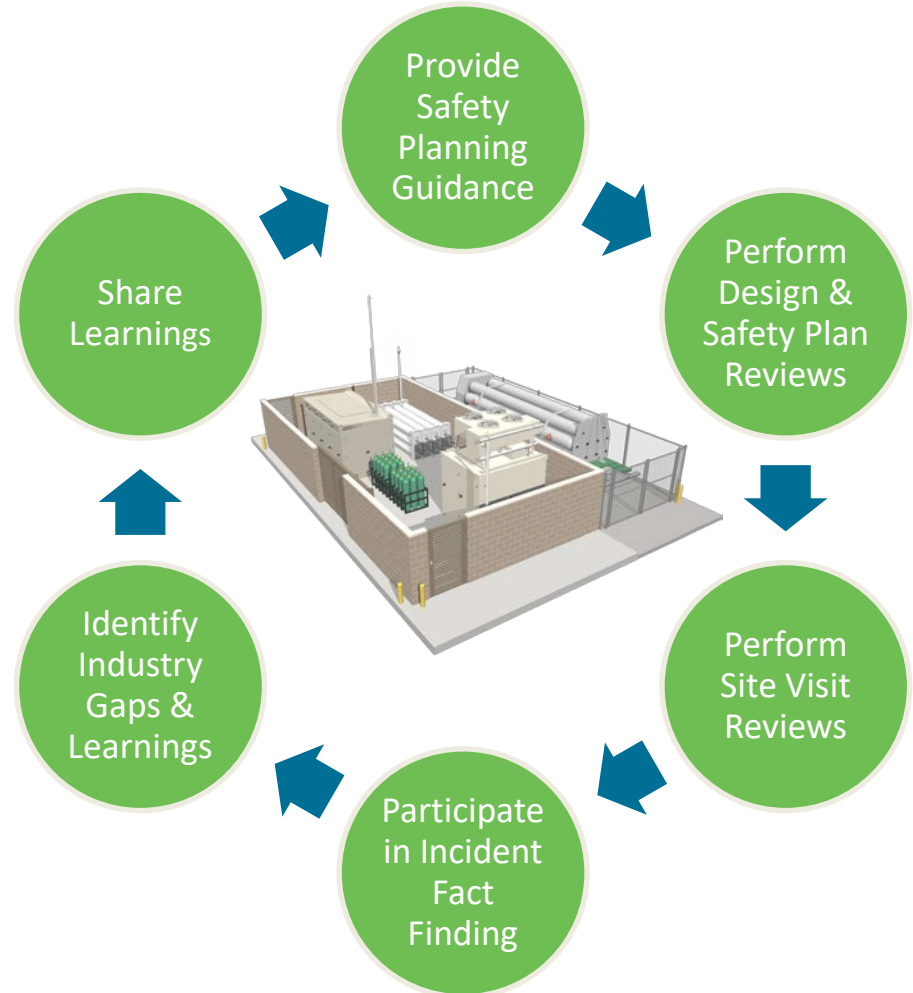
# Approach

## *HSP's purpose and objectives*

*The purpose of the HSP is to share the benefits of extensive experience by providing suggestions and recommendations pertaining to the safe handling and use of hydrogen.*

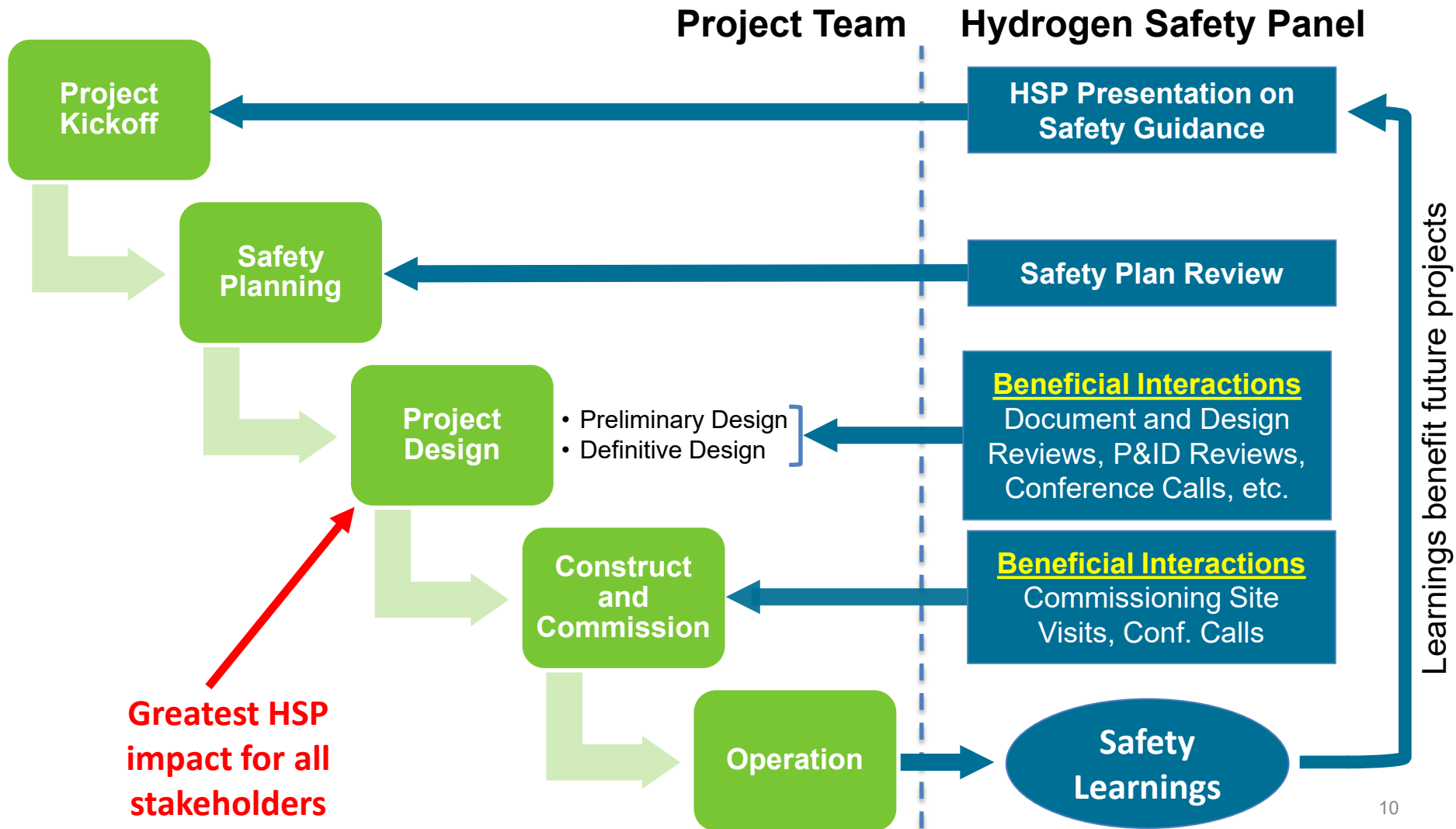
**Objective:** Enable the safe and timely transition to hydrogen technologies by:

