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

NICK BARILO
Hydrogen Safety Panel and Resources Project
Hydrogen Program Annual Merit Review and Peer Evaluation Meeting
Washington, DC
May 1, 2019

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

SCS019

PNNL-SA-141360

Overview

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HYDROGEN SAFETY PANEL (HSP) AND RESOURCES

Project Timeline

- Project start date: March 2003
- Project end date: September 2019[1]

Barriers Addressed[2]

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

Budget

- FY18 DOE funding: $265K
- Planned FY19 DOE funding: $1,075K

Partners

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

[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, 2015, pp. 21-22 (updated June 2015), https://www.energy.gov/sites/prod/files/2015/06/f23/fcto_myrdd_safety_codes.pdf.

Relevance

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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)
C. Safety is not always treated as a continuous process G. Insufficient technical data to revise standards	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
A. Safety data and information — limited access and availability D. Lack of hydrogen knowledge by AHJs	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 Participate in key outreach opportunities to share HSP learnings and safety information with AHJs and code officials
E. Lack of hydrogen training materials and facilities for emergency responders	Implement a national hydrogen emergency response training resource program with downloadable materials that are adaptable to the specific needs of first responders (FRs) and training organizations Identify enhancements to FR 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; 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

HYDROGEN
Tools

- Identify and develop new tools and methods to support hydrogen and fuel cell commercialization and disseminate hydrogen safety knowledge through the Hydrogen Tools Portal (http://h2tools.org)
- Bring greater visibility to hydrogen safety and the project's safety knowledge tools through presentations to relevant audiences not familiar with fuel cell technologies

HYDROGEN
Emergency Response Training Resources

- Collaborate with key industry organizations to update training materials for transition to the Center for Hydrogen Safety (CHS)

PNNL Hydrogen Safety Program Timeline

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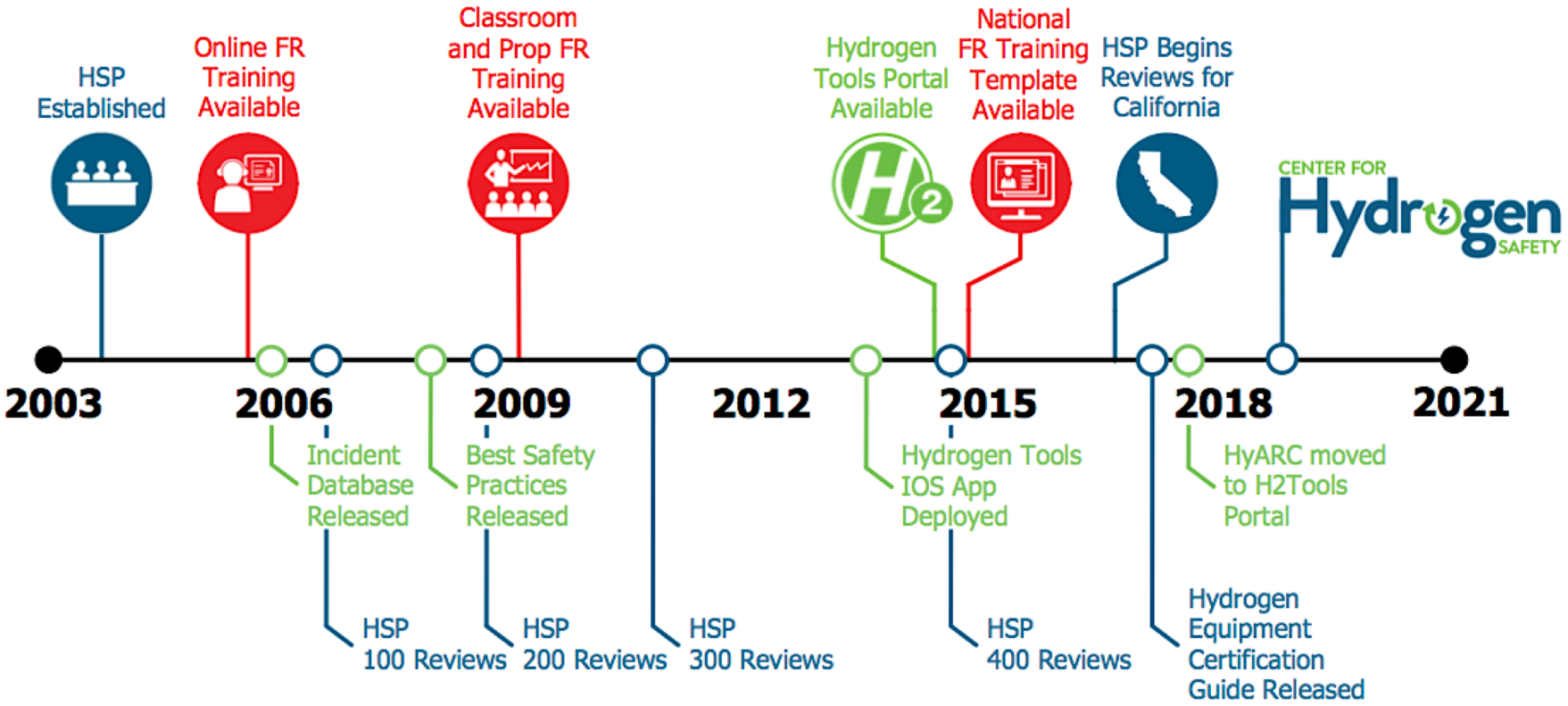
- Hydrogen Safety Panel
- Safety Knowledge Tools
- First Responder Training



