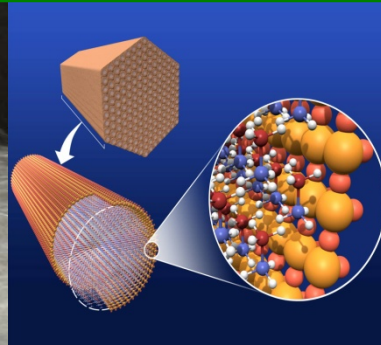




U.S. DEPARTMENT OF
ENERGY



Safety Codes & Standards - Plenary -

Will James

Fuel Cell Technologies Office

*2015 Annual Merit Review and Peer Evaluation Meeting
June 8 - 12, 2015*

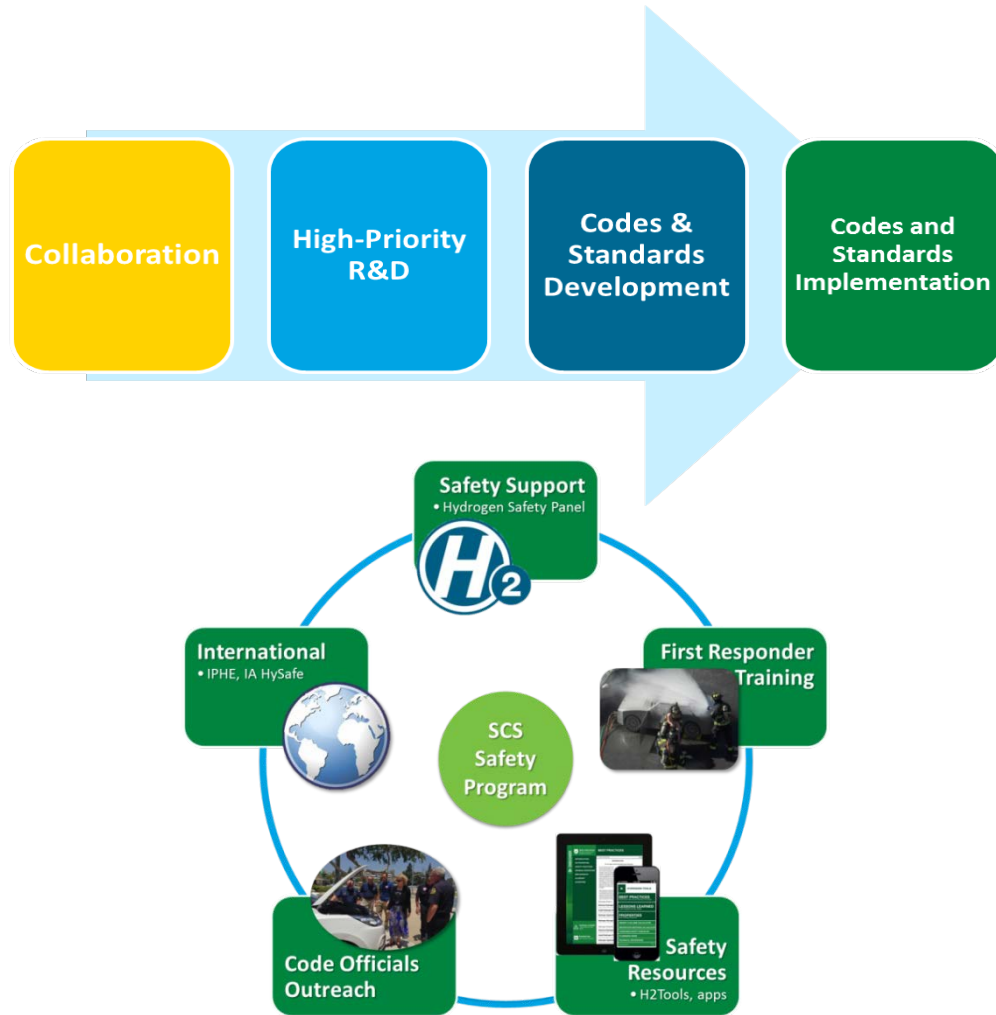
SCS Program Goal and Objectives

Codes & Standards Objectives:

- Support and facilitate development and promulgation of essential codes and standards to enable widespread deployment and market entry of hydrogen and fuel cell technologies and completion of all essential domestic and international regulations, codes and standards (RCS)
- Conduct R&D to provide critical data and information needed to define requirements in developing codes and standards.

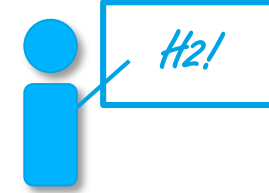
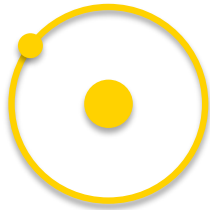
Hydrogen Safety Objectives:

- Ensure that best safety practices underlie research, technology development, and market deployment activities supported through DOE-funded projects.
- Develop and enable widespread sharing of safety-related information resources and lessons learned with first responders, authorities having jurisdiction (AHJs), and other key stakeholders.



Enable the widespread commercialization of hydrogen and fuel cell technologies through the timely development of codes and standards and dissemination of safety information

Safety, Codes & Standards Program Strategy



Research & Development

- Hydrogen Behavior
- Hydrogen Risk Assessment
- Materials Compatibility
- Fuel Quality
- Component Testing
- Sensors (both Safety and Contaminant Detection)

