



HYDROGEN
Safety Panel

Learnings from Hydrogen Fueling Station Projects

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The Case for Safety

- ▶ Safety issues **must** be addressed for successful hydrogen technology development
- ▶ Safety issues can be a 'deal breaker'
- ▶ Hydrogen technology proponents and stakeholders cannot begin to individually understand or know how to effectively address all relevant safety issues
- ▶ Proponents and stakeholders are on a challenging 'technology highway' that is improved when they all collaborate
- ▶ A trusted source of information on hydrogen safety can drastically change the 'view from the road' and 'success of the trip'



PNNL's Hydrogen Safety Resources



HYDROGEN Safety Panel

- ▶ Identify Safety-Related Technical Data Gaps
- ▶ Review Safety Plans and Project Designs
- ▶ Perform Safety Evaluation Site Visits
- ▶ Provide Technical Oversight for Other Program Areas



HYDROGEN Tools

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



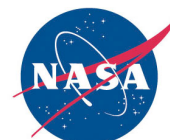
HYDROGEN Emergency Response Training Resources

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

Overview of the Hydrogen Safety Panel

- ▶ Formed in 2003
- ▶ 15 members having a combined 400+ years of experience
- ▶ Portfolio includes in safety reviews of vehicle fueling stations, auxiliary power, backup power, combined heat and power, industrial truck fueling, portable power and R&D activities
- ▶ Produces white papers and industry guides
- ▶ Supports the development and dissemination of safety knowledge through the Hydrogen Tools Portal (h2tools.org)
- ▶ Conducted 23 Hydrogen Safety Panel meetings since 2003, engaging a broad cross-section of the hydrogen and fuel cell community

Select Panel member organizations



Hydrogen Safety Panel Activities

Hydrogen Safety Panel (HSP) expert resource... *knowledgeable, neutral, experienced*

Specific activities

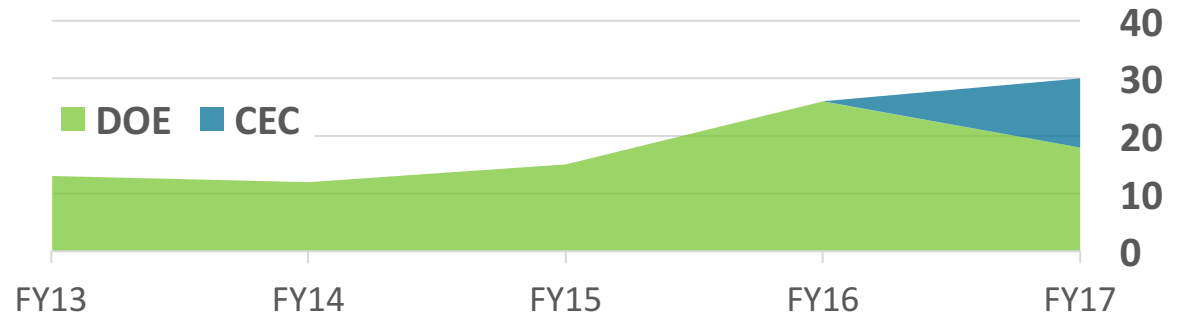
- ▶ Provide safety planning guidance
- ▶ Review project designs and safety plans
- ▶ Participate in site safety reviews
- ▶ Share safety knowledge and best practices
- ▶ Participate in outreach activities
- ▶ Participating in incident fact finding and investigations



Select HSP members at the California Fuel Cell Partnership in West Sacramento, CA, for the 21st meeting

Hydrogen Safety Panel Stats

The past two years have seen expanded use of the HSP reviewing federal and state projects



Activity	Since the 2016 AMR	Total for the Project Duration
Project Reviews (including safety plans, site visits reviewed, follow-up interviews and design review activities)	30*	474 (320 projects)
Panel Meetings	1	23
White Papers, Recommendations, etc.	1	8
Accident Investigations	1	4
Publications, Presentations, and Webinars (all tasks combined total)	9	66

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.

