HYDROGEN
Safety Panel

# Introducing the Hydrogen Safety Panel and Safety Resources

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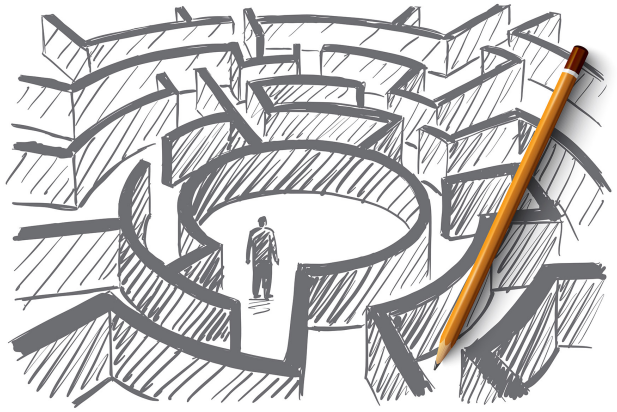
# Purpose of this Meeting

- Introduce the Hydrogen Safety Panel (HSP)
- Introduce key hydrogen safety resources that are available
- Open discussion on your hydrogen safety issues and needs
- Explore how the HSP can help the safe rollout of hydrogen and fuel cell technologies
- Identify projects that could utilize the HSP for impactful safety reviews

# The Safety Challenge

- Safety issues must be addressed for successful hydrogen technology acceptance and deployment
- Safety issues can be a ‘deal breaker’
- Hydrogen technology stakeholders may not be able to identify and effectively address all safety issues
- Stakeholders benefit from an independent and experienced hydrogen safety review (ISR) resource involved in early design and safety planning activities
- Hydrogen Safety Panel feedback and learnings help individual projects and the entire industry remove barriers and ease future deployments



# PNNL's Hydrogen Safety Resources

## Hydrogen Safety Panel (HSP)

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

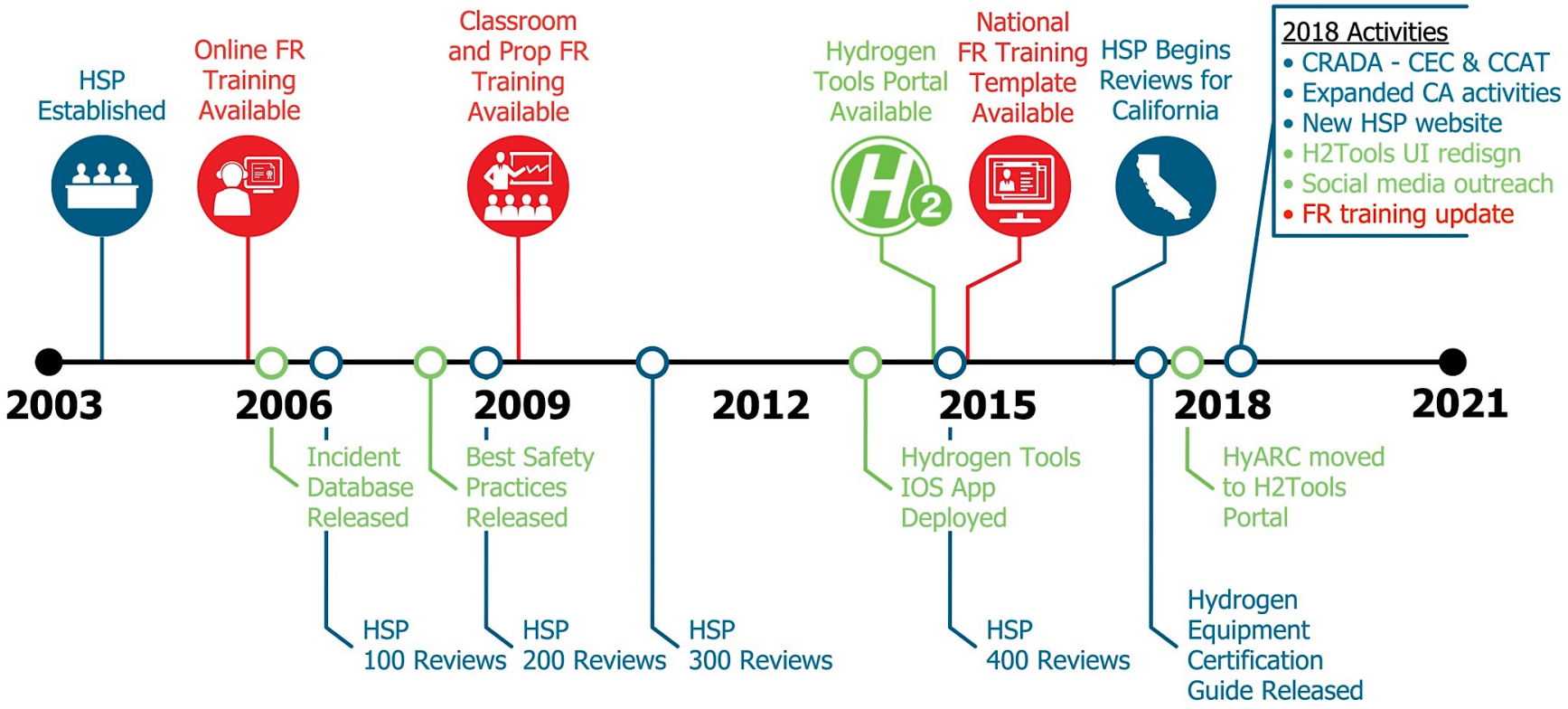
## Hydrogen Tools *Web Portal* (*http://h2tools.org*)