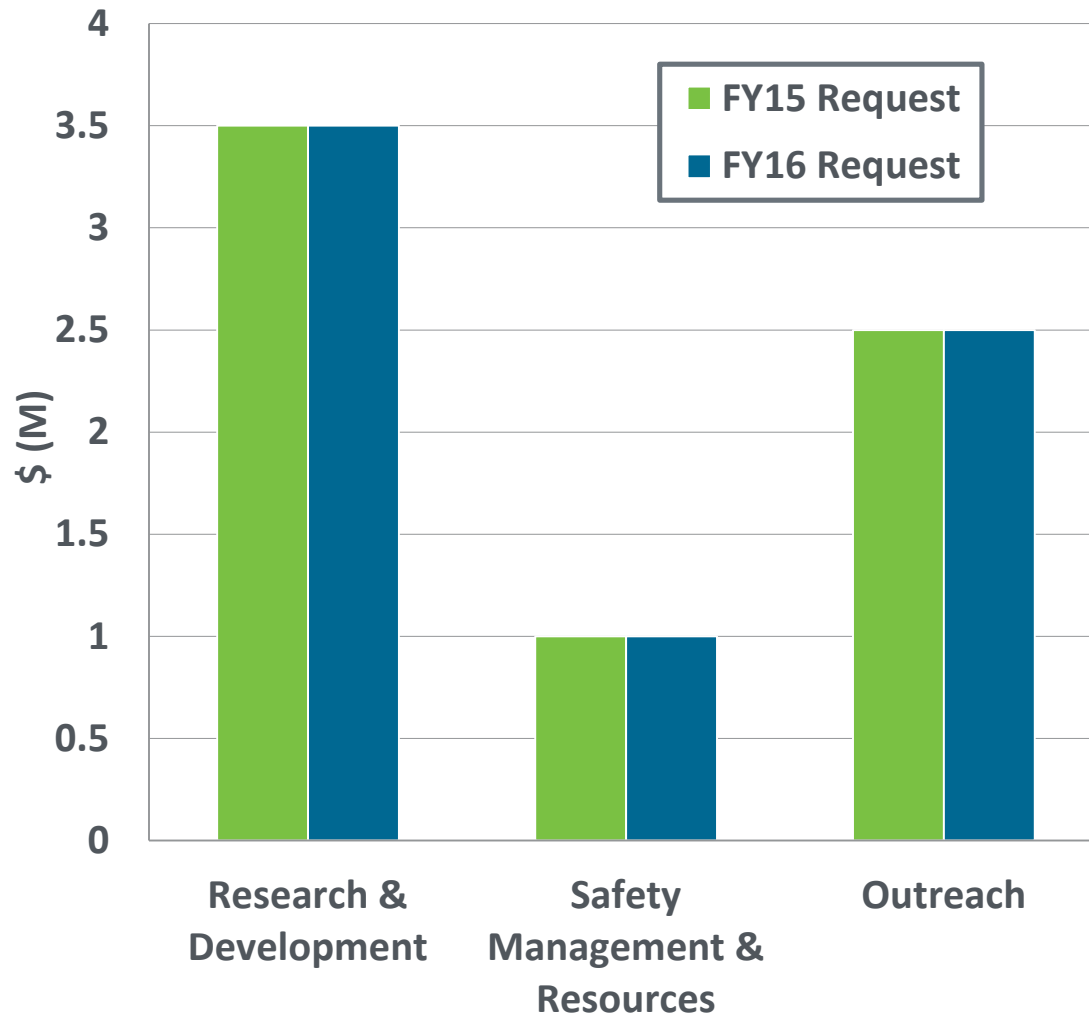
Codes & Standards Support and Implementation

- Domestic and International CDO and SDO participation and support
- Hydrogen Risk Assessment Models (HyRAM)
- Alternative Code Compliance Methods
- Continuous Codes and Standards Improvement
- Sensor Validation (industry engagement)

Outreach

- Hydrogen Safety Panel
- Codes Official Training
- First Responders Training
- State Engagement and Support (e.g. – California and 8 State MOU)
- International Collaboration (e.g. – IPHE RCSWG, IA-HySAFE)
- Resource Development and Dissemination (training prop, H2Tools.org)

An integrated approach to safety, codes and standards: research and development informs codes and standards implementation efforts, which support outreach efforts



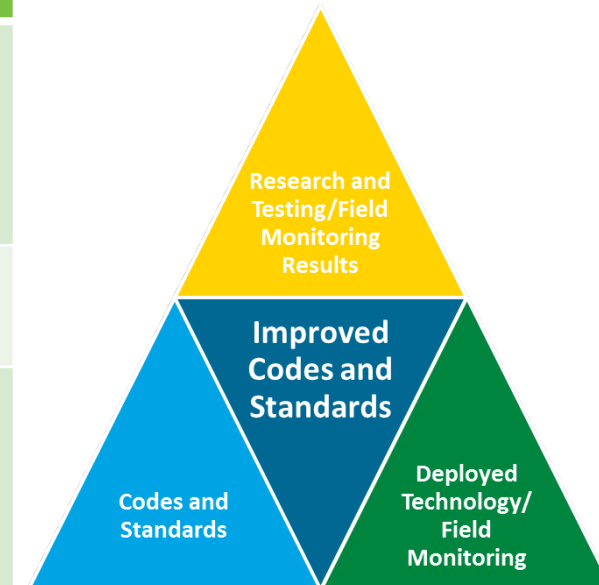
FY 2016 Request = \$7M
FY 2015 Appropriation = \$7M

Emphasis

- **R&D Activities:** H₂ Behavior, Risk Assessment/Mitigation, Materials Compatibility, H₂ Fuel Quality, Metering, Sensors, Component Testing
- **Safety Management & Resources:** Hydrogen Safety Panel, Databases, and Training Props
- **Outreach:** Codes & Standards and Permitting, Continuous Codes and Standards Improvement, Resource Dissemination

FY 2016 request maintains stable funding and allows for continued emphasis on critical RCS and safety

| Barrier | Action |
|--|--|
| 1. Increase HRS performance and reliability to level required for deployment | Continue testing and support RCS development by engaging with component manufacturers, system designers and CDOs/SDOs. |
| 2. Simplify RCS to the level to support deployment | Use field data through CCSI to streamline the RCS process |
| 3. Provide SCS information that is accessible and useable to the infrequent user | Provide easily accessible information that would quickly provide the necessary requirements to the user |



Examples of Utilizing CCSI:

- Hydrogen Code Improvement (HCI) Team (thru FCHEA Transportation Working Group)
- Joint NFPA 2/55 Task Group to address separation distances for gaseous and liquid hydrogen storage

CCSI encourages the safe and rapid growth of hydrogen fueling infrastructure

Approach: Support of Lab to Full Scale H₂ Testing

Mechanical Testing

- Fundamental mechanical testing to determine root-cause failure modes
- **Advantages:** Flexibility of design, root-cause isolation
- **Limitations:** Difficulty in scaling, requires test apparatus



Sub-Component Level Testing

- Reliability and sub-component life testing (such as compressor valves)
- **Advantages:** uses the actual equipment, lower-cost than full-scale component testing
- **Limitations:** higher cost than mechanical testing, harder to isolate failure mode



Component-Level Testing

- Reliability and accelerated life testing at full component level
- **Advantages:** use of real hardware, laboratory control environment
- **Limitations:** costly experimentation, hard to isolate failure modes, degradation



System-Level Field Testing

- Data from hydrogen demonstration and fueling station installations
- **Advantages:** large sample size, real-life stresses
- **Limitations:** limited control of test parameters