Accomplishment: PNNL and AIChE Partnered to Establish the Center for Hydrogen Safety

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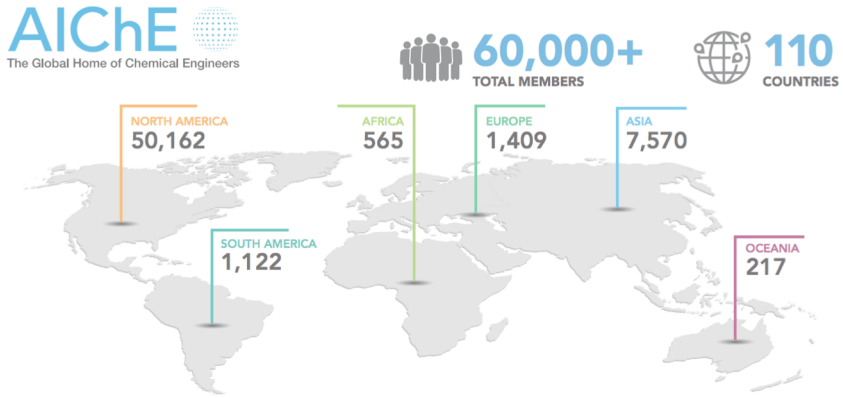
CENTER FOR Hydrogen SAFETY

An AIChE Technical Community • A Global Resource On Hydrogen Safety

The CHS is a not-for-profit, global, membership organization within the American Institute of Chemical Engineers (AIChE) that promotes the safe operation, handling, and use of hydrogen and hydrogen systems across all installations and applications. The CHS identifies and addresses concerns regarding the safe use of hydrogen:

- As a sustainable energy carrier
- In commercial and industrial applications
- In hydrogen and fuel cell technologies