- Hydrogen Facts, Training, Forums, HyARC Tools
- Hydrogen Lessons Learned, Best Practices, Workspaces

## Emergency Response Training Resources

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

# Project Timeline



# Introducing the Hydrogen Safety Panel (HSP)

*Experienced, Independent, Trusted Expertise*

## *The HSP promotes safe operation, handling, and use of hydrogen*

- Formed in 2003
- 15 members with **400+ yrs** combined experience
- **492 hydrogen safety reviews completed** – hydrogen fueling, auxiliary power, backup power, CHP, portable power, and lab R&D
- White papers, reports, and guides
- Provides support on the application of hydrogen codes and standards
- **$H_2$ safety knowledge shared through the $H_2$ Tools Portal** (h2tools.org)

*Some of the fire officials and hydrogen experts that comprise the Hydrogen Safety Panel (24th meeting, 2017, Cambridge, MA)*

# HSP Membership

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

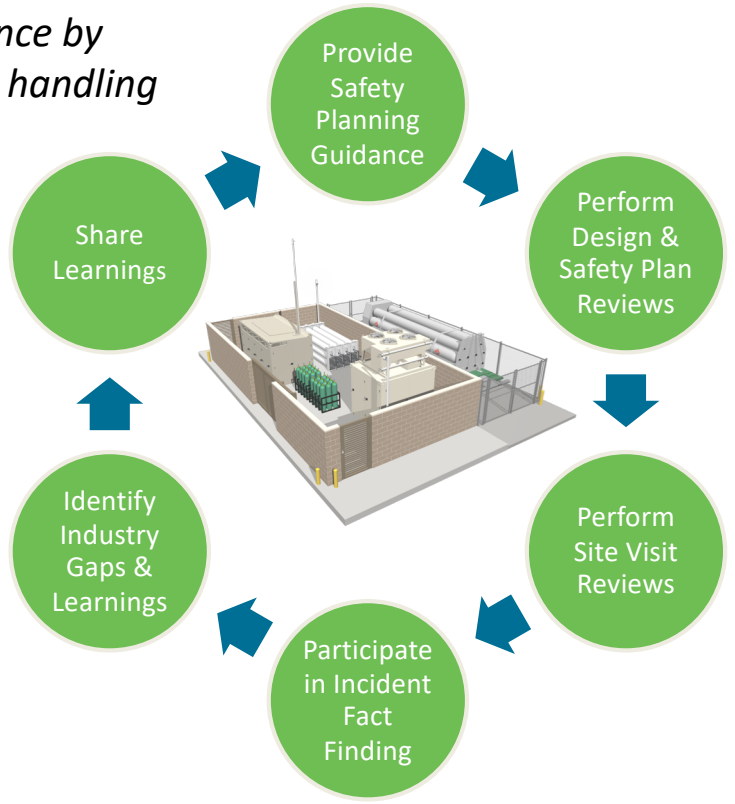
| Name | Affiliation |
|---|---|
| Nick Barilo, Manager | Pacific Northwest National Laboratory |
| Richard Kallman, Chair | City of Santa Fe Springs Fire Dept. |
| Eric Binder | Santa Monica Fire Department |
| Ken Boyce | UL |
| David Farese | Air Products and Chemicals |
| Donald Frikken | Becht Engineering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

