CALIFORNIA GOVERNOR'S OFFICE OF BUSINESS AND ECONOMIC DEVELOPMENT

Hydrogen Station Permitting
Guidebook

California Governor's
Office of Business and Economic
Development (GO-Biz)

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Any errors in the Guidebook are the sole responsibility of the Governor's Office of Business and Economic Development. With that in mind, we are always looking for ways to improve the resources we create. Please send suggestions to zev@gobiz.ca.gov.

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Executive Summary

Transportation remains the largest contributor of greenhouse gas and criteria pollutant emissions in California. Combating this to improve environmental and human health requires a massive transition from internal combustion engines to zero-emission drivetrains. The State of California is a national and international leader in this transition, with an ambitious goal of five million zero-emissions vehicles (ZEVs) on our roads by 2030. But, success hinges on rapidly scaling up infrastructure and vehicle development. We cannot achieve this without success at the local level.

The Hydrogen Station Permitting Guidebook is intended to help local jurisdictions and hydrogen station developers navigate and streamline the station development process.[1] It also provides stakeholders with background on hydrogen and fuel cell electric vehicles, California's efforts to accelerate infrastructure development, and insights into the upward momentum of this market since its launch in 2015. The first edition of the guidebook was published in October 2015. Since then, the market has grown from just two retail stations and fewer than 200 vehicles to 46 stations built and opened to drivers with 16 more currently under development, and nearly 8,600 vehicles as of September 1, 2020.[2] In this short time, we have also seen the birth of a nascent medium- and heavy-duty vehicle market, as well as an increase in renewable hydrogen production and supply dedicated for transportation fuel, and a rise in private sector investments.

The Guidebook consists of six parts. Below, we provide a brief summary of each part. For readers who wish to solely focus in on the station development steps and process, we recommend going directly to ***Part 3: Station Development.***

Part 1: Setting the Stage: Provides a background on California's ZEV status and targets, an overview of hydrogen stations and fuel cell electric vehicles (FCEVs) in California and the state's investments to support this market, the 2030 vision for the market, progress that has been made since the release of the 2015 Hydrogen Station Permitting Guidebook, and additions to the guidebook to reflect advancement of the market.

Part 2: The Hydrogen and Fuel Cell Electric Vehicle Ecosystem: Discusses hydrogen as a fuel—its properties, how it is produced, and the growing focus on renewable hydrogen. It provides an overview of fuel cell electric vehicles (FCEVs), how they work, emissions reduction benefits, and the synergies between the light-duty and medium- and heavy-duty applications in driving scale and reducing costs across the supply chain. It also provides an overview of hydrogen stations, including typical components and layouts, delivered hydrogen versus on-site generation, what happens during the vehicle fueling process, and requirements and guidelines for selling hydrogen fuel in California.

Part 3: Station Development: Walks through the five steps of the development process. In each step, we describe key activities and average timeframes for completion, and offer tips and best practices for streamlining the development process. Part 3 also provides a more in-depth discussion on utility power considerations and connecting to the grid.

1. **Pre-application Outreach:** Prior to submitting a permit application, engagement with a city or county's planning agency can be valuable

1 This guidebook is a sister document to GO-Biz's Electric Vehicle Charging Station Permitting Guidebook, which focuses on plug-in electric vehicle charging station development.

2 As of the publishing of this guidebook, 45 are open retail; the West Los Angeles station closed permanently in January 2020 due to residential redevelopment of the station site.

for flagging local requirements and uncovering potential issues upfront, as well as establishing channels of communication and a permitting pathway. During the pre-application meeting, the applicant should layout the plan, describe the proposed path forward, learn what permits or approvals will be required to complete the project, and gain a clear understanding of the level of detail each department would like to see in the permit application submittal package. During this phase, station developers should also ensure they have secured site control before moving forward with planning review.

