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Deploying Fuel Cell Systems - What Have We Learned?

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Hydrogen Safety Panel

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Core Principle: Safe practices in the production, storage, distribution, and use of hydrogen are essential for the widespread acceptance of hydrogen and fuel cell technologies.

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HYDROGEN
SAFETY PANEL

Hydrogen Safety Panel (HSP)
Objectives and background

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Objectives

- Provide expertise and recommendations to DOE and assist with identifying safety-related technical data gaps, best practices and lessons learned.
- Help DOE integrate safety planning into funded projects to ensure that all projects address and incorporate hydrogen and related safety practices.

Background

- Formed in 2003 to support U.S. DOE Hydrogen and Fuel Cell Technologies Program
- 14 Members – over 400 years of industrial experience, representing various sectors and technical areas of expertise
- Includes committee members from NFPA 2 and 55, and technical committees of ASME, SAE and ISO
- Contribute to peer-reviewed literature on hydrogen safety
- Review safety plans and project documentation for H_2 facilities and activities
- Perform onsite safety reviews
- Support accident investigations

Hydrogen Safety Panel

Fuel cell deployment projects

The Panel's work (shown in the table to the right) has focused on project investments intended to accelerate the commercialization and deployment of fuel cells and fuel cell manufacturing, installation, maintenance and support services.

Application	Location
Auxiliary Power	Troy, MI
Backup Power	Various NASCAR sites; Warner Robins, GA; Ft. Irwin, CA; telecommunications applications in CA, CT, NJ, NY, UT, CO, AZ, NM, IL, IN, MI, FL
Combined Heat And Power	Irvine, CA
H_2 Road Vehicle Fueling Stations	Irvine, CA; Detroit, MI; Las Vegas, NV; Oakland, CA; Sacramento, CA; Washington, DC; Multiple locations on the Hawaiian Islands
Industrial Truck Fueling and Operation	Springfield, MO; Charlotte, NC; Graniteville, SC; Landover, MD; Philadelphia, PA; Pottsville, PA; San Antonio, TX; Houston, TX
Portable Power	Albany, NY; Jacksonville, FL

Learnings from fuel cell deployment projects
Project Integration

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Learning: A thorough and integrated approach to project safety planning needs to involve all parties.

- Applications aside, all of these deployment projects involve several different types of partners:
  - hydrogen/fuel cell equipment suppliers
  - facility operators
  - maintenance and repair providers

- One fuel cell provider noted:

"The operation phase of the project turns responsibility of the system over to the customer. This is a change from a more experienced to a less experienced user, which opens the possibility for human error. Customer organizations must execute safety policies and training requirements to limit human error. Lack of training and a lack of communication are the largest sources for safety risks."

Learnings from fuel cell deployment projects
Hazards Analysis

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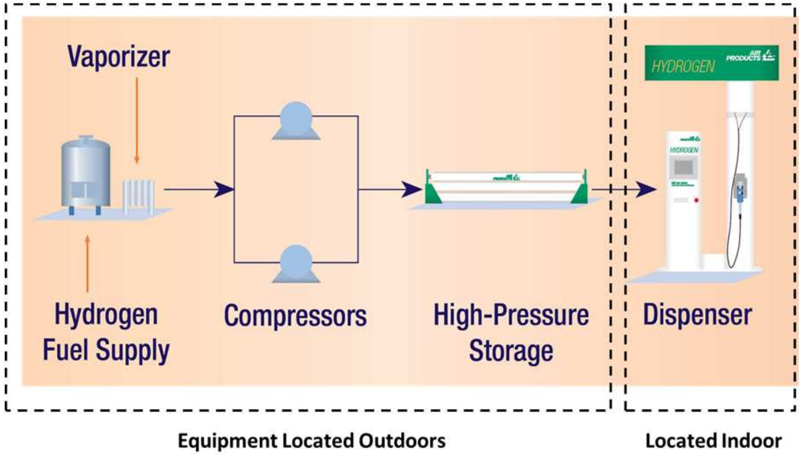
Learning: Safety vulnerability analysis needs to comprehensively consider all potential incident scenarios introduced by hydrogen/fuel cell deployment and equipment operations and exposures.

- A thorough hazards analysis is critical for ensuring safety deployment of hydrogen and fuel cell technologies.
- Many projects did not comprehensively address the potential safety vulnerabilities of all operations regardless of the fuel cell application.
- Hazard analysis was cited the most frequently and also had most "no actions."