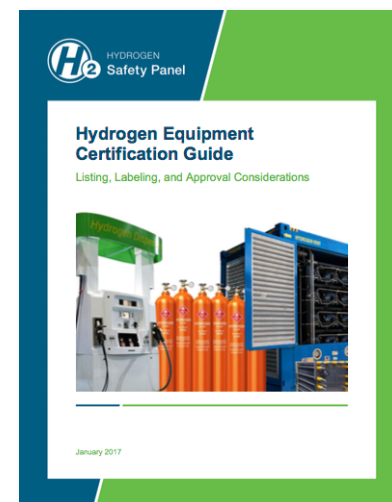
Gaps Addressed

- ▶ 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

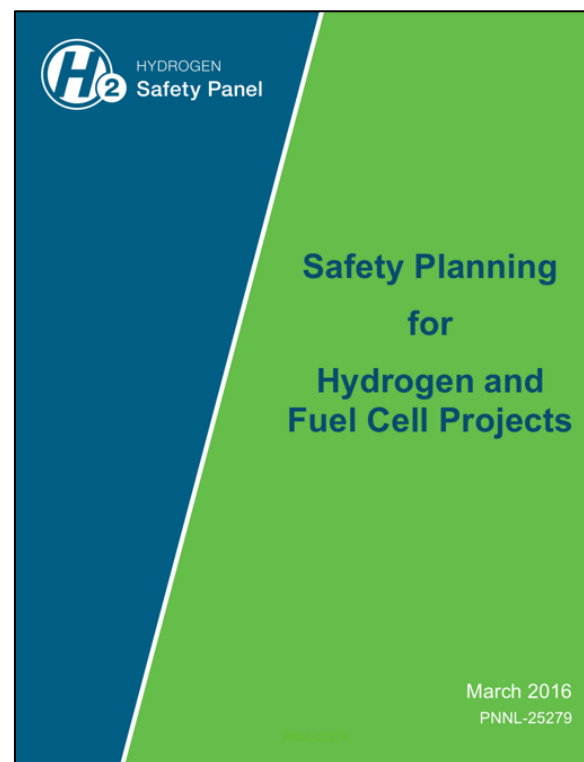
The *Guide* is available at <https://h2tools.org/certification-guide/overview>.



Guidance for Safety Planning of H₂ Projects

Safety planning should be an integral part of the design and operation of an H₂ system.

- ▶ Originally developed by the HSP for the U.S. Department of Energy in 2005
- ▶ The document provides information on safety practices for hydrogen and fuel cell projects
- ▶ The project safety planning process is meant to help identify risks and avoid potential hydrogen and related incidents
- ▶ This document can aid in generating a good safety plan that will serve as a guide for the safe conduct of all work related to the development and operation of hydrogen and fuel cell equipment
- ▶ An update of the document is planned for this summer



Recent Panel Activities for H₂ Fueling Stations

- ▶ California hydrogen fueling station GFO applicant safety plan reviews
- ▶ March 2017 HSP visit to 7 California locations
- ▶ Review of consultant report for Northeast US stations



South San Francisco



Woodside and Long Beach

GFO Activities – 2016 Call for H₂ Fueling Stations

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
- ▶ Provided comments to the CEC in support of award decisions
- ▶ Additional support to be provided until funded stations have been complete for three years








Safety Plan Reviews of GFO-15-605 Applications



- ▶ 12 applications
- ▶ Up to 35 locations per application
- ▶ Safety plans, narrative documents and site information reviewed
- ▶ Review report provided for each applicant (can be viewed at <https://h2tools.org/hsp/reviews> - screenshot on right)
- ▶ The reviews and process were evaluated for potential learnings
- ▶ The safety planning guidance document will be updated to benefit future station projects