PNNL principal investigator jointly appointed to AIChE as Director of CHS



CHS URL: www.aiche.org/chs

CHS Member Benefits

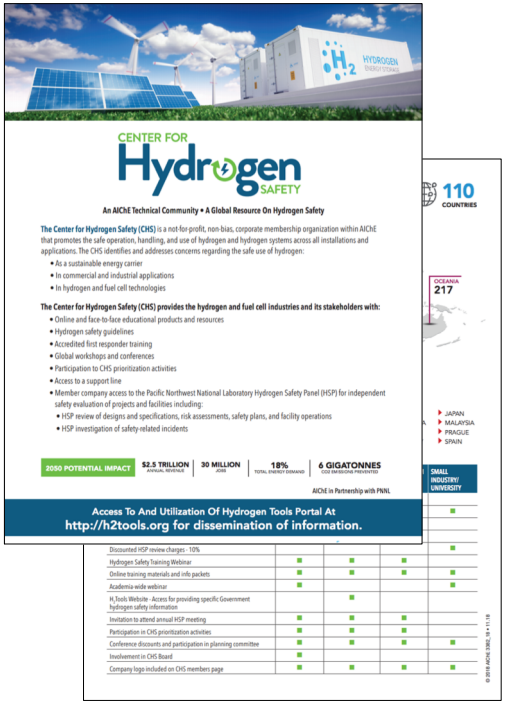
CHS launch held on April 2 at AIChE Spring Meeting in New Orleans

Direct

- Access to the U.S. HSP for reviews and support
- Education (continuing education units [CEUs]), training, and outreach materials
- Provide leadership and facilitation of hydrogen safety issues
- Conferences and networking opportunities

Indirect

- Messaging: Membership in CHS can demonstrate commitment to stakeholders and the public that safety is a priority for your organization (organization logos can be added to the CHS website and members can use the CHS member logo)
- Participate in a global community addressing safety issues and barriers



Membership info and benefits

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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.
Ken Boyce	UL
David Farese	Air Products and Chemicals
Donald Frikken	Becht Engineering
Livio Gambone	Nikola Motors
Aaron Harris	Air Liquide
Brian Ladds*	Calgary Fire Department
Chris LaFleur	Sandia National Laboratories
Miguel Maes	NASA-JSC White Sands Test Facility
Steve Mathison	Honda Motor Company
Larry Moulthrop	Proton OnSite (retired)
Andrei Tchouvelev*	A.V. Tchouvelev & Associates Inc.
Tom Witte	Witte Engineered Gases
Robert Zalosh	Firexplo

* New HSP member since 2018 AMR

Relevance

HSP's overall purpose and objectives

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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

Accomplishments
Highlights

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- 25th HSP Meeting in New Orleans: This atypical meeting was held in conjunction with the launch of the Center for Hydrogen Safety at the AIChE Spring Meeting
  - Included guests from the AIChE Spring Meeting and CHS launch event attendees
  - President of IA HySafe
- HSP members performed a site visit safety review at Argonne National Laboratory focusing on facilities and activities with test engines and turbines using 100% hydrogen as a fuel
- HSP members performed a site visit at the Navy's Keyport, WA

HYDROGEN Safety Panel

499 Safety Reviews

338 Projects

100+ Publications and Presentations

25 Panel Meetings

10 White Papers

4 Investigations

Accomplishments
Other highlights

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- HSP task group on mobile applications (CEC funded)
  - Identify and evaluate diverse mobile hydrogen equipment applications
  - 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
- HSP provided a testimony letter to the City of Walnut Creek Planning Department regarding a proposed hydrogen fueling station (HFS)
  - Station reviewed by HSP during California grant funding application
  - Consultant report reviewed and errors identified regarding safety of the proposed station

HYDROGEN Safety Panel

h2tools.org

October 15, 2018

Trishia Caguiat
City of Walnut Creek Planning Department
1666 North Main Street
Walnut Creek, CA 94596

Dear Ms. Caguiat:

Proposed Walnut Creek Hydrogen Fueling Station

I am providing this correspondence to inform the Walnut Creek Planning Commission of the Hydrogen Safety Panel's (HSP's) activities related to the subject hydrogen fueling station. Let me start with a short background on who we are and then provide information on our involvement in activities for the subject facility.

