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
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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 2017

Barriers Addressed
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 (AHJ)
E. Lack of hydrogen training materials and facilities for emergency responders
G. Insufficient technical data to revise standards

Budget
► FY16 DOE Funding: $895K
► Planned FY17 DOE Funding: $775K
  ▶ Hydrogen Safety Panel (HSP): $525K
  ▶ Safety Knowledge Tools: $125K
  ▶ First Responder (FR) Training: $125K

Partners
► Panel member organizations
► California Fuel Cell Partnership (CaFCP)
► National Renewable Energy Laboratory (NREL)
► Sandia National Laboratories (SNL)
► California Energy Commission

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)
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

Tools
- Hydrogen Lessons Learned
- Hydrogen Best Practices
- Hydrogen Tools web portal (http://h2tools.org)

Emergency Response Training Resources
- Online awareness training
- Operations-level classroom/hands-on training
- National hydrogen and fuel cell emergency response training resource
Objectives

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

**Hydrogen Safety Panel (HSP)**
- 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.

**Safety Knowledge Tools and Dissemination**
- 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.”

**First Responder Training**
- Implement a national hydrogen emergency response training resource program with downloadable materials that are adaptable to the specific needs of first responders and training organizations.
- Identify enhancements to first responder training content, techniques and delivery.
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
- Utilize 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 first responders and bring visibility to the program’s safety resources
PNNL Hydrogen Safety Program Timeline

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

2003

- Hydrogen Safety Panel Established
- Online FR Course Released
- Best Practices Online Manual Released
- Incident Database Released

2005

- Classroom and Prop FR Training Available

2007

- HSP ARRA Project Report

2009

- First HSP Review of Non-DOE Project
- Certification Guide Released

2011

- Updated Online FR Training

2013

- National FR Template Released

2015

- Hydrogen Tools Portal Available

2017

- Hydrogen Tools App Available

2018

- HyARC added to Portal
Accomplishments:
Hydrogen Safety Panel
Safety practices, incorporating a wealth of historical experience with new knowledge and insights gained, are in place. Continuous and priority attention is being given to safety in all aspects of hydrogen and fuel cell technologies: research, development, and demonstration; design and manufacturing; and deployment and operations.

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Nick Barilo, Manager</td>
<td>Pacific Northwest National Laboratory</td>
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<tr>
<td>Richard Kallman, Chair</td>
<td>City of Santa Fe Springs Fire Dept.</td>
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<tr>
<td>*Eric Binder</td>
<td>Santa Monica Fire Department</td>
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<td>*Ken Boyce</td>
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<tr>
<td>David Farese</td>
<td>Air Products and Chemicals</td>
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<td>Donald Frikken</td>
<td>Becht Engineering</td>
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<td>Livio Gambone</td>
<td>CSA Group</td>
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<td>Aaron Harris</td>
<td>Air Liquide</td>
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<td>Chris LaFleur</td>
<td>Sandia National Laboratories</td>
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<tr>
<td>Miguel Maes</td>
<td>NASA-JSC White Sands Test Facility</td>
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<tr>
<td>Steve Mathison</td>
<td>Honda Motor Company</td>
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<tr>
<td>Larry Moulthrop</td>
<td>Proton OnSite (retired)</td>
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<tr>
<td>Glenn Scheffler</td>
<td>GWS Solutions of Tolland</td>
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<tr>
<td>Tom Witte</td>
<td>Witte Engineered Gases</td>
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<td>Robert Zalosh</td>
<td>Firexpo</td>
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*Indicates a new member since 2016 AMR
Accomplishments

Finding solutions... Hydrogen Equipment Certification Guide

A Hydrogen Equipment Certification Guide has been released to assist code officials, designers, owners, evaluators, and others with the application of the listing and approval requirements pertinent to the design and/or installation of hydrogen equipment as regulated by the model codes.

