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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

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

PNNL-SA-152630

Overview

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HYDROGEN SAFETY PANEL (HSP) AND RESOURCES

Project Timeline

- Project start date: March 2003
- Project end date: September 2020[1]

Budget

- FY19 DOE funding: $1140K
- FY20 DOE funding received a/o February: $272K
- Planned FY20 DOE funding: $425K new

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

Partners

- Panel member organizations
- California Fuel Cell Partnership (CaFCP)
- 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

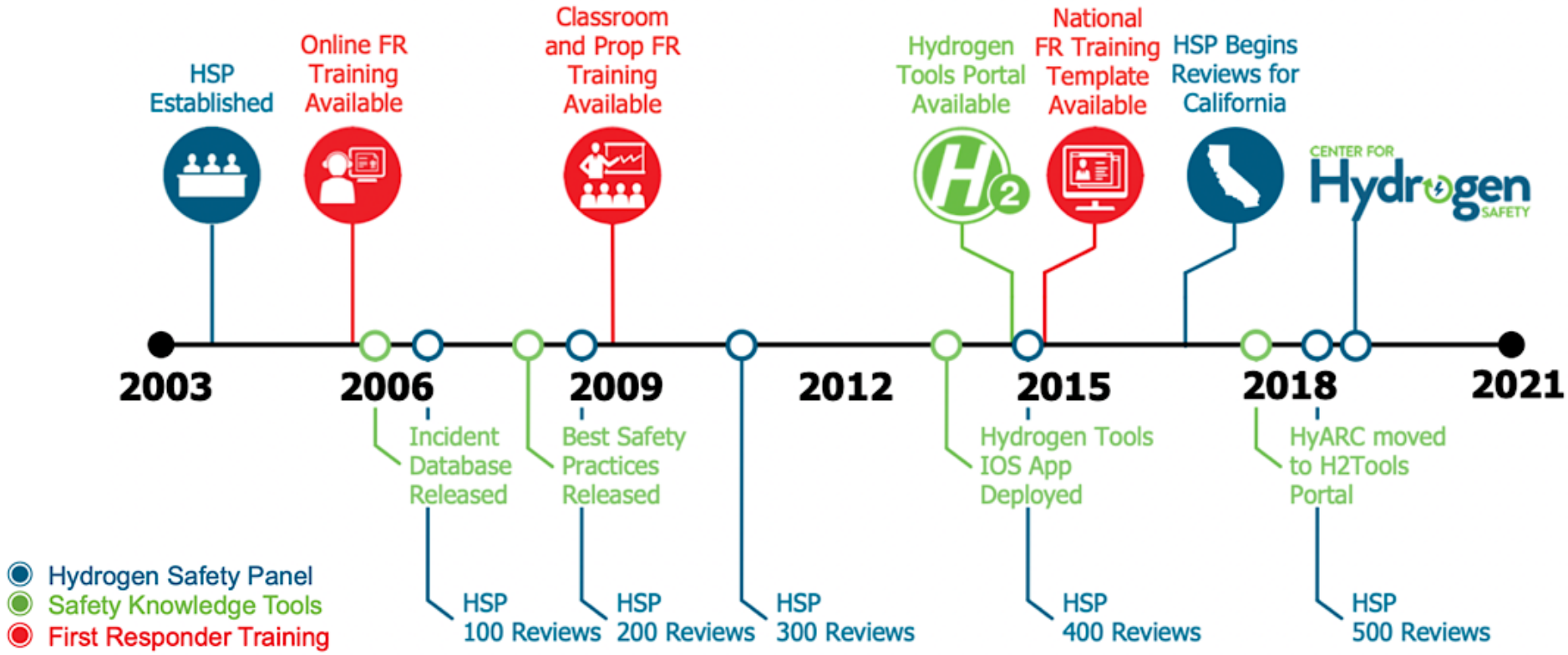
HYDROGEN
Tools

- 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

Hydrogen Safety Panel Membership

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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.

