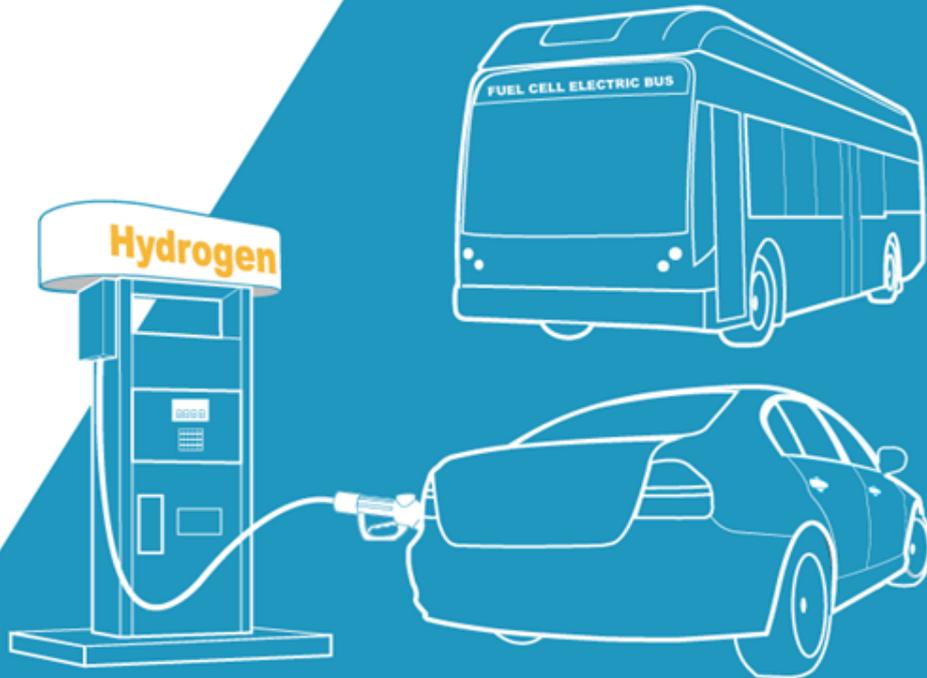
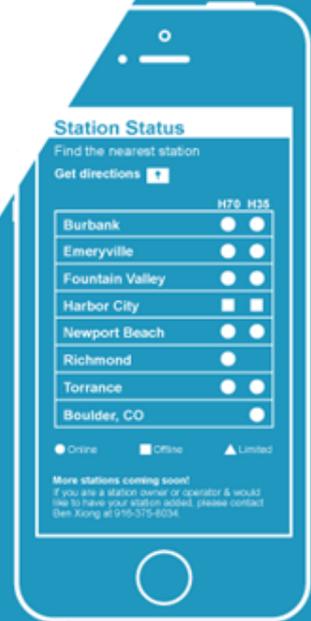


# Resources & Training for Hydrogen & Fuel Cells

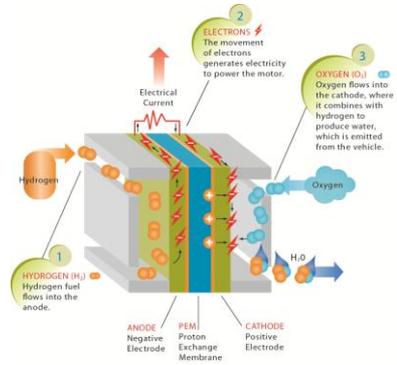
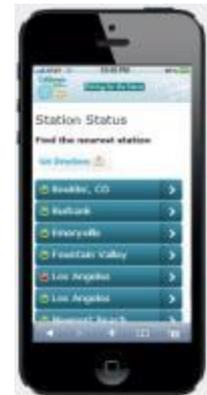
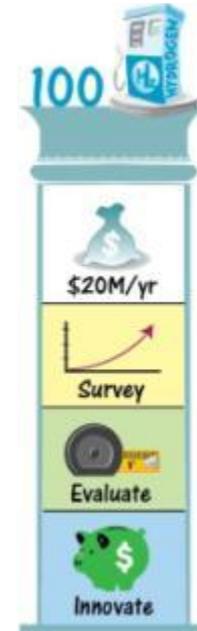
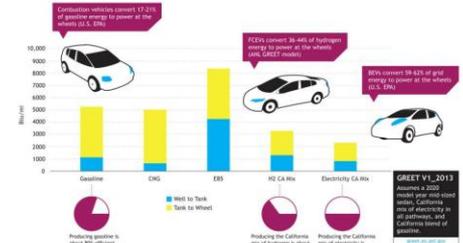
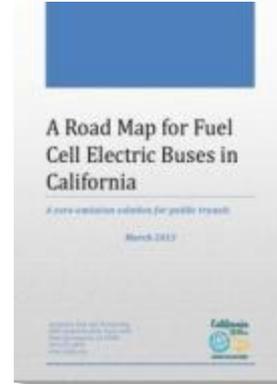
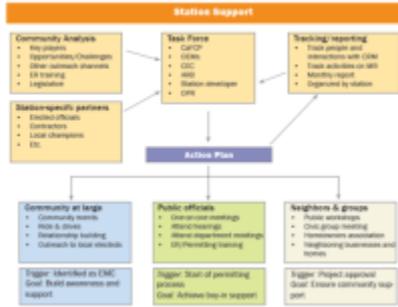
April, 2016







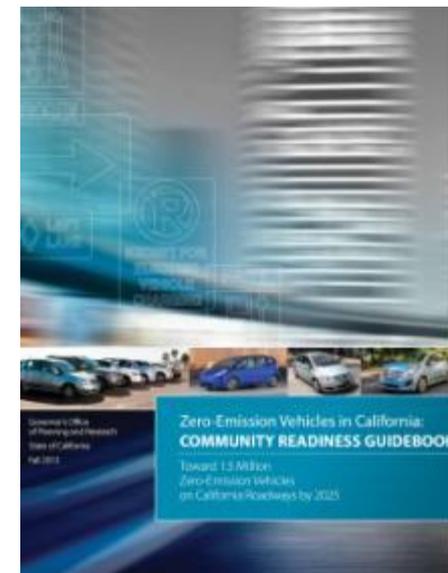
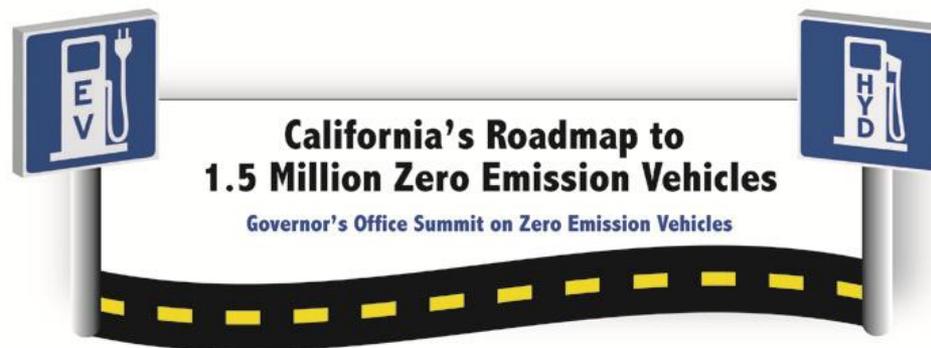
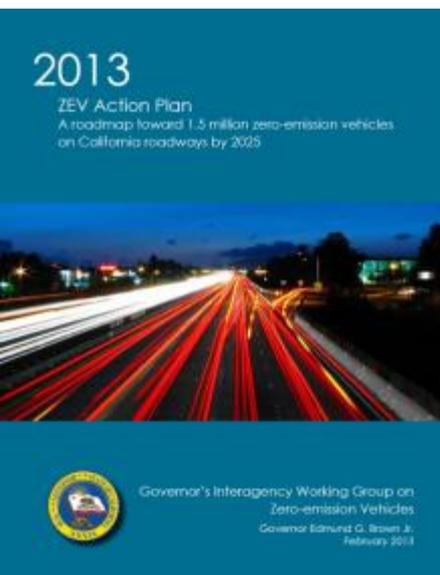
# What we do





# California ZEV Action Plan

- By 2015: California major metropolitan areas “ZEV-ready” with infrastructure and streamlined permitting
- By 2020: California ZEV infrastructure can support up to 1 million vehicles
  - Including widespread use of ZEVs for freight and public transit
- By 2025: Over 1.5 million ZEVs in California





# California is taking the lead



Funding

For at least 100 H<sub>2</sub> stations through California Energy Commission



ZEV Action Plan

Agency actions to enable FCEVs and BEVs



ZEV Manager

Governor appointee to help with planning and permitting for H<sub>2</sub> and charging stations



State Fire Marshal

Including hydrogen and FCEVs in state training guidelines



Weights & Measures

Setting standards for certifying dispensers



Evaluation

Survey of OEM deployment plans



# Here come the FCEVs....



With more to follow,  
including...