# Hydrogen Safety Panel: Objective and Activities

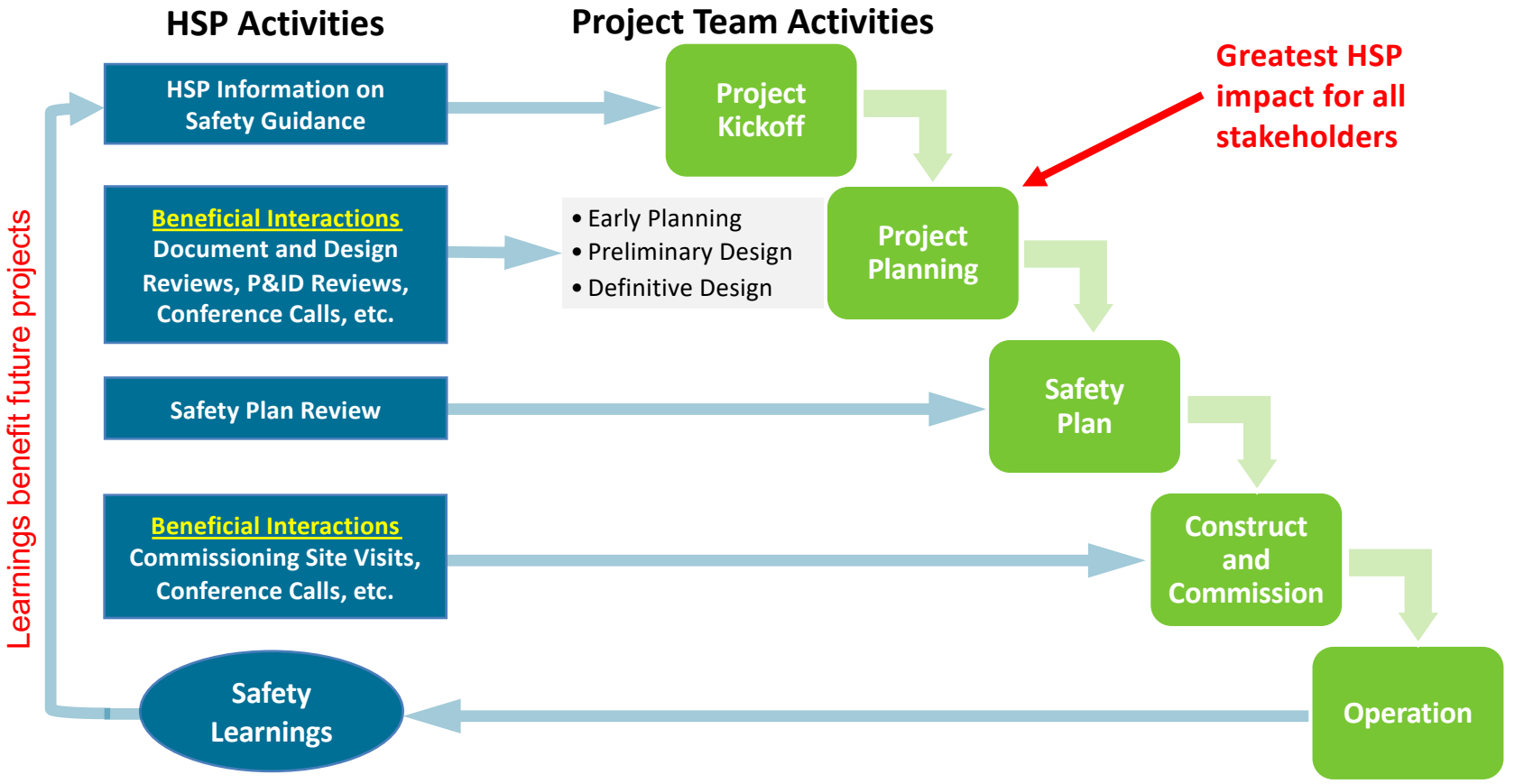
*The purpose of the HSP is to share the benefits of extensive experience by providing suggestions and recommendations pertaining to the safe handling and use of hydrogen.*

**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



# HSP Project Interaction



# Recent Panel Activities for $H_2$ Fueling Stations

- California hydrogen fueling station GFO applicant safety plan reviews
- March 2017 HSP visit to 7 California locations

South San Francisco


Woodside and Long Beach

# Involvement in Hydrogen Fueling Station Rollouts

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

# 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

# Technical Learnings from California Infrastructure Rollout

**Select Technical Learnings**

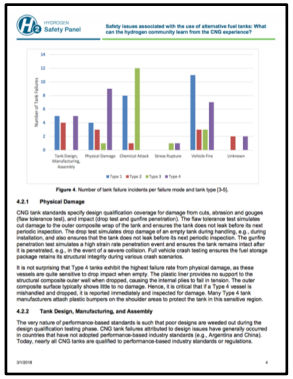
- Station design
  - Most stations are challenged to meet separation distance requirements (and typically don't for separation from lot lines)
  - Innovation is needed to address the safety and code issues regarding separation distances. While the current focus of research and development has been reactive to separation distance limitations, new thinking on the entire station design is needed to address the location restrictions more holistically
  - Unloading locations for hydrogen tankers should be considered early in the design process to avoid unsafe conditions for store customers and impact on customer traffic routes (and codes may not be adequate to address potential safety issues)
- First responders
  - FRs are likely not ready to appropriately handle an incident at a fueling station
  - FR training should consider jurisdictions beyond just those having a fueling station

**7 Station Locations**
- >100 pages of notes
- 45 learnings

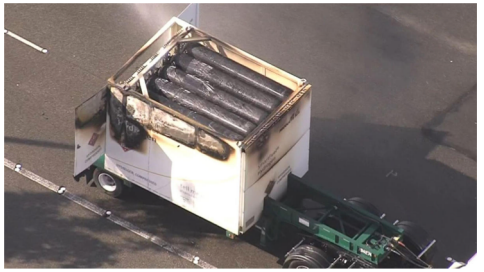
**12 Applications**
- Safety plan reviews included up to 35 locations per application
- 277 comments

