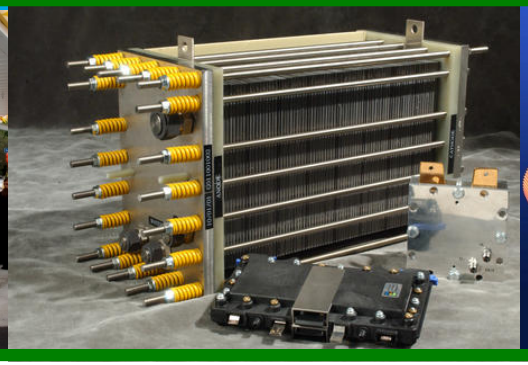
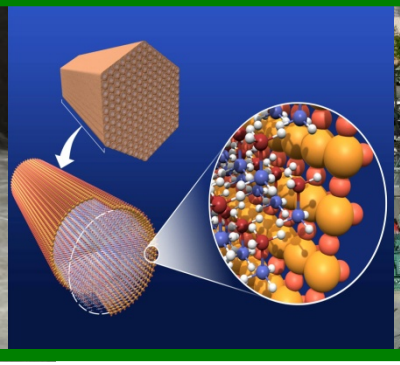
U.S. DEPARTMENT OF ENERGY

# Safety, Codes & Standards Program Area

# -Plenary Presentation-


*Will James*

*Fuel Cell Technologies Office*



***2017 Annual Merit Review and Peer Evaluation Meeting***

***June 5 - 9, 2015***

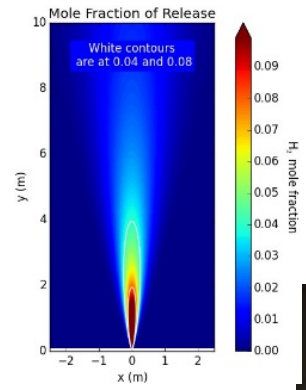
# Goals & Objectives

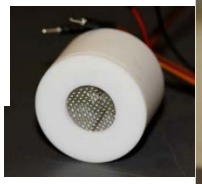


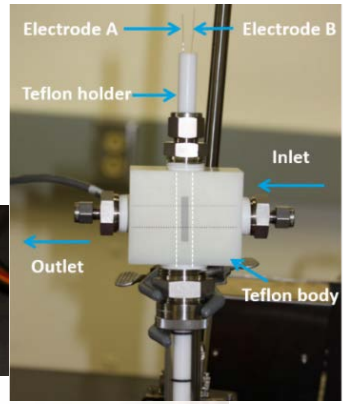
## Codes & Standards

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

HYRAM
HYDROGEN RISK ASSESSMENT MODELS







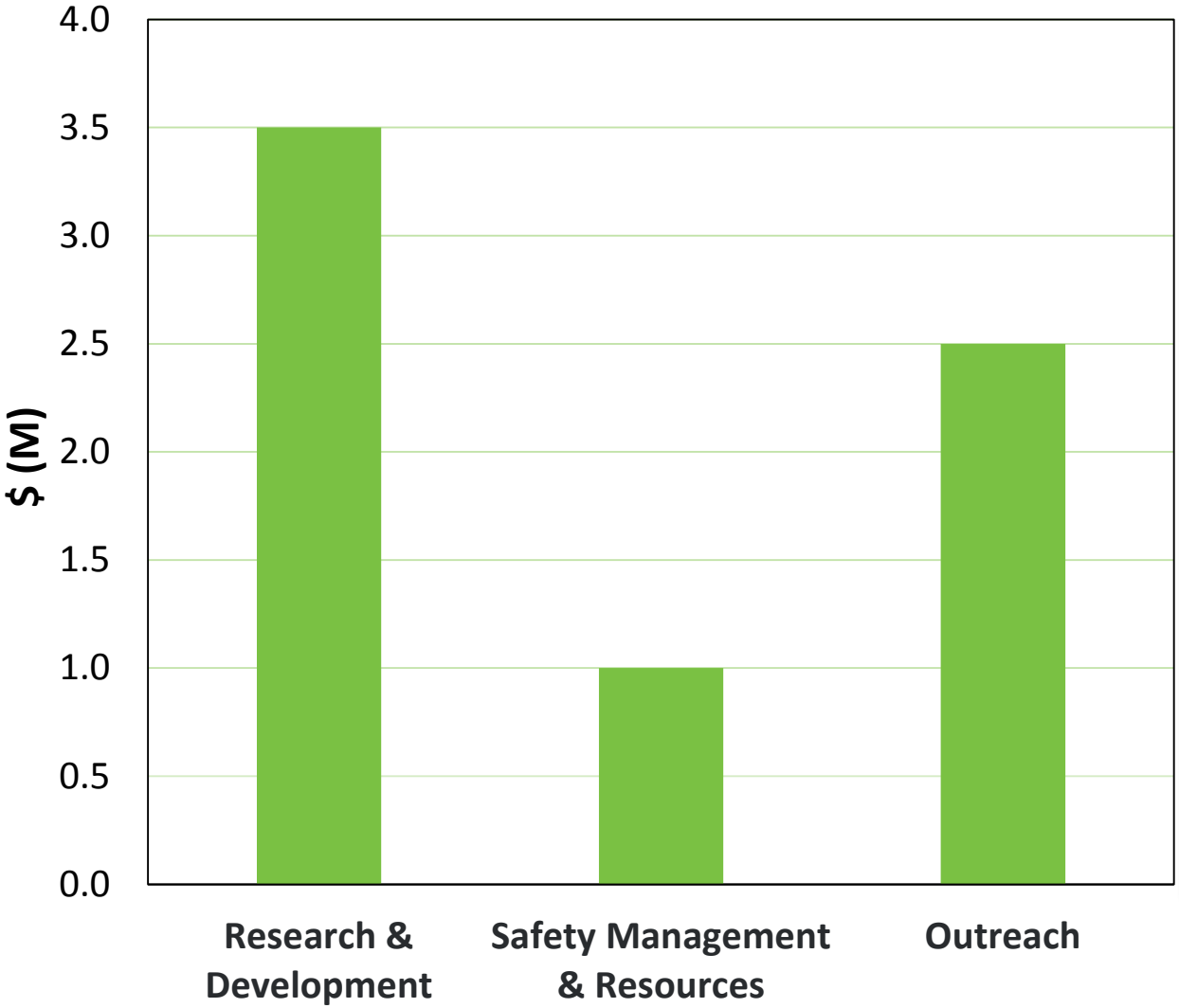

## Safety

- Ensure that **best safety practices** underlie activities supported through DOE-funded projects.
- Enable **widespread sharing** of **safety-related information resources** and lessons learned with key stakeholders.