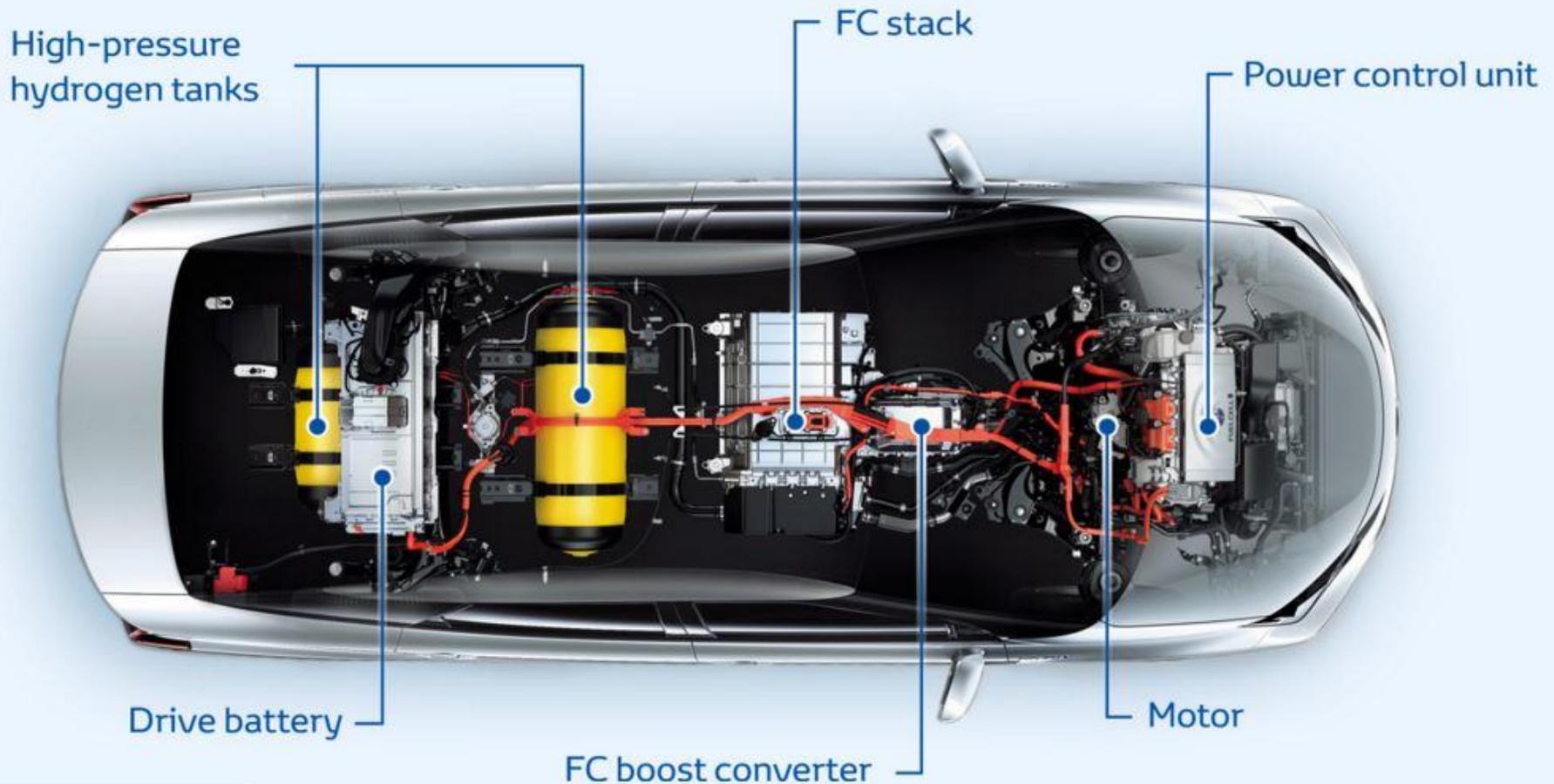
Mercedes  
GM  
Nissan  
BMW  
Volkswagen  
Audi





# FCEVs are electric vehicles

The Toyota Fuel Cell System (TFCS) moves the Mirai



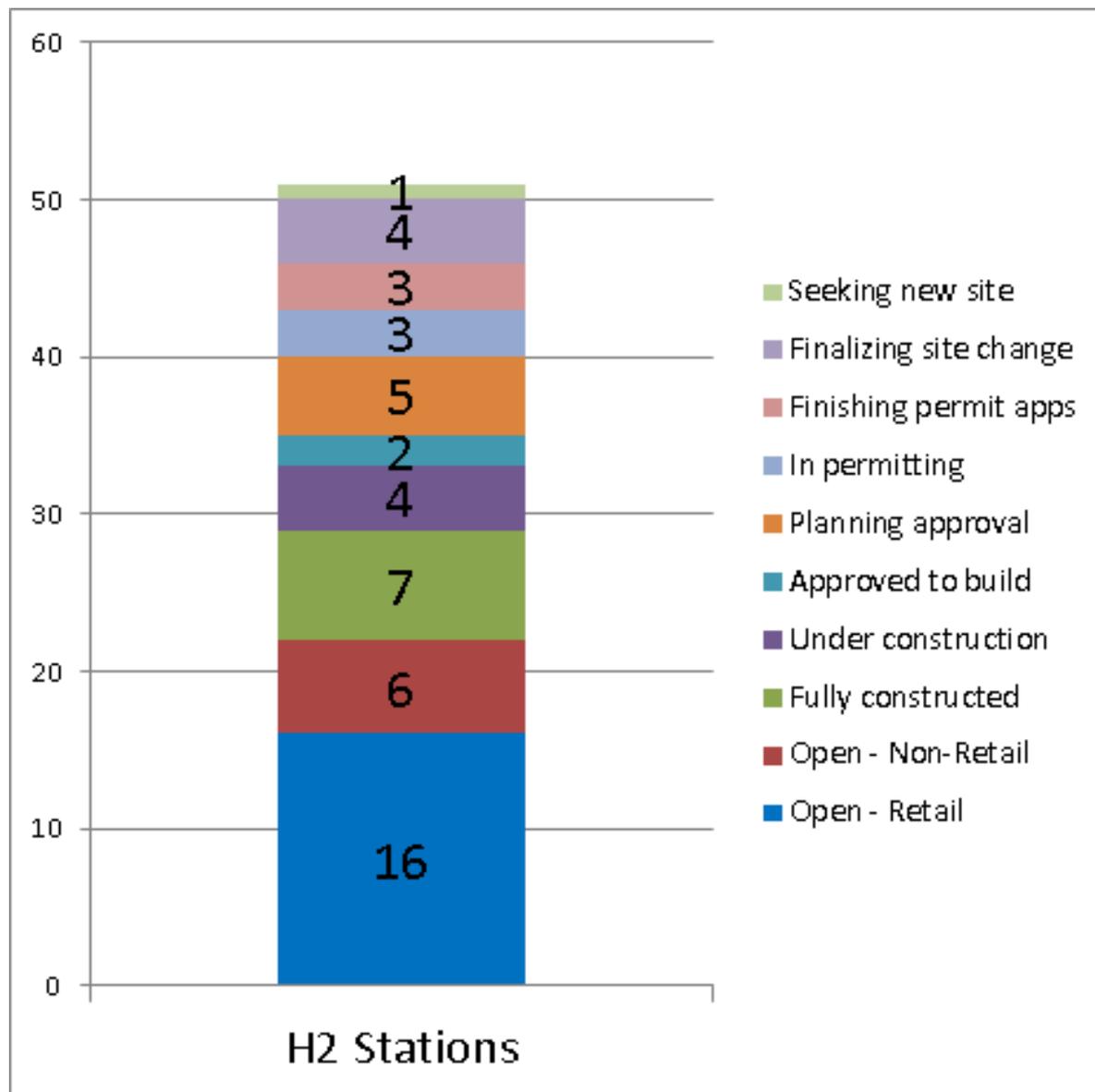


# Today in California

- Hyundai and Mercedes lease cars
  - 300+ FCEVs on the road
- Toyota introduced the Mirai in 2015; Honda in late 2016
  - Many automakers will come to market:
  - Audi, BMW, Ford, GM, Lexus, Mercedes, Nissan, Volkswagen
- 3 transit agencies operate 19 buses
  - East Bay
  - Coachella Valley
  - Irvine
- 16 open stations
  - 35 stations in development
  - GFO on the streets (minimum of \$17.3 million)



# California's Hydrogen Network as of 4/9/16



- Includes Santa Barbara
- Hayward as of 4/27/16



# Open Retail H2 Stations - Northern & Central CA

West Sacramento



San Jose



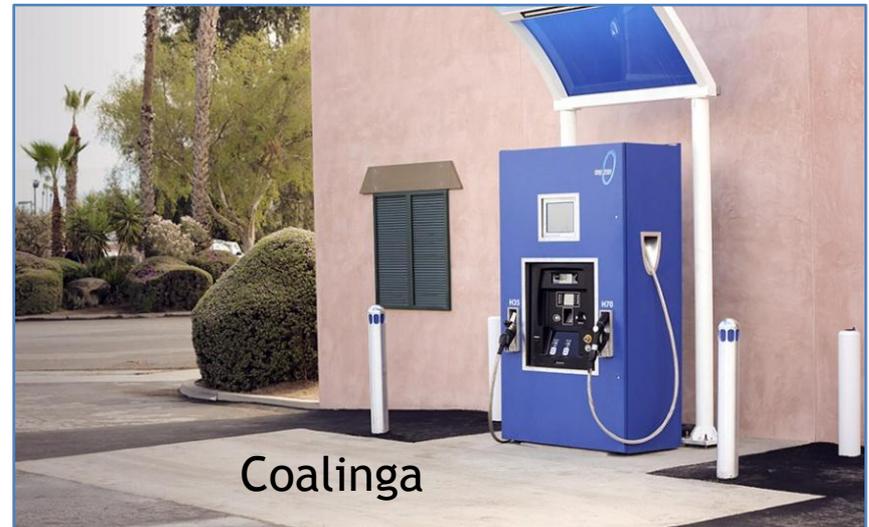
Saratoga



So. San Francisco



Coalinga



Not pictured: Hayward



# Open Retail H2 Stations - Southern CA



Not pictured: San Juan Capistrano, Santa Monica, and Lake Forrest, Santa Barbara

March 2016

# Northern CA Hydrogen Stations

## Retail: Open

- San Jose
- Saratoga
- South San Francisco
- West Sacramento
- \*Coalinga
- Hayward