The HSP was established in 2003 to support U.S. Department of Energy efforts to encourage the commercialization of fuel cell technologies. The 15-member panel has over 400 years of cumulative experience and is composed of a cross-section of expertise from the commercial, industrial, government, and academic sectors. The HSP is managed by Pacific Northwest National Laboratory (PNNL) and works to address concerns about hydrogen as a safe and sustainable energy carrier. The HSP is a neutral and unbiased resource to enable the safe and timely transition to hydrogen and fuel cell technologies. The HSP's principal objective is to promote the safe operation, handling, and use of hydrogen and hydrogen systems across all installations and applications. To date, the HSP has completed 493 hydrogen safety reviews across 334 projects covering a large spectrum of project types – hydrogen fueling, auxiliary power, backup power, combined heat and power, portable power, mobile applications, and lab research and development. I have included a one-page information document that further details the HSP and its activities.

The California Energy Commission (CEC) contracted PNNL in 2016 to have the HSP perform several safety activities, including review of pre-award safety plans for applications to GFO-15-605 for hydrogen fueling stations. The criteria for development of the safety plans is provided in "Safety Planning for Hydrogen and Fuel Cell Projects" (https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-

HSP testimony letter for Walnut Creek HFS

Accomplishments

Cooperative Research and Development Agreement (CRADA) awards/activities

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California Energy Commission CY19-21

- 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

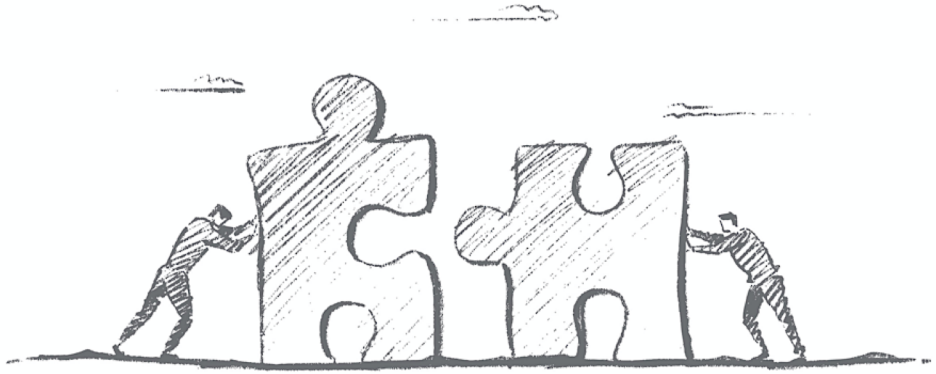
Connecticut Center for Advanced Technologies (CCAT) CY18-19

- 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/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*