***Funding R&D needed to develop science-based codes and standards, thereby enabling the safe deployment of $H_2$ and fuel cell technologies***

# Budget

## FY 2017 Appropriation = $ 7M




## Emphasis

- Liquid $H_2$ behavior
- Quantitative risk assessment
- $H_2$ compatibility of metallic and non-metallic materials
- $H_2$ contaminant detector for fuel quality
- Support critical stakeholders in $H_2$ safety best practices

# Current Status – Codes & Standards

**Vehicle Standards**

GTR-13
SAE J2579
HGV 2-2014
HGV 3.1-2015
CSA HPRD 1-2013
ANSI/CSA FC 3-2004

**Fueling and Communication**

SAE J2601
SAE J2799
SAE J2600

**Separation Distances**

NFPA 2/55

**Fuel Quality**

SAE J2719

***U.S. DOE R&D efforts resulted in significant time saved in the development of station-related codes and standards.***

# Strategy and Barriers



| Focus areas | Barriers* | Objectives |
|---|---|---|
| Hydrogen Behavior | Insufficient data for code revision (e.g.- large station footprints) | R&D model development and verification to establish scientific basis for codes and standards revisions |
| Risk Assessment | Usage and access restrictions; Limited reliability data | Develop tools on a scientific foundation which can be used for various hydrogen applications |
| Materials Compatibility | Lack of information on new materials compatibility with hydrogen | Establish a foundational materials understanding, which will enable and support the C&S development |
| Detection & Sensors | High cost and limited commercial availability of products | Develop $H_2$ contaminant detectors for fuel quality at $H_2$ station. |
| Outreach & Support | Limited access and understanding of safety data and information | Support critical stakeholders in understanding hydrogen safety best practices. |

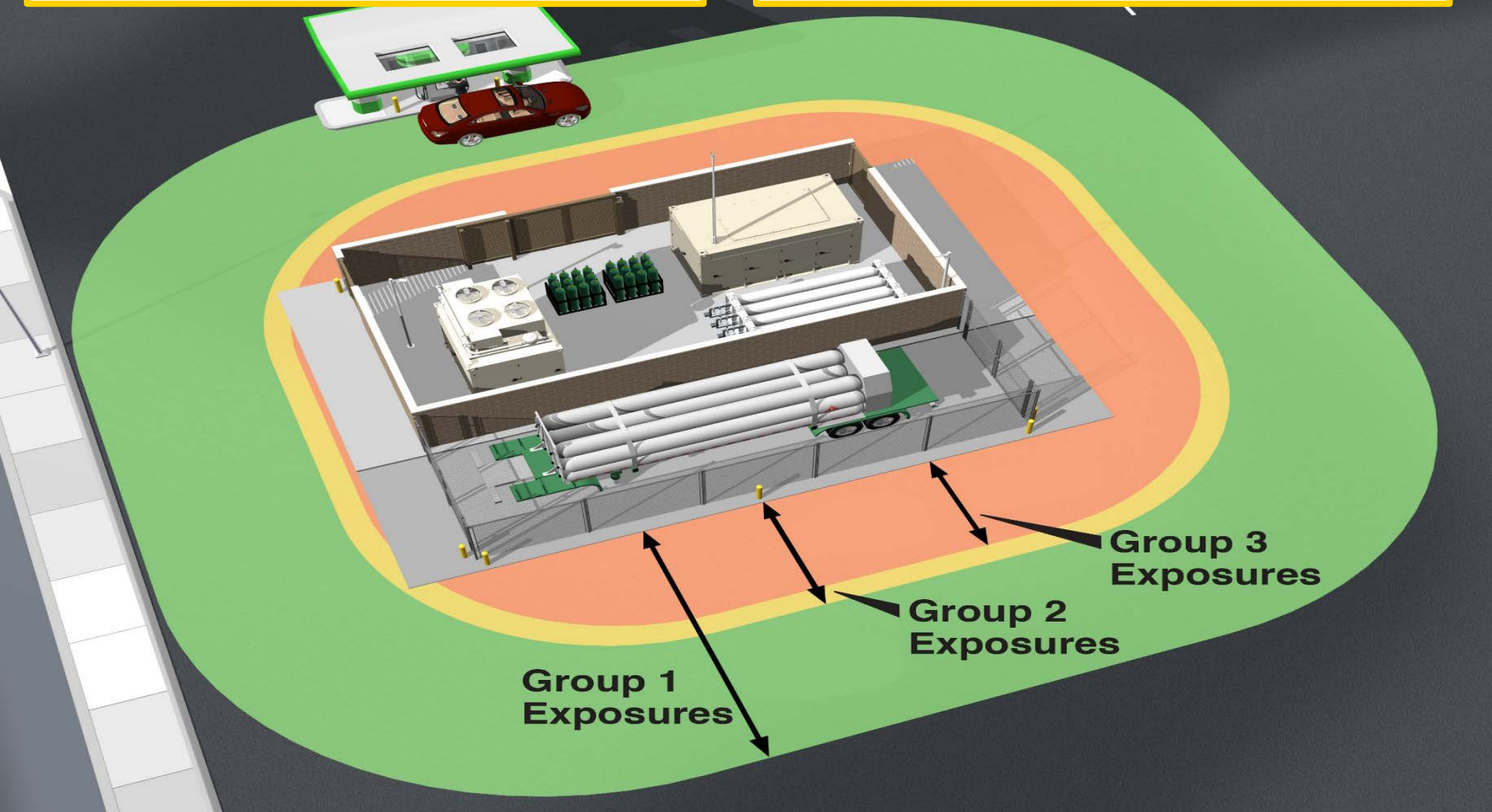
* From Safety, Codes and Standards MYRD&D (June 2015)

# Barrier: LH2 Separation Distances



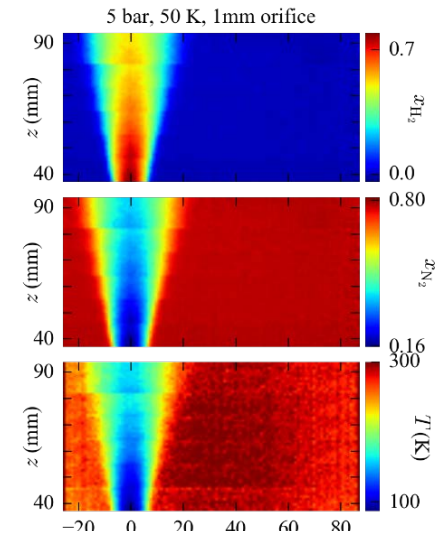
**Barrier**: Insufficient data for code revision (large LH2 station footprints)