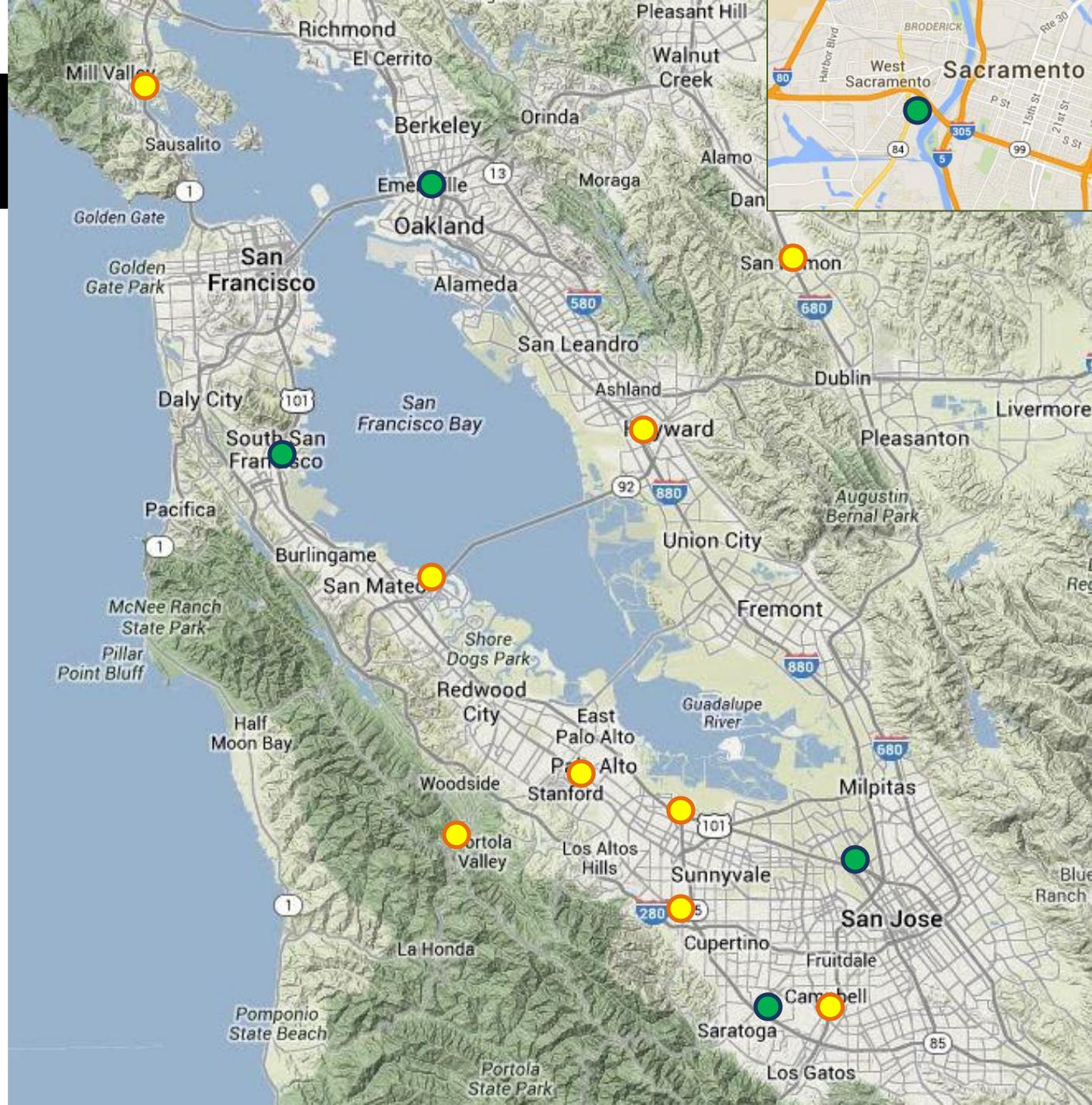
## Other: Open

- Emeryville - AC Transit

## Retail: In Development

- Campbell
- Foster City
- Los Altos
- Mill Valley
- Mountain View
- Palo Alto
- \*Rohnert Park
- San Ramon
- \*Truckee
- Woodside

*\*Not shown on map*



# Southern CA Hydrogen Stations

## ● Retail: Open

- Costa Mesa
- Diamond Bar
- Irvine - UC Irvine
- La Cañada Flintridge
- Lake Forest
- Long Beach
- Los Angeles - Santa Monica Blvd.
- San Juan Capistrano
- Santa Monica
- \*Santa Barbara

## ● Other: Open

- Burbank
- Fountain Valley - OCSD
- Los Angeles - Harbor City
- Newport Beach
- \*Thousand Palms - SunLine Transit
- Torrance

## ● Retail: In Development

- Anaheim
- Burbank (upgrade)
- Chino (upgrade)
- Lawndale
- Los Angeles - Beverly Blvd.
- Los Angeles - Cal State LA
- Los Angeles - LAX (upgrade)
- Los Angeles - Lincoln Blvd.
- Los Angeles - Hollywood Blvd.
- Los Angeles - Pacific Palisades
- Los Angeles - Woodland Hills
- Ontario
- Orange
- \*Riverside
- \*San Diego
- South Pasadena

\*Not shown on map



California Fuel Cell Partnership  
[www.ca-fcp.org/stationmap](http://www.ca-fcp.org/stationmap)

# CaFCP Station Map

<http://cafcf.org/stationmap>



Search by Zip Code or Address  **GO** **Filter By** **Station Types**

Map Satellite

**RETAIL - OPEN**

**Coalinga**  
Commissioning Complete  
24505 West Dorris Avenue  
93210 Coalinga, CA  
Details >

**RETAIL - IN DEVELOPMENT**

**Santa Barbara**  
Construction Complete  
150 South La Cumbre Road  
93105 Santa Barbara, CA  
Details >

**RETAIL - OPEN**

**La Cañada Flintridge (Soft Opening)**  
Commissioning Complete  
550 Foothill Boulevard  
91011 La Canada Flintridge, CA  
Details >

**NON-RETAIL - OPEN**

**Burbank**  
Commissioning Complete  
145 W Verdugo Avenue  
91510 Burbank, CA  
Details >

**RETAIL - IN DEVELOPMENT**

**Los Angeles - Woodland Hills**  
Approval to Build Complete  
5314 Topanga Canyon  
91364 Woodland Hills, CA  
Details >

**RETAIL - IN DEVELOPMENT**

**Los Angeles - Hollywood Blvd**  
Approval to Build Complete  
5700 Hollywood Boulevard  
90028 Los Angeles, CA  
Details >

**Download Stations**

© CALIFORNIA FUEL CELL PARTNERSHIP 3300 Industrial Blvd, Suite 1000 West Sacramento, CA 95691 SOSS | 916.371.2870



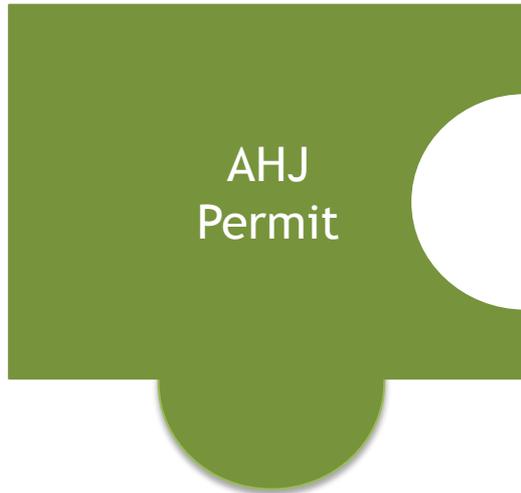
# Next Stations

- Los Angeles - Woodland Hills
- Los Angeles - Beverly Blvd.
- Cal State LA
- Riverside
- Hayward
- Campbell



For estimated open dates, please see the CaFCP station map at [www.cafc.org](http://www.cafc.org)

# Commissioning Process





# Global launch

- Germany
- Japan
- South Korea
- U.S. (California)
- U.S. (other states)
  - Northeast corridor: 12 stations funded by Toyota
  - 8-state MOU regarding zero-emission vehicles in 2014
- United Kingdom
- Scandinavian countries