Safety Resources and Reviews

SAFETY PLANNING RESOURCES

- Safety Planning for Hydrogen and Fuel Cell Projects - Latest Version 
 - Safety Planning for Hydrogen and Fuel Cell Projects - March 2016 
- Safety-Planning-for-the-2014-2016-H-Prize-Competition.pdf 
- Safety Planning Guidance for Hydrogen and Fuel Cell Projects - April 2010 (DOE projects) 
- Hydrogen Safety Checklist 

SAFETY PANEL REVIEWS

Title	Activity Type	Project Number	Date ▾	Links
Everfuel Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
A3L/Next Hydrogen Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
Shell Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
ITM Power/Greenlight Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
ITM Power/Linde Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
Jensen Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
Hydrogen-XT Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
Air Liquide Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
FirstElement Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
HTEC Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
Air Products Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 
StratosFuel Hydrogen Fueling Station	Safety Plan Review	GFO-15-605	December 2016	Download 

Technical Learnings from GFO-15-605 Reviews

- ▶ **Equipment siting** from property lines is not in accordance with NFPA 2 requirements
- ▶ **Courtyards** are provided with four walls, not complying with NFPA 2 requirements
- ▶ **Certification** of unlisted equipment needs to be verified against all applicable standards and requirements
- ▶ It is unclear how the performance and reliability of **control equipment** for safety systems is validated
- ▶ The potential safety impacts of hydrogen tanker **offloading activities** should be given greater consideration by project proponents and code development organizations
 - Hazards to the station's customers (public)
 - Risks from simultaneous tanker drops for hydrogen and hydrocarbons

Process Learnings from GFO-15-605 Reviews

- ▶ Detailed project-specific information is needed to perform a thorough evaluation
 - Timing of the review (application stage) may have affected the availability of important information
 - Utilizing the HSP for review at a later stage, perhaps early in the definitive design process, could result in a more impactful review and confidence in the project team's safety approach
- ▶ A site evaluation document incorporating the basis for the separation distances should be provided for each site as part of the safety plan
 - Any site not meeting the distance requirements of NFPA 2 should contain a technical basis for equivalent safety
- ▶ The project safety plan should cover all project partners and project phases (design, commissioning, operation and maintenance)
- ▶ Numerical grading of the safety plans (rather than qualitative grading) could assist applicant evaluations

Safety Guidance Document Improvements

- ▶ Expand the “additional documents” section to include:
 - A site plan showing distances to property lines and other necessary separation distances
 - Detailed information on vent system design
 - Critical safety equipment shutdown table
- ▶ Include new example material
 - Flow diagram showing safety related devices such as block valves, instruments and relief devices
 - Description of work (scope)
 - Operating procedures
- ▶ Require a list of codes tied to the applicable equipment and a discussion on equipment certification

A revision of the safety guidance document is expected by late summer 2017

March 2017 California Station Meetings

- ▶ Meetings were held at 7 California locations to discuss fueling station deployments
- ▶ Attendance included:
 - hydrogen fueling station builders
 - code officials
 - other state officials and stakeholders
- ▶ Goal – discuss safety issues and lessons learned from recent station deployments
- ▶ Resulted in over 100 pages of notes which were subsequently reviewed, categorized and binned
- ▶ Results were assembled into learnings and further reviewed by the entire HSP



Feedback and Learnings from CA Meetings

Items were organized into topical areas

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



Top Feedback/Learnings

► Station design

- There is a need for new innovation for station design
- Most stations are challenged to meet separation distance requirements (and typically don't for separation from lot lines)
- Already required prescriptive features are being credited to reduce separation distances