2. **Planning Review:** This is a required part of the permitting process that ensures that a proposed station fits within a community's zoning codes, General Plan and overall aesthetics. This phase includes zoning approval to ensure the station complies with local ordinances and architectural review to ensure the project fits the local aesthetic. It also includes identification of CEQA requirements. It may also include the fire department's review of the project.[3] Experience has shown that gaining planning approval can be the most time-consuming portion of the permitting process, underscoring the importance of early engagement with the planning department. Typical timeframes for completing this phase range from one day to six months, although station developers have reported instances that were significantly longer (e.g., greater than a year). It is also important to kick off discussions with utility providers to understand the process and timeline for connecting to the grid. Depending on the station location, type, and project size, this piece can be very time consuming and has been the source of significant project delays.

3. **Building review:** In this phase, building departments review complete, fully detailed plans to ensure that projects comply with applicable structural, mechanical, and electrical codes, and local ordinances. In some jurisdictions, planning review and building review can occur in parallel. In others, planning approval must be received before building review can begin. In either case, final construction plans must incorporate all of the planning agency's conditions of approval. When the project is approved, the authority having jurisdiction (AHJ) will issue the approval to build. Typical timeframes for completing this phase range from one day to six months.

Photo credit: FirstElement Fuel Inc.

3 The timing on a fire department's review varies by jurisdiction and project. Some fire departments will engage early in the process (in parallel with planning review), others will begin their review once a project has Planning Approval.

4. **Construction:** Once the AHJ issues the final approval to build, construction can begin. During and at the completion of construction, the station is subject to inspections and final approval by the local authorities to ensure that project developers build their projects in compliance with the agreed upon specifications. Typical timeframes for completing this phase range from three to nine months.

5. **Commissioning:** When construction is complete, the station developer will file a notice of completion and begin commissioning the station. This entails five steps: 1) station developer fills the system with hydrogen and administers tests to ensure the station performs as expected, and final inspection is performed by the AHJ; 2) hydrogen fuel quality testing to ensure it complies with SAE J2719; 3) fueling protocol confirmation by the California Air Resources Board's Hydrogen Station Equipment Performance (HyStEP) device to ensure the station complies with SAE J2601; 4) commercial testing and certification by California Department of Food and Agriculture's Division of Measurement Standards (DMS) to ensure that a kilogram of hydrogen sold is a kilogram of hydrogen received, that the point of sale system functions properly, and that hydrogen dispensed meets the purity requirements for use in a FCEV; 5) official opening the station to the public. Typical timeframes for this phase range from one to three months.

In general, station development overtime has become faster and easier as station developers have incorporated lessons learned and local authorities have become more familiar with hydrogen; timeframes have decreased from more than four years to complete to just over two years.[4] We anticipate this trend to continue as more jurisdictions approve hydrogen stations in their communities, more entities enter the supply chain, and economies of scale are achieved.

Part 4: Other Topics: Touches on topics that are relevant to station development including safety planning, interfacing with Certified Unified Program Agencies, air quality permits, permitting temporary fuelers, codes applicable to repair facilities, and human resources that can help AHJs and station developers with the learning curve.

Part 5: Looking Forward: Offers a perspective on where the market is headed and what we must do, collectively, in order to achieve California's targets. Local jurisdictions are critical in this effort, as is private industry. Together, we must continue to actively collaborate to overcome barriers and take tangible steps to accelerate the hydrogen and fuel cell market.

Part 6: Additional Resources: Includes several resources to help deepen readers' understanding of hydrogen and FCEVs and streamline station development, and provides key organizational contacts that can help overcome challenges and barriers.

Today, as we turn our focus to market scale, our success hinges on the ability to demonstrate the business case and attract growing private investment. Leadership at the local-level focused on minimizing permitting uncertainty and streamlining processes are essential for achieving these outcomes more rapidly. This action also sets the stage for other jurisdictions to learn and for statewide improvement.