## Examples

- German consortium to build 400 hydrogen stations
- Tokyo government commits \$330 million to showcase hydrogen economy at 2020 Olympics
- California commits to 100 stations



# More than cars...





# Fuel cell buses and trucks

- 19 fuel cell buses in California
- >1.5M miles in service
- >2.5M passengers carried
- Buses adopt technology first; pave the way for heavy-duty vehicles
- Medium and heavy-duty are coming
  - Demonstration projects
  - Action plan in draft to develop commercial path





# Target Areas for Next CEC Funding

Core Market Areas	Maximum # of Stations to be Funded*
San Francisco	2
Berkeley/Oakland/Walnut Creek/Pleasant Hill	2
Greater LA/Sherman Oaks/Glendale/Pacific Palisades	1
San Diego/La Mesa	1
Torrance/Manhattan Bch/Redondo Bch	1
South San Diego/Coronado	1
Pasadena/San Gabriel/Arcadia	1
Long Bch/Huntington Bch/Buena Park/Fullerton	1
Santa Cruz	1
Irvine/Tustin	1
San Mateo/Palo Alto/Cupertino/Campbell/San Jose	1
Sacramento/Carmichael	1
San Clemente	1
Laguna Beach	1

CEC GFO15-605, April 2016: <http://www.energy.ca.gov/contracts/GFO-15-605/>



## A Transformative Step Towards Hydrogen Adoption

### CENTRALIZED LOCATION

organizes current H<sub>2</sub> resources in one robust location—including many proven tools, with plans for adding future content

### FOCUSED CONTENT

tailored to the specialized needs of H<sub>2</sub> user groups

### RESPONSIVE DESIGN

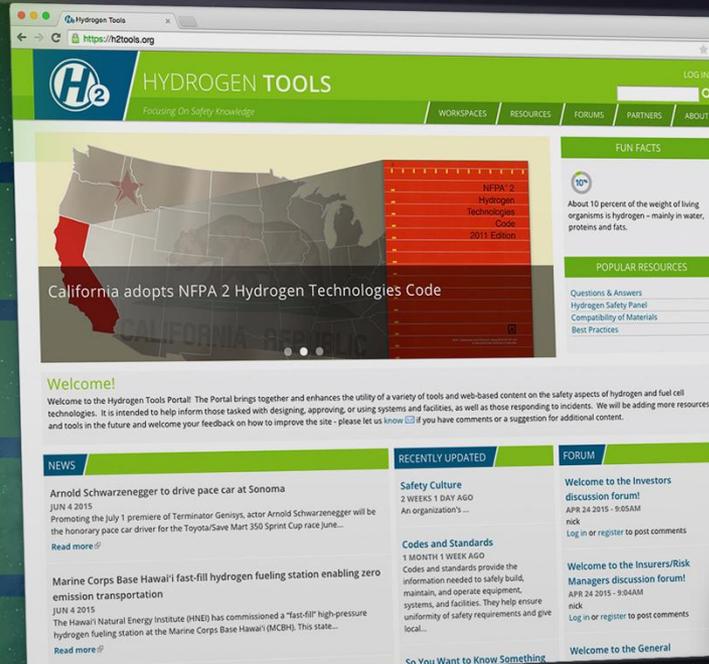
enables H<sub>2</sub> safety work across both desktop and mobile devices

### TRUSTED COMMUNITIES

fostered through social networking around H<sub>2</sub> 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



## ...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

<http://h2tools.org/bestpractices>

**HYDROGEN TOOLS**  
Focusing On Safety Knowledge

MY ACCOUNT LOG OUT

EDITOR ROLES RESOURCES TOOLS COMMUNITY PARTNERS ABOUT

Home » Best Practices » Facility Design » Properties Impact Design

### Best Practices

**Hydrogen Introduction**

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  
Properties Impact Design

Passive Ventilation  
Active Ventilation  
Electrical Classification  
Use of Detectors  
Proper Storage, Use and Venting  
Loss Prevention  
Selection of Materials  
Inherently Safer Design  
Concepts  
Piping Layout and Design  
Safety Interlock Systems  
Storage & Piping  
Operating Procedures  
Equipment Maintenance  
Laboratory Safety  
Indoor Refuelling

### Impact of Hydrogen Properties on Facility Design

View Edit Track

An understanding of the properties of hydrogen is critical for the proper design of a facility or workspace. A workspace can be configured to mitigate hazards by understanding and taking advantage of some of the characteristics of hydrogen.

Designers and operators of hydrogen storage facilities must be aware that hydrogen's flammability range is very wide compared to other fuels. Additionally, under optimal combustion conditions (at a 29% hydrogen-to-air volume ratio), the energy required to initiate hydrogen combustion is much lower than that required for other common fuels (e.g., a small spark).

Property	Hydrogen H <sub>2</sub>	Methane CH <sub>4</sub>	Gasoline
Normal boiling point <sup>1</sup> (NBP) [°C]	-253	-162	37 - 205
Physical state at 25°C, 1 atm	Gas	Gas	Liquid
Heating Values <sup>2</sup> LHV (kJ/g) HHV (kJ/g)	120 142	50 55.5	44.5 48
Flammability limits [vol% in air]	4.0-75	5.3-15	1.0-7.6
Molecular weight	2.02	16.0	-107
Flame temperature in air <sup>3</sup> [°C]	2045	1875	2200
Minimum ignition energy <sup>4</sup> [mJ]	0.02	0.29	0.24
Quenching distance [mm]	0.64	2.0	2.0
Density at NBP (g/L)	70.8	423	-700
Vapor specific gravity at 25°C, 1atm (air=1)	0.070	0.54	3.7

<sup>1</sup>The boiling point at 1atm pressure  
<sup>2</sup>Heating values are the energy, per gram of fuel, generated by a combustion reaction. The higher heating value (HHV) is obtained when all of the water formed by combustion is liquid. The lower heating value (LHV) is obtained when all of the water formed by combustion is vapor.  
<sup>3</sup>Experimentally determined flame temperatures are shown in the table. These values do not differ significantly from theoretical adiabatic flame temperatures. See Ref. [3] for discussion.  
<sup>4</sup>In air at 1 atm pressure

For any incident involving hydrogen, keep in mind the properties of hydrogen and watch for potential ignition sources that can ignite a hydrogen leak:

- electrical (e.g., static electricity, electric charge from operating equipment)
- mechanical (e.g., impact, friction, metal fracture)
- thermal (e.g., open flame, high-velocity jet heating, hot surfaces, vehicle exhaust)

There should be no grass or shrubs planted near areas where hydrogen potentially may be released to prevent the need for using powered garden tools in the area. According to NFPA 55, both compressed gaseous hydrogen storage vessels and liquid hydrogen storage vessels must be located at least 50 feet from combustible materials.

Mixtures near optimal combustion conditions should be considered prone to spontaneous ignition.

**References**

Supporting References:  
Basic Hydrogen Properties  
CGA G-5, Hydrogen  
CGA H-4 Terminology Associated with Hydrogen Fuel Technologies  
B. Lewis and G. von Elbe, Combustion, Flames and Explosions of Gases, 3rd ed., Academic Press, Orlando, 1987, pg. 717.  
Hydrogen Data Book  
Babrauskas, Vytenis, "Ignition Handbook" Fire Science Publishers, Issaquah, WA.  
J. Hord, Is Hydrogen Safe? National Bureau of Standards (NBS) Technical Note 690, October 1976.  
F.J. Edeskuty and W.F. Stewart, Safety in the Handling of Cryogenic Fluids, Plenum Press, New York, 1996, pg. 102.  
Glossary | Acronyms | Bibliography  
Codes & Standards  
Safety Snapshot  
NFPA 2, Hydrogen Technologies Code, 2011 Edition

Twitter Facebook LinkedIn

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

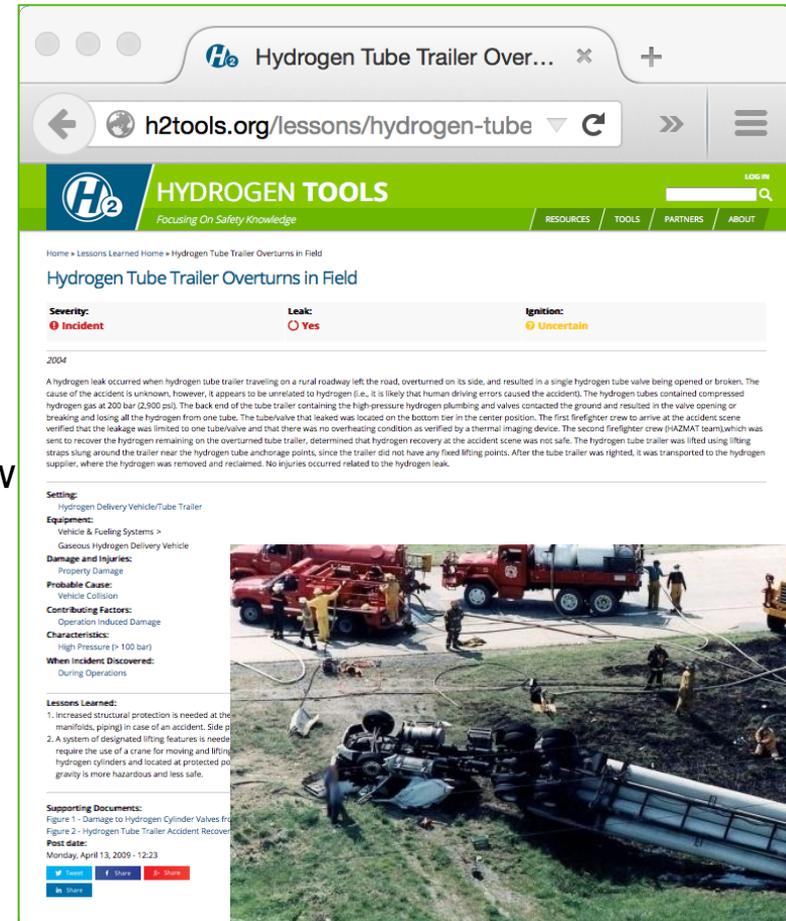
# H2tools.org/lessons

## ...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

<http://h2tools.org/lessons>



Hydrogen Tube Trailer Over...