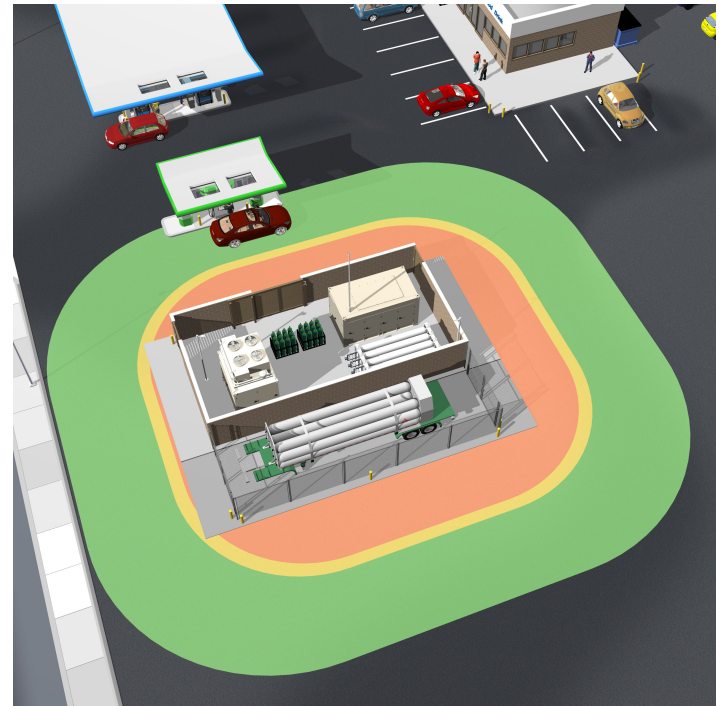
► First responders (FR)

- FR 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 (FCEVs)
- Short YouTube videos could be beneficial to reach broader audiences

► The lack of listed hydrogen equipment may result in an increase in station costs (third-party certification is needed for each new station)

Separation Distances

- ▶ Need for new innovative approach to station design/layout
- ▶ Separation distances cannot be met at most stations (particularly for lot lines)
- ▶ Station storage systems are typically enclosed by a four-wall court which does not comply with existing NFPA 2 requirements
- ▶ Comparisons between hydrogen and other fuels need to be correct, especially when considering separation distances
- ▶ Some code officials (incorrectly) felt strongly that installing hydrogen tanks underground would fully address separation distances issues, including the future need for liquid hydrogen



Certification

- ▶ The lack of listed hydrogen equipment may result in an increase in station costs (third-party certification is needed for each new station)
- ▶ Hydrogen equipment having non-US listing/certifications may not be accepted by AHJs in the US



Typical CE ATEX Label



Emergency Shutdown Systems (ESD)

- ▶ Projects should utilize control equipment for safety functions that has a high reliability and performance capabilities consistent with its intended use
- ▶ Station operators experience with false alarms of the flame detectors suggest that more reliable triple-IR detectors may be a better option
- ▶ Avoid cross-tying ESD for hydrogen with similar devices for hydrocarbon or other gaseous fuels because of a high rate of nuisance trips
- ▶ The number and location of manual ESD switches should be given thorough consideration with the objective of reducing the number of nuisance trips and cost of the station
 - Some ESD manual locations were susceptible to being tripped as a result of car doors being opened or malicious activations
- ▶ There were variations between sites on how system alarms and shutdown functions operated, which could cause confusion for first responders