# Recent Publications and Current Activities

- Compressed Natural Gas (CNG) White Paper: *Safety issues associated with the use of alternative fuel tanks: What can the hydrogen community learn from the CNG experience?*
- Liquid Hydrogen Qualification White Paper
  - A tool for permitting authorities to ensure qualified personnel have the necessary credentials
- HSP task group on California mobile applications
  - Identify and evaluate diverse mobile hydrogen equipment applications in California
  - Will consider equipment design and configuration, previous equipment safety reviews, applicable state and federal regulations, pertinent consensus standards, and equipment incidents
  - Provide a report to summarize the status, offer conclusions, and provide recommendations for the safe use of this equipment in California



CNG White Paper



Picture source: NBC Los Angeles

# Supporting Rollout of Hydrogen Technologies

**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

**California Energy Commission CY19-21**

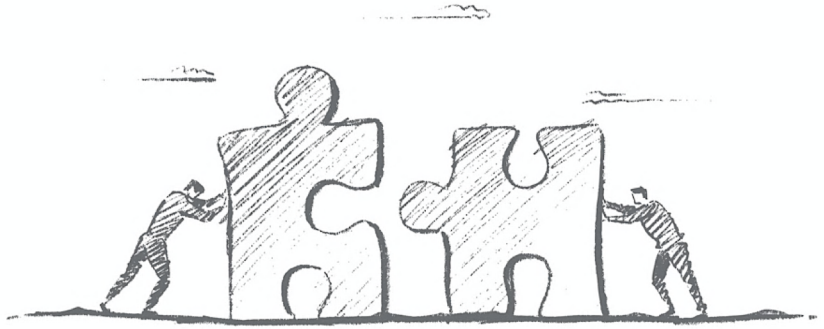
- Activities will be performed in support of the California fueling structure infrastructure including renewable hydrogen production facilities
  - Provide safety planning webinars and consultations
  - Review funding opportunity applicant safety plans
  - Participate in funded project design reviews
  - 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***

# Impact of the HSP's Activities

Involving the HSP in hydrogen project and program activities will have these beneficial impacts:

- Serves as a non-regulatory, objective and neutral expert resource
- Responds with a balanced solution to questions, problems and issues
- Sees the "big picture"
  - Shares learnings
  - Identifies gaps
- Helps reduce costs by avoiding
  - Over-engineering and unnecessary features
  - Delayed approvals
  - Missed safety considerations/features
- Aids in avoiding repeating costly mistakes among disparate project proponents
- Helps project proponents avoid industry-impacting incidents
- Helps establish stakeholder and public confidence and receptivity



# Sharing Safety Learnings

- Project Interaction
  - Reports, recommendations, guides and white papers
- Outreach and Presentations
  - Stakeholders
  - Code Officials
  - First Responders
- Hydrogen Tools Portal (http://h2tools.org)


# Hydrogen Tools Portal

**CENTRALIZED LOCATION** organizes current $H_2$ resources in one robust location—including many proven tools, with plans for adding future content

**FOCUSED CONTENT** tailored to the specialized needs of $H_2$ user groups

**RESPONSIVE DESIGN** enables $H_2$ safety work across both desktop and mobile devices

**TRUSTED COMMUNITIES** fostered through social networking around $H_2$ 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

# Hydrogen Tools Portal Stats

## Site Content

- **3,629** Total Pages
- **2,414** Bibliographic References
- **217** Lessons Learned Pages
- **142** Best Safety Practices Pages

## Usage Stats*

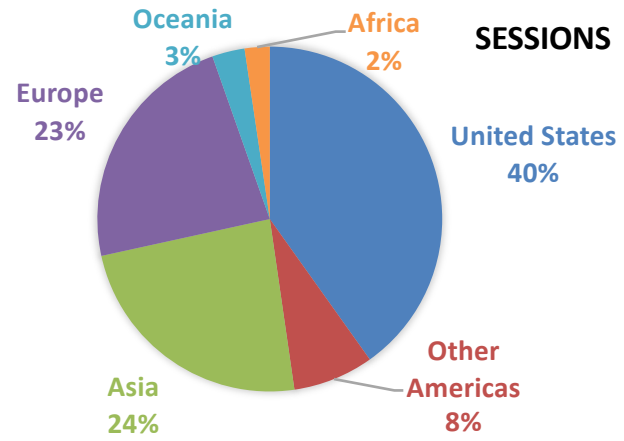
- **279,678** Total Pageviews
- **56,951** Sessions