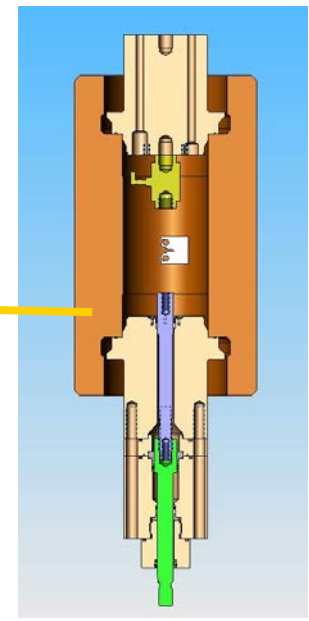
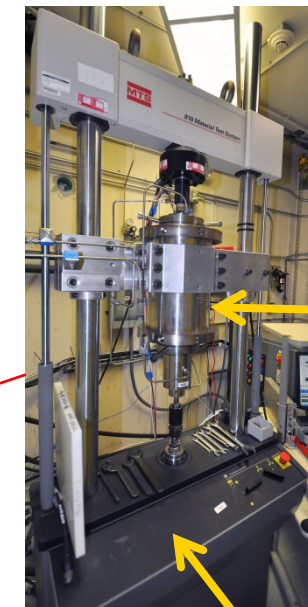
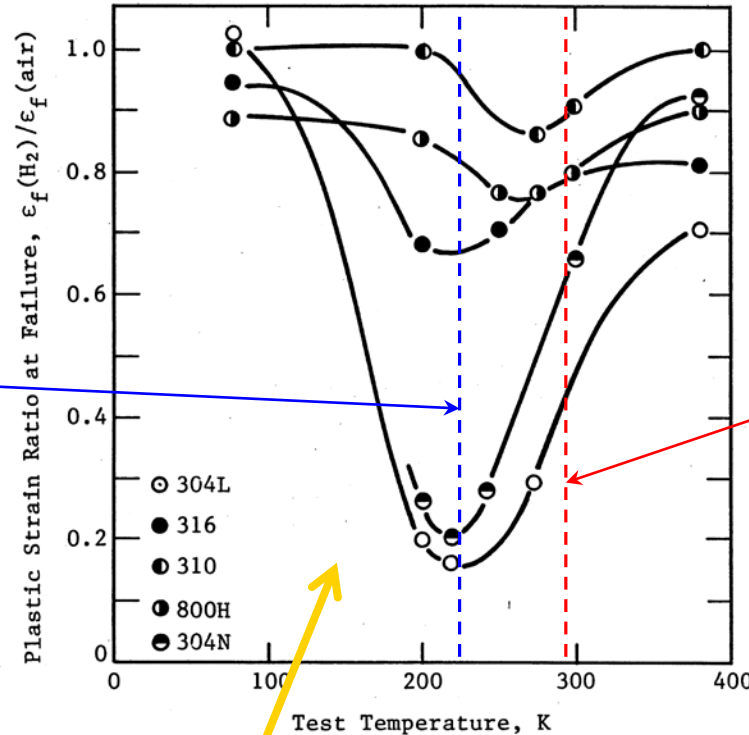
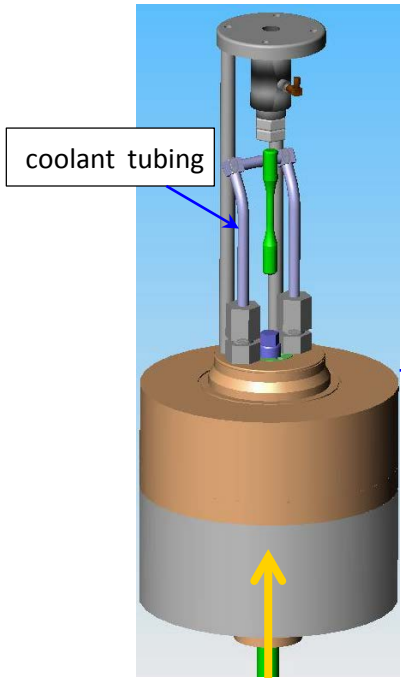
SCS supports a bottom-up component research approach, covering testing from the material level to system – level field testing

SCS involvement with the H2FIRST project, in support of the goals of H2USA

- **Hydrogen Contaminant Detector Task:** report and highlights
 - **Hydrogen Contaminant Detection Report**, published in April 2015, describes the current commercial state of the art technologies in contamination detection. The report is available at: <http://www.nrel.gov/docs/fy15osti/64063.pdf>
- **Reference Station Design Task:** report and highlights
 - **Reference Station Design Report**, published in April 2015, evaluates station economics using HRSAM and includes detailed schematics which include piping and instrumentation designs, bills of material, and descriptions of layouts that ensure compliance with the National Fire Protection Association. These reference designs are meant to help stakeholders quickly evaluate the station configurations that best suit their applications. The report is available at: <http://www.nrel.gov/docs/fy15osti/64107.pdf>
- **Hydrogen Station Equipment Performance (HyStEP) Device:**
 - Objective is to accelerate commercial hydrogen station acceptance by developing and validating a prototype device to measure hydrogen dispenser performance according to CSA HGV 4.3/SAE J2601.



Progress: Low-Temperature Materials Testing Capability (SNL)



Low-temperature pressure vessel internal structure

Ductility of stainless steels in H₂ gas normalized by ductility in air

Current capability for fatigue testing in high-pressure H₂: room temperature only

New capability developed for testing hydrogen embrittlement of stainless steels at sub-ambient temperature

Progress: H₂ Behavior and Risk Assessment



Cold Hydrogen Release Laboratory

Validate liquid H₂ (LH₂) models enable risk assessment tools. New cryo-temperature laboratory will bring a science-based approach to LH₂ at the code committees.

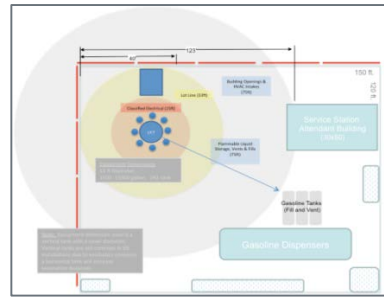
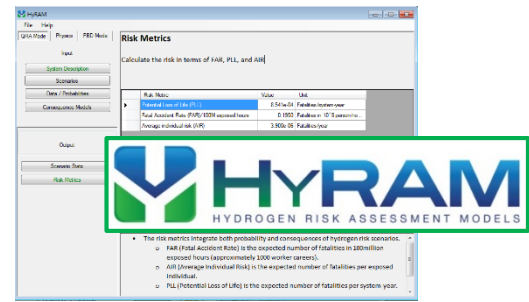
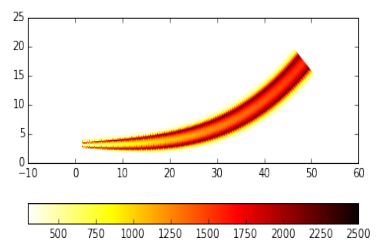
Hydrogen Risk Assessment Models (HyRAM)

Quantitative risk assessment (QRA) utilizes engineering models to produce risk metrics which enable performance risk-based design.