- ▶ Participating in hydrogen projects to ensure safety is adequately considered
- ▶ Providing expertise and recommendations to stakeholders and assisting with identifying safety-related gaps, best practices, and lessons learned



# Approach

## Project interaction



# Accomplishments

## *Learnings from California infrastructure rollout*

ACTIVITIES

### Safety Plan Reviews

Reviewed safety plans submitted by 12 applicants to California's GFO-605 and provided comments to the CEC in support of award decisions

### March 2017 AHJ/Stakeholder Meetings

Held meetings at 7 California locations with hydrogen fueling station builders, code officials, and other state officials and stakeholders to discuss safety issues and lessons learned from recent station deployments

RESULTS

### Technical Learnings

- ▶ Separation distances
- ▶ Certification
- ▶ Emergency shutdown
- ▶ Permitting
- ▶ Training
- ▶ NFPA 2 considerations
- ▶ Public perception
- ▶ Miscellaneous

### Process Learnings

- ▶ Using the HSP for review early in the definitive design process could result in a more impactful review and confidence in the project team's safety approach
- ▶ All project partners should be included in the project safety plan

### Safety Guidance Learnings

- Expand guidance to require:
- ▶ A site plan
  - ▶ Critical safety equipment shutdown table
  - ▶ Flow diagram showing safety-related devices such as block valves, instruments, and relief devices

# Accomplishments

## *Technical learnings from California infrastructure rollout*

### Select Technical Learnings

#### ▶ Station design

- Most stations are challenged to meet separation distance requirements (and typically don't for separation from lot lines)
- Innovation is needed to address the safety and code issues regarding separation distances. While the current focus of research and development has been reactive to separation distance limitations, new thinking on the entire station design is needed to address the location restrictions more holistically
- Unloading locations for hydrogen tankers should be considered early in the design process to avoid unsafe conditions for store customers and impact on customer traffic routes (and codes may not be adequate to address potential safety issues)

#### ▶ First responders

- FRs are likely not ready to appropriately handle an incident at a fueling station
- FR training should consider jurisdictions beyond just those having a fueling station