With a supportive government backdrop, industry can and must work to achieve scale—with stations, vehicles, and the hydrogen and fuel cell supply chain. Together, government and industry must continue to actively collaborate to overcome barriers and take tangible steps to accelerate the hydrogen and fuel cell market.

GO-Biz is committed to working with these partners to create sustainable and scalable systems necessary to create the future our health and climate depends on.

4 Change in development time between PON-09-608 and GFO-15-605. Source: Baronas, Jean, Gerhard Achtelik, et al. 2019. Joint Agency Staff Report on Assembly Bill 8: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California. California Energy Commission and California Air Resources Board. Publication Number: CEC-600-2019-039. https://ww2.energy.ca.gov/2019publications/CEC-600-2019-039/CEC-600-2019-039.pdf

Photo credit: American Honda

Photo credit: SunLine Transit Agency

Photo credit: FirstElement Fuel Inc.

PART 01:

Setting the Stage

Transportation remains the largest contributor of greenhouse gas and criteria pollutant emissions in California.[5] We cannot meet our state climate and air quality objectives without a massive, near-term shift from internal combustion engines to zero-emission drivetrains.

The State of California is a national and international leader in the deployment of zero-emission vehicles (ZEVs). These cars are any type of vehicle that has no tailpipe emissions. They run on electric motors and are powered by electricity stored in batteries or created onboard using hydrogen and fuel cells.

In contrast to conventional internal combustion vehicles, ZEVs produce zero tailpipe emissions, preventing harmful greenhouse gas and criteria pollutants from being released into the environment. They can also help integrate renewable energy into the transportation sector. Moreover, the communities most burdened by air pollution are often the ones along major transportation and shipping corridors and a switch to ZEVs will help alleviate that burden.

To support California's ambitious ZEV deployment goals—five million ZEVs in California by 2030—the state is prioritizing the development of hydrogen and charging infrastructure to support these vehicles. At the most fundamental level, infrastructure enables the deployment of ZEVs. When consumers look to buy a new or used car, they need confirmation that it will be able to take them where they want to go. Widespread availability of infrastructure ensures that Californians will have that confidence.

Ultimately, a successful transition to zero emissions hinges on success at the local level. Success to this point has been a necessarily iterative process as the ZEV stakeholder community has learned how to best develop hydrogen stations in several cities in California. This guidebook reflects the latest best practices collected from stations developers, local jurisdictions, and other stakeholders with experience in the hydrogen stations development process. We hope this experience can save time and minimize iterations for both station developers and local jurisdictions. The faster we deploy safe and reliable infrastructure, the sooner we accumulate the benefits ZEVs bring to our communities, the state, and ultimately the world.

Retail fuel cell electric vehicles (FCEVs)
are available to drivers and adoption is accelerating—a robust and reliable hydrogen fueling station network is critical to realize the environmental, social, and economic potential of this growing market.

Hydrogen and Fuel Cells in California Today

Hydrogen fuel cell electric vehicles (FCEVs) and battery electric vehicles (BEVs) are complementary and necessary technologies. Only with both

5 California's 2017 Climate Change Scoping Plan.

technologies together can California offer a defensible pathway to reach our long-term ZEV goals across the full portfolio of transportation needs, including the state's global commitment of 100% zero-emission transit bus fleets by 2040 and 100% of new passenger vehicle sales to be zero-emission by 2050. We need FCEVs because they provide:

- **Zero emissions without requiring a change in behavior.** To meet our ZEV goals, California needs options that will ultimately appeal to every driver on the road. Pure battery electric vehicles will meet many, but likely not all, of drivers' needs in California. FCEVs fuel like conventional vehicles (3-5 minutes of fuel time equates to 300-plus miles of range) at centrally-located retail stations.

- **Increased flexibility and utility.** FCEVs are especially well suited for long-range, larger-sized high-payload activities such as medium- and heavy-duty trucks. In addition to quick refueling, adding more range to a vehicle adds minimal weight compared to battery only applications. Commercial fuel cell vehicle deployments enable 24/7, double shift transportation applications.