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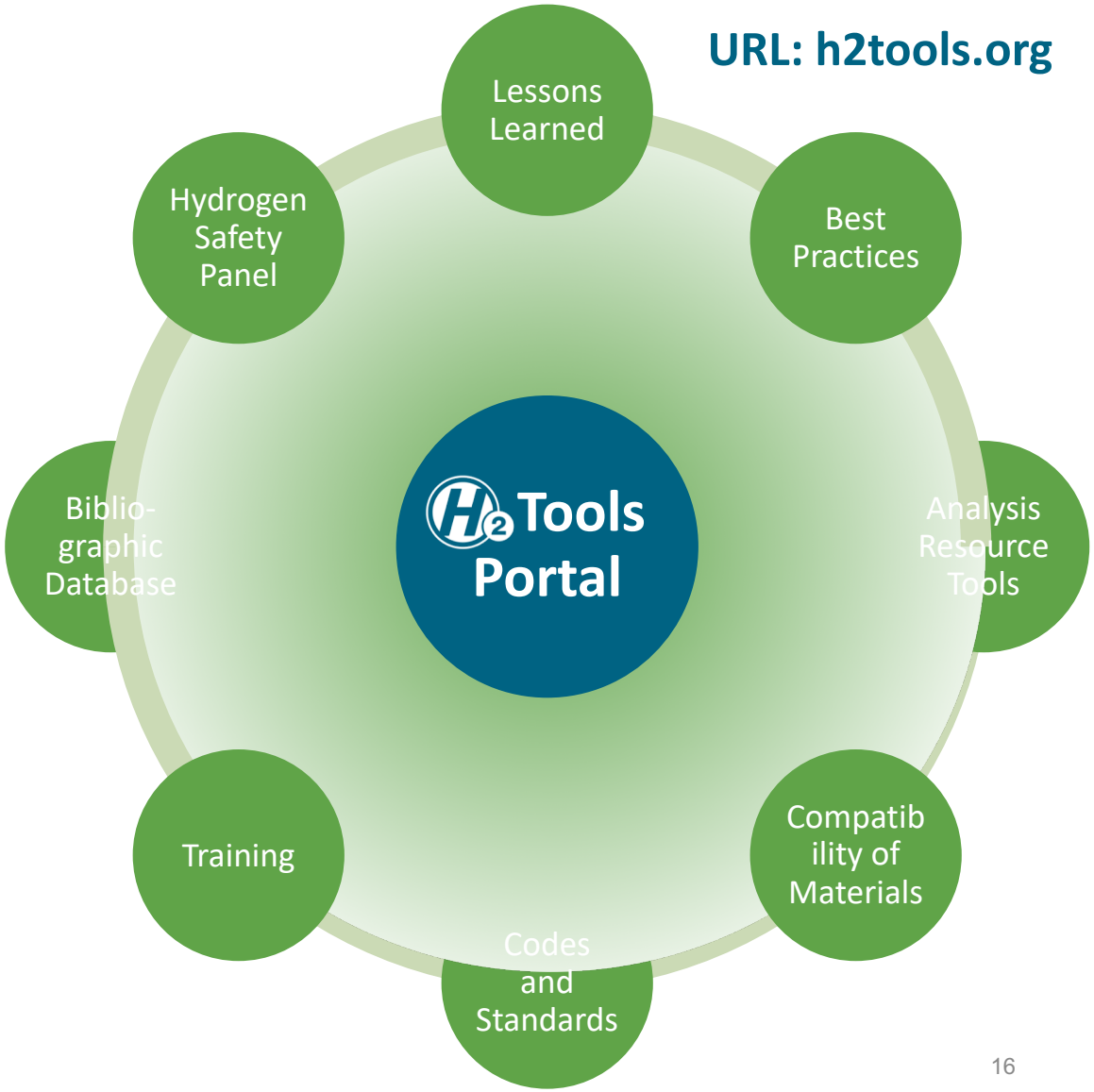
HydrogenTools

Significant hydrogen safety resources in one location

The goal of the Portal is to support implementation of the practices and procedures that will ensure safety in the handling and use of hydrogen in a variety of fuel cell applications. The portal brings together and enhances the utility of a variety of tools and web-based content on the safety aspects of hydrogen and fuel cell technologies to help inform those tasked with designing, approving or using systems and facilities, as well as those responding to incidents.

URL: h2tools.org



Accomplishments

Hydrogen Tools website stats

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Site Content

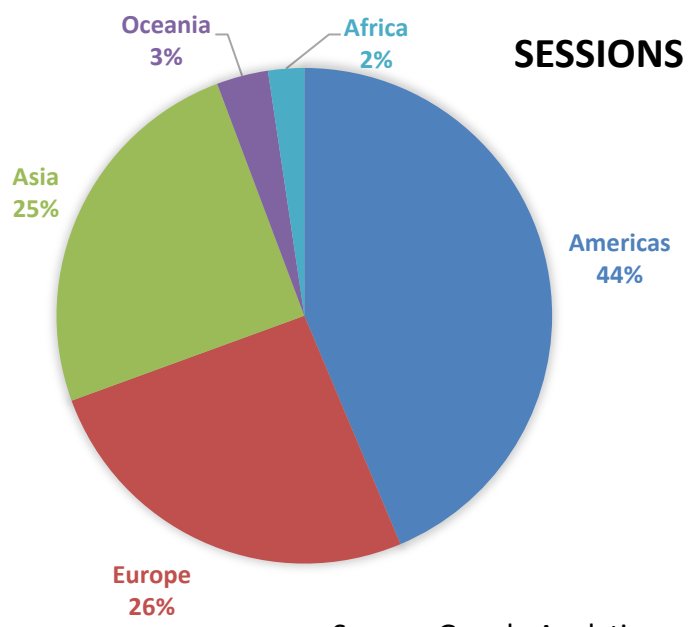
- **2,944** Total pages
- **2,297** Bibliographic references
- **217** Lessons learned pages
- **142** Best safety practices pages