Gaps Addressed

► In the early market, the availability of systems or equipment that are listed, labeled, or certified is limited
► When equipment is not listed or available, “approval” by the code official is required before installation occurs

Benefits Provided

► Enables code users to better apply the requirements where the use of listed, labeled, certified, or approved equipment or methods is required, and to increase awareness and understanding of what the equipment is expected to do
► Increased consistency in the application of requirements with the expectation of an expedited permitting process
► Consistent application of requirements among providers, regardless of hydrogen experience, results in a level playing field as the technology emerges

Accomplishments

Supporting the safe rollout of California infrastructure

- Contracted by the California Energy Commission (CEC) to support the construction of new hydrogen fueling stations through the following services
  - Provided guidance for preparing safety plans
  - Participated in pre-award safety consultation for applicants
  - Reviewed safety plans submitted by 12 applicants to California’s GFO-605 and provided comments to the CEC in support of award decisions
  - Additional support to be provided until funded stations have been complete for three years

- March 2017 — 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
  - Pertinent learnings from the meetings may be added to the Best Safety Practices online resource
Accomplishments

Other Highlights

- 23rd HSP Meeting in Washington, DC — Participation included representatives from the Department of Transportation and Department of Defense, and included discussion of timely topics on transportation issues (mobile applications, tank issues, etc.) and unique DOD fuel cell applications
- H-Prize site visit (SimpleFuel) in support of the final prize award
- Participated in a hydrogen incident fact finding visit at a major university
- To measure the HSP’s impact, submittal of safety review comments now include a request for feedback from principal investigator
  - Was the interaction helpful?
  - What did the HSP do well?
  - What could the HSP do better?

“I cannot emphasize enough how vital & timely the HSP involvement was during this [H-Prize] competition – appropriately informing our product safety architecture, and enabling us to galvanize our appliance design.”

Darryl Pollica, IVYS Energy Solutions
Accomplishments

HTAC Event Response Subcommittee Report

A subcommittee of the Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) members worked together beginning in January 2016 to review and assess current resources such as safety plans; event response plans; current federal, state, and local requirements; and case studies to identify gaps and recommend actions to address current and projected needs.

Recommendation #1 - Maximize the Role of the Hydrogen Safety Panel

DOE should develop a strategic plan that positions the HSP as a trusted resource on hydrogen safety, invests in marketing to make the HSP more visible, and provides resources to enable the HSP to develop relationships with safety officials at the local, state, and national levels. While state and privately funded projects should also budget for HSP involvement, DOE should enable federal funding to support non-DOE funded projects with the goal of broadly advancing hydrogen FCEVs. The recommendation identifies four objectives:

▶ Raise awareness of the HSP and H2Tools targeting project developers and state/local officials
▶ Establish working relations (MOUs, etc.) with key state and local organizations for incident response
▶ Identify methods to facilitate outside organizations paying for HSP services
▶ Identify types of projects that would benefit from HSP involvement

The strategic plan is currently being drafted by PNNL.

Note: Any proposed future work is subject to change based on funding levels.
The past two years have seen expanded use of the HSP reviewing federal and state projects

### Accomplishments

#### Hydrogen Safety Panel scorecard

<table>
<thead>
<tr>
<th>Activity</th>
<th>Since the 2016 AMR</th>
<th>Total for the Project Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Reviews (including safety plans, site visits reviewed, follow-up interviews and design review activities)</td>
<td>30*</td>
<td>468</td>
</tr>
<tr>
<td>Panel Meetings</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>White Papers, Recommendations, etc.</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Accident Investigations</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Publications, Presentations, and Webinars (all tasks combined total)</td>
<td>9</td>
<td>66</td>
</tr>
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* (includes 12 California fueling station submittals under contract with the CEC)
Hydrogen Tools Portal

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.

http://h2tools.org

Credible and reliable safety information from a trustworthy source.
Accomplishments

Enriching the content of the Hydrogen Tools portal

Completed

► 633 papers (with searchable content) from the International Conference on Hydrogen Safety added to the Hydrogen Tools portal (https://h2tools.org/ichs)
► HyRAM discussion forum (https://h2tools.org/forums/hyram)
► Permitting Hydrogen Fueling Station videos (https://h2tools.org/videos)