- **A solution for residents of multi-unit dwellings and renters.** Approximately 40% of Californians live in multi-unit dwellings, while nearly half of Californians are renters.[6] FCEVs, paired with a local fueling station, are a solution for increasing access to ZEVs in this critical market segment.

- **Opportunities to grow renewable energy consumption.** As an energy carrier, hydrogen facilitates increases in renewable energy production and excels in seasonal, long-term energy storage applications. An active hydrogen transportation market creates scalable business opportunities to generate and sell renewable hydrogen, increasing overall renewable energy penetration in California.

As of September 1, 2020, three commercial FCEV models are available, with 8,573 FCEVs on the road in California. A survey of automakers by the California Air Resources Board (CARB) projects 48,000 FCEVs on the road by 2025.[7] Additionally, 48 FCEBs operate in California—with more than 4,600,000 combined miles of operational service—and 7 more buses (as well as four shuttles) will be on the road soon.[8] There are also several efforts underway to develop medium- and heavy-duty fuel cell vehicles, with commercial vehicles under development by manufacturers such as Cummins, Hyundai, Kenworth, Nikola, and Toyota.[9]

Photo credit: FirstElement Fuel Inc.

The State of California is working closely with communities and the private sector to ensure a robust hydrogen fueling infrastructure is in place to support vehicle deployment and market scale. Two guiding principles, coverage and capacity, underlie the process of determining the number and location of stations necessary to support commercial FCEV deployment. Coverage emphasizes installation of an adequate number of hydrogen fueling stations in locations of high demand and to support the wide variety of trip types — commuting to work, running errands, driving to national parks and sightseeing areas, and road trips, among others — for which typical consumers use their vehicles. Capacity describes the amount of fuel available in a station or group of stations, which defines the maximum number of vehicles those stations can support.

As of September 1, 2020, 46 retail hydrogen stations have been approved by local jurisdictions and opened to drivers,[10] with 16 stations currently under development. All of these are expected to open

6 Renters are less likely than homeowners to make capital improvements, such as installing additional electrical capacity in an older home.

7 https://ww2.arb.ca.gov/sites/default/files/2019-07/AB8_report_2019_Final.pdf

8 California Fuel Cell Partnership https://cafcp.org/by_the_numbers

9 Hyundai and H2 Energy (a Swiss company) are establishing a joint venture called Hyundai Hydrogen Mobility, in which Hyundai will initially supply 1,600 Class 8 fuel cell trucks from 2019 to 2025; Nikola Motor is developing three fuel cell vehicles (Class 6-8) as well as a network of renewable large capacity hydrogen stations. https://nikolamotor.com/motor; Toyota (partnering with Kenworth and with funding support from the California Energy Commission) is building 10 Class 8 fuel cell trucks that will be used at the Port of Los Angeles/Port of Long Beach complex. It is also testing a fuel cell yard truck to move shipping containers within the Port of Los Angeles.

10 As of the publishing of this guidebook, 45 are open retail; the West Los Angeles station closed permanently in January 2020 due to residential redevelopment of the station site.

in 2020 and 2021. On December 26, 2019, the California Energy Commission (CEC) released Grant Funding Opportunity (GFO) 19-602, announcing the availability of up to $115.7 million in grant funds, subject to future appropriations and Clean Transportation Program Investment Plan funding allocations, for hydrogen fueling infrastructure projects that will expand California's early commercial light-duty hydrogen fueling and FCEV markets and to accommodate the projected FCEV roll-out in 2021-2024. Additionally, stations are now also being approved under CARB's Low Carbon Fuel Standard (LCFS) Hydrogen Refueling Infrastructure (HRI) program.