**Barrier**: Usage and access restrictions; Limited reliability data



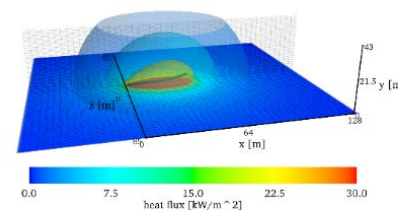
# R&D Accomplishment: Separation Distances

- **Hydrogen Behavior (SCS010)**
  - **Developed and implemented Raman imaging technique to measure cryogenic plumes at 50K**

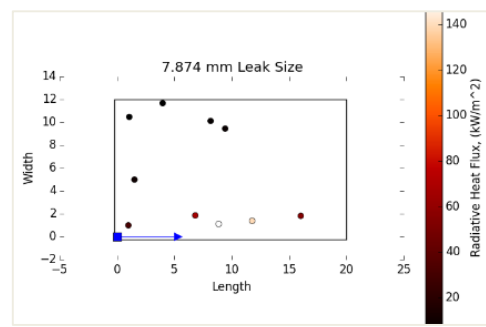



- **Quantitative Risk Assessment (SCS011): HyRAM 1.1 released with new features**
  - Incorporated the curved flame module now in QRA mode – **improved physical accuracy**
  - Achieved **67% reduction in curved flame computing time**

HYRAM
HYDROGEN RISK ASSESSMENT MODELS

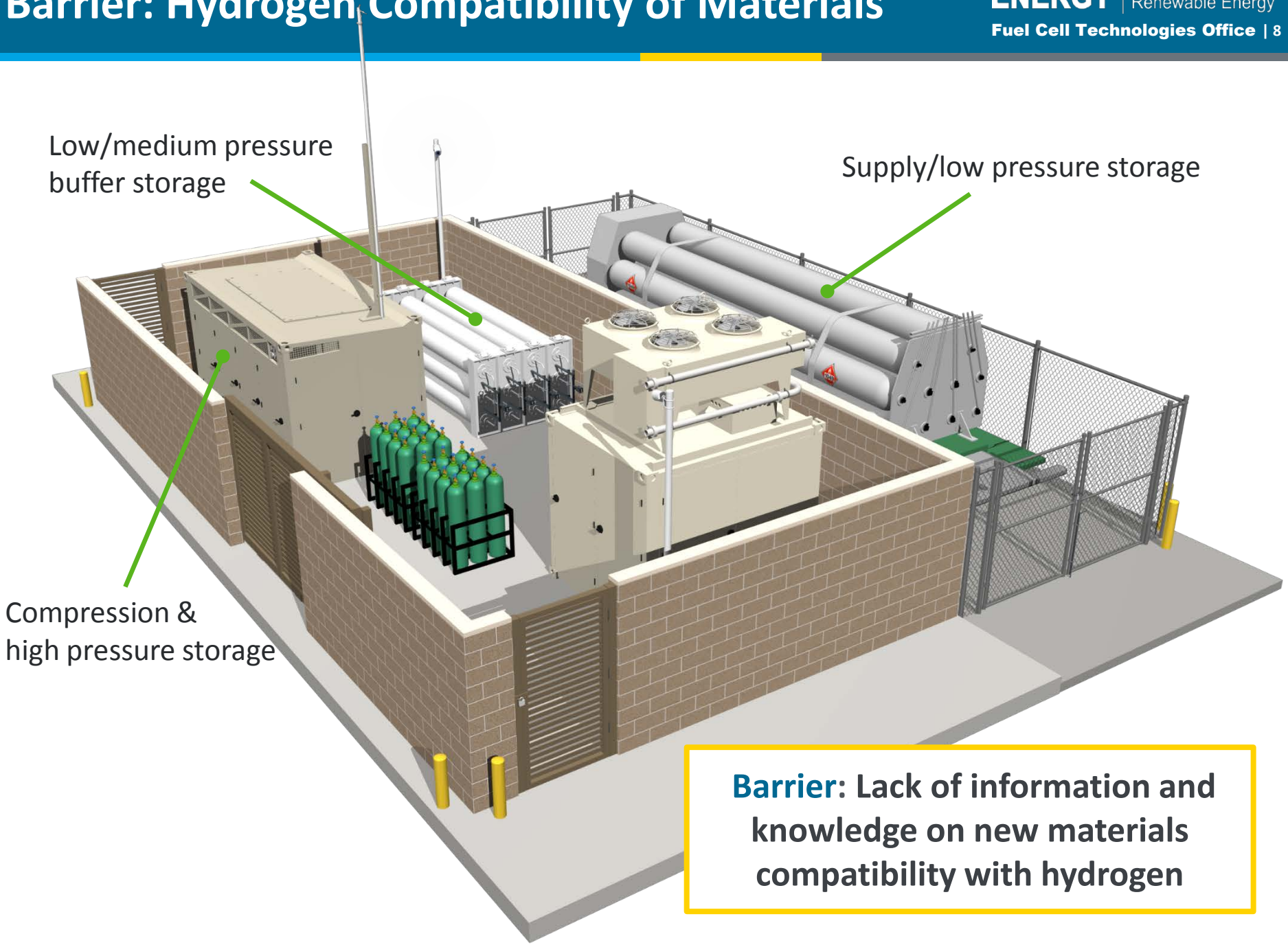



- **Enable Hydrogen Infrastructure through Science-based Codes and Standards (SCS025)**
  - **Achieved additional 50% reduction for GH2 in 2020 edition of NFPA 2**
  - **Initiated the evaluation multiple leak scenarios to demonstrate that the alternate design ensures equivalent system safety, which could help to provide variances.**