Alternative Compliance Methods

Performance-based design is a risk-enabled (via QRA), NFPA 2 - compliant option for station design.

Station Deployment



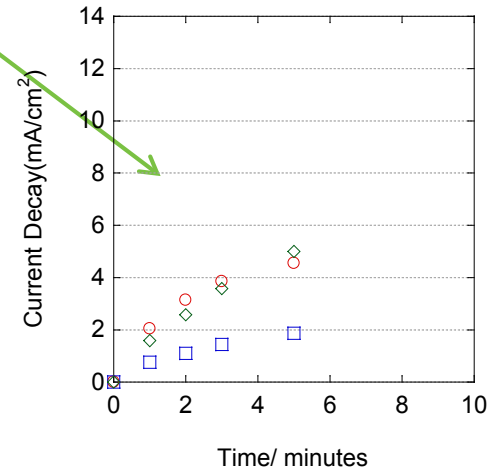
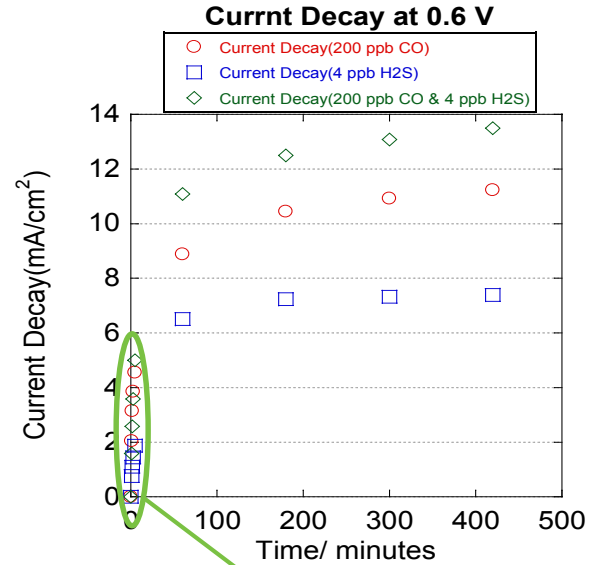
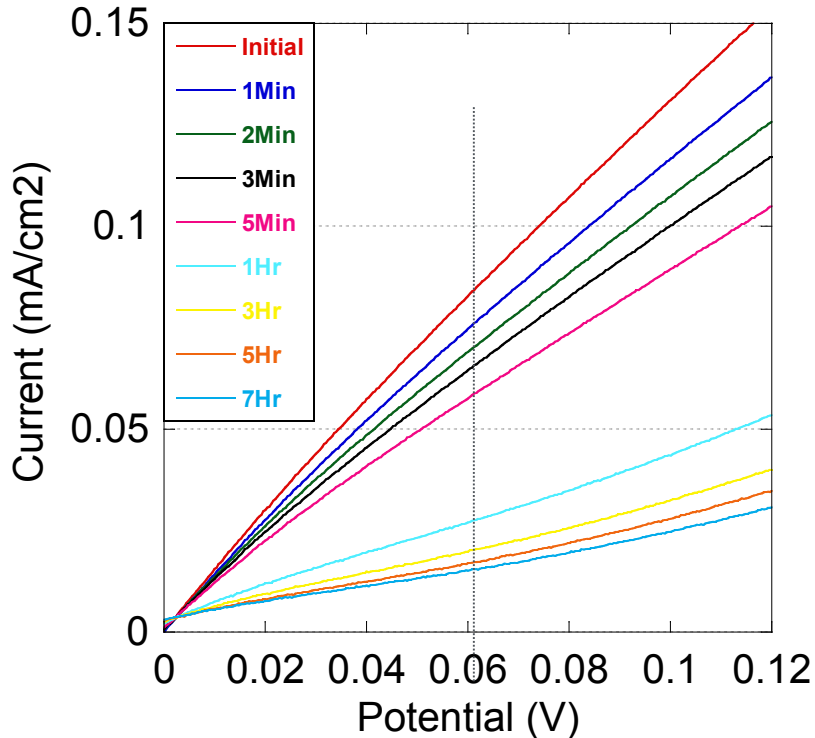
- **New DOE Record #15006:** DOE research has demonstrated up to a 50% reduction in separation distances (for GH₂)
- Design Brief Template developed to demonstrate the performance-based design process

Leveraging science to enable infrastructure through understanding hydrogen behavior, analyzing risk, and implementing inherently safe design options

Accomplishment: Fuel Quality Analyzer (LANL)