Recommendations and actions from Panel safety review (development and deployment projects)

Category	Recommendations Implemented	In Progress	No Action	Total Recommendations
Safety Vulnerability/ Mitigation Analysis	23	4	13	40
System/Facility Design Modifications	11	5	1	17
Equipment/Hardware Installation and O&M	18	7	2	27
Safety Documentation	16	7	0	23
Training	3	3	0	6
Housekeeping	14	6	1	21
Emergency Response	9	3	3	15
Total	94	35	20	149

Hydrogen Safety Checklist



(Figure - courtesy of Air Products and Chemicals, Inc.)

- The HSP developed a checklist (partially shown at the right) to assist projects in analyzing hazards from an outdoor storage for indoor use of hydrogen.
- The checklist is available at http://h2bestpractices.org/docs/HydrogenSafetyChecklist.pdf and in the Hydrogen Tools iPad and iPhone apps.

Hydrogen Safety Considerations Checklist

	Approach	Examples of Actions
Plan the Work	Recognize hazards and define mitigation measures	☐ Identify risks such as flammability, toxicity, asphyxiates, reactive materials, etc. ☐ Identify potential hazards from adjacent facilities and nearby activities ☐ 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. ☐ 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. ☐ Consider excess flow valves/chokes to size of hydrogen leaks ☐ Define countermeasures to protect people and property. ☐ Follow applicable codes and standards.
	Isolate hazards	☐ Store hydrogen outdoors as the preferred approach; store only small quantities indoors in well ventilated areas. ☐ Provide horizontal separation to prevent spreading hazards to/from other systems (especially safety systems that may be disabled), structures, and combustible materials. ☐ Avoid hazards caused be overhead trees, piping, power and control wiring, etc.
	Provide adequate access and lighting	Provide adequate access for activities including: ☐ Operation, including deliveries ☐ Maintenance ☐ 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. ☐ Contain: Design or select equipment, piping and instrumentation that are capable of maximum credible pressure using materials compatible with hydrogen service. ☐ Relieve: Provide relief devices that safely vent the hydrogen to prevent damaging overpressure conditions. ☐ 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. ☐ Mount vessels and bottled gas cylinders securely. ☐ Consider that systems must operate and be maintained in severe weather and may experience earthquakes and flood water exposures. ☐ De-mobilize vehicles and carts before delivery transfers or operation. ☐ Protect against vehicle or accidental impact and vandalism. ☐ Post warning signs.
	Size the storage appropriately for the service	☐ Avoid excess number of deliveries/change-outs if too small. ☐ Avoid unnecessary risk of a large release from an oversized system.

Learnings from fuel cell deployment projects

Codes and Standards

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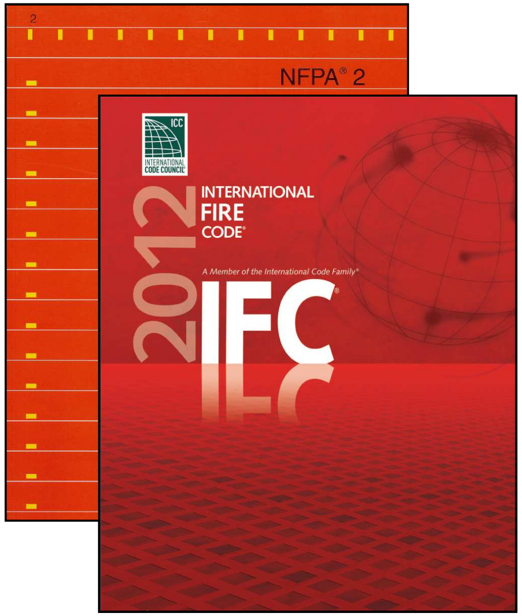
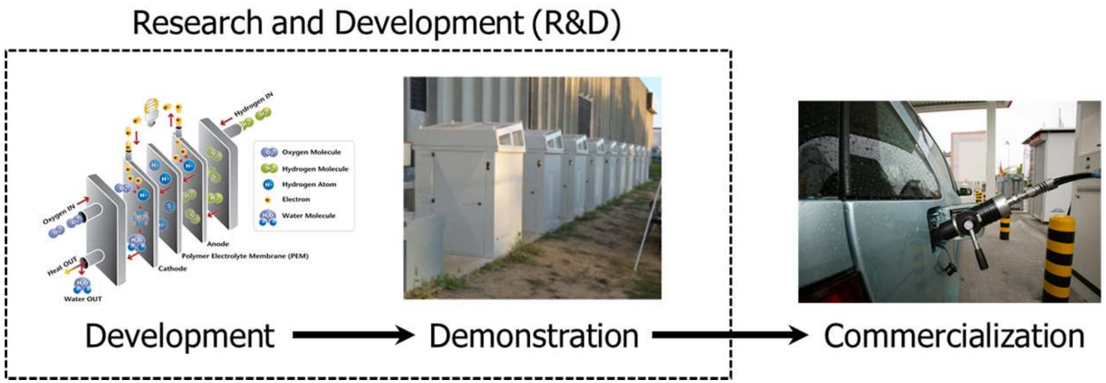
- Code compliance is essential for ensuring public safety and confidence in commercial activities, particularly for those deploying new technologies.
- The Panel's site reviews revealed that codes and standards were not fully applied to fuel cell deployment projects
- Learnings:
  - Practices in technology development phases don't necessarily translate to safe or code compliant configurations for deployment.
  - Safety issues associated with the modular design approach for fueling equipment need to be better understood by both manufacturers and code developers for safe and economical deployments.