HSP at 2019 Panel Meeting

Name	Affiliation
Nick Barilo, Manager	Pacific Northwest National Laboratory
Rick Tedeschi, Chair	Tedeschi Consulting Solutions, LLC
Harold Beeson	WHA International, Inc
Ken Boyce	UL, LLC
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
Larry Moulthrop	Proton Onsite (retired)
Spencer Quong	Quong & Associates
Brian Somerday	Somerday Consulting, LLC
Tom Witte	Witte Engineered Gases and Cryogenics
Robert Zalosh	Firexplo

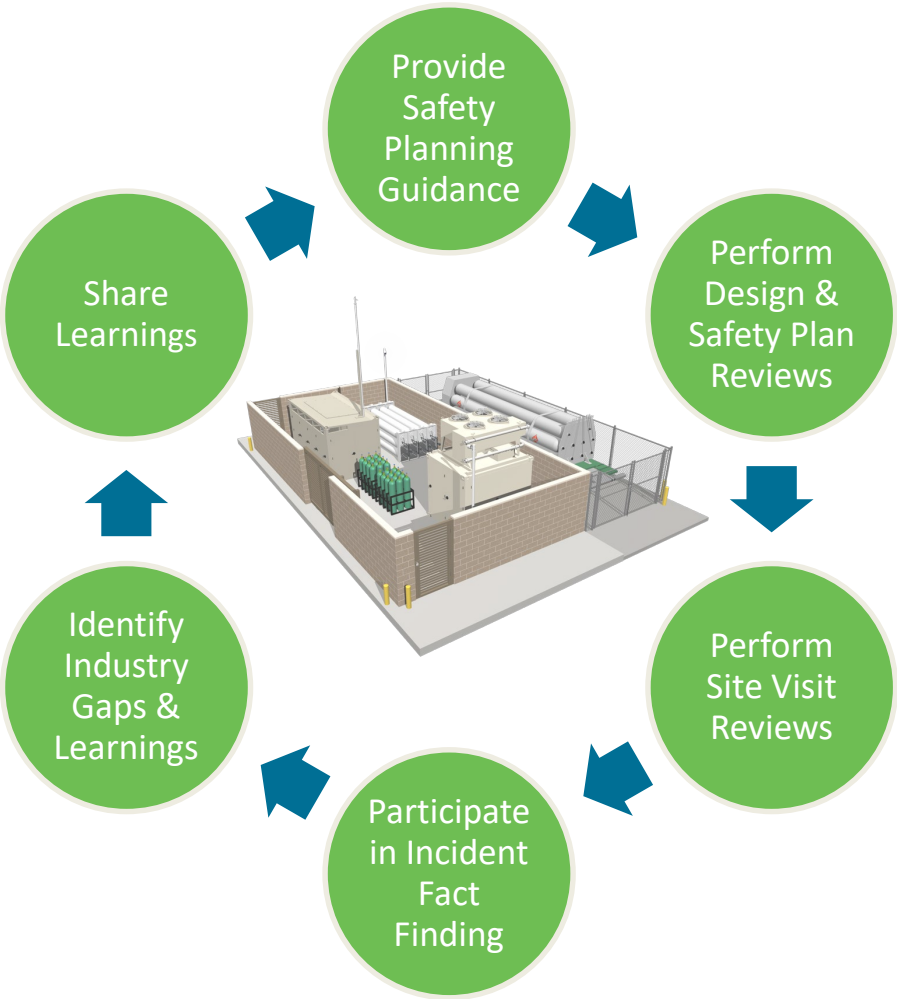
Relevance

HSP's overall 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



Accomplishments
Highlights

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- 26th HSP Meeting in Sacramento, CA

  Evaluated laboratory training, connected on potential NRC scope, discussed recent hydrogen incidents, changes to codes and standards, update from task groups on mobile applications and materials compatibility
- HSP members performed a hazard analysis review for the US Navy at General Atomics in San Diego, CA
- NREL site visit to evaluate the use of high-temperature hydrogen
- Performed a significant update of the document "Safety Planning for Hydrogen and Fuel Cell Projects"
- Led a hydrogen safety planning webinar for the State of California
- Developed a document to simplify access to the H2Tools Lessons Learned information