The 2030 Vision

Governor's Office Vision

In September 2019, Governor Gavin Newsom signed Executive Order N-19-19 to align transportation funding with state goals on climate and the environment. It directs "every aspect of state government to redouble its efforts to reduce greenhouse gas emissions and mitigate the impacts of climate change while building a sustainable, inclusive economy." It focuses specifically on transportation systems, state assets and operations, and ZEV market expansion. It also created a Climate Investment Framework to leverage a $700 billion investment portfolio to advance California's climate leadership.

Executive Order B-48-18 (January 2018) sets ambitious targets of 200 hydrogen fueling stations and 250,000 plug-in electric vehicle chargers by 2025. These infrastructure goals are designed to enable at least 1.5 million drivers across California to use a ZEV to meet their driving needs by 2025, and catalyze the momentum necessary to scale to 5 million ZEVs by 2030. Publicly available hydrogen fueling and charging stations are fundamental to ZEVs going mainstream. Success of the ZEV market depends on contributions from multiple stakeholders, both public and private. The Executive Order sets targets for stakeholders to organize around, and tasks state agencies to exercise their authority to enable the success of each market contributor and participant.

California's Investment

The State of California is investing significantly in the hydrogen station infrastructure network and vehicle uptake to launch the market and help get it on the path to self-sufficiency.

- Clean Transportation Program (formerly Alternative and Renewable Fuel and Vehicle Technology Program): The CEC provides funding for the development of hydrogen stations across the state. Assembly Bill 8 (statutes of 2013) enables CEC to allocate $20 million per year, not to exceed 20 percent of the moneys appropriated by the Legislature from the Alternative and Renewable Fuel and Vehicle Technology Fund, to fund at least 100 hydrogen stations through a competitive process. To date, the recipients of funds have included a diverse range of hydrogen station integrators, industrial gas companies, and designers and builders partnered with gas station owners and operators.
- Clean Vehicle Rebate Project (CVRP): CARB (administered by the Center for Sustainable Energy), provides residents rebates between $750-$7,000 for the purchase or lease of a new zero-emission or plug-in hybrid light-duty vehicle or motorcycle.
- Low Carbon Fuel Standard (LCFS) Program: Beginning January 1, 2019, hydrogen stations and direct current fast charging stations can generate LCFS credits based on station capacity, in addition to fuel sold.
- Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP): CARB (administered by CALSTART) provides up to $315,000 in point-of-sale discounts for the purchase of low-carbon clean trucks and buses.
- Carl Moyer Program: CARB works collaboratively with California's air pollution control and air quality management districts or oversee and implement this program, respectively. It provides more than $60 million in grant funding annually to public and private entities to go beyond regulatory emissions reductions requirements by retrofitting, repowering, or replacing more polluting technologies, especially from emission sources in areas disproportionately impacted by air pollution.
- Advanced Technology Freight Demonstration Projects: CARB provides funding for pre-commercial demonstration projects to accelerate the next generation of zero or near zero-emission vehicle, equipment, or emissions controls technology.

Photo credit: Shell Hydrogen

The California Fuel Cell Revolution

In July 2018, the California Fuel Cell Partnership (CaFCP) released "The California Fuel Cell Revolution: A Vision for Advancing Economic, Social, and Environmental Priorities." The document presents CaFCP's[11] collaborative member vision for the hydrogen and fuel cell market in 2030, and sets forth strategic priorities to accelerate growth and achieve a self-sustaining market.

The key to achieving this vision is scale. Larger hydrogen volumes and more station throughput lead to significant cost reductions and economies of scale. Hydrogen stations are projected to generate attractive rates of return and FCEVs will be sold for profit at competitive prices, enabling a virtuous cycle of growth. Rapid development and expansion of hydrogen station infrastructure must occur to unlock this potential.