In-Progress

► Relocation of the Hydrogen Analysis Resource Center (HyARC) to the Portal (HyARC provides well-documented, reliable data for use in evaluating hydrogen-related technologies)
► Updates to and new content provided for the Best Safety Practices resources, including short topic-related videos from HSP members
► HyRAM resource information page and download link
► Hydrogen Equipment Certification Guide information pages
Accomplishments

Hydrogen Tools Portal Stats

Site Content

- **3,581** Total Pages
- **2,414** Bibliographic References
- **217** Lessons Learned Pages
- **142** Best Safety Practices Pages

Usage Stats*

- **135,160** Total Pageviews
- **23,805** Sessions
- **5.68** Pages Visited per Session
- **7:26** Minutes per Session

*Nonbounce statistics through March 31, 2017

H2Tools.org - A Global Resource!

- United States: 51%
- Asia: 18%
- Europe: 20%
- Other Americas: 7%
- Oceania: 2%
- Africa: 2%

Usage over time (Jun-15 to 17-Mar):

- Pageviews:
  - Jun-15: 0
  - Sep-15: 8000
  - Dec-15: 8000
  - Mar-16: 12000
  - Jun-16: 12000
  - Sep-16: 12000
  - Dec-16: 12000
  - 17-Mar: 8000
Accomplishments

Disseminating safety knowledge to reach critical audiences

International Collaboration

- PNNL worked with Hydrogen South Africa, hySafe, and the U.K.’s Health and Safety Laboratory to provide an online hydrogen safety awareness webinar/panel discussion for code officials and stakeholders in South Africa in October 2016
- PNNL presented “Safety Resources for Hydrogen and Fuel Cell Applications” to Korean and Japanese Delegations in January 2017

U.S. Stakeholder Outreach

- NFPA Conference and Expo (June 2017)
- Maryland Tunnel Authorities (February 2017)
- Boston, MA, Tunnel Authorities and First Responders (October 2016)
- Washington State Energy Employees (July 2016)

“Many thanks for your presentations yesterday, and making time available over the last couple of months in preparation for yesterday. I think the event went really well. So again thanks for an excellent job, I really do appreciate your dedication to knowledge dissemination on the subject of Hydrogen safety. We could maybe consider replicating an event like this in other cities, such as Johannesburg or Polokwane, where there are talks of Hydrogen buses roll-out.” - Brian North, Clean Energy Tech. at CSIR, South Africa
Accomplishments

Establishing long term goals – Multi-lab Outreach Plan

**Outreach Plan Goal: Proactively reaching stakeholders to ensure a safe transition to hydrogen and fuel cell technologies**

- Recent outreach activities have identified the need for a more formal systematic approach to reach stakeholders
- The outreach plan helps ensure that important stakeholder organizations have necessary knowledge to ensure the safe and timely deployment of this technology
- The plan is expected to include participation by PNNL, NREL, and SNL, with support from DOE FCTO
Accomplishments

Federal Energy Management Program (FEMP) Outreach

► Goal: Provide agencies and organizations with the information, tools, and assistance they need to deploy clean energy technologies

► A key challenge is educating early adopters and other stakeholders on FCEVs as fleet vehicles and the operation of associated hydrogen infrastructure

► PNNL and NREL will collaborate to develop training material and train agencies over a 5 year effort, transitioning in a strategic, coordinated way as FCEVs become more widely available in federal fleets

Anticipated PNNL Funding
FY17
FEMP - $40K
FCTO - $40K

FY18
FEMP - $40K
FCTO - $25K

FY19-FY21
FEMP - $55K/year
FCTO - $20K/year

Note: Any proposed future work is subject to change based on funding levels.
Accomplishments/Future Work

Federal Energy Management Program (FEMP) Outreach

FY17
► Incorporate introductory hydrogen information into FEMP training and outreach material
   ► PNNL will present at the August 2017 Energy Exchange

FY18
► Develop a follow-on FEMP training webinar
► Training and/or workshops will be expanded to three additional federal agencies and include a module on fleets