h2tools.org/lessons/hydrogen-tube

**HYDROGEN TOOLS**  
Focusing On Safety Knowledge

RESOURCES TOOLS PARTNERS ABOUT

Home » Lessons Learned Home » Hydrogen Tube Trailer Overturns in Field

### Hydrogen Tube Trailer Overturns in Field

**Severity:** ● Incident      **Leak:** ○ Yes      **Ignition:** ○ Uncertain

2004

A hydrogen leak occurred when hydrogen tube trailer traveling on a rural roadway left the road, overturned on its side, and resulted in a single hydrogen tube valve being opened or broken. The cause of the accident is unknown, however, it appears to be unrelated to hydrogen (i.e., it is likely that human driving errors caused the accident). The hydrogen tubes contained compressed hydrogen gas at 200 bar (2,900 psi). The back end of the tube trailer containing the high-pressure hydrogen plumbing and valves contacted the ground and resulted in the valve opening or breaking and losing all the hydrogen from one tube. The tubevalve that leaked was located on the bottom tier in the center position. The first firefighter crew to arrive at the accident scene verified that the leakage was limited to one tubevalve and that there was no overheating condition as verified by a thermal imaging device. The second firefighter crew (H2MAT team), which was sent to recover the hydrogen remaining on the overturned tube trailer, determined that hydrogen recovery at the accident scene was not safe. The hydrogen tube trailer was lifted using lifting straps slung around the trailer near the hydrogen tube anchorage points, since the trailer did not have any fixed lifting points. After the tube trailer was righted, it was transported to the hydrogen supplier, where the hydrogen was removed and reclaimed. No injuries occurred related to the hydrogen leak.

**Setting:**  
Hydrogen Delivery Vehicle/Tube Trailer

**Equipment:**  
Vehicle & Fueling Systems >  
Gaseous Hydrogen Delivery Vehicle

**Damage and Injuries:**  
Property Damage

**Probable Cause:**  
Vehicle Collision

**Contributing Factors:**  
Operation Induced Damage  
High Pressure (> 100 bar)

**When Incident Discovered:**  
During Operations

**Lessons Learned:**

1. Increased structural protection is needed at the manifolds, piping) in case of an accident. Side p
2. A system of designated lifting features is needed require the use of a crane for moving and lifting hydrogen cylinders and located at protected po gravity is more hazardous and less safe.

**Supporting Documents:**  
Figure 1 - Damage to Hydrogen Cylinder Valves from  
Figure 2 - Hydrogen Tube Trailer Accident Recovery  
**Post date:**  
Monday, April 13, 2009 - 12:23

[Twitter](#) [Facebook](#) [StumbleUpon](#) [Reddit](#)

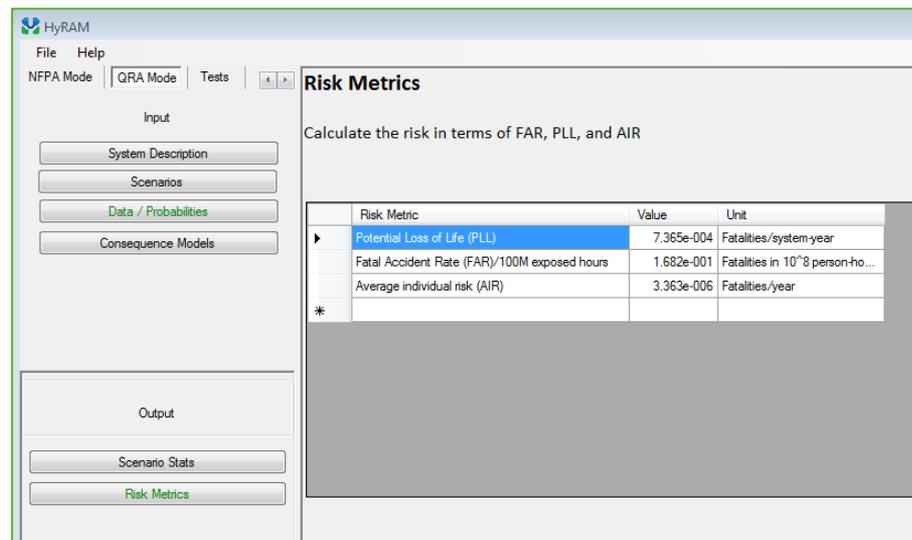
[In More](#)



Tube Trailer Rollover

# Quantitative Risk Assessment

- Developed toolkit to enable integrated probabilistic and deterministic modeling
  - Relevant H2 hazards (thermal, mechanical)
  - Probabilistic models (traditional QRA models) & H2-specific component data
  - H<sub>2</sub> phenomena (gas release, heat flux, overpressure)
- Variable Users
  - High level, generic insights (e.g., for C&S developers, regulators)
  - Detailed, site-specific insights (e.g., station designers, engineers)
- Currently, two interfaces (views):
  - “QRA mode” and “Physics mode”
  - Planned “performance-based design” mode for targeted analyses



First-of-its-kind software tool for integrating H2 consequence models w/ QRA models  
Includes behavior models & data developed through FY12

Now available at: <http://hyram.sandia.gov>

Press Release: [https://share.sandia.gov/news/resources/news\\_releases/sandias-hydrogen-risk-assessment-models-toolkit-now-available/#.Vx\\_ljvkrLIU](https://share.sandia.gov/news/resources/news_releases/sandias-hydrogen-risk-assessment-models-toolkit-now-available/#.Vx_ljvkrLIU)



# Introduction to Hydrogen for Code Officials

*Provides an overview of hydrogen and fuel cell technologies, discusses how these technologies are used in real-world applications and discusses the codes and standards required for permitting them.*

- Hydrogen and fuel cell basics
- Hydrogen and fuel cell applications
- Hydrogen fueling stations
- Fuel cell facilities

*Developed by the National Renewable Energy Laboratory*

The screenshot shows a web-based training interface. At the top, it says 'Introduction to Hydrogen for Code Officials' and 'U.S. Department of Energy Hydrogen Program'. Below that are navigation tabs: 'COURSE MATERIALS', 'LIBRARY', and 'EXIT\*'. There are also checkboxes for 'Hydrogen & Fuel Cell Basics', 'Hydrogen & Fuel Cell Applications', 'Hydrogen Fueling Stations', and 'Fuel Cell Facilities'. The main content area has a paragraph: 'While a hydrogen fueling station is still on the drawing board, developers conduct a safety analysis to analyze, quantify, and mitigate potential risks.' Below this is a list of safety planning tools: Failure modes and effects analysis (FMEA), What-if analysis, Hazard and operability analysis (HAZOP), Checklist analysis, Fault tree analysis, Event tree analysis, and Probabilistic risk assessment (PRA). To the right of the list is an image of a hydrogen fueling station in Oakland, California, with a caption: 'A hydrogen fueling station in Oakland, California. Graphic courtesy of California Fuel Cell Partnership'. On the far right, there is a section titled 'To view references for related hydrogen codes and standards and learn more about hydrogen safety, visit the following links:' with two bullet points: 'Operation Approvals for Fire Safety and Emergency Planning' and 'Safety Planning Guidance for Hydrogen Projects document (PDF 157 KB)'. At the bottom of the slide, there is a flowchart with three boxes: 'Project Considerations' (orange), 'Construction Approval' (yellow), and 'Operation Approval' (green), connected by arrows. At the very bottom, there are navigation controls: 'Back', 'Slide 2 of 27', 'Next', and a refresh icon.

<http://h2tools.org/content/training-materials>



# Codes & Standards Permitting Tools

- Cooperative with National Renewable Energy Lab
  - AHJ workshops
- Hydrogen Technologies Safety Guide (Jan. 2015)
- DOE permitting web site link
- In development: Permitting video with OCFA



Home

## Codes & Standards - Permitting Tools

A National Renewable Energy Laboratory resource



### Permitting Hydrogen Fueling Station Stations

Video giving basic background on hydrogen technologies followed by a description of the permitting process done through the Orange County Fire Authority in Irvine, CA. Contains interviews with code officials, emergency responders, and technical experts as well as footage of hydrogen stations. (available early 2016)

### Code Official Training Course

Online interactive format. This online training is divided into the following modules:

- Module 1 Hydrogen & Fuel Cell Basics
- Module 2 Hydrogen & Fuel Cell Applications
- Module 3 Hydrogen Fueling Stations
- Module 4 Fuel Cell Facilities

The course includes questions at the end of each module to confirm the student has learned the basic points of the module. Currently available online at [http://www.hydrogen.energy.gov/code\\_official\\_training.html](http://www.hydrogen.energy.gov/code_official_training.html). <sup>16</sup> (Update available early 2016.)