#### 7 Station Locations

- >100 pages of notes
- 45 learnings

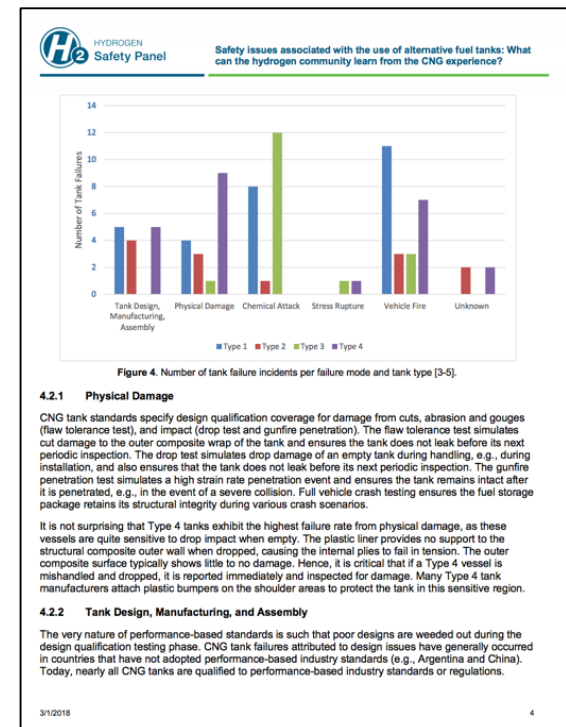
#### 12 Applications

- Safety plan reviews included up to 35 locations per application
- 277 comments

# Accomplishments

## Highlights

- ▶ 24<sup>th</sup> HSP Meeting in Cambridge, MA: Participation included representatives from the American Institute of Chemical Engineers (AIChE) and FirstElement Fuel. Discussion of timely topics on the long-range sustainability of the HSP, liquid hydrogen station safety and certification, and qualifications for liquid hydrogen designers and operators
- ▶ Updated Safety Guidance Document (November 2017)
  - Now one document for both DOE and non-DOE projects
  - Reflects learnings from involvement with California fueling station projects
- ▶ Compressed Natural Gas (CNG) White Paper: *Safety issues associated with the use of alternative fuel tanks: What can the hydrogen community learn from the CNG experience?*
- ▶ Liquid Hydrogen Qualification White Paper
  - A tool for permitting authorities to ensure qualified personnel have the necessary credentials

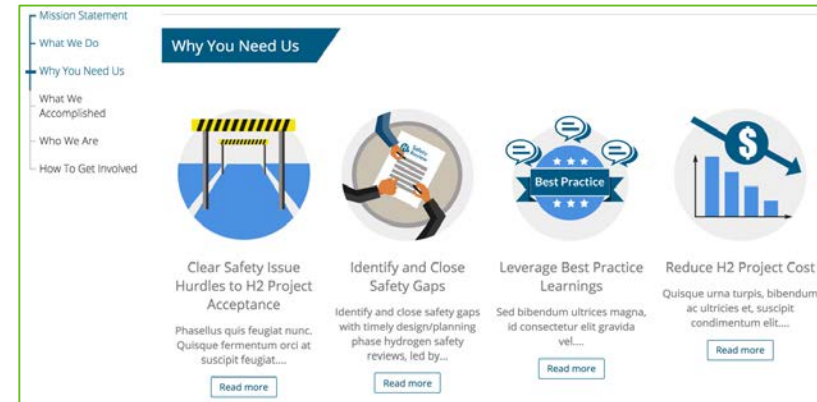


CNG White Paper

# Accomplishments

## Other highlights

- ▶ HSP website update
  - Focusing on modern and engaging content
  - Telling the story of who we are, what we do, our accomplishments, and how to connect with us
- ▶ HSP task group on California mobile applications
  - Identify and evaluate diverse mobile hydrogen equipment applications in California
  - Will consider equipment design and configuration, previous equipment safety reviews, applicable state and federal regulations, pertinent consensus standards, and equipment incidents
  - Provide a report to summarize the status, offer conclusions, and provide recommendations for the safe use of this equipment in California



Mobile applications incident – February 2018



Picture source: NBC Los Angeles

# Accomplishments

## Cooperative Research and Development Agreement (CRADA) awards/activities

### California Energy Commission CY18-20

- ▶ Activities will be performed in support of the California fueling structure infrastructure including renewable hydrogen production facilities

- Provide safety planning webinars and consultations
- Review funding opportunity applicant safety plans
- Participate in funded project design reviews
- Perform site safety reviews
- Provide outreach to code officials and stakeholders
- Review hydrogen incidents
- Conduct post startup project team interviews

*Learnings from these activities are brought back to California, DOE, and the hydrogen community*

### Connecticut Center for Advanced Technologies (CCAT) CY18-19

- ▶ The objectives include:
  - Raising awareness of the HSP among state/local officials and project developers
  - Establishing working relationships with key state and local organizations to enable seamless incident response and development of safety lessons learned
  - Identifying types of projects that would benefit from HSP involvement
  - Identifying methods to facilitate outside organizations paying for HSP

# Accomplishments

## Hydrogen Safety Panel scorecard

Activity	Since the 2017 AMR	Total for the Project Duration
Project Reviews (including safety plans, site visits reviewed, follow-up interviews, and design review activities)	17	<b>485</b>
Panel Meetings	1	<b>24</b>
White Papers, Recommendations, etc.	2	<b>10</b>
<i>Hydrogen Equipment Certification Guide</i> Downloads	52	<b>52</b>
Accident Investigations	0	<b>4</b>
*Publications, Presentations, and Webinars (all tasks combined total)	13	<b>70</b>

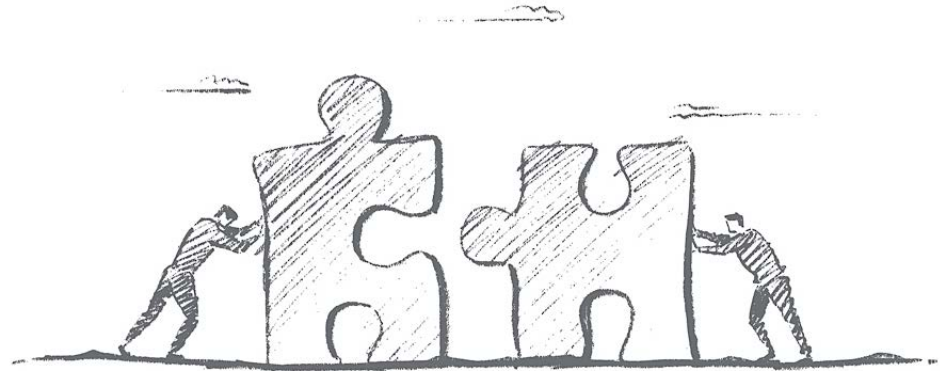
\* Includes a report for the Hydrogen Council November 2017 meeting titled “Assuring Safety for Deployment of Hydrogen and Fuel Cell Technologies.”