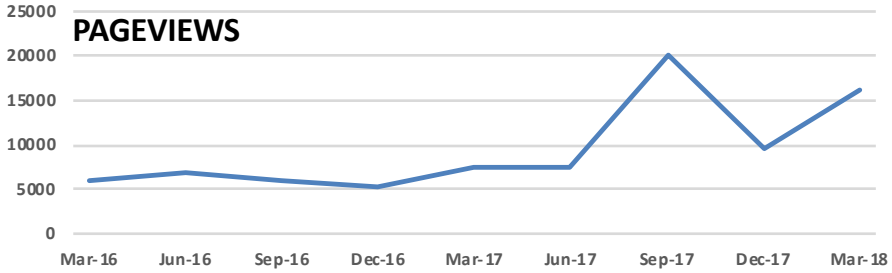
>100% growth since 3/2017

- **4.91** Pages Visited per Session
- **6:36** Minutes per Session

* Nonbounce statistics through March 31, 2018

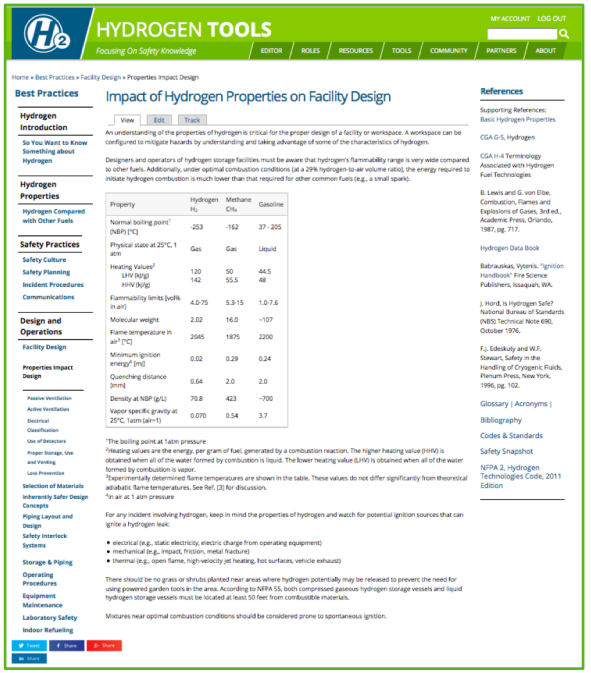
## H2Tools.org - A Global Resource!



# H2tools.org/bestpractices
# …Sharing Experience, Applying Best Practices

- Introduction to Hydrogen
  - So you want to know something about hydrogen?
- Hydrogen Properties
  - Hydrogen compared with other fuels
- Safety Practices
  - Safety culture
  - Safety planning
  - Incident procedures
  - Communications
- Design and Operations
  - Facility design considerations
  - Storage and piping
  - Operating procedures
  - Equipment maintenance
  - Laboratory safety
  - Indoor refueling of forklifts

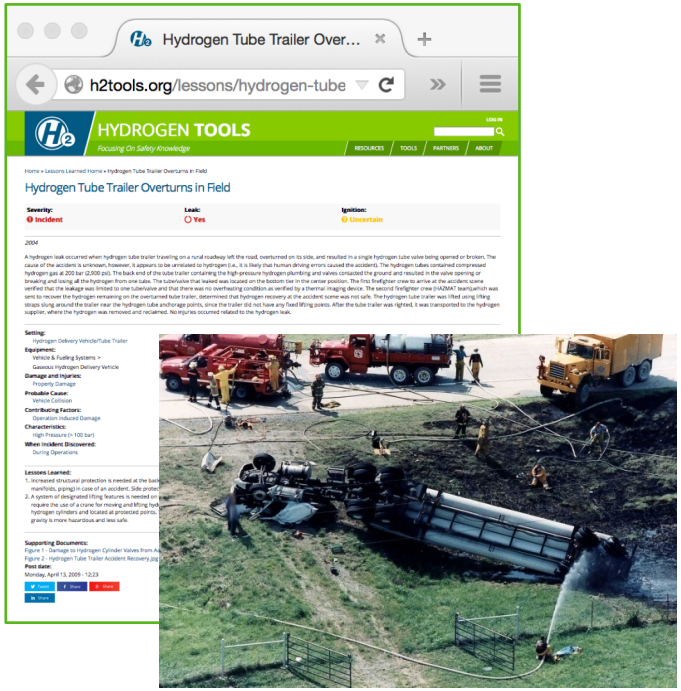



Safety events from “H2incidents.org” illustrate what can go wrong if best practices are not followed.