HSP Team at NREL - 2019

HYDROGEN Safety Panel

529 Safety Reviews

364 Projects

100+ Publications and Presentations

26 Panel Meetings

12 White Papers

4 Investigations

Accomplishments
Other highlights

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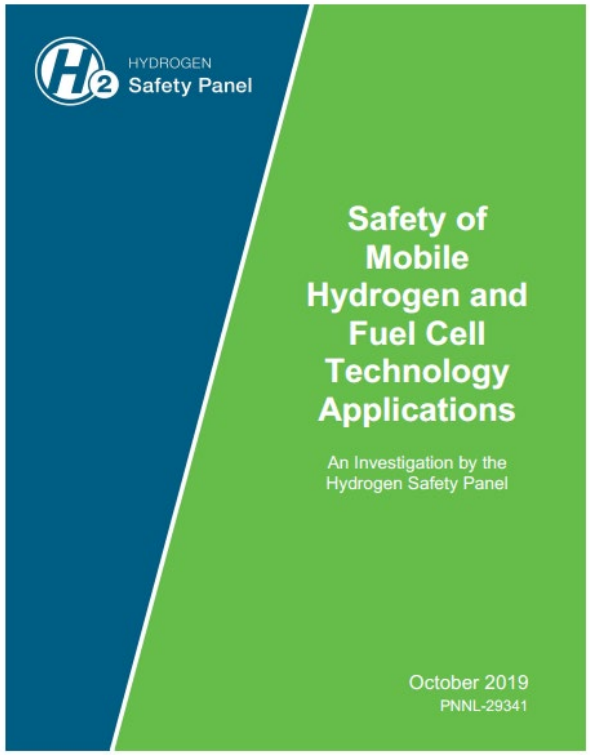
HSP completed a report on mobile applications (CEC funded)

- Evaluated diverse mobile hydrogen equipment applications for high pressure trailers, mobile/emergency powers supplies, mobile generators, seaport and airport remote cargo applications and unmanned aircraft systems
- Considered equipment design and configuration, previous equipment safety reviews, applicable state and federal regulations, pertinent consensus standards, and equipment incidents
- Summarized the status, offered conclusions, and provided recommendations for the safe use of this equipment in California



Accomplishments

Cooperative Research and Development Agreement (CRADA) awards/activities

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California Energy Commission CY19-23

- Activities 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) CY18-21

- 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

Accomplishments/Relevance

Highlighting activities that can benefit from HSP involvement

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Activities that can Benefit from Project/Facility Support

Early Concept Support

Pre-Project

- **Safety planning webinars**
- Pre-project outreach to stakeholders
- ***H_2 Safety training and orientation for code officials**
- Project team safety planning consultations

Early Design

- Safety plans reviews
- ***Review project/facility early designs**
- Participate in risk analyses development
- **Review risk analyses**
- *Address AHJ safety questions

Early Operation

- Evaluate safety features of completed facilities
- **Onsite safety evaluations**
- Provide first responder H_2 safety training

Program Support

- **Identify safety gaps**
- Develop industry guides
- ***Expert support for incident fact-finding and investigations**
- Bolster stakeholder and public confidence

Successful Project Implementation

* Support for AHJ and code officials can bridge the gap for inexperienced staff, facilitate faster approvals, support a greater confidence in project safety and provide more technically justified safety features or alternate means and methods

Accomplishments/Relevance

Highlighting the impact of HSP activities

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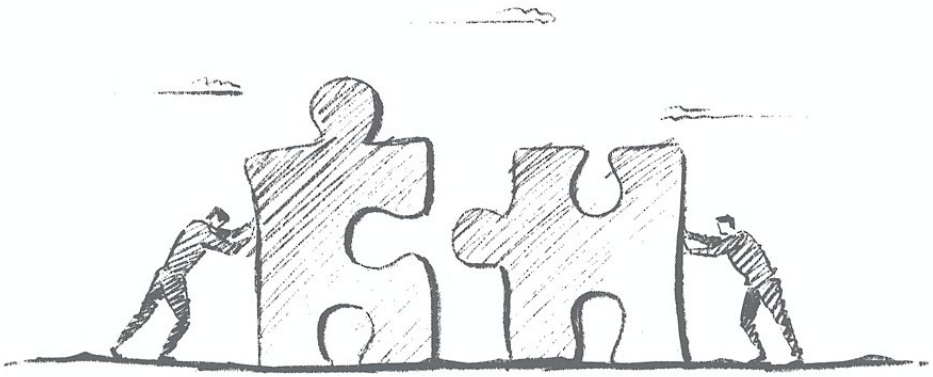
- Serves as a non-regulatory, objective, and neutral resource
- Sees the "big picture"
  - Shares learnings
  - Identifies gaps
- Can help reduce costs
  - Over-engineering resulting in unnecessary features
  - Delayed approvals
  - Missed safety considerations/features