# Accomplishments/Relevance

## *Highlighting the impact of HSP activities*

- ▶ Serves as a non-regulatory, objective, and neutral resource
- ▶ Sees the “big picture”
  - Shares learnings
  - Identifies gaps
- ▶ Can help reduce costs
  - Over-engineering resulting in unnecessary features
  - Delayed approvals
  - Missed safety considerations/features
- ▶ A group with diverse experience can:
  - Respond with a balanced solution to questions, problems, and issues
  - Aid in avoiding repeating costly mistakes among disparate project proponents
  - Help project proponents avoid industry-impacting incidents
  - Help establish stakeholder and public confidence





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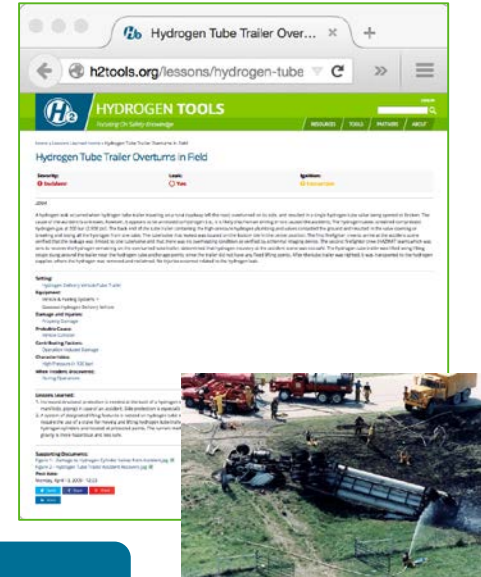
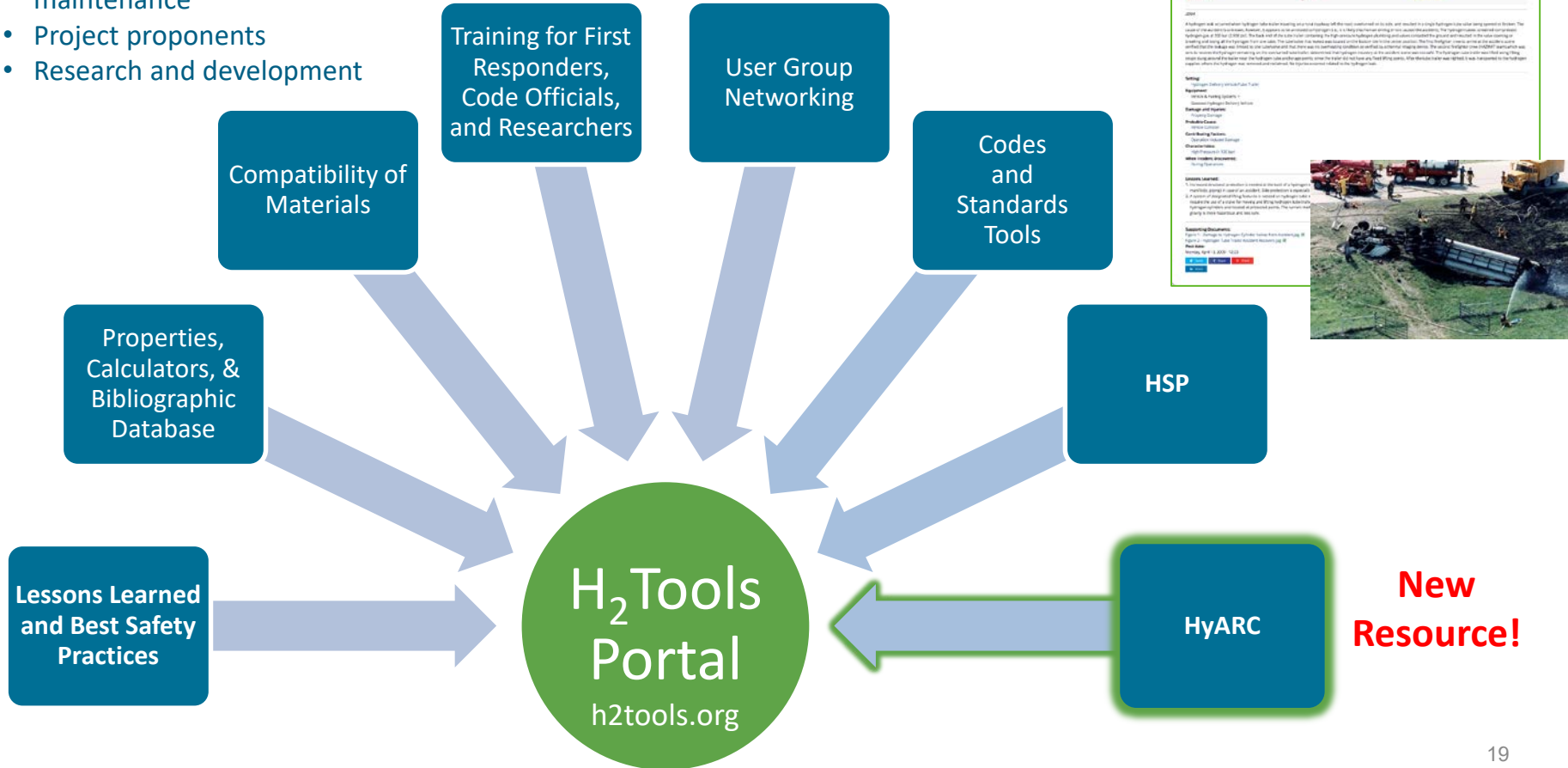
# Safety Knowledge Tools and Information Dissemination