# H2tools.org/lessons
# …Capturing the Event, Focusing on Lessons Learned

Each safety event record contains:

- Description
- Severity (Was hydrogen released? Was there ignition?)
- Setting
- Equipment
- Characteristics (High pressure? Low temperature?)
- Damage and Injuries
- Probable Cause(s)
- Contributing Factors
- Lessons Learned/Suggestions for Avoidance/Mitigation Steps Taken




Tube trailer rollover

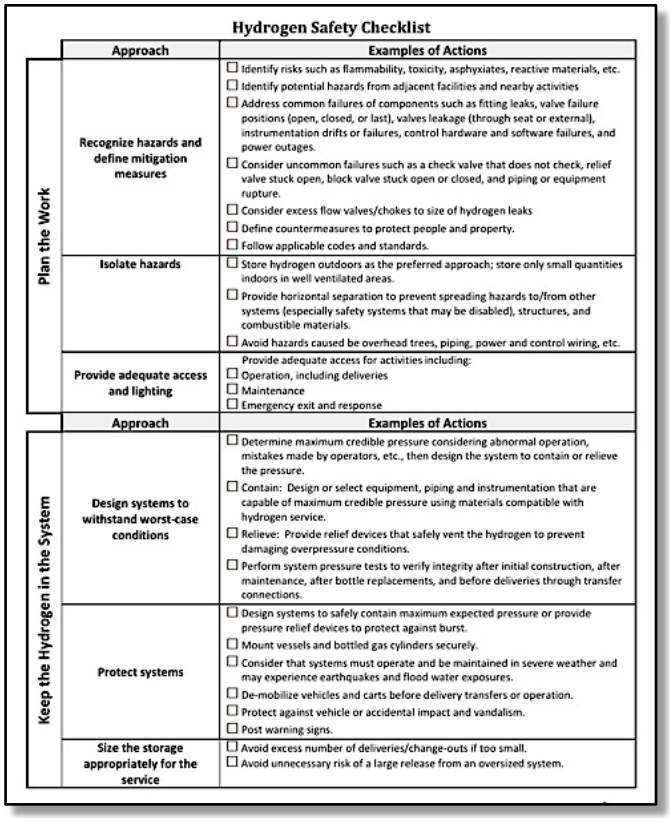
# Guidance for Safety Planning of Hydrogen Projects

**Safety planning should be an integral part of the design and operation of an $H_2$ 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.

# Hydrogen Safety Considerations Checklist

- Intended users
  - Those developing designs for hydrogen systems
  - Those involved with the risk assessment of hydrogen systems.
- While fairly inclusive, it is not possible to include all variables that need to be considered
- A formal hazard analysis process should include
  - Personnel who are familiar with applicable codes and standards
  - Team members with expertise in the technical aspects of the specific project

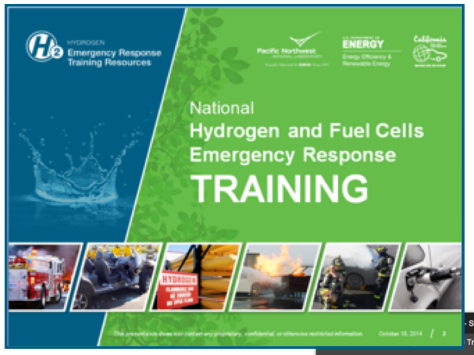


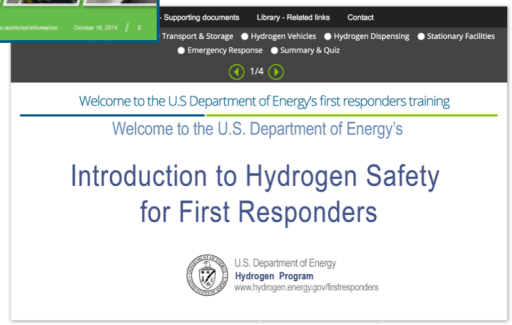
**Hydrogen Safety Checklist**

| | Approach | Examples of Actions |
|---|---|---|
| Plan the Work | Recognize hazards and define mitigation measures | ☐ Identify risks such as flammability, toxicity, asphyxiates, reactive materials, etc.<br>☐ Identify potential hazards from adjacent facilities and nearby activities<br>☐ Address common failures of components such as fitting leaks, valve failure positions (open, closed, or last), valves leakage (through seat or external), instrumentation drifts or failures, control hardware and software failures, and power outages.<br>☐ Consider uncommon failures such as a check valve that does not check, relief valve stuck open, block valve stuck open or closed, and piping or equipment rupture.<br>☐ Consider excess flow valves/chokes to size of hydrogen leaks<br>☐ Define countermeasures to protect people and property.<br>☐ Follow applicable codes and standards. |
| | Isolate hazards | ☐ Store hydrogen outdoors as the preferred approach; store only small quantities indoors in well ventilated areas.<br>☐ Provide horizontal separation to prevent spreading hazards to/from other systems (especially safety systems that may be disabled), structures, and combustible materials.<br>☐ Avoid hazards caused be overhead trees, piping, power and control wiring, etc. |
| | Provide adequate access and lighting | Provide adequate access for activities including:<br>☐ Operation, including deliveries<br>☐ Maintenance<br>☐ Emergency exit and response |
| | **Approach** | **Examples of Actions** |
| Keep the Hydrogen in the System | Design systems to withstand worst-case conditions | ☐ Determine maximum credible pressure considering abnormal operation, mistakes made by operators, etc., then design the system to contain or relieve the pressure.<br>☐ Contain: Design or select equipment, piping and instrumentation that are capable of maximum credible pressure using materials compatible with hydrogen service.<br>☐ Relieve: Provide relief devices that safely vent the hydrogen to prevent damaging overpressure conditions.<br>☐ Perform system pressure tests to verify integrity after initial construction, after maintenance, after bottle replacements, and before deliveries through transfer connections. |
| | Protect systems | ☐ Design systems to safely contain maximum expected pressure or provide pressure relief devices to protect against burst.<br>☐ Mount vessels and bottled gas cylinders securely.<br>☐ Consider that systems must operate and be maintained in severe weather and may experience earthquakes and flood water exposures.<br>☐ De-mobilize vehicles and carts before delivery transfers or operation.<br>☐ Protect against vehicle or accidental impact and vandalism.<br>☐ Post warning signs. |
| | Size the storage appropriately for the service | ☐ Avoid excess number of deliveries/change-outs if too small.<br>☐ Avoid unnecessary risk of a large release from an oversized system. |