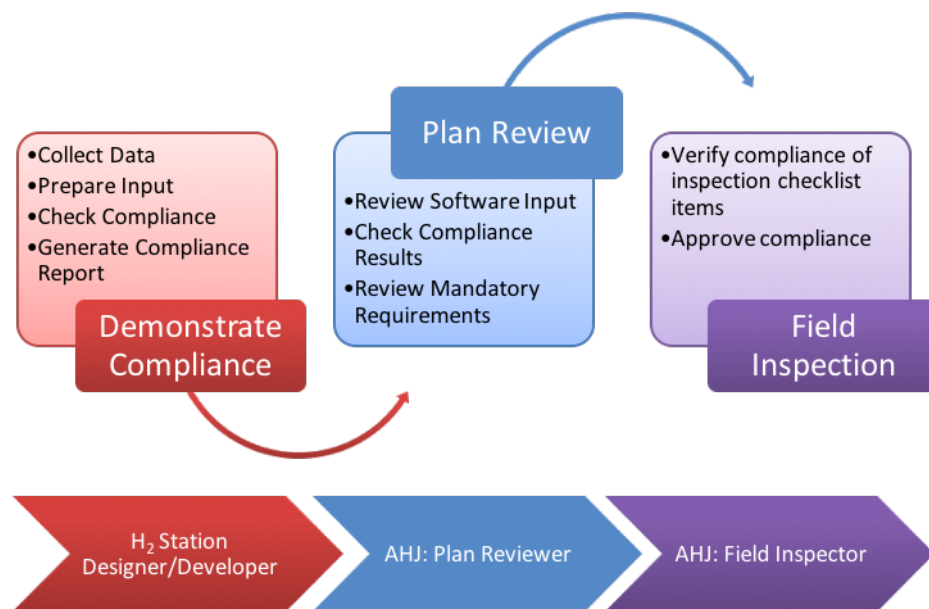
Permitting – Slide 1

- ▶ Stations are being permitted with one or more significant exceptions to the prescriptive requirements of NFPA 2
- ▶ Required prescriptive safety features should not be solely credited for establishing equivalent safety of unmet requirements
- ▶ Code officials may not be aware of the sources of independent information available to help them with their review
- ▶ Most code officials on their first hydrogen project did not reach out to their more experienced counterparts in other jurisdictions
 - Code officials that reviewed station designs were overwhelmingly supportive of allowing others to reach out to them for advice and support
- ▶ Permit applications should be comprised of succinct and accurate information to facilitate the code official's review



Permitting - Slide 2

- ▶ For code officials without much hydrogen experience, going line by line through the code will greatly improve their understanding and application of the requirements
 - Having a question and answer online tool for hydrogen fueling station code verification was seen as potentially beneficial by all attendees
- ▶ ADA requirements are typically required and should be applied for hydrogen fueling dispensers
- ▶ Requirements are not harmonized across jurisdictions, and requirements beyond the code minimum are location dependent
- ▶ Code consultants having minimal hydrogen experience may be used for performing the code official review



Training

- ▶ Lack of first responder (FR) training for new station locations
- ▶ Expand FR training beyond jurisdictions having a station
- ▶ Short YouTube videos may be beneficial for reaching FR
- ▶ Training for first responders and code officials should be in "fire-related language"
- ▶ Code official training before the design review stage may be beneficial
- ▶ Attendees will receive maximum value if they are involved in or affected by a hydrogen project



Miscellaneous Observations and Learnings

- ▶ The sequence of operations (functions and shutdowns) for normal and off-normal events wasn't communicated well between station providers and operators/owners/first responders
- ▶ Safety information should be made available at an obvious location at the fueling station to assist in emergency response and for training first responders
- ▶ Use of single or two tire grounding pad at the dispenser
- ▶ How to coordinate gasoline, diesel and hydrogen tanker unloading should be considered early in the design process to avoid unsafe conditions and impact on customer traffic routes
 - Prescriptive requirements may be necessary to address the potential for, and hazards of, simultaneous gasoline and hydrogen tanker unloading activities
 - Engineered features or separation of tanker drop locations are preferred over administrative controls
- ▶ Code officials highlighted the benefits of NFPA 2 annex material... perhaps NFPA 2 handbook should be consider

Interactions with the Public



- ▶ Good, basic safety information for the public should be further developed and made broadly available
- ▶ Developing and maintaining current public outreach materials could be very beneficial

Positive Feedback



- ▶ Cooperative relationships between station applicants, suppliers, and AHJs were universally reported
- ▶ Generally, the public was receptive to the fueling station installations with only limited dissent which was satisfied through outreach activities
- ▶ Some of the stations were showing high usage (up to maximum capacity) soon after opening

Hydrogen Tools

A Transformative Step Towards Hydrogen Adoption

CENTRALIZED LOCATION

organizes current H₂ resources in one robust location—including many proven tools, with plans for adding future content