- 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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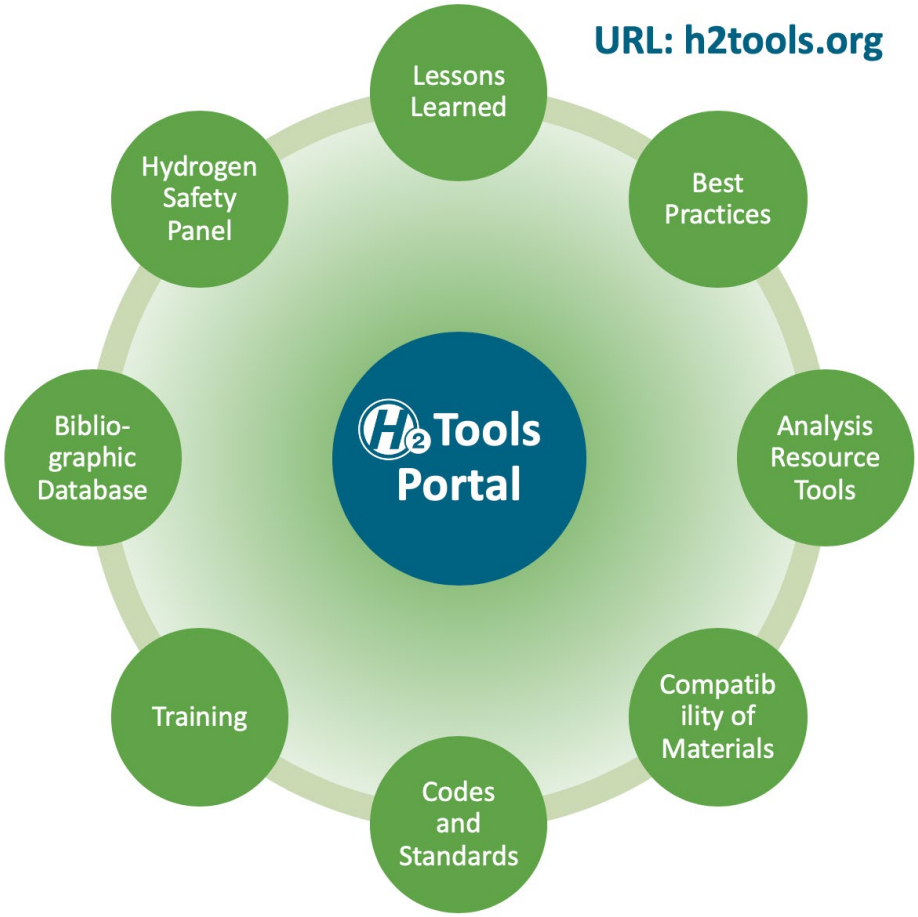
HydrogenTools

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.



Accomplishments

Hydrogen Tools website stats

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Site Content

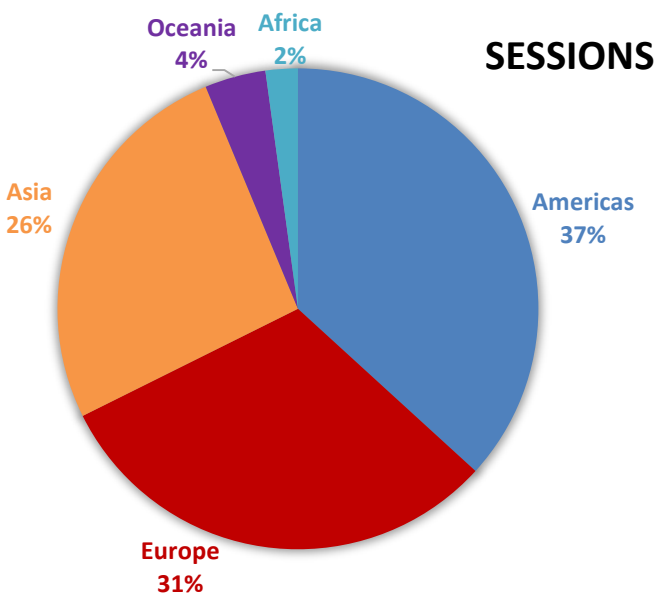
- **2,968** Total pages
- **2,385** Bibliographic references
- **222** Lessons learned pages
- **140** Best safety practices pages

Usage Stats*

- **20,650** Maximum pageviews in one month
- **17,528** Average pageviews/month
- **3.85** Pages visited per session
- **5:40** Minutes per session

HydrogenTools

A Global Resource!