California's target of 200 stations by 2025 is a key marker on the way to economic sustainability for the state's hydrogen and FCEV system. It will enable FCEVs to follow the same adoption trajectory as hybrid vehicles and put the market on the path to 2030. Achieving the 1,000 station target will require continued collaborative public policies, increasing private funding to move from a government push to a market pull, and dynamic leadership and deliberate action to bring the necessary market elements together.

California Fuel Cell Partnership Vision

Enable market conditions to support 1,000 hydrogen stations and 1 million FCEVs by 2030.

One thousand stations is more than just a convenient number. One thousand hydrogen stations would replicate the fuel availability of California's eight thousand gasoline station network that exists today. This means nearly every resident of California—including nearly all historically under-represented communities—would have convenient access to hydrogen.

Benefits of 1,000 Stations + 1,000,000 Cars:

- **693.5M gallons gasoline displaced per year**
- **2.7M metric tons GHG avoided per year***
- **3,900 metric tons NOx avoided per year**
- **97% of disadvantaged communities within the station network coverage**

* ***with today's energy mix of 33% renewable hydrogen. The hydrogen industry has a goal of 100% decarbonized hydrogen fuel in transport by 2030.***

Scale Leads to Virtuous Cycles of Growth

Shell Hydrogen has shown that its hydrogen station capital costs could be reduced by 50% through economies of scale by as early as 2020, if they were to build as few as 30 hydrogen stations per year globally.

In 2018, Toyota announced that by 2020 it will produce 10 times as many FCEVs annually as it did in 2017.

11 CaFCP is comprised of more than 40 partners, including auto, truck & bus manufacturers, energy companies, fuel cell technology companies, government agencies, non-governmental organizations and universities. www.cafcp.org.

Purpose of the Guidebook

In October 2015, GO-Biz released the first Hydrogen Station Permitting Guidebook, aimed at providing a starting point to aid in the timely completion of hydrogen fueling stations. Since then, significant progress has been made and the hydrogen fuel cell market has evolved, for example:

- Hydrogen awareness continues to grow among local permitting and building officials.
- Fire and safety officials are increasingly familiar with, and supportive of, hydrogen. Thousands of first responders in California have been trained to effectively manage an event.
- Average development times have dropped nearly in half from more than four years to just over two years.[12] Notably, the Citrus Heights station was completed and opened in just 15 months.
- Private sector investment is increasing in stations, hydrogen production and supply, and vehicles (both in light-duty models and larger vehicle classes).[13]
- Distribution and storage at stations are moving toward liquid hydrogen to increase capacity and reduce costs. There have been gaseous hydrogen improvements as well, such as new storage tanks.
- Station developers are building larger retail stations with multiple fueling positions.
- Utilization across the network is growing with several open stations already exceeding daily nameplate capacity on high driver demand days.
- More than doubling of the number of higher capacity heavy-duty bus and truck fleet stations.[14]

The hydrogen fueling and FCEV community is now focused on rapidly scaling up vehicles and infrastructure to support a mainstream market and nascent heavy-duty vehicle market. This updated guidebook provides the current state of play and, when possible, offers insights about emerging trends in the market. It also includes some new elements:

- Updates to California's vehicle and infrastructure investments
- Trends for increasing renewable/carbon-free hydrogen for transportation
- New section on the importance of and opportunities in the medium- and heavy-duty sector and inclusion of insights for permitting infrastructure in this sector throughout the document
- Expanded discussion on connecting to the grid
- Discussion on the Hydrogen Station Equipment Performance (HyStEP) device and future plans for hydrogen station verification
- Code updates from the 2020 edition of National Fire Protection Association (NFPA) 2 Hydrogen Technologies Code

This Guidebook and the Electric Vehicle Charging Station Permitting Guidebook serve as companion documents aimed at providing station developers, local jurisdictions, and other stakeholders with a firm understanding of the ZEV market and necessary steps to develop the infrastructure that is critical to bending the curve.