FY19
► Develop a third FEMP training webinar as a follow-on to the FEMP training webinar
   ► Materials will be prepared for FEMP’s certificate series and deploy it on the FEMP training website
   ► Training and/or workshops will be expanded to five additional federal agencies

FY20
► Update technical and training tools and create train the trainer and virtual training material to reach a broader group of stakeholders

FY21
► Update the train-the-trainer training to include not just light duty vehicles but other applicable vehicles such as medium and heavy-duty vehicles
► Training and/or workshops will expand to an additional five federal agencies

Note: Any proposed future work is subject to change based on funding levels.
Opportunities for New Resources

Proposed Online Code Verification Tool

Enabling those with limited experience... An online tool to make it fast and easy for builders, designers, and contractors to determine whether their proposed hydrogen fueling stations meet the requirements of NFPA 2 (Hydrogen Technologies Code) and the International Fire Code (IFC), and simplify efforts of building and fire officials, plan checkers, and inspectors responsible for verification of compliance with those requirements by allowing them to quickly identify the requirements for a specific installation and apply them to their code enforcement tasks.

Potential Impact

- Decrease the time and costs needed for preparing and reviewing plans and issuing permits
- Ensure accuracy and consistency in the application of NFPA 2 and the IFC
- Enable paperless plan checks and code studies (green)
- Speed up the transfer of information

Note: Any proposed future work is subject to change based on funding levels.
Accomplishments:
First Responder Training
Accomplishments
First Responder Outreach – Northeast U.S.

Supporting the Rollout of Infrastructure and Vehicles

- Fall 2016 – more than 250 Attendees
  - Hempstead, NY
  - Stow, MA
  - Hartford, CT
- Fall 2017 Proposed Activities
  - Classroom training
  - Prop demonstration
  - Virtual reality exercises

Activity Partners

Fall 2016 Training
Accomplishments

First responder training...by the numbers

Online Training
>Refreshed in February 2017

Classroom Training
>1,350 attendees since 2009

National Template
>330 downloads since 2014
Accomplishments/Future Work

What’s coming next... enriching training content

PNNL is now utilizing 3D simulation software for picture and video content

► Training First Responders
  ► Scenario development
  ► Attack strategies
  ► Visualize results of modeling (code officials, tunnel engineers, etc.)

Flame impingement on tunnel ceiling

TPRD release

Examples of beneficial uses

Video clips & pictures for visualizing scenarios...

Content for outreach meetings and reports

... and Identifying approaches and attack strategies
Proposed Future Work, Collaborations and Presentation Summary
Proposed Future Work

Remainder of FY 2017

Hydrogen Safety Panel
► Continue early project engagements and safety reviews for DOE funded projects
► Continue to support the California Energy Commission hydrogen fueling station deployment activities
► Finalize the HSP strategic plan
► Conduct the 24th Hydrogen Safety Panel meeting in Quincy, MA

Safety Knowledge: Tools and Dissemination
► Update and incorporate new content into the Best Safety Practices resource
► Finish relocation of the HyARC and HyRAM resources to the Hydrogen Tools portal

First Responder Training
► Revise training materials based on learnings from recent trainings in the Northeast (Fall 2016)
► Continue planning for a significant operations-level training in the Northeast in the Fall 2017 which will include classroom training, prop demonstrations and may also include virtual reality training

Note: Any proposed future work is subject to change based on funding levels.
Proposed Future Work
FY 2018

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 activities

Safety Knowledge Tools and Dissemination
► Expand the value and impact of the Hydrogen Tools portal by incorporating new tools and resources from other national laboratories and private organizations
► Develop a codes and standards guide – a drill down, question based tool to provide an outline or checklist of code requirements for a specific application (if funding is made available)
► Outreach to a variety of stakeholders and organizations in accordance with the formal outreach plan

First Responder Training
► Bring classroom, props and virtual reality training (in collaboration with CRISE/HyResponse) to the Northeast in April 2017
► Incorporate 3D simulation software outputs into all training resources (online, classroom and the downloadable National Hydrogen and Fuel Cell Emergency Response Training Resource)