# First Responder Hydrogen Safety Training

- **National Goal**
  - Support the successful implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders
- **Integrated Activities**
  - Online, awareness-level training (https://www.h2tools.org/firstresponder)
  - Classroom and hands-on operations-level training
  - National training resource (enabling trainers) (http://h2tools.org/fr/nt)




***A properly trained first responder community is critical to the successful introduction of hydrogen fuel cell applications and their transformation in how we use energy.***

# Introducing the Center for Hydrogen Safety

***A timely partnership to enable broader impact and sustainability of significant safety resources***

Pacific Northwest NATIONAL LABORATORY

AIChE

*A not-for-profit membership organization within AIChE*

Promotes the safe operation, handling, and use of hydrogen across all applications by providing

- Diverse accredited education and outreach resources, including training for first responders
- Global hydrogen safety conferences
- Greater accessibility to the PNNL Hydrogen Safety Panel for industry, state, and government agencies
- Leadership in addressing safety gaps

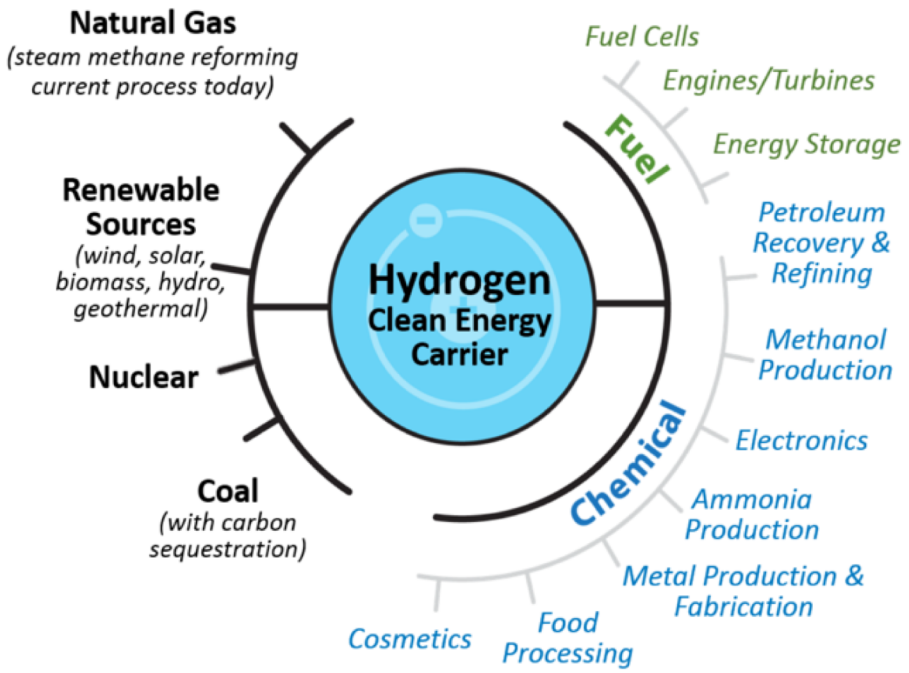
CENTER FOR Hydrogen SAFETY

HYDROGEN Safety Panel