FOCUSED CONTENT

tailored to the specialized needs of H₂ user groups

RESPONSIVE DESIGN

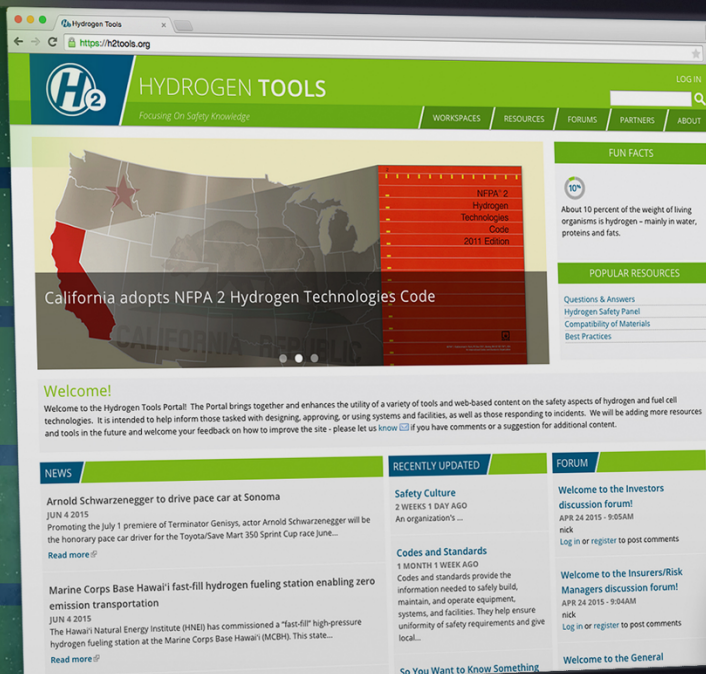
enables H₂ safety work across both desktop and mobile devices