Source: Google Analytics

* Nonbounce statistics through December 13, 2019

Accomplishments

Disseminating safety knowledge to reach critical audiences

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Hydrogen Safety Training and Stakeholder Meetings

- Public Outreaches to Stakeholders in New Jersey and Delaware
  - Raise awareness of the PNNL HSP among state/local officials and project developers.
  - Establish working relationships with key state and local organizations to enable seamless incident response and development of safety lessons learned.
  - Identify types of projects that would benefit from PNNL involvement.
  - Develop market strategies for additional safety reviews.
- Moved maintenance of H2tools to Drupal Connect to provide greater reliability of the site

drupalconnect

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First Responder Training

First Responder Training

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Accomplishments

- Transferred online hydrogen safety First Responder ttraining course to CHS (available on the AIChE Academy site)
- Created videos to make available for online training, and obtaining CEUs (completed by May 2020)

Future Plans

- Online training and National Training resources will be updated:
  - with video clips
  - to address NTSB concerns on Diamond Bar incident

Links

- H2tools Training Resources
  https://h2tools.org/training-materials
- AIChE Academy
  https://www.aiche.org/academy/courses/ela253/introduction-hydrogen-safety-first-responders

First Responder Training Videos

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- Five Videos
  - Introduction
  - Extrication
  - Fire Response
  - Transport
  - Station
- Interviews, actual equipment inspection, CGI operation, and staged scenarios
- Supported by fire departments, manufacturers, and training companies
- Directed by PNNL; produced by Campbell Training Solutions and MōViz Films

See https://h2tools.org/sites/default/files/Intro5_2.0.mp4 for an example of the videos

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Update on Center for Hydrogen Safety Activities

Accomplishments

Update on the Center for Hydrogen Safety

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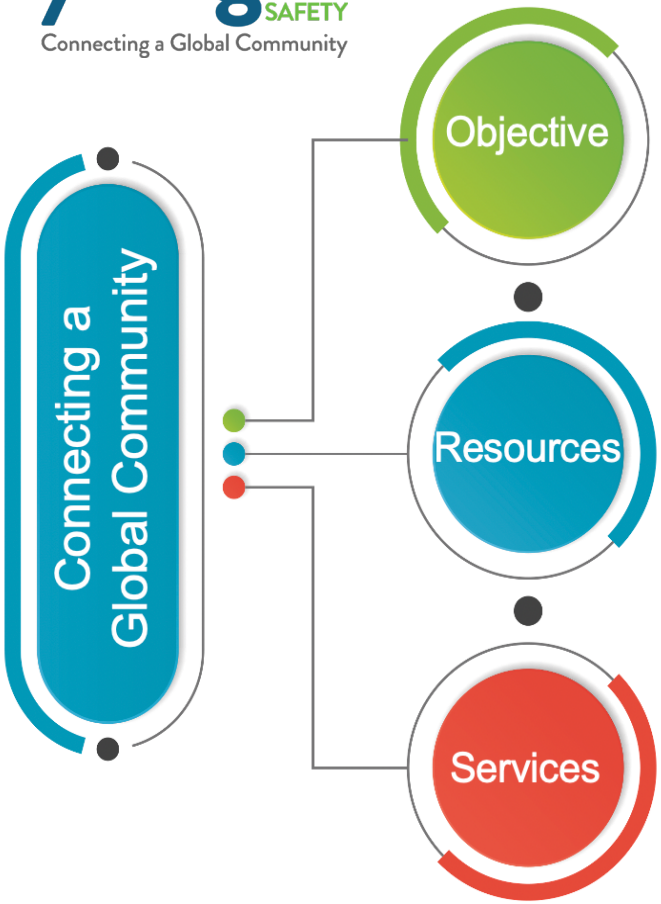
CENTER FOR Hydrogen SAFETY
Connecting a Global Community