Issues associated with moving from demonstration to commercial deployment

The purpose of R&D is to develop new products, and the approaches used there don't necessarily translate to safe or code compliant configurations for commercial deployment.



Some potential reasons why:

- Manufacturers generally use design engineers rather than safety engineers to design products. This can result in a product that performs well but may not comply with the safety, health or environmental standards or requirements[1].
- Designers and AHJs may not have the experience to recognize specific safety issues.
- AHJs may be responding to installers who can cite approval at other locations as a basis for a new installation's acceptability (regardless of how safe they are).

If unsafe practices are accepted during the demonstration phase, they may become standard practice for commercialization.

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1 American Council of Independent Laboratories, The Value of Third Party Certification, Washington, DC, April 11, 2002.

Hydrogen Equipment Enclosures

Are these buildings, or equipment enclosures? The answer impacts what requirements should be applied.

- Safety issues associated with the modular design approach for fueling equipment need to be better understood by both manufacturers and code developers for safe and economical deployments.

Safety of Hydrogen Enclosures

- There is currently no consistent set of requirements that can be applied by designers or regulators that govern the:
  - construction of the enclosures,
  - ventilation systems,
  - leak or fire detection systems,
  - electrical classification, and
  - separation distances between the enclosure and other structures.
- Without clear requirements for the different types of enclosures, designers have little guidance on how to design safe systems and code officials have a difficult time determining which code requirements may apply to which enclosures.
- A sound technical basis is needed to provide a basis for prescriptive (and performance-based) requirements for the range of enclosures used for hydrogen systems.

Learnings from fuel cell deployment projects

Third party certification

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Learning: The role and scope of third-party certification of hydrogen and fuel cell systems need to be clarified to facilitate their commercialization.

Certification presents significant challenges. The issues include:

- Confusion with terminology used in the various codes and standards
- Difficulties applying certification standards or even the absence of such standards, as well as a lack of certification organizations
- Significant costs since the technology and products are still rapidly changing and each new iteration would require recertification
- Lack of clarity on what a certification covers relative to a particular piece of equipment, system or facility
- Few systems or facilities that are listed, labeled or certified

ISO 9001:2008 CERTIFICATION™
Intertek

NRTL/C

Learnings from fuel cell deployment projects

Third party certification

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Why the issues are a problem…

- Facility owners/operators:
  - Have no internal or hired expertise on hydrogen safety issues
  - Believe they are buying a commercial product where all the safety issues have been handled and as such rely on the equipment suppliers to ensure the safety is addressed
- Regulators:
  - May be assuming that a company's "cerftication" implies that all code and safety issues are addressed
  - May not have expertise to evaluate equipment that is not certified (codes and standards require unlisted equipment to be approved by the AHJ)