Usage Stats*

- **20,096** Maximum pageviews in one month
- **14,500** Average pageviews/month
- **4.32** Pages visited per session
- **6:01** Minutes per session

HydrogenTools

A Global Resource!



Source: Google Analytics

* Nonbounce statistics through February 13, 2019

Accomplishments

Disseminating safety knowledge to reach critical audiences

Hydrogen Safety Training and Stakeholder Meetings

- October 2018 – NY and MA
- September 2018 – CT, RI, NY, MA, and NJ (first outreach in NJ and was attended by Assemblyman Gordon Johnson)

- In collaboration, CCAT and the Fuel Cell and Hydrogen Energy Association (FCHEA) provided a webinar titled, “Increasing the Value Proposition: Hydrogen Safety”

- Participation in hydrogen safety outreach and training activities in South Australia (non-DOE funding)

Outreach at New Haven, CT

Outreach at Rutgers, NJ

Accomplishments
Measuring success

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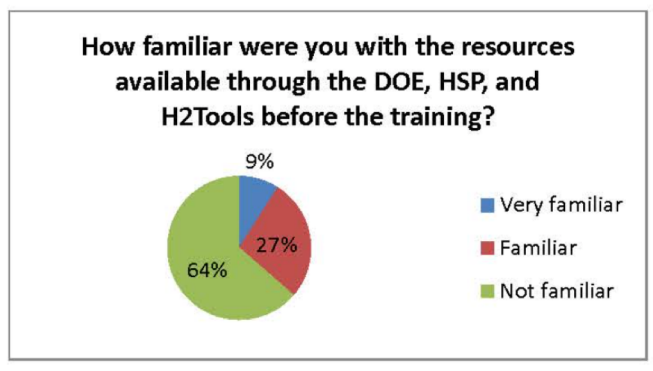
Training and stakeholder meeting locations: New Haven, CT; Westerly, RI; New Brunswick, NJ; Amherst, MA; Albany, NY; Stow, MA and Cambridge, MA

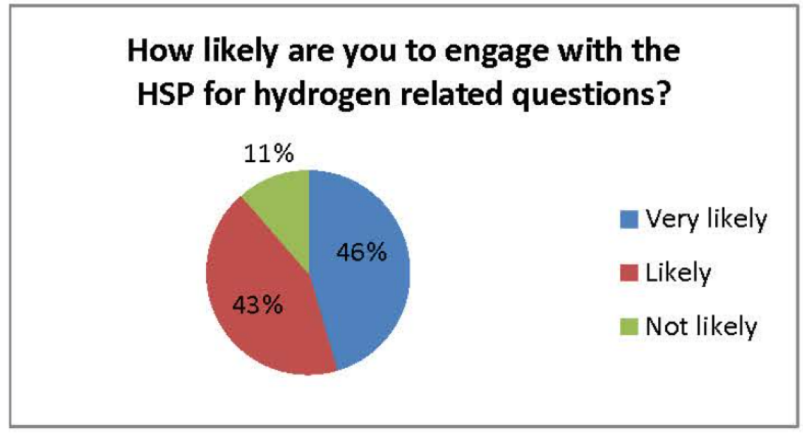
To build attendance and magnify impact, most stakeholder meetings were combined with hydrogen safety training

The training was well received and many of the training attendees stayed for stakeholder meetings