# Barrier: Hydrogen Compatibility of Materials



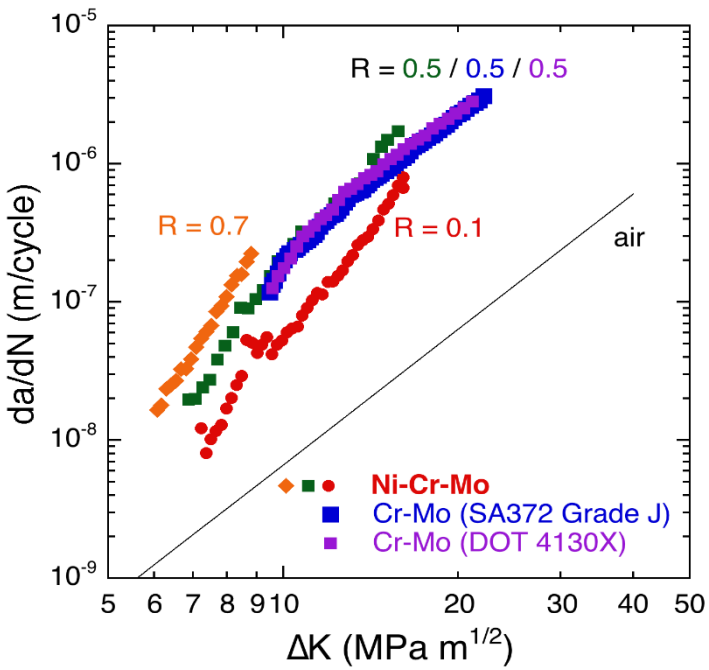



**Barrier: Lack of information and knowledge on new materials compatibility with hydrogen**

# R&D Accomplishment: $H_2$ Materials Compatibility

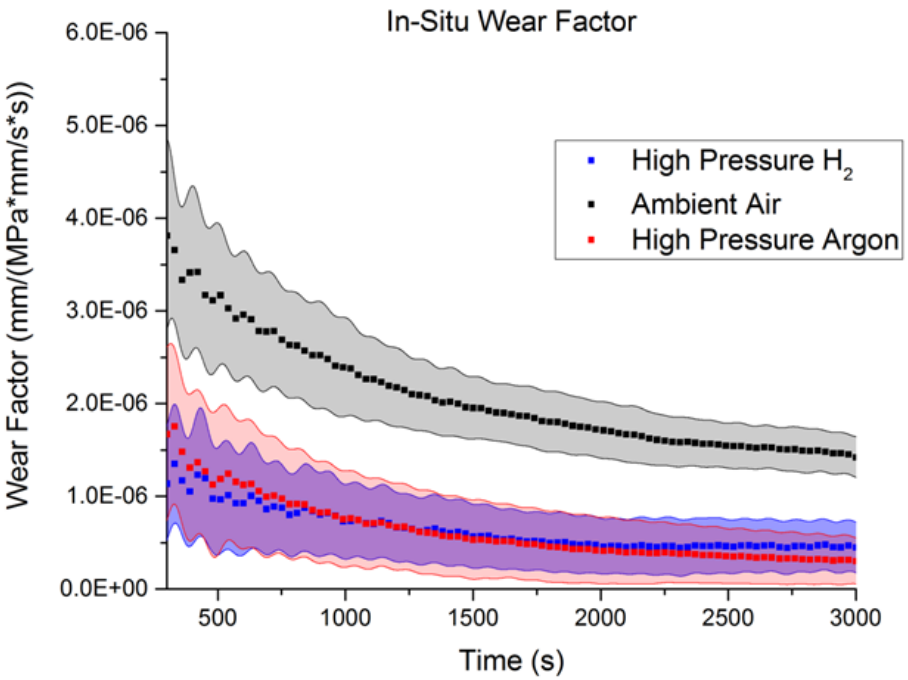
## Metallic Materials Compatibility (SCS005)

- FY2017: High-hardenability steels (Ni-Cr-Mo) show similar fatigue crack growth rates as common PV steels (Cr-Mo) in gaseous hydrogen




## Non-Metallic (Polymer) Compatibility (SCS026)

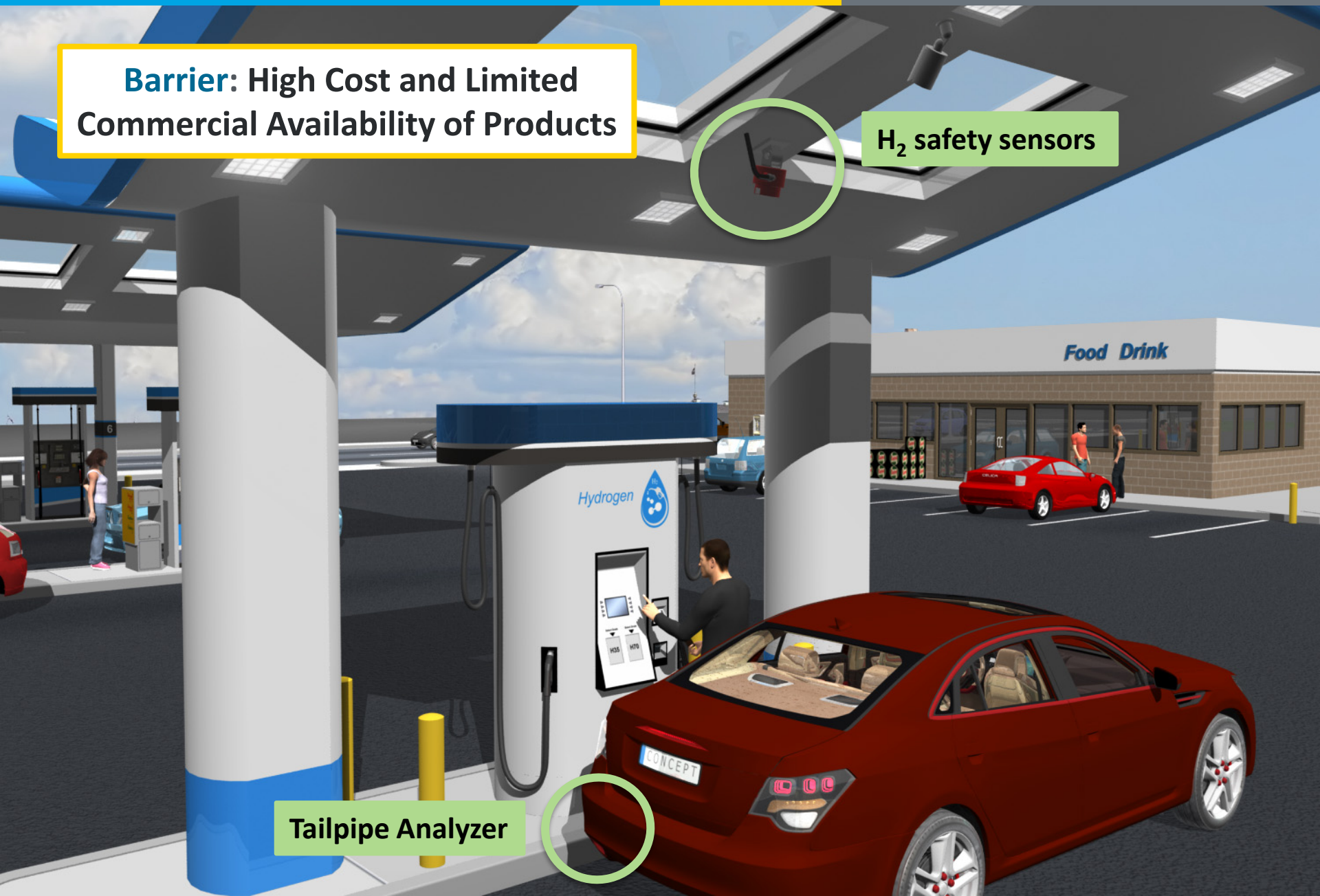
- FY2017: Initiated testing program of critical materials to understand behavior (e.g.- Tribology in 500 bar $H_2$