TRUSTED COMMUNITIES

fostered through social networking around H₂ subject matter expertise

EXPANDABLE FORMAT

built with frequently requested future feature sets in mind



+ Mobile Friendly



<http://h2tools.org>

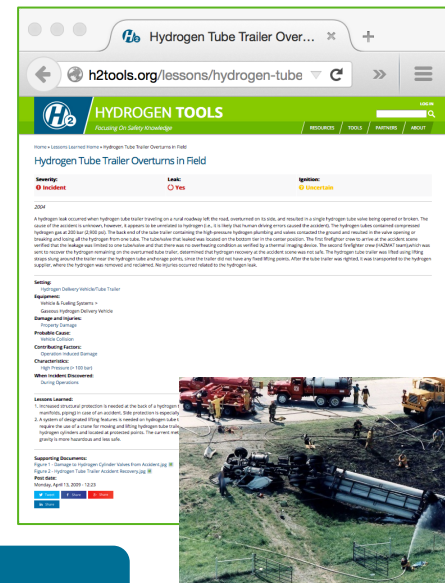
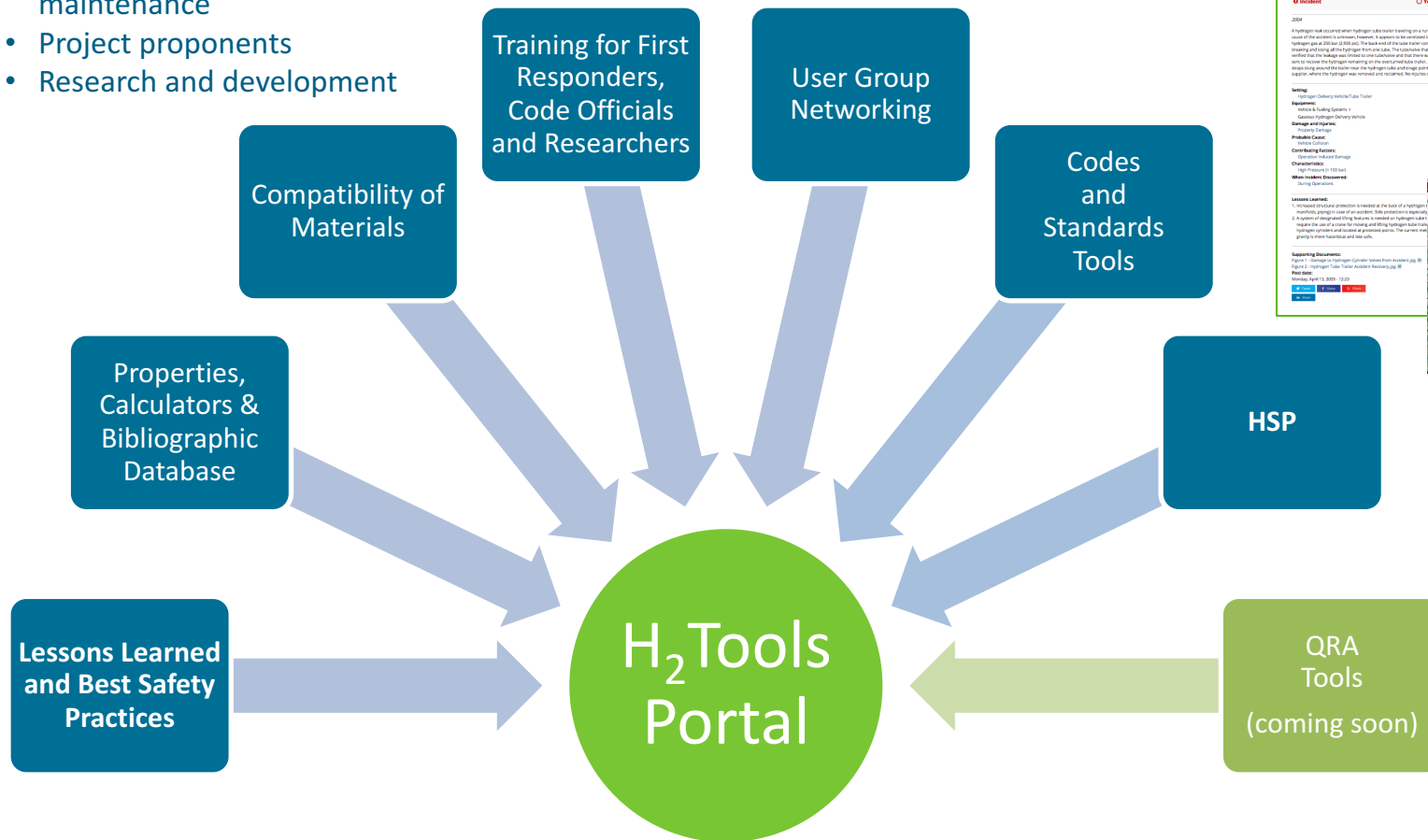


➤ **Credible and reliable** safety information from a **trustworthy** source

Key Resource – Hydrogen Tools Portal

User Groups

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



Hydrogen Safety Panel

The Panel is a unique resource and can be a valuable asset for supporting the safe commercial rollout of fuel cell vehicles, stationary applications and the supporting infrastructure.

Can Provide Support to:

- ▶ Federal agencies
- ▶ State agencies, code officials, and permitting authorities
- ▶ Private industry and commercial installers

Types of Activities:

- ▶ Design and document reviews
- ▶ Participation in or review of risk assessments
- ▶ Site reviews



Photo courtesy of the California Fuel Cell Partnership

Safety is paramount - its the first question we get asked in California when we go into local communities. If anything, we need to figure out how to expand the Safety Panel's reach. The reviews from the Panel have already shown benefit to the state - its a crucial, trusted 3rd party resource. – 2015 DOE AMR Reviewer Comment

For additional information...

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OR VISIT:

<http://h2tools.org>

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