### National Permit Guide for Hydrogen Fueling Stations

PDF Format. Complete update of the 2004 document including updated references to the 2016 edition of NFPA 2 Hydrogen Technologies Code (available early 2016)

### Permitting Web Site

# Technical Reference for Hydrogen Compatibility of Materials

DRIVING FOR THE FUTURE



*Consists of material specific chapters (as individual PDF files) summarizing mechanical-property data from journal publications and technical reports*

- Plain Carbon Ferritic Steels
- Low-Alloy Ferritic Steels
- High-Alloy Ferritic Steels
- Austenitic Steels
- Aluminum Alloys
- Copper Alloys
- Nickel Alloys
- Nonmetals

<http://h2tools.org/tech-ref/technical-reference-for-hydrogen-compatibility-of-materials>

The screenshot shows the 'HYDROGEN TOOLS' website. The header includes the H<sub>2</sub> logo, the title 'HYDROGEN TOOLS', and the tagline 'Focusing On Safety Knowledge'. Navigation links for 'RESOURCES', 'TOOLS', 'PARTNERS', and 'ABOUT' are visible. The main content area is titled 'Technical Reference for Hydrogen Compatibility of Materials' and is identified as a Sandia National Laboratories Resource. It features the Sandia National Laboratories logo and a paragraph of introductory text. Below this, there are two tables: one for 'Plain Carbon Ferritic Steels' and one for 'Low-Alloy Ferritic Steels'. Each table has columns for 'Sub Metal Type', 'Designation', 'Nominal composition', 'Revision', and 'Section'.

Plain Carbon Ferritic Steels				
Sub Metal Type	Designation	Nominal composition	Revision	Section
	C-Mn Alloys	Fe-C-Mn	5/07	1100

Low-Alloy Ferritic Steels				
Sub Metal Type	Designation	Nominal composition	Revision	Section
Quenched & Tempered Steels	Cr-Mo Alloys	Fe-Cr-Mo	12/05	1211
Quenched & Tempered Steels	Ni-Cr-Mo Alloys	Fe-Ni-Cr-Mo	12/05	1212

# H2USA Public-Private Partnership to address H2 Infrastructure Challenges



<http://h2usa.org>

*The mission of H2USA is to promote the commercial introduction and widespread adoption of FCEVs across America through creation of a public-private collaboration to overcome the hurdle of establishing hydrogen infrastructure.*



Fuel Cell &  
Hydrogen Energy  
Association



Mercedes-Benz



TOYOTA



HNEI



\*Representative sample of member logos



# How can you be ready?

- Resources
  - Fuel Cells and Hydrogen Energy Association (<http://www.fchea.org/>)
    - Safety Report: <http://www.hydrogenandfuelcellsafety.info/>
  - NFPA Alternative Fueled Vehicles Safety Training Program (<http://www.nfpa.org/training/online/alternative-fuel-vehicle-safety-training>)
  - CaFCP (<https://cafcp.org>) - stations status, fueling video, resource links, downloadable documents



# How can you be ready?

- Education/training
  - AHJ workshops
  - ER training

## Free Training for Permitting Officials

From



December 9th, 2014 (Morning refreshments & lunch provided)

9:00 AM to 2:00 PM

Sprinkler Fitters Local Union 483  
2531 Barrington Court  
Hayward, CA 94545

RSVP: <http://dec9h2permitworkshop.eventbrite.com>

A hydrogen station is coming to your community.  
Learn codes & standards and permitting best practices at this free workshop.



### Hydrogen Fuel Cell Vehicles California Deployment

In the next five years a commercial hydrogen fueling infrastructure (and other associated facilities) will be constructed in California. Several of these proposed stations will be located in the greater San Francisco Bay Area and Northern California.

This training will include the following topics:

- Overview of Hydrogen Fuel Cell Vehicles (HFCV) and hydrogen fueling stations
- Codes and Standards for hydrogen technologies infrastructure
- Existing hydrogen fueling station performance
- Resources available on hydrogen technologies

### Training Audience:

Code officials, Project Developers, Municipal planners

[www.cafcp.org/toolkits/cities](http://www.cafcp.org/toolkits/cities)



HYDROGEN  
Emergency Response  
Training Resources



Pacific Northwest  
NATIONAL LABORATORY  
*Proudly Operated by Battelle Since 1985*

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy



# National Hydrogen and Fuel Cells Emergency Response TRAINING





# National First Responder Training Resource



HYDROGEN  
Emergency Response  
Training Resources



Pacific Northwest  
NATIONAL LABORATORY  
Provided Operated by Battelle for DOE



U.S. DEPARTMENT OF  
**ENERGY**  
Energy Efficiency &  
Renewable Energy

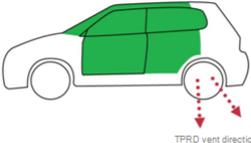


California  
ENERGY CENTER  
powered by solar

## National Hydrogen and Fuel Cells Emergency Response TRAINING

### 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 / 51

Can be downloaded at <http://h2tools.org/fr/nt>



HYDROGEN  
Emergency Response  
Training Resources

## National Hydrogen and Fuel Cells EMERGENCY RESPONSE TRAINING

A properly trained first responder can perform critical tasks that hydrogen and fuel cell emergency response training resource as a comprehensive training materials are provided to organizations and are intended to serve their mission. This nationally-focused training resource is intended for delivery of a variety of presentations for different presentation formats and comprehensive classroom training.

This nationally-focused training resource is intended for delivery of a variety of presentations for different presentation formats and comprehensive classroom training.

- L1 (Overview)** - This resource has little knowledge that is limited to basic technologies and additional slides
- L2 (Short Course)** - This resource has an intermediate level of knowledge that is not necessarily classroom session minimized and classroom session
- L3 (Full Course)** - This resource contains materials that are intended for classroom session purposes intended for classroom session

Feedback from presenters and first responders is used to update training content and resource. Feedback should be provided to the training resource.

Revision Date: September 30, 2014

### A TEMPLATE for TRAINING

Example Uses of Training Slides	Example Uses of Training Slides		
	L1 Overview	L2 Short Course	L3 Full Course
<b>NATIONAL HYDROGEN AND FUEL CELLS EMERGENCY RESPONSE TRAINING</b>			
Slide #1: <i>What and Why</i>			
Slide #2: <i>National Hydrogen and Fuel Cells Emergency Response Training</i>			
<b>1. Introduction and Background</b> Slide #3			
Slide #4: <i>Fuel Cells Overview and Benefits</i>	✓	✓	✓
Slide #5/6/7: <i>Fuel Cells – Where are We Today?</i>			✓
Slide #8: <i>Diverse Fuel Cell Transportation Applications</i>			✓
<b>2. Hydrogen and Fuel Cell Basics</b> Slide #9			
<b>2.1 Hydrogen – Where does it come from and how do we use it now?</b>			
Slide #10: <i>Why Hydrogen?</i>		✓	✓
Slide #11: <i>Where Do We Get Hydrogen?</i>	✓	✓	✓
Slide #12: <i>Hydrogen Uses</i>	✓	✓	✓
Slide #13: <i>Hydrogen Distribution</i>			✓
Slide #14: <i>Transporting Hydrogen Today</i>			✓
<b>2.2 Properties of hydrogen and its safe use</b>			
Slide #15: <i>Hydrogen Properties and Behaviors</i>	✓		✓
Slide #16: <i>Hydrogen Properties: A Comparison</i>	✓	✓	✓
Slide #17: <i>Relative Vapor Density</i>			✓
Slide #18: <i>Auto-Ignition Temperature</i>			✓
Slide #19: <i>Comparison of Flammability</i>	✓	✓	✓
Slide #20: <i>Flammability Range</i>			✓
Slide #21: <i>Explosive Range</i>			✓
Slide #22: <i>Comparison of Fuel Odorants and Toxicity</i>			✓
Slide #23/24/25: <i>Designing Safe Systems – Gaseous Hydrogen</i>			✓
Slide #26: <i>Designing Safe Systems – Liquid Hydrogen</i>			✓

Revision Date: September 30, 2014



# What and Why?

## National Hydrogen and Fuel Cell Emergency Response Training

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. We envision that hydrogen and fuel cell-related first responder training will be delivered locally to serve missions to protect life and preserve property, utilizing this national emergency response training resource as a consistent source of accurate information and current knowledge. These training materials are adaptable to the specific needs of first responders and training organizations and are meant to complement the extensive training programs already in place to serve their missions. **The note pages format of these slides provides more details for the instructor to conduct the training. Instructors should share this information when presenting the slides.**

The nationally-focused training template that accompanies these materials is intended to serve as a resource and guide for the delivery of a variety of training regimens to various audiences. These materials are adaptable for different presentation styles, ranging from higher level overview formats to more comprehensive classroom training. Three example uses of the slides are provided in the companion Word file.