Transfer knowledge in applied safety through:

- communication of best safety practices and lessons learned
- expert-based support for project design and operations issues
- outreach and education for stakeholders and first responders

- Utilize the Hydrogen Tools website portal for public sharing of safety information, lessons learned, best safety practices, codes and standards, etc.
- Online hydrogen safety education resources for a variety of audiences
- Educational videos, publications and information
- Newsletters and technical bulletins
- Incident response resources and guides
- Member only online resources and tools

- Hydrogen Safety Panel for expert-based reviews and support
- Hydrogen safety training and workshops
- First Responder training - classroom and live-fire evolutions
- Conferences and workshops

See www.aiche.org/chs for additional information

Accomplishments

Update on the Center for Hydrogen Safety

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CHS Membership

Industry Members (14)

- AC Transit
- Air Liquide
- Air Products
- DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.
- TRUE ZERO FirstElement
- TOYOTA
- nationalgrid
- Nebraska Public Power District
- nel
- pdc MACHINES.COM
- PLUG POWER
- SHELL
- SCEJ The Society of Chemical Engineers, Japan
- SunLine Transit Agency

Small Business Members (8)

- Astra Rocket Company
- ALAKAI TECHNOLOGIES
- BAYOTECH
- HySUT
- POWER INNOVATIONS
- PROTIUM
- WHA

University Members (4)

- HySA Infrastructure Hydrogen South Africa
- RIO HONDO COLLEGE
- THE UNIVERSITY OF CALIFORNIA IRVINE
- WASHINGTON STATE UNIVERSITY

National Laboratory Members (6)

- Pacific Northwest NATIONAL LABORATORY
- UL
- Argonne NATIONAL LABORATORY
- NREL NATIONAL RENEWABLE ENERGY LABORATORY
- Sandia National Laboratories
- SRNL SAVANNAH RIVER NATIONAL LABORATORY

Government (2)

- STATE OF CALIFORNIA ENERGY COMMISSION
- AUSTRALIA

(Coming soon)

Executive Board (5)

- AIChE
- Air Liquide
- hySafe INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY
- STATE OF CALIFORNIA ENERGY COMMISSION
- SHELL

Strategic Partners (5)

- IPHE
- Hydrogen Council
- California FUEL CELL PARTNERSHIP DRIVING FOR THE FUTURE
- RHA RENEWABLE HYDROGEN ALLIANCE
- INERC BV Quality Services for Operations

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CHS Goals for 2020

Program	Goals
Networking	• Hold two global conferences • Develop plan for engagement with global H_2 community through speaking opportunities
Communication	• Deliver 10 newsletters to CHS members • Create and deploy 3 technical bulletins
Education and Training	• Create a second version of the First Responder course with enriched content • Develop strategy for translating CHS materials into non-English languages • Create Hydrogen Safety for Researchers/Technicians course • Create many hydrogen safety courses based on Best Safety Practices from H2Tools.org
Capabilities	• Stand up incident response resource guide • Enhanced website for incident tracking • Perform seven Hydrogen Safety Panel reviews • Launch members only section of website for resources

Proposed Future Work, Collaborations, and Presentation Summary

Proposed Future Work

Remainder of FY 2020

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Hydrogen Safety Panel

- Continue safety reviews for DOE-funded projects
- Continue to support the CEC hydrogen fueling station deployment and renewable production facility activities
- Work with AIChE to support hydrogen safety reviews for the CHS

Safety Knowledge: Tools and Dissemination

- Maintain Hydrogen Tools Portal
- 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 2021

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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 in 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 the 2019 International Conference on Hydrogen Safety in Adelaide, South Australia
- 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
- AIChE through support of the Center for Hydrogen Safety resources and activities

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.

  The HSP's availability and accessibility as a resource for these applications are expanded to a broader industry and stakeholder community through the CHS.

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

First Responder Training

- The National Training Resource has been well received and provides the best opportunity to support FR training for hydrogen and alternative fuels. The transition of first responder training to the CHS will ensure that these benefits will be maintained.

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Responses to Select 2019 AMR Reviewer Comments

Response to 2019 Reviewer Comments

1. The project should consider whether it is time to start migrating some of these tasks to other individuals and organizations.