0.2 PPM CO & 4 ppb H₂S MEA:

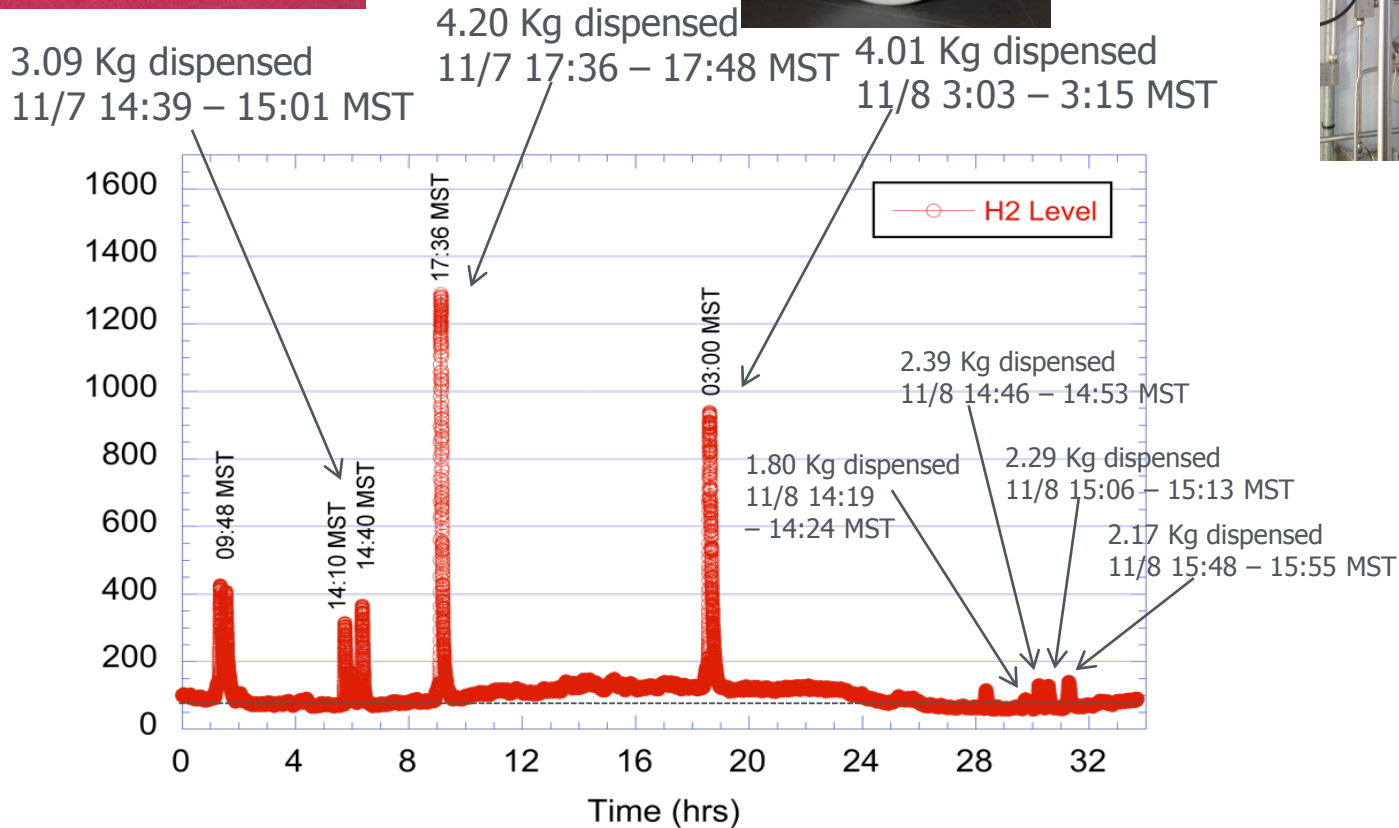
Working Electrode: 0.0409 mg Pt/cm²
 100% RH; 100 sccm H₂



- Measurements taken at shorter exposure time favors CO adsorption
- Decay levels are not additive (as anticipated)

Sensitivity of 200 ppb CO and 4 ppb H₂S achieved at short time scales

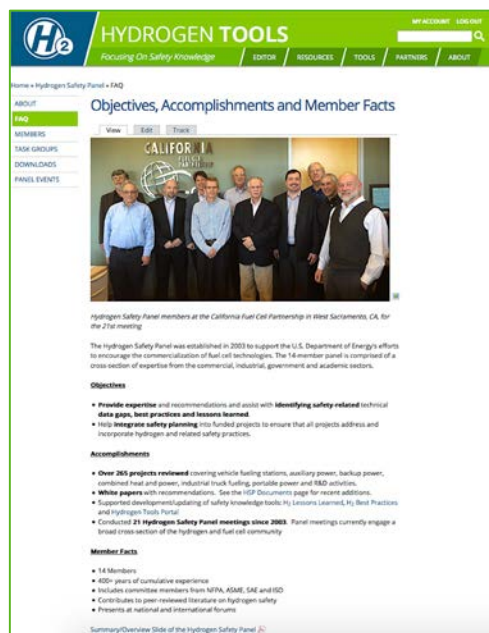
Field Validation: Hydrogen Safety Sensors (LANL)



Investment since 2008 has turned the LANL/LLNL-developed solid state electrochemical safety sensor into a commercially-ready technology

Hydrogen Safety Panel continues to support best hydrogen safety practices through project plan reviews, site visits, and other activities:

- March 2015 Panel Meeting in Sacramento, CA, which included a project review during the meeting
- **18 project reviews since last AMR (412 total)**
- Assisting the H2USA market acceleration working group to remove barriers
- Supporting the California Governor's Office and CA Green Team




New Website: H2tools.org/hsp

| Training Resource | Impact |
|---|---------|
| First Responder Training (in-person) | 1,035 |
| First Responder Training (online) | >32,000 |
| Code Official Training (in-person) | 565 |
| Code Official Training (online) | 1,117 |
| Hydrogen Tools App Downloads | 1,272 |
| NEW! Hydrogen & Fuel Cell Emergency Response Training Resource Downloads | 257 |
| Hydrogen Researcher Training (online) | 179 |

– Over 2,400 first responders and code officials trained in 2014

SCS supports continued code official and first-responder training, both online and in-person, with over 35,000 individuals reached!

Accomplishment: National First Responder Training Resource (PNNL)



National Hydrogen and Fuel Cells EMERGENCY RESPONSE TRAINING TEMPLATE

A properly trained first responder hydrogen fuel cell applications that hydrogen and fuel cell-related missions to protect life and property training materials as a consistent training resource as a consistent training materials are adapted organizations and are meant to serve their missions. The instructor to conduct the training slides.

This nationally-focused training delivery of a variety of training for different presentation styles comprehensive classroom training

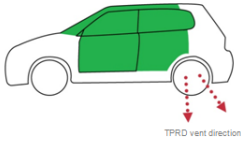
- L1 (Overview)** – This example that has little knowledge is limited to background technologies and their additional slides appropriate
- L2 (Short Course)** – A slide has an intermediate level not necessarily including classroom session for minimized and operation
- L3 (Full Course)** – A slide materials contained in a group would discuss in for purposes intended for

Feedback from presenters and Fuel Cells Emergency Response Training updated training content and technical resource. Feedback should be provided

Revision Date: September 30, 2014

Hydrogen Vehicle Safety Systems

- When a leak is detected by hydrogen sensors, solenoid valves close, shutting off the flow of hydrogen, and the vehicle safely shuts down
- When collision sensors activate:
 - Tank solenoid valves close so that hydrogen remains locked in the tank.
 - In FCVs, high-voltage relays open so that the high-voltage battery/capacitors are isolated from the system
- Tank solenoid valves also close when the vehicle is turned off or the power is disrupted
- Tanks have thermally activated pressure relief devices (TPRDs)