Feedback from presenters and audiences to the developers of the National Hydrogen and Fuel Cells Emergency Response Training will help ensure that the development of new and updated training content and techniques serves to continually enhance the value of this resource.

This material was prepared as an account of work sponsored by an agency of the United States Government. NEITHER THE UNITED STATES GOVERNMENT NOR THE UNITED STATES DEPARTMENT OF ENERGY, NOR ANY OF THEIR EMPLOYEES, NOR ANY OF THEIR CONTRACTORS, SUBCONTRACTORS OR THEIR EMPLOYEES, MAKES ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS OR ANY INFORMATION, APPARATUS, PRODUCT, OR PROCESS DISCLOSED, OR REPRESENTS THAT ITS USE WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS.

Revision Date: December 22, 2015



This nationally-focused training template is intended to serve as a resource and guide for the delivery of a variety of training regimens to various audiences. These materials are adaptable for different presentation styles, ranging from higher level overview formats to more comprehensive classroom training. Three example uses of the slides are provided in the included Excel file National\_HFC\_ER\_Training\_Guide\_Examples.xlsx based on the discussion below.

- **L1 (Overview)** – This example refers to a course directed to a responder audience that has little knowledge about hydrogen and fuel cell technologies. The presentation is limited to background information to provide the attendee with an overview of the technologies and their applications. The instructor may very well choose to use additional slides appropriate for the audience.
- **L2 (Short Course)** – A short course would be directed to a responder audience that has an intermediate level of knowledge about alternative fuel vehicle technologies not necessarily including hydrogen. One example could be an auto extrication classroom session for which background and other detailed information are minimized and operations-related slides are highlighted.
- **L3 (Full Course)** – A day-long classroom curriculum could very well cover training materials contained in all the slides including practical exercises for which small groups would discuss incident scenarios. Some of these slides could also be used for purposes intended for an L1 and/or L2 training regimen.



# 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

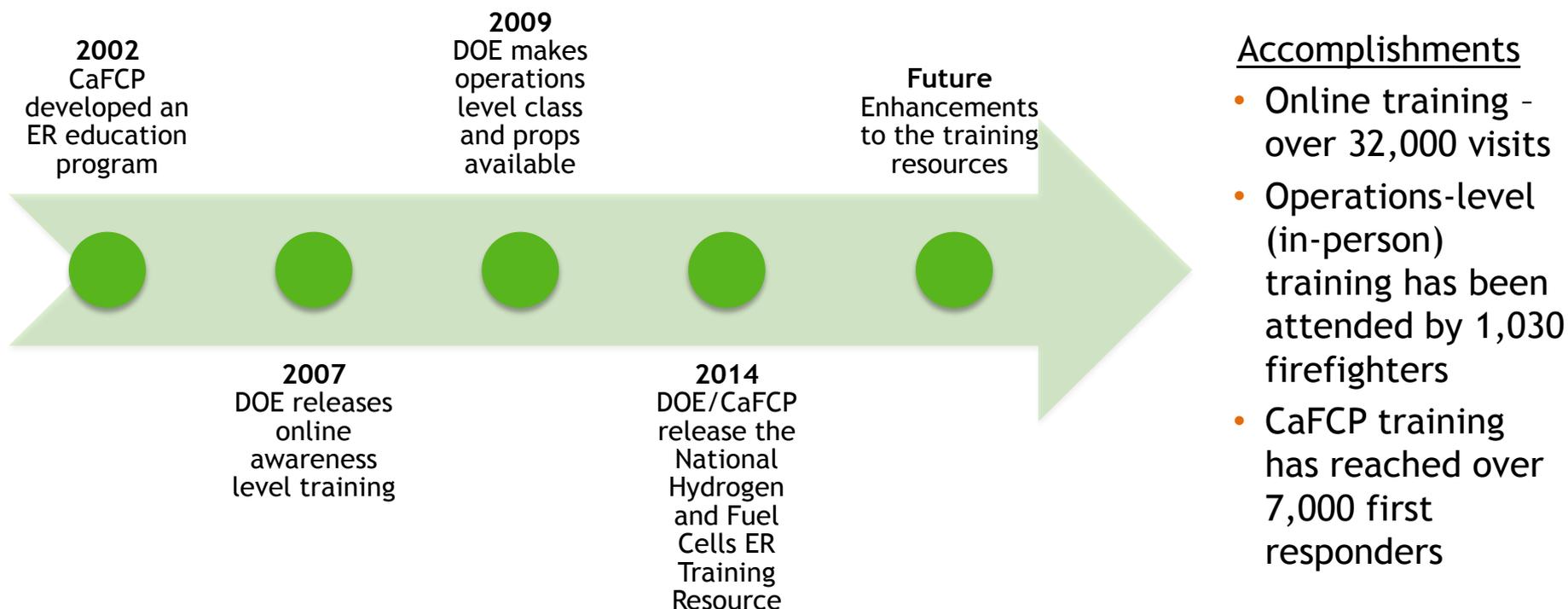
- Online, awareness-level training  
(<http://hydrogen.pnl.gov/FirstResponders/>)
- Classroom and hands-on operations-level training
- National training resource (enabling trainers)  
(<http://h2tools.org/fr/nt>)



*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.*



# Training Resources Timeline and Accomplishments



# Online Awareness-level Training



Address <http://www.ehammertraining.us/energy/hydrogen/controller.cfm> Go Links

## Introduction to Hydrogen Safety for First Responders

U.S. Department of Energy  
Hydrogen Program  
[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

**COURSE MATERIALS** LIBRARY EXIT ▶

Hydrogen Basics  Transport & Storage  Hydrogen Vehicles  Hydrogen Dispensing  Stationary Facilities  Codes & Standards  Emergency Response  Summary

INCREASE YOUR  
**H<sub>2</sub>IQ**  
[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

The Course Materials cover the following topics:

- Hydrogen Basics
- Transport & Storage
- Hydrogen Vehicles
- Hydrogen Dispensing
- Stationary Facilities
- Codes & Standards
- Emergency Response

**Online course content**

You can view the topic modules in sequence or select them in random order using the top navigation bar.

A short quiz follows at the end of the course. User responses will be collected but will not be attributed to you as an individual.

Begin the Course ▶

<http://hydrogen.pnl.gov/FirstResponders>

Internet

- 100 from hydrogen and emergency response community conduct broad review (Summer 2006)
- On-line training launched January 27, 2007
- 200-300 unique visits monthly; >30,000 total.



# Classroom and Hands-on Training

## ▶ Classroom Content

- Hydrogen and Fuel Cell Basics
- Hydrogen Vehicles
- Stationary Facilities
- Emergency Response
- Incident Scenarios

## ▶ Demonstrations/Hands-on Exercise with FCEV Prop

- Demonstration of Hydrogen Flame Characteristics
- Student Participation in Rescue Evolutions



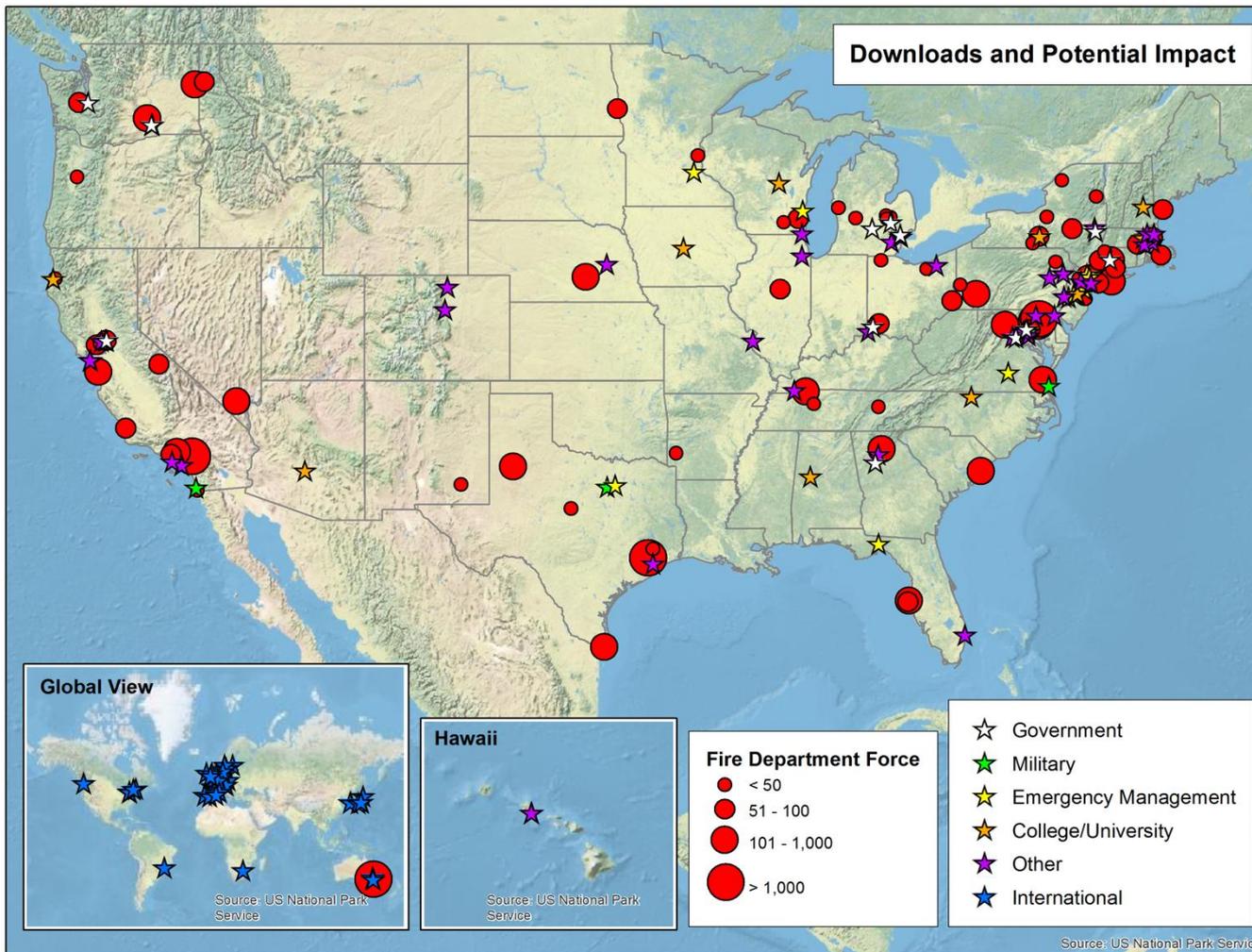
*Multiple instructors for classroom training*