# Accomplishments

## Hydrogen Tools Portal

### User Groups

- AHJ/code officials
- First responders
- Operations and maintenance
- Project proponents
- Research and development



**New Resource!**

# Accomplishments

## Hydrogen Tools Portal update

The focus was on providing a modern interface and reducing resources needed for maintenance activities

- ▶ Upgrade from Drupal 7 to 8
- ▶ Complete user interface update
- ▶ Tools added to simplify content update
- ▶ Tools added to reduce site maintenance labor requirements
- ▶ Site moved to Amazon Web Services to improve performance, increase reliability, and minimize hosting costs

The screenshot displays the Hydrogen Tools Portal website. At the top, there is a green navigation bar with a 'LOG IN' link and a search box labeled 'Enter keywords'. Below the navigation bar, the 'HydrogenTools' logo is visible, along with a menu of links: Editor, Resources, Hyarc, Forums, Partners, and About. The main content area features a large blue-tinted image of a molecular structure. To the right of this image is a text box titled 'Technical Reference for Hydrogen Compatibility of Materials' with a 'SEE MORE' button. Below the main image is a 'Welcome to the Hydrogen Tools Portal' section. This section includes a welcome message and a 'News' section with two articles. The first article is titled 'Exxon Mobil Backs FuelCell Effort to Advance Carbon Capture Technology' and is dated 11/10/2017. The second article is titled 'Hydrogen fuel cell e-bike takes 2 minutes to fill and has a 60+ mile range' and is dated 11/01/2017.

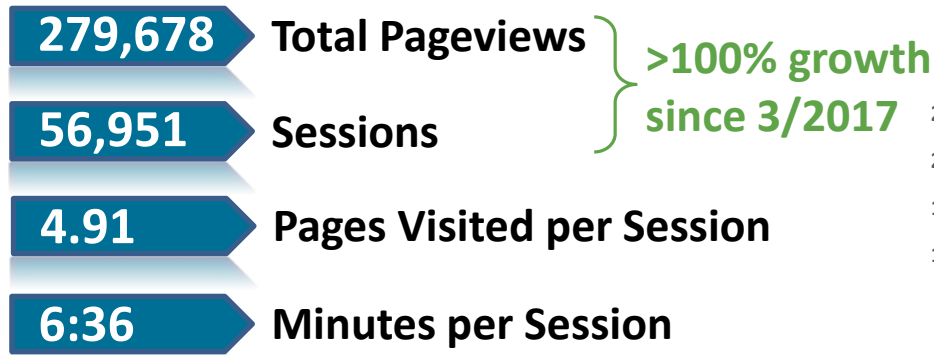
# Accomplishments

## Hydrogen Tools Portal stats

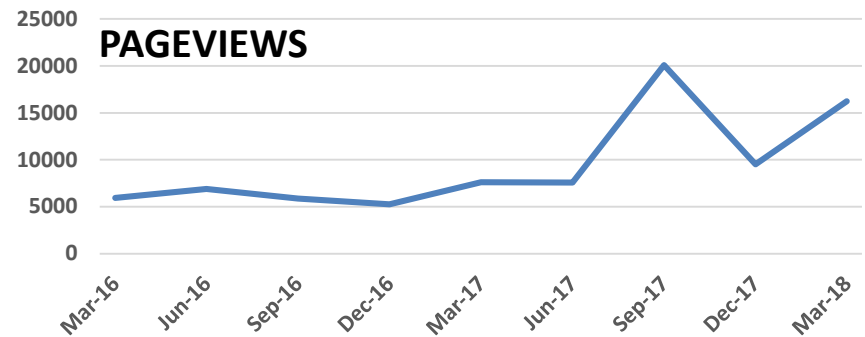
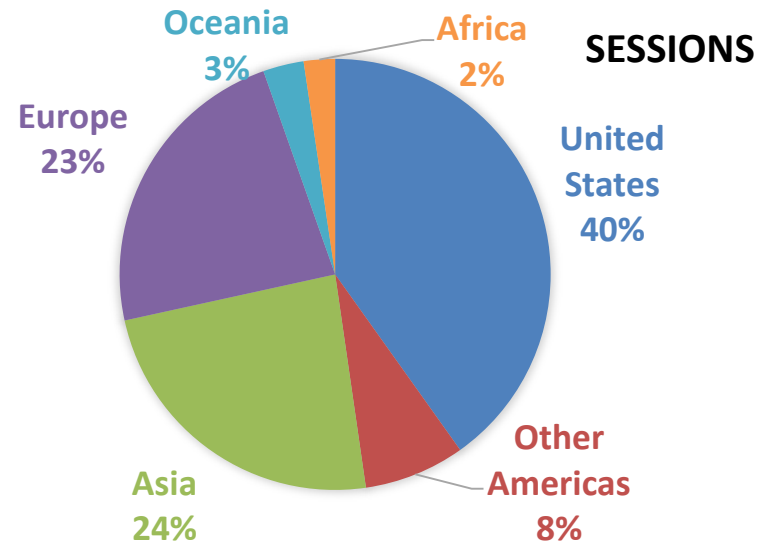
### Site Content