***Performing critical materials R&D to understand material behavior in high pressure hydrogen, which will enable RCS in support of infrastructure deployment***

# Barrier: Safety Sensors





# R&D Accomplishment: Safety Sensors

**Objective**: **Develop low cost, low power, durable, and reliable $H_2$ safety sensor for vehicle and infrastructure applications.**

1. **Vehicle Repair Facility**: NREL-KPA/Toyota (sensors mandated by IFC). Deployed in CA and NE on-going
   - NREL successfully qualified sensor for application, facilitating AHJ acceptance.
   - On-going support to assure continued success.
2. **Vehicle Tailpipe $H_2$ Emissions**: NREL, in support of Global Technical Regulation (GTR)
   - Developed FCEV Exhaust Analyzer for verification of GTR-13 requirements.
   - Performance verified in the laboratory; Field tested on FCEV; detected hydrogen successfully

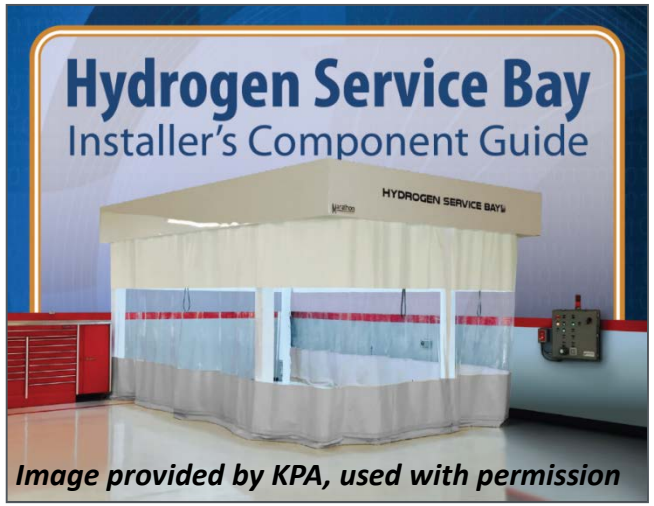
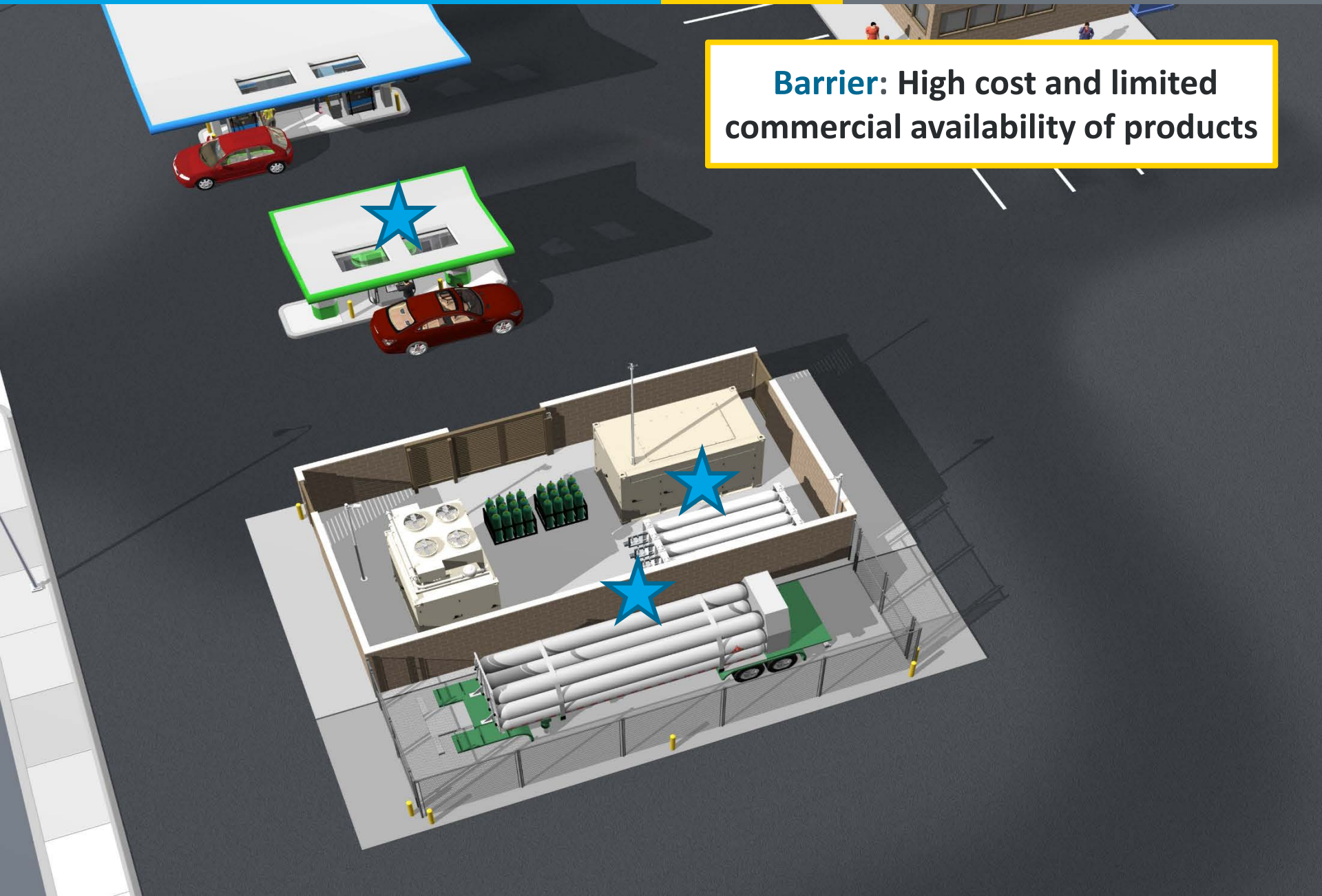


*Image provided by KPA, used with permission*

***Comprehensive knowledge on safety sensor behavior is improving safety for FCEVs, infrastructure, and repair garages; all critical components of broad commercialization of hydrogen technology.***