12 Change in development time between PON-09-608 and GFO-15-605. Source: Baronas, Jean, Gerhard Achtelik, et al. 2019. Joint Agency Staff Report on Assembly Bill 8: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California. California Energy Commission and California Air Resources Board. Publication Number: CEC-600-2019-039. https://ww2.energy.ca.gov/2019publications/CEC-600-2019-039/CEC-600-2019-039.pdf

13 For example: Air Liquide is investing $150 million to build a 30 tonne per day liquid hydrogen plant in Nevada to support the West Coast mobility market. Construction began in 2019 and is expected to come online in 2022. https://energies.airliquide.com/air-liquide-build-first-world-scale-liquid-hydrogen-production-plant-dedicated-supply-hydrogen; In June 2020, FirstElement Fuel, the prominent California-based hydrogen station developer, secured $25 million from Mitsui & Co. and $23 million from Japanese Bank for International Cooperation. FirstElement plans to deploy the capital to grow the California hydrogen station network and improve operations to bring down the cost of hydrogen to consumers, and is making progress on future equity investments from Mitsui to expand into heavy duty and commercial. https://www.mitsui.com/jp/en/topics/2020/1231534_11245.html In 2019, Air Liquide and Cummins acquired Hydrogenics, a leader in electrolysis hydrogen production equipment and fuel cells, indicating these companies' longer-term commitment to the hydrogen energy markets.

14 An increase from three (SunLine (1) and AC Transit (2)) heavy-duty transit bus stations to seven (SunLine (new station replacing the previous), AC Transit (2 with one upgraded), Orange County Transit Authority (1), Shell (3 in Long Beach, Ontario, and Wilmington)).

Photo credit: Shell Hydrogen

PART 02:

The Hydrogen and Fuel Cell Electric Vehicle Ecosystem

Hydrogen as a Fuel

Hydrogen is a carbon-free, non-toxic fuel that is domestically produced from local resources.[15] Hydrogen is a recognized fuel for transportation and has been classified as such by the State of California.[16] Most hydrogen is made from natural gas, but increasingly it is made from water, biogas, and biomass. For more than 75 years, hydrogen has been safely handled, distributed, and dispensed. It is commonly used in large quantities in the petroleum refinery process, in several industrial applications, and as fuel for space exploration. These uses resulted in reliable standards to safely produce, store, and transport hydrogen. Building codes and technical standards have been created to address hydrogen's specific properties: a small, lighter-than-air molecule with quick diffusion in its gaseous state.

The application of appropriate codes and standards make hydrogen fuel as safe as gasoline or other commonly used fuels, such as compressed natural gas (CNG). Retail and fleet hydrogen stations are designed to be operated safely by new hydrogen users with minimal training. However, a general understanding of the physical properties of hydrogen can be beneficial.

To date, widespread commercial and government fleet CNG stations have provided valuable experience as equipment for hydrogen fueling becomes more readily available. CNG stations have a safe operating record and, similarly, hydrogen stations have not exhibited safety concerns when applying appropriate codes and standards during the development process.

Properties of Hydrogen

Hydrogen is lighter than other fuels: Diatomic hydrogen is the lightest molecule in the universe and diffuses rapidly in its gaseous state, elevating at approximately 65 feet per second. This property is known as high buoyancy. High buoyancy makes it unlikely to accidentally form a flammable mixture with hydrogen in open and well ventilated spaces. Codes and standards consider the buoyancy and diffusivity of hydrogen in their requirements for storing, transporting, and using hydrogen safely.

Hydrogen is odorless, colorless, and tasteless: Hydrogen sensors are used to detect leaks and have been used to meet safety standards for decades. By comparison, natural gas is also odorless, colorless, and tasteless; in this case, a sulfur-containing odorant, called mercaptan, is typically added to make natural gas detectable by smell. Hydrogen fuel would not work well with odorants because they degrade and damage most fuel cell systems, so other safety measures, like sensors, are used.