### Usage Stats\*



### H2Tools.org - A Global Resource!



\* Nonbounce statistics through March 31, 2018

# Accomplishments

*Disseminating safety knowledge to reach critical audiences*

## International Collaboration

- ▶ PNNL is working with Hydrogen South Africa, HySafe, and the U.K.'s Health and Safety Laboratory to provide a second online hydrogen safety awareness webinar/panel discussion for code officials and stakeholders in South Africa in May 2018
- ▶ Presented and collaborated at ICHS, September 2017
- ▶ PNNL worked with Air Liquide to present safety messaging to the Hydrogen Council (September/November 2017)



## U.S. Stakeholder Outreach

- ▶ Green Transportation Summit and Expo, Tacoma, WA (April 2018)
- ▶ Berkeley, CA Town Hall Meeting (March 2018)
- ▶ NFPA Conference and Expo (June 2017)

## Federal Energy Management Program (FEMP)

- ▶ Presented at the Energy Exchange (EE) conference (August 2017)
  - EE presentation was video recorded and PNNL produced an online training course (<http://www.wbdg.org/continuing-education/femp-courses/femp59>)





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# First Responder Training

# Accomplishments


## Updating and enriching training content

A substantial update of the FR training material was completed in February 2018 in support of training provided in the Northeast U.S. in early March

- ▶ Learnings from previous in-person training activities were used to evaluate the benefit of each slide in the National Training resource
- ▶ Many slides were updated or replaced with more current content, and less impactful slides were removed (>75% of the slides impacted)
- ▶ A practical scenario video and pictures were added to enrich classroom discussion and facilitate identification of beneficial attack strategies
- ▶ **Feedback from the March Northeast U.S. training will be incorporated into the National Training resource and be made available for download in Summer 2018**

### Hydrogen Delivery System

Fuel Cell Powertrain




Lithium-ion battery

High-pressure hydrogen tank

<http://www.ford.com/CLARITY/technology/index.html>

Distribution lines contain lower pressures than storage cylinders

Tank TPRDs vent directly or are connected to fuel vent line(s)