Post event polls from attendees show:

- **95% believe 60 -to 90-minute training is best**
- **93% rated training good**
- **89% likely to engage with HSP**
- **80% believe regional training is effective**
- **64% learned of hydrogen safety resources for the first time**





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First Responder Training

Accomplishments and Future Plans

Transitioning first responder training to CHS

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We're moving… PNNL → AIChE CENTER FOR Hydrogen SAFETY

Resources that are moving…

- National Hydrogen and Fuel Cell Emergency Response Training Resource (training template)
- Online awareness training
- In-person training
- Training props

Benefits

- Better aligns the resource with industry needs and focus
- Allows for participants to receive CEUs for completion of the online training
- Provides a long-term home for the resources

Accomplishments and Future Plans

- February 2019, revision of training template
- March 2019, PNNL works with CHS to deploy a first responder online training with CEUs in AIChE's online academy
- June 2019, first responder training videos produced utilizing a fuel cell vehicle
- September 2019, final PNNL training template update and transition of all training material and props to CHS

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Proposed Future Work, Collaborations, and Presentation Summary

Proposed Future Work

Remainder of FY 2019

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Hydrogen Safety Panel

- Continue safety reviews for DOE-funded projects
- Continue to support the CEC HFS 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. and Mid-Atlantic states
- Continue exploring opportunities to review projects for the South Australian government
- Work with AIChE to support hydrogen safety reviews for the CHS

Safety Knowledge: Tools and Dissemination

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

First Responder Training

- Complete the update of the National Training Resource
- Transfer training resources and props to the CHS

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

Proposed Future Work

FY 2020

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Hydrogen Safety Panel

- Review project safety plans and design and participate in site visits in support of the DOE fuel cell program
- 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 California in support of CRADA activities

First Responder Training

- None as this resource will be transferred to the CHS

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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- HySafe through participation in identifying hydrogen safety research priorities (workshop in Buxton, UK, September 2018)
- South Australian government through hydrogen safety outreach and training activities in Adelaide, South Australia (non-DOE funding)
- Organizations supporting HSP members
- NREL on NFPA 2 liquid hydrogen task group, safety outreach, and code development activities
- CaFCP in support of FR training activities
- CEC in support of safe infrastructure deployment and safety learnings
- CCAT through outreach activities and HSP involvement in hydrogen projects
- FCHEA on a webinar titled, “Increasing the Value Proposition: Hydrogen Safety”

Summary

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 . Its transition to the CHS will ensure that it is available to continue these benefits

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Responses to Select 2018 AMR Reviewer Comments

Response to 2018 Reviewer Comments

"Funding continues to be a challenge for this important and well-respected activity."

"The project's limited budget is probably its biggest weakness. There is much more work to be done than is budgeted."

"This work is very important, and there is still so much more to do faster. It is not clear that resources are sufficient."

"The lack of a secured funding stream for the Center for Hydrogen Safety is a weakness."

" The issue of resources for planned future work should be addressed."

- *Thanks for the comments. It was evident in 2017 that the project would need to identify new opportunities for long-term sustainability and broader impact. The principal investigator met with three organizations to consider how the current project resources could be utilized and funded by non-DOE organizations. This process led to what is now the AIChE Center for Hydrogen Safety (CHS). The CHS will be a global membership organization comprised of industry, government, university and other stakeholders having a desire to ensure that hydrogen safety. Income for the CHS will come through membership and services rendered such as safety plan reviews, site visits, outreach events, first responder training and conferences. This approach should provide long-term sustainability for these highly impactful safety resources.*

Thank You!