We agree. In 2020 First Responder training resources will be fully transitioned to the CHS. We continue to evaluate timing and scope for transitioning other resources to the CHS, for example, the H2tools website and the HSP, consistent with DOE's and industry's needs.

2. The project should begin to anticipate the future needs to help spread hydrogen to new regions and into new applications. Planning appropriately for this expansion will be crucial to ensuring the longevity of the project's efforts in their current form at the CHS.

We have developed a streamlined contracting process for access to the HSP. Contracting time has been reduced from 3-6 months to 1-2 weeks. We have projected an increase in HSP reviews, and are continually reassessing HSP resources for future viability.

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
- First Responder Video Companies and Agencies
  - Campbell Training Solutions
  - MōViz Films
  - Los Angeles County Fire Department
  - Del Valle Regional Training Center
  - Richland, Washington Fire Department
  - Hyundai-Kia Motors
  - Toyota Motors North America, Inc.
  - Iwatani Corporation of America
  - Air Products and Chemicals, Inc.
  - SunLine Transit Agency

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Technical Backup Slides for the 2020 Annual Merit Review and Peer Evaluation

Project Safety Plan and Topical Reviews

Since the 2019 AMR

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#	Firm	Topic	Date
1	Giner ELX	Anode-Boosted Electrolyzer	04/12/2019
2	Skyre	Electrolyzer Integrated Modular Nano-Array Monolithic Catalytic Reactors	05/16/2019
3	Vanderbilt Univ.	Composite PEMs from Electrospun Crosslinkable Polyphenylene Sulfonic Acids	05/16/2019
4	H2B2	SoHyCal Hydrogen Production Facility	05/19/2019
5	Hydrogenics	Stratos Fuel ZIP Renewable Production Plant	05/22/2019
6	Univ. of Kansas	Stationary Direct Methanol Fuels Using Pure Methanol	06/26/2019
7	Iwatani	Hydrogen Fueling Station, Revision	07/30/2019
8	WA State Univ.	Cryo-Catalysis Hydrogen Experiment Facility	07/31/2019
9	Plug Power	Heisenberg Vortex Tube Project	07/31/2019
10	Giner	High Efficiency Reversible Alkaline Membrane Fuel Cells	09/16/2019
11	Skyre	Electrolyzer Integrated Modular Nano-Array Monolithic Catalytic Reactors-Update	10/01/2019
12	DOD-Navy	APED Fuel Cells	11/06/2019
13	NREL	Thermal and Catalytic Process Development Unit	12/10/2019
14	First Element	Alternative and Renewable Fuel and Vehicle Technology Program Infrastructure-Update	12/11/2019
15	Xergy	Membrane Electrode Assembly for Fuel Cell Development	12/12/2019
16	Penn. State. Univ.	Advanced AEM's with Tunable Water Transport	01/06/2020

Documents, Publications, and Presentations

Since the 2019 AMR

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1. Barilo N.F. 04/30/2019. “Hydrogen Safety Panel Evaluation of Hydrogen Facilities." PNNL-SA-141332. Richland, WA: Pacific Northwest National Laboratory.
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5. Barilo N.F. 09/25/2019. “An Investigation of Mobile Hydrogen and Fuel Cell Technology Applications.” PNNL-SA-147238. Richland, WA: Pacific Northwest National Laboratory.
6. Barilo N.F. et al. 2019. “An Investigation of Mobile Hydrogen and Fuel Cell Technology Applications.” Presentation to the International Conference on Hydrogen Safety. PNNL-SA-142286. Richland, WA: Pacific Northwest National Laboratory.
7. Barilo N.F. 01/15/2020. “Safety Planning for Hydrogen and Fuel Cell Projects – California.” PNNL-SA-150422. Richland, WA: Pacific Northwest National Laboratory.
8. Barilo, N.F. 2019. “Safety of Mobile Hydrogen and Fuel Cell Technology Applications.” PNNL-29341. Richland, WA: Pacific Northwest National Laboratory.
9. Barilo N.F. 2019. “Safety Planning for Hydrogen and Fuel Cell Projects.” PNNL-25279-2. Richland, WA: Pacific Northwest National Laboratory.
10. Barilo N.F. “Hydrogen Safety Panel, Safety Knowledge Tools and First Responder Training Resources.” PNNL-29432. Richland, WA: Pacific Northwest National Laboratory.