*A "rescue" at Sunnyvale (CA)  
Department of Public Safety*



# National Training Resource Downloads



Since October 2014

- 278 downloads
- in 6 Continents
- and 35 of 50 states
- translated into Japanese in support of Japan fuel cell activities



# CaFCP/NREL events

## Free Training for Firefighter Instructors

Train the Trainer for the National Hydrogen & Fuel Cell Emergency Response Program\*

From



August 4th, 2015 - Morning refreshments & lunch provided

10:00 AM to 3:00 PM

Cerritos College, Advanced Transportation, Technology and Renewable Energy (ATRE)  
Automotive Partners Building, Room AP-12A  
11111 New Falcon Way, Cerritos, CA 90703

RSVP: <https://eventbrite.com/event/17694876853/>

## Free Training for Permitting Officials

Permitting Workshop for Hydrogen Fueling Installations

From



August 5th, 2015 - Morning refreshments & lunch provided

10:00 AM to 3:00 PM

Cerritos College, Advanced Transportation, Technology and Renewable Energy (ATRE)  
Automotive Partners Building, Room AP-12A  
11111 New Falcon Way, Cerritos, CA 90703

RSVP: <https://eventbrite.com/event/17694966120/>

Hydrogen fuel cell vehicles and stations are coming to your community.  
Get the training information you need to ready your department.



### Hydrogen Fuel Cell Vehicles California Deployment

In the near future a commercial hydrogen fueling infrastructure (and other associated facilities) will be coming to your area. Several of these proposed stations will be located in the greater Los Angeles and Orange Counties. <http://cafcf.org/stationmap>

This class will take trainers through the National Program and discuss topics such as:

- Overview of hydrogen properties and safety
- Hydrogen vehicle and station safety
- Recommended response
- Resources available on hydrogen technologies

#### Training Audience:

Fire Department Training Officers and Trainers

A hydrogen station is coming to your community.  
Learn codes & standards and permitting best practices at this free workshop.



### Hydrogen Fuel Cell Vehicles California Deployment

In the next five years a commercial hydrogen fueling infrastructure (and other associated facilities) will be constructed in California. Several of these proposed stations will be located in the greater Los Angeles and Orange Counties. <http://cafcf.org/stationmap>

This training will include the following topics:

- Overview of Hydrogen Fuel Cell Vehicles (HFCV) and hydrogen fueling stations
- Codes and Standards for hydrogen technologies infrastructure
- Existing hydrogen fueling station performance
- Resources available on hydrogen technologies

#### Training Audience:

Code officials, Project Developers, Municipal planners



# Agenda

**Introductions, ZEV Action plan, station locations priority announcement-** J. Hamilton, 10:00 -10:30

**Hydrogen 101, Vehicles, Stations & Overall safety** – 10:30-11:15 - Jennifer Hamilton, CaFCP

**Break-** 11:15-11:30

**C&S overview for hydrogen fueling stations and facilities** – 11:30 – 12:00 -Carl Rivkin, NREL

**Repair Facilities** – Spencer Quong, QAI

**Lunch and Static Display of vehicles**– 12:00-12:45

**NFPA 2** – Susan Bershad, NFPA

**Brief overview** 12:45-13:15 (compare 2011 and 2016)

**QRA/Chapter 5** – 13:15 – 13:45

**Progress on ‘helping’ the AHJ (work at NREL/ESIF, HyStEP, PNNL, etc.) and resources (web sites)** – Carl

Rivkin, NREL - 13:45-14:00

**Break-** 14:00-14:15

**CA stations update** - 14:15-14:30 – Joe Gagliano & Jennifer Hamilton, CaFCP

**Questions and wrap up** – 14:30-15:00 - All



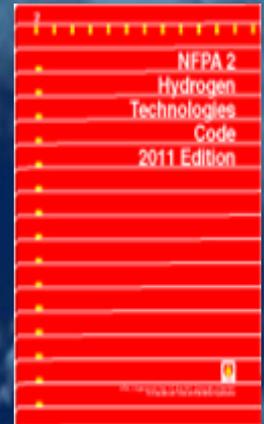
## **Hydrogen safety, much like all flammable gas safety, relies on five key considerations:**

- ▶ Recognize hazards and define mitigation measures
- ▶ Ensure system integrity
- ▶ Provide proper ventilation to prevent accumulation (manage discharges)
- ▶ Ensure that leaks are detected and isolated
- ▶ Train personnel



**National Fire Protection Association**  
The authority on fire, electrical, and building safety

# NFPA 2, Hydrogen Technology Code



---

Training Seminar

August 3<sup>rd</sup>, 2015 | Susan Bershada: NFPA Fire Safety Engineer



# We're here to help

[www.cafcp.org](http://www.cafcp.org)

[info@cafcp.org](mailto:info@cafcp.org)

@cafcp

Facebook.com/cafcp



# Contact Information

Please let us know if you have any questions or comments!

## Jennifer Hamilton



Safety, Education, Codes & Standards  
California Fuel Cell Partnership  
(916) 375-4914  
[jjhamilton@cafcp.org](mailto:jjhamilton@cafcp.org)

## Nick Barilo, P.E.



Hydrogen Safety Program Manager  
Pacific Northwest National Laboratory  
509-371-7894  
[nick.barilo@pnnl.gov](mailto:nick.barilo@pnnl.gov)

## Carl H. Rivkin, P.E.



Manager, Safety, Codes and Standards  
National Renewable Energy Laboratory  
[carl.rivkin@nrel.gov](mailto:carl.rivkin@nrel.gov)

# Tri-Counties Hydrogen Readiness Plan

## Project Summary

January, 2017

- Introductions
- Hydrogen Station Siting
- Permitting and Plan Check
- First Responder Awareness
- FCEV Promotion
- Recommendations

Ivor John, Project Coordinator  
Jack Armstrong, Safety Professional



## Hydrogen Station Priorities

- Thousand Oaks/Newbury Park/ Westlake (eastern Ventura Co.)
- Simi Valley/Moorpark (eastern Ventura Co.)
- Santa Barbara County South Coast (second station)
- Camarillo/Ventura (western Ventura Co.)
- San Luis Obispo County (first station)

For San Luis Obispo, the need is two-fold – (1) to provide 101 connector station, and (2) to initiate local FCEV use



## Streamlining H<sub>2</sub> Permitting and Plan Check

- SB City successfully permitted the first station locally
- Positive feedback from City Fire and Planning & Development
- Cooperation and support from California Fuel Cell Partnership
- Adapting Governor's office Hydrogen Permit Guide (Go-Biz) for local application
- Emphasis on NFPA 2, Hydrogen Technology Codes



## Safety – Training and Awareness for Responders

- Hydrogen ER training courses have been developed by the DOE, partnering with organizations such as the California Fuel Cell Partnership
- Their website H2Tools.org has an Emergency Response portal for hydrogen and fuel cells designed specifically for first responders
  - L1 – Overview – basic awareness of hydrogen and fuel cell technologies
  - L2 – Short course, focused on response operations
  - L3 – Full Course, day long course

<https://h2tools.org/content/training-materials>



## Training Resources

---

1. Tri-Counties Hydrogen Readiness Plan Overview
2. First Responder Training Template
3. Hydrogen - Emergency Response Training Guide (matrix)
4. Hydrogen - Emergency Response Training Slides (Powerpoint)
5. Vehicle Emergency Response Manual (example for Hyundai)
6. Link to "Lessons Learned" website (maintained by DOE)

Website Links:

<https://h2tools.org/>

<https://www.ourair.org/wp-content/uploads/THRP-Part-2-Permitting-Guidance-082816.pdf>



## THRP Recommendations

---

- Keep the plan a living document
- For permitting and planning, provide resources to agencies and access to peers with previous experience
- Provide access to training resources and support for local first responder trainers.
- Ensure ongoing local support