HYDROGEN Emergency Response Training Resources

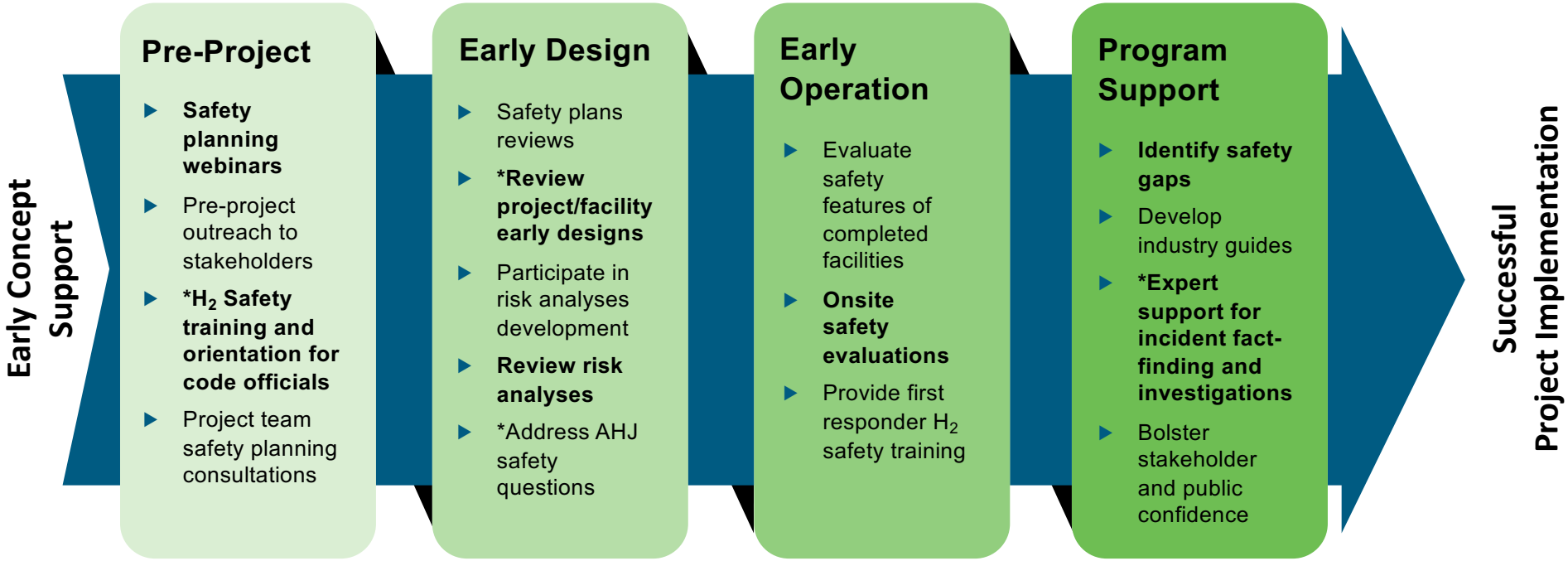
# Concluding Thoughts

- The future will likely see an increase in the use of hydrogen and fuel cell technologies
- Because hydrogen as a fuel is still relatively new, best methods of handling, storage, transport, and use may not be well understood by participants
- Safe practices for production, storage, distribution, and use of hydrogen are essential for deployment of hydrogen and fuel cell technologies
- The Center for Hydrogen Safety, HSP and Hydrogen Tools portal (http://h2tools.org) are available to help project participants to understand and apply safe practices for successful use



# Support for the Safe Implementation of Hydrogen Technologies

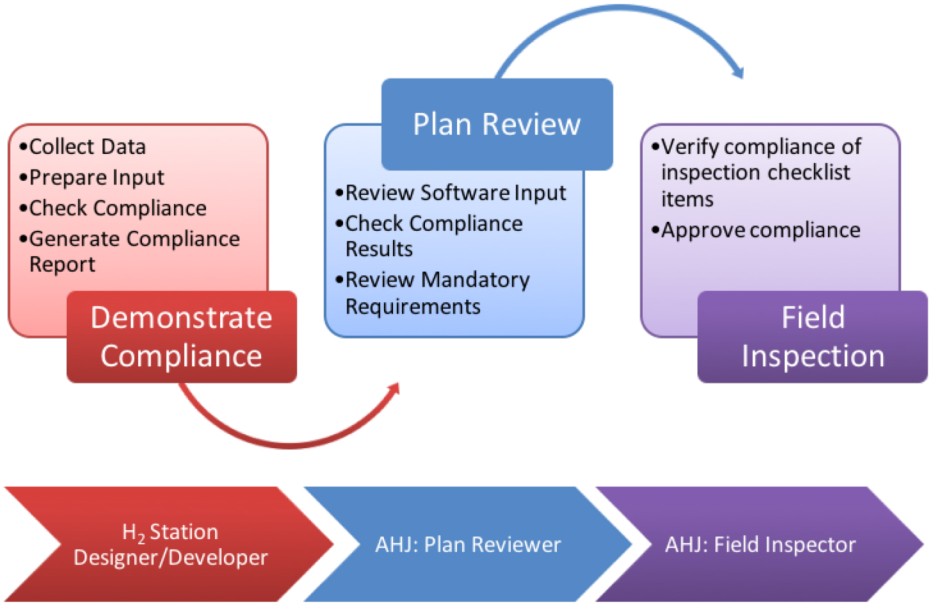
## Activities that can Benefit from HSP Involvement




* 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

# Open Discussion

- What are your hydrogen safety issues and needs?
- How can PNNL and the Center for Hydrogen Safety help enable the safe rollout of hydrogen and fuel cell technologies?
- Do you have any projects that could benefit from a review by HSP?



# For additional information…

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**OR VISIT:**

**http://h2tools.org** for additional Hydrogen Safety related resources