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

Hydrogen Safety Panel and Safety Knowledge Tools

- Organizations supporting Hydrogen Safety Panel members
- NREL on NFPA 2 liquid hydrogen task group, safety outreach and code development activities
- SNL on California hydrogen station safety plan reviews and safety outreach activities
- Toyota and Air Liquide – first responder training activities
- California Fuel Cell Partnership in support of first responder training activities
- Council for Scientific and Industrial Research, South Africa in support of outreach activities
- CEC in support of safe infrastructure deployment and safety learnings
- FEMP in support of outreach 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 FCTO’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. Integrating information from DOE and other national laboratories is an opportunity to expand its value and impact, and warrants increased investment.
- 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 first responder training for hydrogen and broader alternative fuels focused activities. Emphasis will be needed to keep the material and training materials relevant and impactful.
Responses to Select 2016 AMR Reviewer Comments
Accomplishments

Responses to 2016 reviewer comments

“There are some concerns regarding the H2Tools portal part of the task. The first concern is in regard to the response of a 2015 reviewer comment pertaining to data maintenance. Although it makes sense to have the owners keep this information updated, this may not happen for a number of possible reasons. Such updating requires resources. There is no clear commitment or plans to provide such resources. There is a risk that the data will not be maintained or that such maintenance may end up needing to be performed by project participants. The second concern has to do with the home page of the H2Tools website, which looks like the Fuel Cell & Hydrogen Energy Association (FCHEA) Hydrogen and Fuel Cell Safety Report, with articles pertaining to codes, standards and regulations—several of which have recently been featured in the FCHEA publication. There are also several articles featured that are unrelated to safety. The home page has the look and feel of a trade association or advocacy group rather than a site to aggregate hydrogen tools focused on safety.”

Thanks for the comments. The goal of the portal is to bring together and enhance the utility of a variety of tools and web-based content on the safety aspects of hydrogen and fuel cell technologies. It is was recognized early in the planning stages that the benefit of the portal would be best realized by bringing content into the site (making it searchable and relatable), rather than just providing links to outside resources. To address the risk of the information becoming outdated, the project works with contributors to ensure that the content is current. If a resource is deemed outdated or no longer beneficial, PNNL will remove from the Portal.

(Response continued on next slide)
Accomplishments

Responses to 2016 reviewer comments

(Continued Response)

- Regarding the second concern, which appears directed at the news articles linked on the home page... The approach for providing relevant news articles (safety or non-safety related) is aimed at enhancing visibility and drawing attention to the site in order to introduce the site’s resources to those who have may have not been aware of them. Additionally, the portal was named “Hydrogen Tools,” as it was anticipated that the Portal may include other non-safety resources that would be beneficial and/or impactful for users.

- “It is time for more attention to be given to the Northeast, with outreach and possibly more direct interaction with the HSP. To provide more resources for the outreach, training, and portal work, maybe a different funding model for the HSP should be considered. Possibly a user-funded model would help—for example, the financial burden of a safety review could be put on the project that is being reviewed, dividing up the financial responsibility among the projects that benefit from that review.”

- PNNL agrees with that there could be significant benefit realized from additional Northeast interaction with the HSP. The HSP’s recent interaction with the California Energy Commission demonstrated that it can be contracted directly. This approach can be used for other federal and state agencies and industry. A strategy plan is being prepared to bring visibility to the HSP’s resources in response to a recommendation in the Hydrogen Technical Advisory Committee communications report. This recommendation includes the need to investigate funding mechanisms for non-DOE projects.
Thank You!

- U.S. Department of Energy
  - Fuel Cell Technologies Office (Sunita Satyapal, Director; Will James, Safety, Codes, and Standards Manager; and Laura Hill)
- California Fuel Cell Partnership
  - Jennifer Hamilton and Bill Elrick
- 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
Technical Back-up Slides for the 2017 Annual Merit Review and Peer Evaluation
Publications and Presentations
(since 2012)


Note: Bold font identifies publications and presentations subsequent to the 2016 Annual Merit Review and Peer Evaluation Meeting


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