# Barrier: Fuel Quality Assurance





**Barrier: High cost and limited commercial availability of products**

# R&D Accomplishment: Fuel Quality and Fuel Quality Assurance

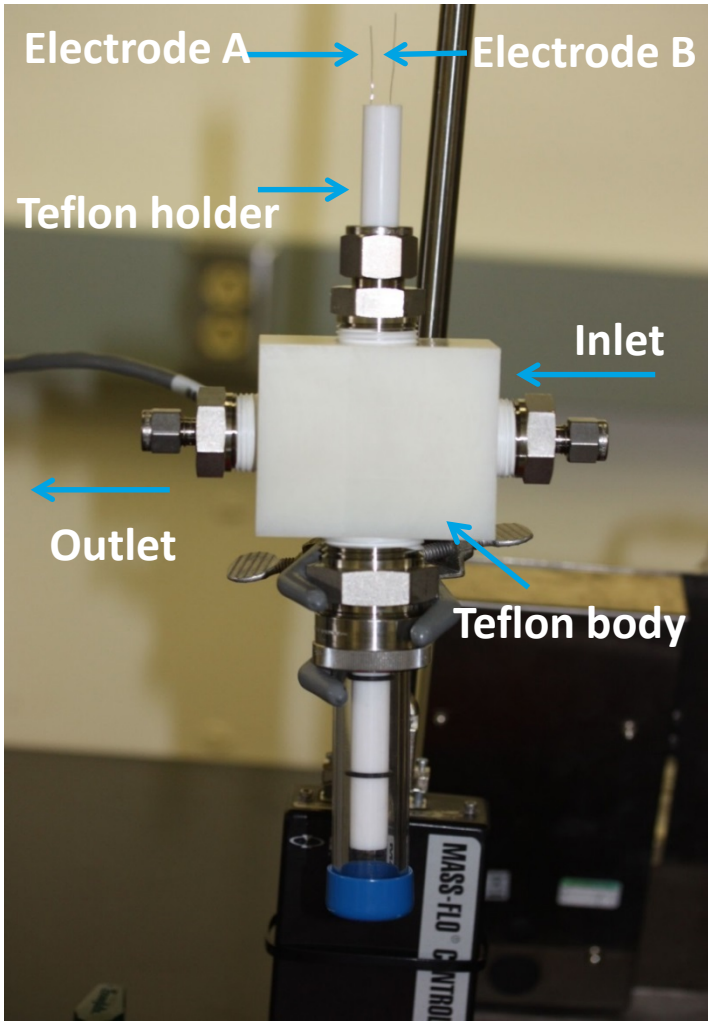


## Hydrogen Fuel Quality (SCS007)

- Determined that low loaded MEAs are not tolerant to SAE J2719 level of impurities.
- Parametric study of impurities underway to quantify CO and H2S tolerance levels of low loaded MEAs.
- Testing under dynamic conditions including impurity mitigation strategies will ultimately determine the future of fuel quality standards.

## Hydrogen In-Line Analyzer (SCS007)

- **Patent application filed for analyzer prototype.**
- One order of magnitude improvement in baseline
- Dramatic improvement in CO sensitivity (sensitive to < 50 ppb)
- Operation under dry H2 for > 1 month




***A means of detecting contaminants in the hydrogen fuel stream is vital to ensure quality according to SAE J2719 and prevent damage to the fuel cell.***

# R&D Accomplishment: Fuel Quality Assurance

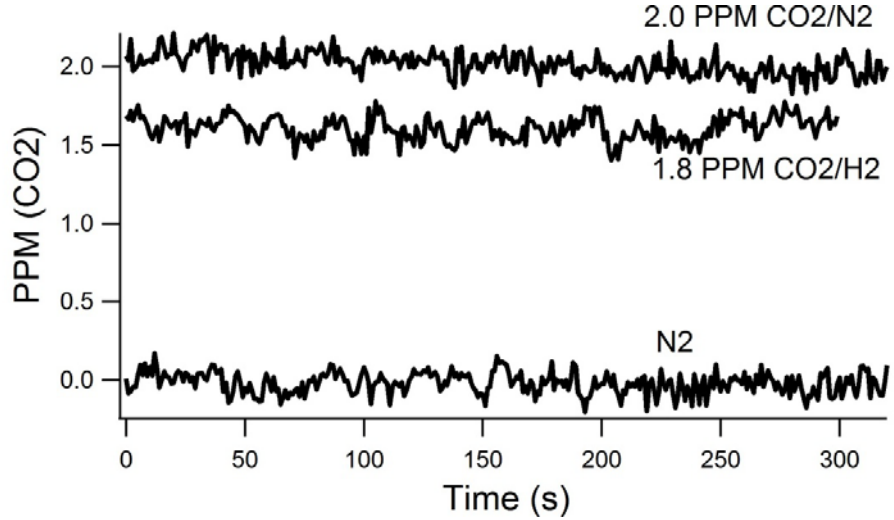
## Leveraging SBIR Program to make impact:

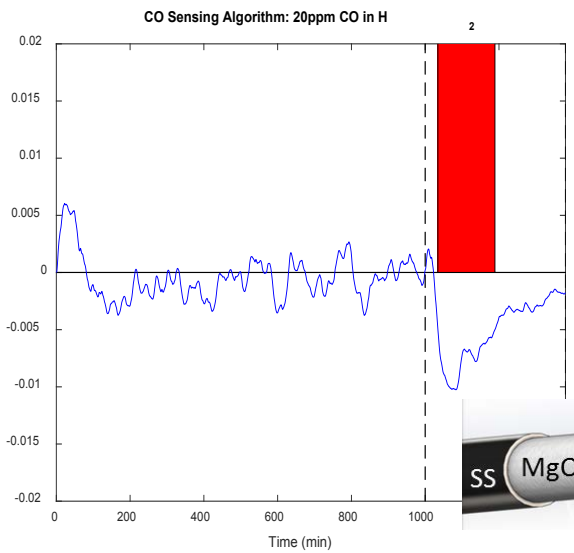
1. **Southwest Science (SCS028): Developing diode laser hydrogen contaminant detector for real-time measurements in fuel station**

- Detection at SAE J2719 levels CO, CO2,CH4, and high levels of S. Expect H2O and NH3 will be demonstrated at better than SAE J2719.