Miral cutaway showing H2 storage tanks, courtesy Ballard

3/5/18 / 34

### Multiple Vehicle Accident



3/5/18 / 108



# Accomplishments

## First responder training...by the numbers



### Online Training

Refreshed in May 2018

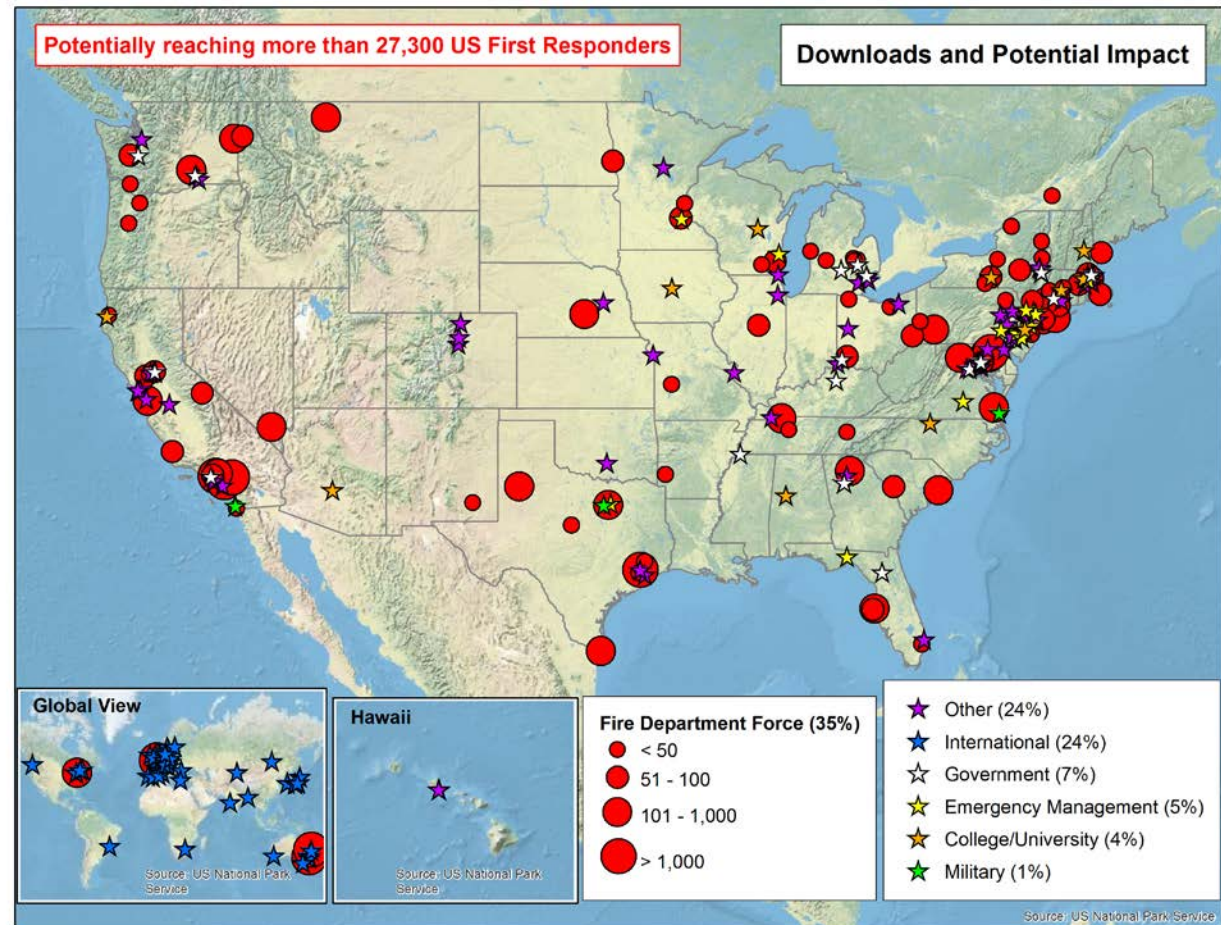
### Classroom Training

>1,500 attendees since 2009

### National Template

388 downloads

(+58 in past 12 months)



National Template: downloads and potential impact



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# Proposed Future Work, Collaborations, and Presentation Summary



AIChE\* is planning to establish a Center for Hydrogen Safety. PNNL will partner with AIChE to expand the HSP's access to new customers by:

- ▶ **Making the HSP more readily available to industry, state, and federal government agencies (national and international)**
- ▶ **Enabling less cumbersome/time-consuming contracting efforts**

PNNL will also identify opportunities to transfer its FR hydrogen training resources to AIChE to enable broader access to online and in-person training resources (with continued subject matter support from PNNL and CaFCP)

*\* AIChE is the world's leading organization for chemical engineering professionals, with more than 60,000 members from more than 110 countries. AIChE has the breadth of resources and expertise to support industries or emerging areas, such as hydrogen and fuel cell technologies.*

# Proposed Future Work

*Remainder of FY 2018*

## Hydrogen Safety Panel

- ▶ Continue safety reviews for DOE-funded projects
- ▶ Continue to support the CEC hydrogen fueling station deployment and renewable production facility activities
- ▶ Continue work on the California mobile application task group
- ▶ Participate in stakeholder meetings with CCAT in the Northeast U.S.

## Safety Knowledge: Tools and Dissemination

- ▶ Maintain Hydrogen Tools website
- ▶ Participate in outreach activities for the Northeast U.S. and California in support of CRADA activities

## First Responder Training

- ▶ Complete the update of the National Training Resource
- ▶ PNNL will transfer its pan burner props to the Massachusetts Fire Academy

**Note: Any proposed future work is subject to change based on funding levels.**

# Proposed Future Work

*FY 2019*

## 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
- ▶ Implement the HSP strategic plan and explore/engage opportunities to directly support states/regional rollout of fuel cell vehicles, stationary applications, and supporting infrastructure
- ▶ Support California's hydrogen fueling station deployment and renewable production facility activities

## Safety Knowledge Tools and Dissemination

- ▶ Provide outreach to stakeholders in the Northeast U.S. and California in support of CRADA activities

## First Responder Training

- ▶ Identify and implement opportunities to transfer training resources to AIChE

**Note: Any proposed future work is subject to change based on funding levels.**

# Collaborations

## Hydrogen Safety Panel and Safety Knowledge Tools



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- ▶ Organizations Supporting Hydrogen Safety Panel Members
- ▶ NREL on NFPA 2 liquid hydrogen task group, safety outreach, and code development activities
- ▶ SNL on Northeast U.S. safety outreach activities
- ▶ CaFCP in support of FR training activities
- ▶ CEC in support of safe infrastructure deployment and safety learnings
- ▶ CCAT in support of outreach activities and HSP involvement in hydrogen projects
- ▶ FEMP in support of outreach activities



## Hydrogen Safety Panel

- ▶ The Panel's involvement in a wide variety of early market demonstration projects puts it in a unique position to analyze issues, identify gaps, and share what it has learned
- ▶ The Panel can be an asset for supporting the safe commercial rollout of fuel cell vehicles, stationary applications, and infrastructure. Dissemination of learnings from the Panel's specific project involvement and interaction with code officials, stakeholders, and project proponents not only broadly benefits the industry, but feeds back to the Fuel Cell Technologies Office's research and development efforts