TPRD vent direction

October 16, 2014 / 61

A TEMPLATE for TRAINING

NATIONAL HYDROGEN AND FUEL CELLS EMERGENCY RESPONSE TRAINING

that and Why National Hydrogen and Fuel Cells Emergency Response Training

| Example Uses of Training Slides | L1 | | | L2 | | | L3 | | |
|--|----------|--------------|-------------|----------|--------------|-------------|----------|--------------|-------------|
| | Overview | Short Course | Full Course | Overview | Short Course | Full Course | Overview | Short Course | Full Course |
| Function and Background | | | | | | | | | |
| Fuel Cells Overview and Benefits | | | | | | | | | |
| Fuel Cells – Where are We Today? | | | | | | | | | |
| Diverse Fuel Cell Transportation Applications | | | | | | | | | |
| Hydrogen and Fuel Cell Basics | | | | | | | | | |
| Hydrogen – Where does it come from and how do we use it now? | | | | | | | | | |
| Slide #10: Why Hydrogen? | | | | | | | | | |
| Slide #11: Where Do We Get Hydrogen? | | | | | | | | | |
| Slide #12: Hydrogen Uses | | | | | | | | | |
| Slide #13: Hydrogen Distribution | | | | | | | | | |
| Slide #14: Transporting Hydrogen Today | | | | | | | | | |
| Properties of Hydrogen and its safe use | | | | | | | | | |
| Slide #15: Hydrogen Properties and Behaviors | | | | | | | | | |
| Slide #16: Hydrogen Properties – A Comparison | | | | | | | | | |
| Slide #17: Relative Vapor Density | | | | | | | | | |
| Slide #18: Auto-ignition Temperature | | | | | | | | | |
| Slide #19: Comparison of Flammability | | | | | | | | | |
| Slide #20: Flammability Flange | | | | | | | | | |
| Slide #21: Explosive Range | | | | | | | | | |
| Slide #22: Comparison of Fuel Oxidants and Toxicity | | | | | | | | | |
| Slide #23/24/25: Designing Safe Systems – Gaseous Hydrogen | | | | | | | | | |
| Slide #26: Designing Safe Systems – Liquid Hydrogen | | | | | | | | | |

September 30, 2014



HYDROGEN TOOLS

Focusing on Safety Knowledge



Hydrogen and Fuel Cell Emergency Response Training Resource

The first responder community is critical to the successful introduction of fuel cell applications and their transformation in how we use energy. We hydrogen and fuel cell-related first responder training will be delivered missions to protect life and preserve property. Utilizing this national response training resource as a consistent source of accurate information knowledge. These training materials are adaptable to the specific needs of and training organizations and are meant to complement the existing programs already in place.

DOWNLOAD:
[Training Materials](#)

SLIDES

Slides are divided into seven topical sections, each with an introductory slide summarizing the materials contained in. Example slides are illustrated below. The note pages format of the slides provides more details for the instructor to training. Instructors should share this information when presenting the slides.



Example 1: Basics
Click to enlarge



Example 2: Comparisons
Click to enlarge



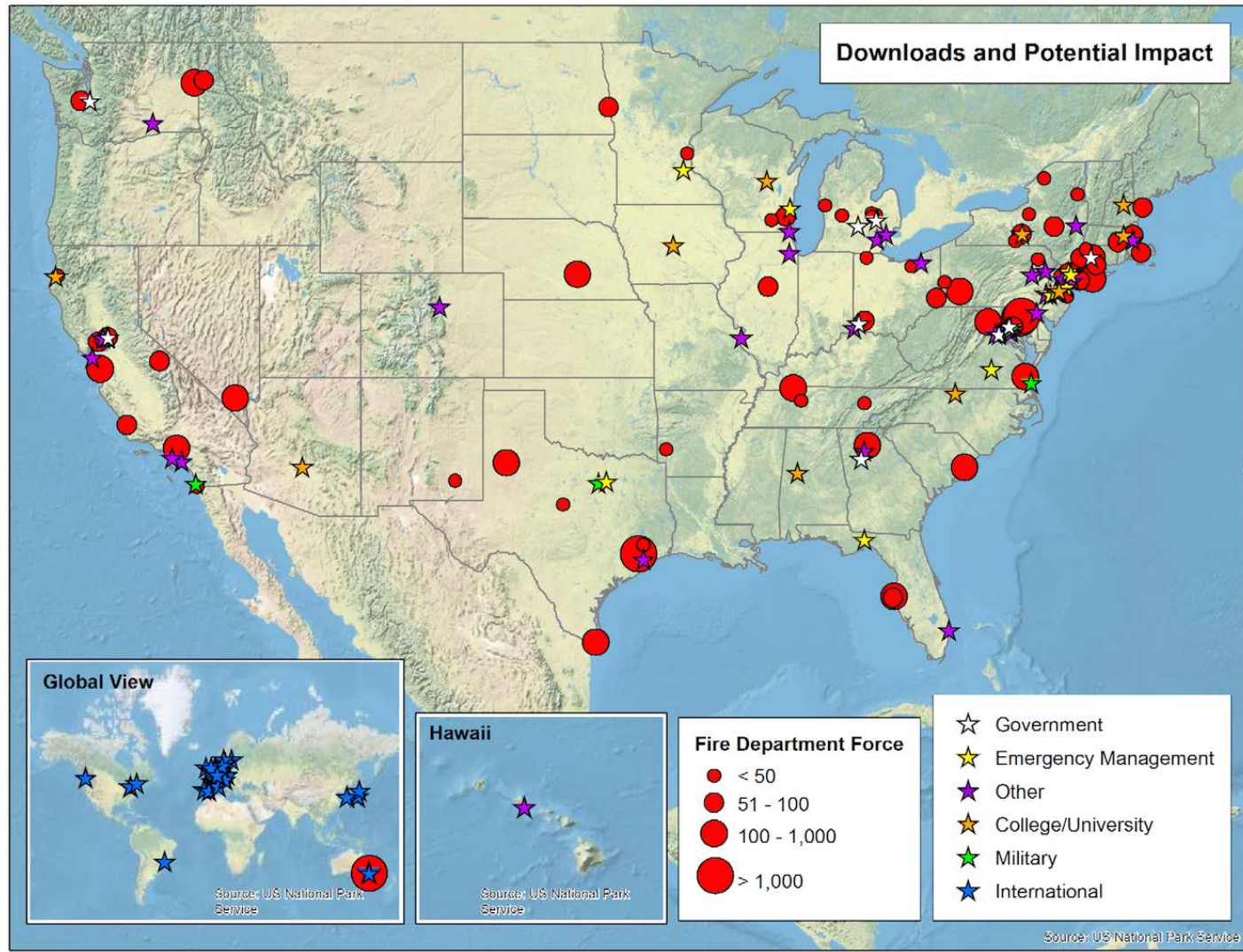
Example 3: Response Considerations
Click to enlarge

- Over 250 downloads since its release in early FY 2015!
- Designed to be delivered by local trainers and complements existing training programs and adaptable to specific needs of first responders
- Updated regularly with the latest information
- Overview webinar held March 2015 (accessible at <http://energy.gov/eere/fuelcells/2015-webinar-archives>)

[Training resource can be downloaded at http://h2tools.org/fr/nt/](http://h2tools.org/fr/nt/)

A properly trained first responder community is critical to the successful introduction of hydrogen fuel cell applications

Accomplishment: National First Responder Training Resource Impact (PNNL)



Clear interest in first responder training resources across the country, including along the northeast corridor!