2. **Sustainable Innovations & UCONN (SCS029): Developing electrochemical hydrogen contaminant detector**

- Preliminary design complete, commercially available components, up to 12 sensors in single housing
- Working to achieve improved durability and lifespan through electrolyte modification



***Detecting contaminants in the hydrogen fuel stream is vital to ensure fuel quality according to SAE J2719 and prevent damage to the fuel cell.***

# R&D Accomplishment: Inter-Laboratory Research Integration Group (IRIG)



## IRIG Objectives (SCS001):

- **Enable R&D to positively impact public safety by writing code proposals based on research**
- **Identify areas of research that are needed to support code development based on deployment priorities**
- **Achieve the above objectives through a structured process that utilizes DOE laboratory work**
- **Implement the Codes & Standards Continuous Improvement (CCSI) process**

## IRIG Team/FY17 Objectives

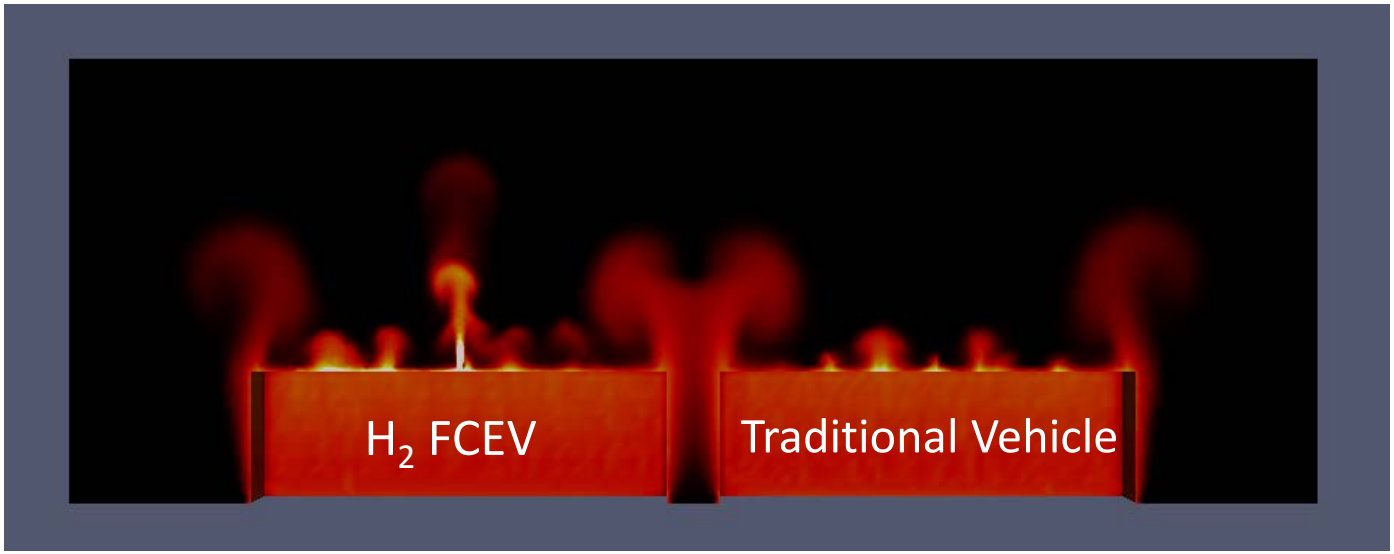
- **Members**: NREL, PNNL, SNL, and LANL
- Submit at least three high impact proposals, potential topics include:
  - NFPA 502: proposal on FCEVs in tunnels
  - NFPA 2: Safe venting for hydrogen stack discharges
  - Component safety (likely hose safety requirements)
  - Multi-fuel stations
  - H2@Scale

***Leveraging DOE research, particularly unused R&D assets, can support major code proposals and enable advances in public safety.***

# Cross-cutting Effort: Tunnel Safety Evaluation

## Tunnel Safety Evaluation Accomplishments (SCS025):

- Developed risk analysis framework and identified scenarios of concern
- Coupled **Computational Fluid Dynamic** (CFD) and **Heat Transfer models** to evaluate hydrogen fire impact on steel structure. Model will evaluate steel strength & potential for explosive spalling of concrete. (one example)
- Work done by SNL with support from NREL and PNNL



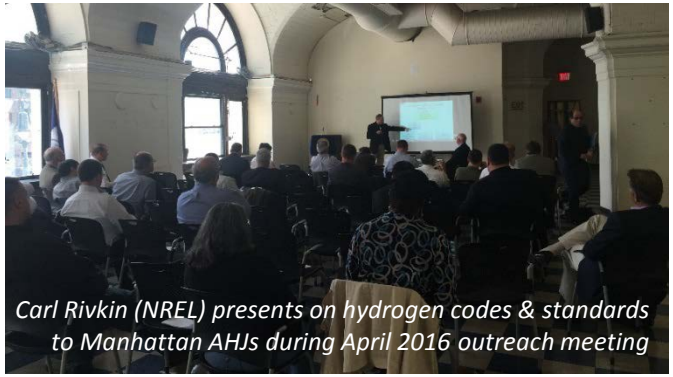

***Risk analysis and modeling results will be communicated to code officials to assist in their decision-making on allowing FCEVs in tunnels.***

# Enabling Safe Deployment: California & the Northeast

## *Safety outreach in both California and Northeast in FY17: Supporting the safe rollout of hydrogen infrastructure (SCS019)*

### Accomplishments:

- **October 2016 – Held meetings in NY (x2), NJ, and MA:**
  - Attendees: Fire marshals, local and state officials, automotive industry and hydrogen developers.
  - Discussed hydrogen station deployment and responded to questions and concerns.



*Carl Rivkin (NREL) presents on hydrogen codes & standards to Manhattan AHJs during April 2016 outreach meeting*

- **March 2017 — Held meetings at 7 California locations:**
  - Attendees: Hydrogen fueling station builders, code officials, and other state officials and stakeholders
  - Discussed safety issues and lessons learned from recent station deployments.
  - Pertinent learnings from the meetings may be added to the Best Safety Practices online resource.

***Safety meetings result in feedback to R&D and code community, helping to ID gaps and improve best practices***

# Enabling Safe Deployment: H2Tools.org



**Objective**: Ensure that best safety practices underlie and inform R&D activities supported through DOE-funded projects (SCS019).