## Safety Knowledge Tools

- ▶ The entire hydrogen community benefits if hydrogen-safety-related knowledge is openly and broadly shared. The Hydrogen Tools Portal represents a significant opportunity to broadly disseminate safety information and knowledge
- ▶ A strong commitment to reaching 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 FR training for hydrogen and broader alternative fuels focused activities



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# Responses to Select 2017 AMR Reviewer Comments



“The reviewer supports looking for alternate funding sources and the usefulness of additional site inspections. However, HSP is not, nor should it become, an authority having jurisdiction (AHJ) or nationally recognized testing laboratory (NRTL). The project should watch the fine line: voluntary project reviews for government projects is fine, but mandatory reviews of private projects is a gross overreach.”

- ▶ *Thanks for the comments. It has never been PNNL’s intent for the HSP to usurp authority of the AHJ or become a certification body. Any feedback from the HSP is provided in a consulting manner and does not carry authority for approval or rejection of a project or its activities. This is a significant benefit of having the HSP involved in a review of a hydrogen project. The project team gains access to substantial safety experience and expertise without a requirement to resolve all comments or recommendations. Additionally, code officials and AHJs can engage the HSP for expert input from an unbiased and neutral third-party perspective.*

“The proposed future work is well planned for continuously focusing on the ongoing barriers or activities. It does not score as “outstanding” since this plan seems still based within its comfortable zones. The plan focuses heavily on coastline areas and on infrastructure (fuel stations), and is not very specific about the personnel who should participate in the first responder training. If it is not a difficult barrier to overcome at this stage, the project should consider developing a future plan to conduct outreach to the states/areas away from coastline areas. Likewise, the project could work to convince OEMs to participate. The project should consider developing a plan to further define who should be the personnel that need to participate in the first responder training.”

- ▶ *This comment appears to focus on the FR training task of the project. PNNL has maximized its FR resources to the greatest extent practicable, but due to limited funding it is not possible to conduct this training in new areas. However, PNNL continues to help with outreach activities sponsored by industry leaders and original equipment manufacturers (e.g., March 2018 outreach to the Northeast). The training focus areas are in direct conjunction/coordination with industry and regional rollout plans to maximize benefit to those communities. We also coordinate locally to ensure the right participants in each training.*

*PNNL also works with with our collaborator, California Fuel Cell Partnership, to update training materials. To enable broader dissemination of training materials and outreach activities, PNNL is in discussion with AIChE regarding transfer of our FR training resource to this highly respected organization.*



# ***Thank You!***

- **U.S. Department of Energy**
  - **Fuel Cell Technologies Office (Sunita Satyapal, Director; Laura Hill, Safety, Codes, and Standards Manager; and Will James)**
- **California Fuel Cell Partnership**
  - **Jennifer Hamilton**
  - **All of my colleagues at Pacific Northwest National Laboratory, the Hydrogen Safety Panel, and other collaborators**
- **AMR Reviewers – your comments and perspectives are important to help us identify areas for improvement and be more impactful**



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# Technical Backup Slides for the 2018 Annual Merit Review and Peer Evaluation

# Project Review Reports and White Papers

*Since the 2017 AMR*

1. White Paper – Qualified Individual for Liquefied Hydrogen, March 8, 2018.
2. White Paper – Safety issues associated with the use of alternative fuel tanks: What can the hydrogen community learn from the CNG experience? Published March 1, 2018.
3. Safety Plan Review – Vapor Deposition Process for Engineering of Dispersed PEMFC ORR Pt/NbOx/C Catalysts, February 26, 2018.
4. Safety Plan Review – Hydrogen Fuel Cell Range Extender for Battery Electric Vehicle, December 21, 2017.
5. Design Review – Carbon Free Data Center, December 18, 2017.
6. Design Review – Overview of the Medium Pressure Reactor System Design, December 8, 2017.
7. Safety Plan Review – Innovative Non-PGM Catalysts for CHP Relevant Proton Conducting Membrane Fuel Cells, November 8, 2017.
8. Safety Plan Review – Revised Hydrogen Fueling Station Safety Plan - CEC-2016-09, October 13, 2017.
9. Safety Plan Review – Applicants to the California GFO-605 for hydrogen fueling stations (12 applications, each with multiple safety plans), December 20, 2016.
10. Safety Plan Review – Advancing Hydrogen Dispenser Technology by Using Innovative Intelligent Networks, June 1, 2017.
11. Safety Plan Review – High Performance PEFC Electrode Structures, May 22, 2017 (2 reviews).
12. Safety Plan Review – Modular SOEC System for Efficient H<sub>2</sub> Production at High Current Density, May 23, 2017 (2 reviews).
13. Safety Plan Review – High Temperature Alkaline Water Electrolysis, May 23, 2017 (2 reviews).
14. Safety Plan Review – Solid Oxide Based Electrolysis and Stack Technology with Ultra-High Electrolysis Current Density (>3 A/cm<sup>2</sup>) and Efficiency, May 23, 2017 (2 reviews).
15. Safety Plan Review – Hybrid Electrochemical Hydrogen/Metal Hydride Compressor, May 17, 2017 (2 reviews).