Accomplishment: Safety and Knowledge Resources

H₂ Safety Best Practices

Welcome!

What is a best practice?
 A best practice is a technique or methodology that has reliably led to a desired result. Using best practices is a commitment to available knowledge and technology to achieve success.

What is H₂BestPractices.org?
 A wealth of knowledge and experience related to safe use and handling of hydrogen exists as a result of an extensive history in a of industrial and aerospace settings. Hydrogen is gaining increasing attention worldwide as a possible energy storage medium, the conversion to electricity through fuel cells or for use as a propulsion fuel. This focus has introduced many new participants to the development, dissemination, and deployment of hydrogen technologies (e.g., fuel cell vehicles and stationary fuel cells).

The purpose of this hydrogen Safety Best Practices website is to share the benefits of a collective experience by providing the best and most accessible guidance to the safe handling and use of hydrogen. Best Practices have been compiled from a variety of sources.

H₂ SAFETY Snapshot
 Vol. 2, Issue 2, July 2011

IDENTIFYING SAFETY VULNERABILITIES

How Do I Perform A Hazard Analysis?
 Perform the hazard analysis at the project's earliest stages using any of the established industry methods described on page 2.

What is it?
 A hazard analysis typically consists of:

1. Define Item Scope
2. System Description
3. Hazard Identification
4. Hazard Analysis

Exciting New Training Opportunity!

Hydrogen Emergency Response: Training for First Responders

As concerns about our nation's energy security and global climate scenarios, a quiz, and a hands-on, live-fire exercise using a specially designed fuel cell vehicle (FCV) have

H₂ Incident Reporting and Lessons Learned
 About Incidents | Advanced Search

New! Lessons Learned Corner

Welcome to the new Lessons Learned Corner! Key themes from the H₂Incidents database will be presented here and several safety hazards the related lessons learned. Please fill out what you think and what themes you would like to see highlighted in the Management of Change.

Management of Change
 Management of change (MOC) is the process used to review all proposed changes to equipment, procedures, materials, personnel, implemented to determine their effects on safety vulnerabilities. For example, standard operating procedures generally describe the parameters (e.g., flow rates, concentrations, pH ranges, temperatures, pressures). A knowledgeable person should evaluate any proposed operation. Operators should be made aware of changes and trained to respond with the appropriate actions if a parameter falls outside

Hydrogen Program

Home > Safety > Bibliography Database

Hydrogen Safety Bibliographic Database

The **Hydrogen Safety Bibliographic Database** provides references to reports, articles, books, & resources for information on hydrogen safety as it relates to production, storage, distribution, & use. The database includes references related to the following topics:

- Hydrogen properties and behavior
- Safe operating and handling procedures
- Leaks, dispersion, and flammable vapor cloud formation
- Embolism and other effects on material properties
- Fuel cells and other energy conversion technologies
- Sensors, tracers, and leak detection technologies
- Accidents and incidents involving hydrogen

In addition to bibliographic references, the database provides select full text documents or links to related resources.

Hydrogen and Fuel Cells Program

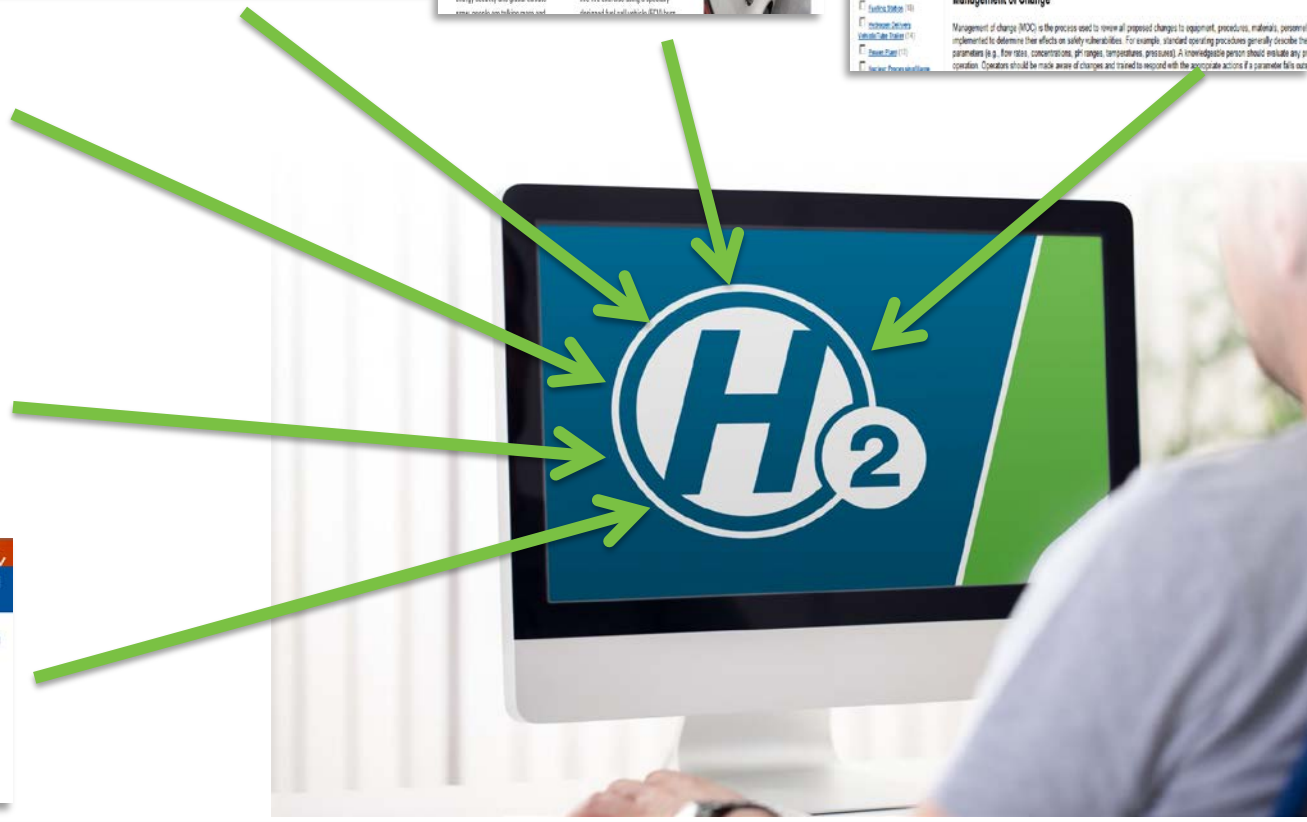
Home > Codes and Standards > Introduction to Hydrogen for Code Officials

Introduction to Hydrogen for Code Officials

The Department of Energy's **Introduction to Hydrogen for Code Officials** online training course provides an overview of hydrogen and fuel cell technologies, how these technologies are used in real-world applications, and references to related codes and standards.