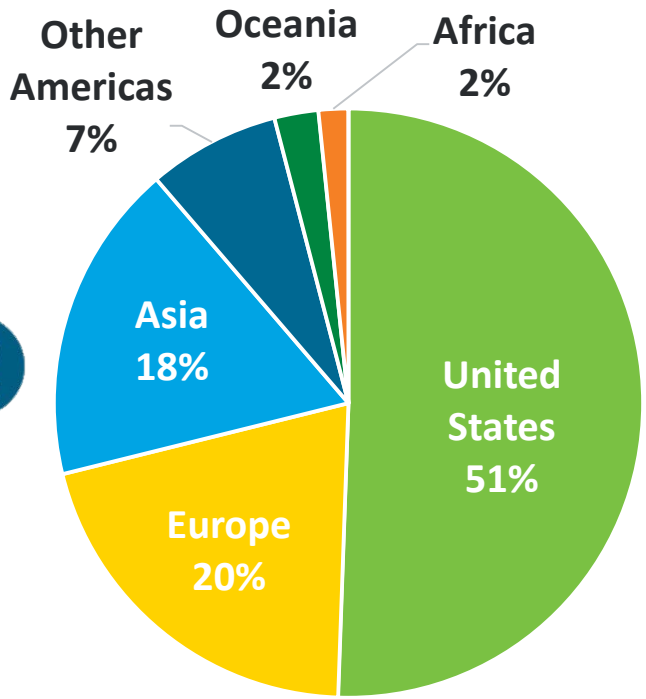
## *Site Content*

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

## *Usage Stats**

- **135,160** Total Pageviews since 2015
- **23,805** Sessions
- **5.68** Pages Visited per Session
- **7:26** Minutes per Session

## H2Tools.org - A Global Resource!




*Nonbounce statistics through March 31, 2017

***The U.S. is a leader in hydrogen safety; H2Tools.org is a key resource to disseminate safety information***

# Enabling Safe Deployment: FEMP Partnership

**FCTO, PNNL, and NREL + Federal Energy Management Program (FEMP) (SCS019): Provide agencies and organizations with information, tools, and assistance needed to deploy clean energy technologies.**

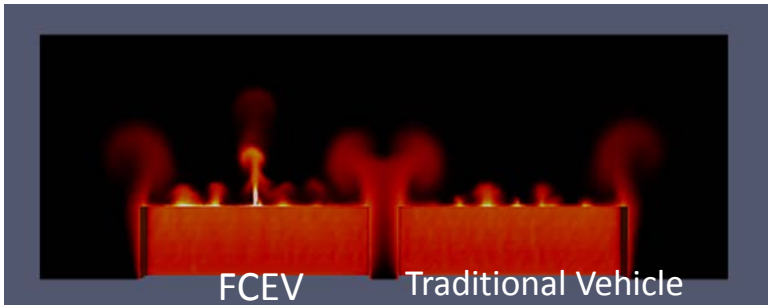
- PNNL and NREL will collaborate to develop training material and train agencies over a 5 year effort
- Trainings will transition as FCEVs become more widely available in federal fleets.
- **FY17**: Incorporate introductory hydrogen information into FEMP training and outreach material.
  - Will present at the August 2017 Energy Exchange

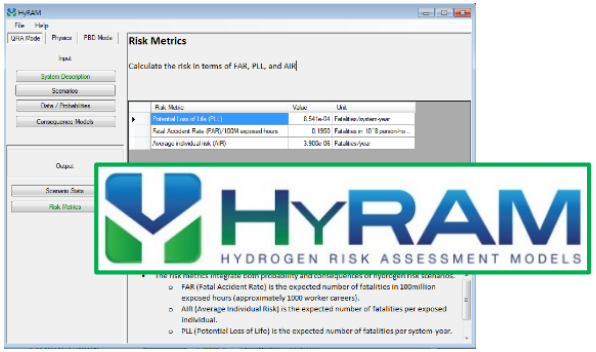
**Note: Any proposed future work is subject to change based on funding levels.**

***As the number of FCEVs on the road continue to increase, it is important to get federal agencies familiar with hydrogen and fuel cell technologies***

# R&D Progress Since AMR 2016

- New techniques measured cryogenic plumes in liquid $H_2$ release laboratory **(SCS 010)**
- Engaged stakeholders for feedback on polymeric materials; identified four of interest and initiated testing and characterization program **(SCS 026)**
- Developed risk analysis framework and identified scenarios of concern for tunnel safety **(SCS 025)**
- Patent application filed for in-line fuel quality analyzer **(SCS 007)**
- HyRAM 1.1 released with new features **(SCS 011)**
- Successfully qualified repair facility sensor for application, facilitating AHJ acceptance **(SCS 021)**



***Continuing to perform critical R&D to enable science-based codes and standards***

# Collaborations

## International

- IPHE - International Partnership for Hydrogen & Fuel Cells in the Economy
  - 18 countries & EC, 30 projects
- International Energy Agency Hydrogen Implementing Agreement (IEA HIA) Task 37
- IA HySAFE
- Independent Projects (EU, Japan, Korea, etc)

## DOE-EERE Safety, Codes and Standards

## Industry Partnerships & Stakeholder Assocations.

- Tech Teams (USCAR, energy companies- U.S. DRIVE) – GM, Ford, DOT, CaFCP, Exxon
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- H2USA
- Various CDOs & SDOs (SAE, NFPA, ISO, CSA, ICC, etc )

**National Collaborations (inter- and intra-agency efforts):**

## State & Regional Partnerships

- California Fuel Cell Partnership
- CT Center for Advanced Technology
- Massachusetts Hydrogen Coalition

## National Laboratories

Los Alamos
NREL
Oak Ridge
Pacific Northwest
Sandia

## Federal Agencies

DOT NASA DOE-FEMP

– Interagency coordination: staff-level Interagency Working Group Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.

# Summary of activities



- **Continue to examine cryogenic releases to increase the ability to cite liquid hydrogen stations**
- **Evaluate metallic materials that could potentially be used in hydrogen service to reduce cost by without sacrificing safety**
- **Develop better understanding of hydrogen effects in non-metallic materials for hydrogen refueling infrastructure including the development of a publicly available technical reference**
- **Continue support for the development of a domestic supply chain of safety, codes & standards-related hydrogen and fuel cell components, including a testing and standard committees providing input for critical components**
- **Outreach to first responders and code officials to support the public acceptance of hydrogen and fuel cell technologies through collaborative partnerships, state, and local initiatives.**

**Foundational understanding in science will help enable the safe deployment of hydrogen and fuel cell technologies safely**

# Thank you

**Will James**
**Project Manager**
**202-287-6223**
**charles.james@ee.doe.gov**

| | |
|---|---|
| Laura Hill<br>*Project Manager*<br>202-586-8384<br>laura.hill@ee.doe.gov | Jay Keller<br>*Consultant*<br>925-519-2043<br>Jay.keller@zces-inc.com |

Leah Fisher, *Contractor*
202-586-1646
leah.fisher@ee.doe.gov

**hydrogenandfuelcells.energy.gov**