An example application

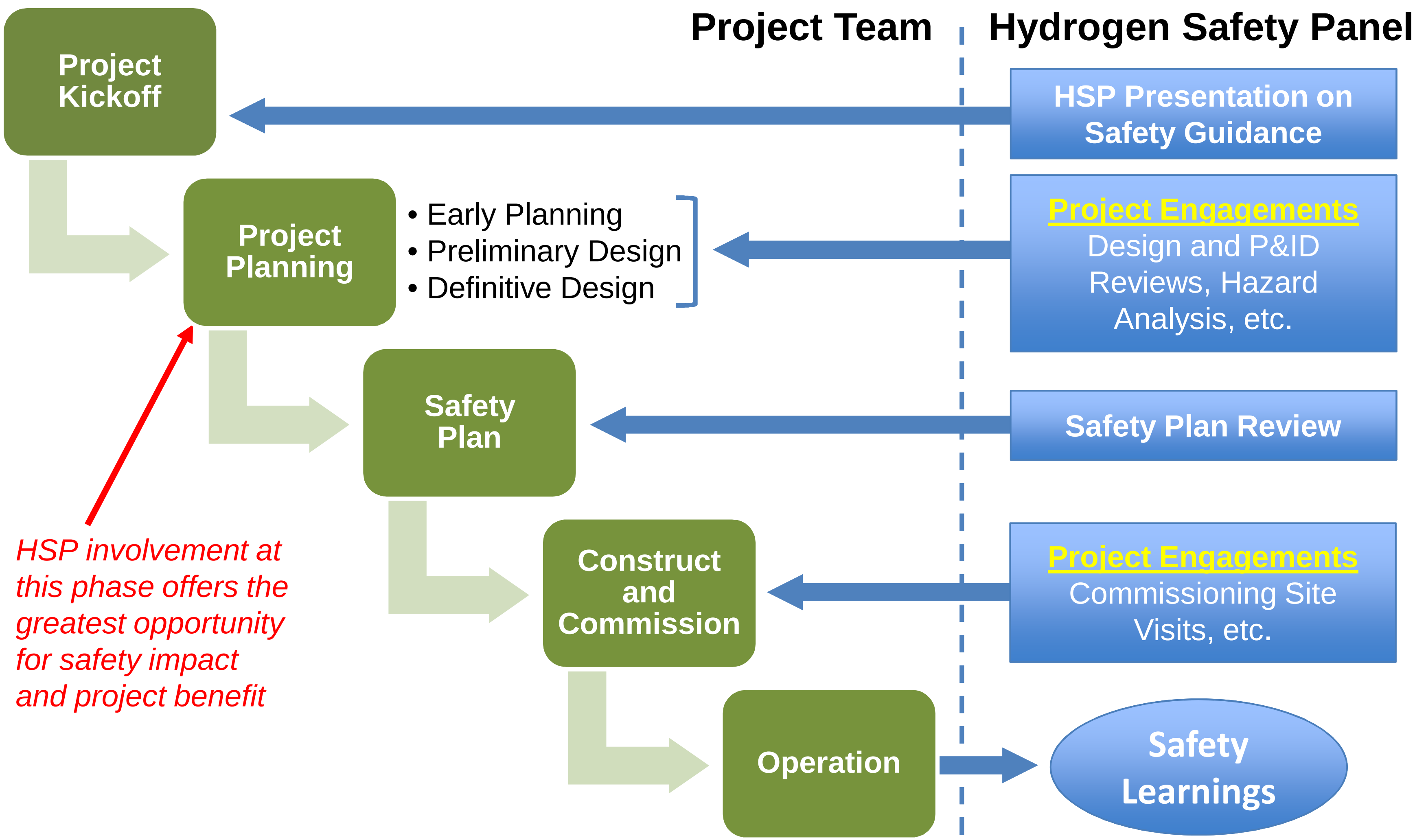
- To understand the issues better, let's look at one example application of backup power for a cell tower site.
- Application: Cell tower backup power
  - Enclosure with 8,000 scf of hydrogen storage (two of the four walls have perforations for ventilation)
  - Storage is refilled via a filling connection on the box
  - Storage and fuel cell enclosure located next to other cell tower equipment

- The following safety assessment questions are considered:
  - Have the ventilation characteristics of the cabinet been determined by testing and/or modeling?
  - Are there special certifications or listings for their use near unclassified electrical equipment?
  - Is the expected ventilation adequate to prevent an internal explosion that would allow gas to be exposed to external ignition sources, or allow significant exhausting to vent a credible release event?
  - What are the hydrogen release rate limits for effective ventilation with perforated cabinet walls?
  - Have all the stakeholders (including other cell tower equipment providers) been made aware of and accepted the risks associated with all equipment positioned on the cell tower pad?

Addressing these and other questions, regardless of equipment or application, helps ensure that all parties consider potential safety issues comprehensively to benefit the deployment of these technologies and systems.

Hydrogen Safety Panel

New review process for deployment projects



What we learned about our review process

Deployment projects require a new review approach…

- **Timing for HSP involvement affects the benefit**
  - HSP review and site visits were provided after equipment was operational
  - It is difficult and costly to implement recommendations affecting equipment and configuration
  - Projects resist input when it occurs after the completion of design or construction activities

- **Benefits of early involvement realized in four deployment projects:**
  - Helped the projects understand and evaluate the safety issues and code requirements
  - Significant design changes were made based on input from the HSP
  - Project management and stakeholders have greater confidence in approving the final configuration

Concluding thoughts

- Safe practices in the production, storage, distribution and use of hydrogen are essential for deployment of hydrogen and fuel cell technologies.
- Because hydrogen's use as a fuel is still a relatively new endeavor, the proper methods of handling, storage, transport and use are often not well understood across the various communities either participating in or impacted by its demonstration and deployment.
- Project proponents and AHJs are encouraged to consider the learnings identified in this paper and to work together to ensure that deployment activities are conducted safely and in a manner that warrants public confidence.
- The Hydrogen Safety Panel will continue to identify initiatives to bring focused attention, action and outreach on key safety issues for deployment of hydrogen and fuel cell systems.

Thank you

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