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- 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
- AIChE staff supporting the PNNL partnership on the Center for Hydrogen Safety
- 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 2019 Annual Merit Review and Peer Evaluation

Project Review Reports and White Papers

Since the 2018 AMR

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1. Safety Plan Review – Laser 3D Printing of Highly Compacted Protonic Ceramic Electrolyzer Stack.
2. Safety Plan Review – Iwatani Hydrogen Fueling Station Safety Plan.
3. Safety Plan Review – ITM Power Hydrogen Fueling Station Safety Plan, January 30, 2019.
4. Site Visit Safety Review – Large Displacement Unmanned Underwater Vehicle, Advanced Power & Energy Demonstration Project, December 17, 2018.
5. Safety Plan Review – Thin-Film, Metal-Supported High-Performance and Durable Proton-Solid, December 5, 2018.
6. Safety Plan Review – Demonstration of a Fuel Cell Powered Ground Support Equipment (GSE) Revised Safety Plan, November 1, 2018.
7. Site Visit Safety Review – Gas Blending System Hydrogen Modifications, September 20, 2018.
8. Safety Plan Review – PGM-free Engineered Framework Nano-Structure Catalyst, July 18, 2018.
9. Safety Plan Review – Super Metallated Frameworks as Hydrogen Sponges, July 2, 2018.
10. Safety Plan Review – Advanced PGM-free Cathode Engineering for High Power Density and Durability, July 2, 2018.
11. Safety Plan Review – Best-in-class platinum group metal-free (PGM-free) catalyst integrated tandem junction photoelectrochemical (PEC) water splitting devices, June 18, 2018.
12. Safety Plan Review – Proton-Conducting Solid Oxide Electrolysis Cells for Large-scale Hydrogen Production at Intermediate Temperatures, June 7, 2018.
13. Safety Plan Review – Characterization and Accelerated Life Testing of a New Solid Oxide Electrolysis Cell, June 6, 2018.
14. Safety Plan Review – Thin-Film, Metal-Supported High-Performance and Durable Proton-Solid, June 4, 2018.

Publications and Presentations

Since the 2018 AMR

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1. Barilo N.F. 2018. "FY2018 PNNL Hydrogen Safety Program Annual Report." PNNL-SA-140012. Richland, WA: Pacific Northwest National Laboratory.
2. Barilo N.F. 12/13/2018. "Update on Hydrogen Safety Panel Sustainability and the AIChE Center for Hydrogen Safety." Presented by N.F. Barilo at Hydrogen Technical Advisory Committee Meetings, Wash, District Of Columbia. PNNL-SA-139915.
3. Barilo N.F. 12/13/2018. "Increasing the Value Proposition: Hydrogen Safety." Presented by N.F. Barilo at Presentation to be given via Webinar, Online Webinar, United States. PNNL-SA-139982.
4. Barilo N.F. 11/13/2018. "Hydrogen and Fuel Cell Technologies – U.S. Standards/Regulations and Government Role in Technology Rollout." Presented by N.F. Barilo at Presentation was given at a meeting in South Australia, Australia. PNNL-SA-139917.
5. Barilo N.F. 09/12/2018. "Introduction to Hydrogen and Fuel Cell Technologies and Safety Considerations." Presented by N.F. Barilo at Stakeholder meetings in the Northeast U.S., New York, New York. PNNL-SA-137745.
6. Barilo N.F. 09/12/2018. "Introducing the Hydrogen Safety Panel and Safety Resources." Presented by N.F. Barilo at DOE CCAD Stakeholder Meetings, New York, New York. PNNL-SA-137746.
7. Barilo N.F. 09/19/2018. "Hydrogen Safety Panel Learnings and Gaps." Presented by N.F. Barilo at HySafe Research Priorities Workshop, Buxton, United Kingdom. PNNL-SA-137902.
8. Barilo N.F. 05/25/2018. "Hydrogen Safety Resources." Presented by Nick F Barilo at Hydrogen South Africa Hydrogen Safety Awareness. PNNL-SA-135026.
9. Barilo N.F. 06/15/2018. "Hydrogen Safety Panel, Safety Knowledge Tools, and First Responder Training Resources." Presented by Nick F Barilo at DOE Annual Merit Review, Wash, District Of Columbia. PNNL-SA-133744.