The course consists of four modules:

- Hydrogen and fuel cell technology basics
- Hydrogen and fuel cell applications
- Hydrogen fueling stations

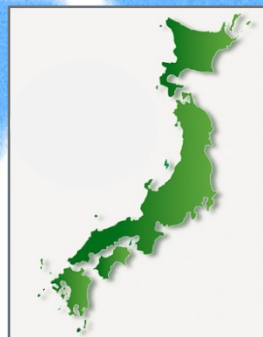


With the launch of H2Tools.org, existing safety and knowledge resources are consolidated into a central location, alongside newly added functionality and content



European Union

- HyCoRa – LANL/ANL, VTT, SINTEF
- MATHRYCE – SNL, VTT, Air Liquide, JRC
- HyResponse – PNNL, ENSOSP, AREVA

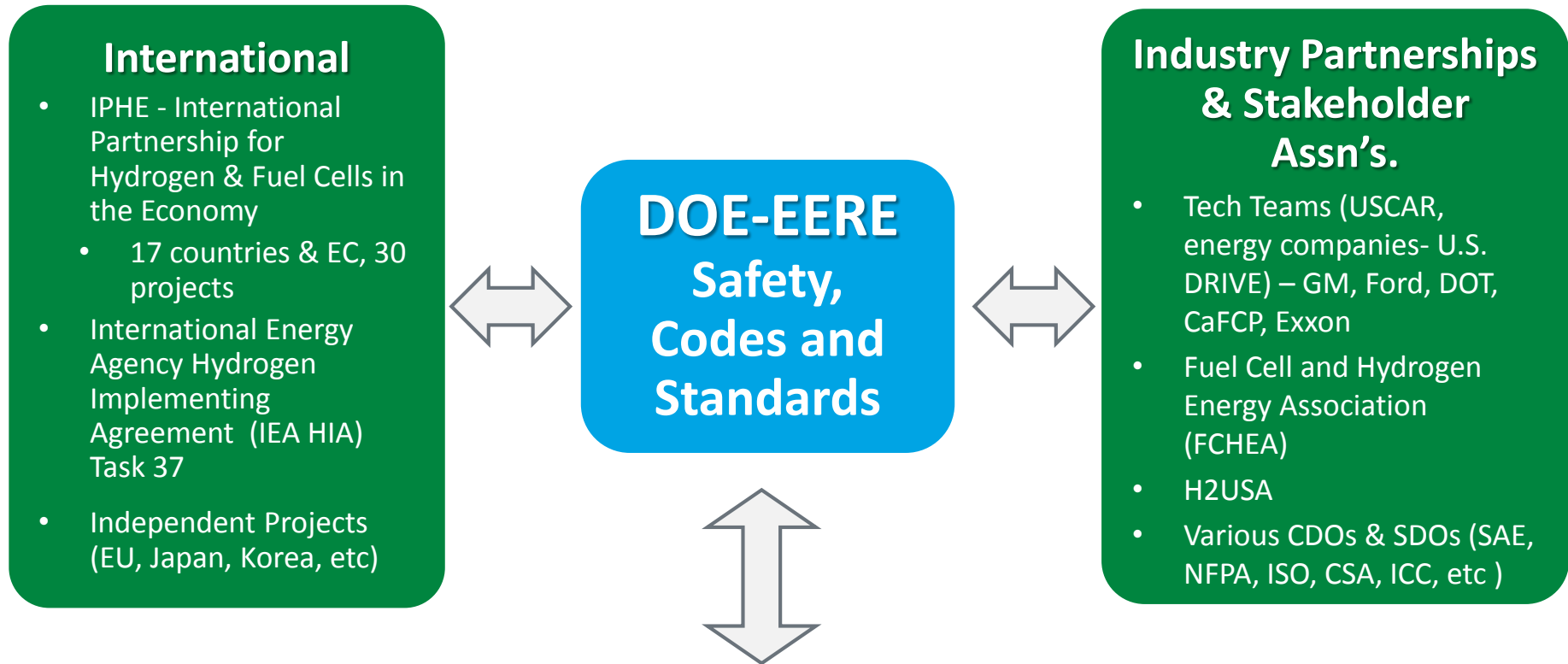


Japan

- I2CNER – SNL, Kyushu University
- Materials Compatibility – SNL, AIST-Tsukuba
- FQ Test Method Development – LANL, JARI, CEA

- Active international collaborations with national and foreign labs, universities, private organizations, and energy companies
- Bilateral and multilateral efforts focus on safety training, materials compatibility for high-pressure hydrogen applications, fuel quality, and sensor testing and validation

Leveraging international collaboration allows for the development and promulgation of essential codes and standards to enable widespread deployment



Summary of activities and upcoming milestones

- Continue efforts in fuel quality and metering to quantify the impact of fast fueling (SAE standard J2601).
- Publish consistent hydrogen fuel quality testing protocols (e.g., PEM stacks) to provide comparable inter-lab results.
- Complete hydrogen fueling station template (including the codes necessary for widespread commercialization of infrastructure).
- Continue outreach and training for relevant stakeholders including code officials and emergency responders
- Develop a predictive engineering model for hydrogen dispersion and ignition.

FY 2014

3Q 2014: Publishing of SAE J2601 Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles

FY 2014: NFPA 2 adopted into the International Fire Code and California adopting NFPA 2 (2011)

FY 2015

2Q FY2015: Hydrogen Tools Portal released (h2tools.org)

FY 2015: Publishing of National Permitting Template in support of H2USA

FY 2016

1Q 2016: 6th Annual International Conference on Hydrogen Safety in Japan

1Q 2016: 2nd Edition of NFPA 2 Hydrogen Technologies Code published

FY 2016: United States adoption of Global Technical Regulation as the Federal Motor Vehicle Safety Standard (FMVSS). Phase 2 begins.

Thank you

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