Hydrogen flames have low radiant heat: When a pure hydrogen flame ignites, it burns with an invisible or near-invisible flame and produces heat and water vapor. A hydrogen fire radiates significantly less energy compared to a typical hydrocarbon fire.

15 The carbon associated with the lifecycle emissions of hydrogen occur during the production processes.

16 Senate Bill 76–Committee on Budget and Fiscal Review, Energy, S. 76, 2005 Leg. § Chapter 91 (Cal. 2005) www.leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200520060SB76

Hydrogen has a wide flammability range: Hydrogen's flammability range in air (between 4% and 75%) is very wide compared to other fuels such as natural gas (5% to 15%) and gasoline vapor (1.4% to 7.6%),[17] and it can ignite more easily than other fuels. Offsetting this characteristic, hydrogen is lighter than air and disperses rapidly. Compared to other fuels, it can be more difficult for hydrogen to reach a combustible state in open air environments.

Hydrogen is non-toxic and non-poisonous: Hydrogen cannot contaminate groundwater. It is a gas under normal atmospheric conditions and must be at -423°F to reach liquid state. As such, liquid hydrogen will vaporize very quickly, and gaseous hydrogen does not contribute to atmospheric pollution. Hydrogen does not create harmful fumes when used in a fuel cell and cannot cause drips, spills, or soil contamination associated with liquid fuels.

Hydrogen has a low risk of asphyxiation: Any non-oxygen gas can cause asphyxiation. Hydrogen's buoyancy and diffusivity make hydrogen difficult to be confined in a space where asphyxiation might occur. Hydrogen station fueling occurs in well ventilated outdoor and indoor areas, just like gasoline fueling.

How it's Made

Most hydrogen today is made from steam methane reformation at a central production plant, often at or near an oil refinery, food processing plant, fertilizer plant, or other industrial chemical process plant.[18] This process typically collects hydrogen from natural gas and water but can also utilize biogas as the primary feedstock. If produced off site, hydrogen is transported to the fueling station by pipeline or truck. It is also possible to have a steam reformer or electrolyzer at a fueling station to produce hydrogen on-site.

Hydrogen is also produced from renewable sources. California Senate Bill 1505 currently requires 33% of hydrogen used for vehicle fuel in California, in aggregate, to be produced from renewable energy sources.[19] Renewable content must be 40% to qualify for the Low Carbon Fuel Standard Hydrogen Refueling Infrastructure program. Two common methods for renewable hydrogen production include electrolyzing (splitting) water with renewable electricity and using renewable biogas as the primary feedstock for steam methane reformation or stationary fuel cell hydrogen generation.[20] Biogas can be collected from a variety of sources of biomass and waste. Today, most renewable hydrogen for fueling stations is produced from the reformation of biogas, but electrolyzers powered with renewable electricity are making an increasing contribution. Electrolyzers have tremendous potential to provide load balancing services to the grid, perhaps increasing the potential for renewable electricity production more broadly.

The abundance of naturally occurring material resources that contain hydrogen opens up the potential for a number of cutting edge, lab-proven renewable production methods, such as enzymatic bio-hydrogen and photo electrochemical production. The establishment of a robust hydrogen transportation market is expected to spur investments required to scale up these creative production techniques.

As the FCEV market continues to grow, widespread availability of renewable hydrogen will rise. For more information on research involving renewable hydrogen projects, visit the National Renewable Energy Laboratory (NREL) website.

Fuel Cell Electric Vehicles

Fuel cell electric vehicles are an important part of California's long-term strategy to reach climate goals, improve air quality, and diversify the zero-emission transportation sector. FCEVs provide vehicle operators with the range, refill time, performance, and comfort comparable to today's gasoline vehicles, along with zero tailpipe emissions. FCEVs are quiet, smooth, and low maintenance.

FCEVs are powered by electricity generated by an on-board fuel cell that electrochemically combines hydrogen (from the tank) and oxygen (from the air), with only harmless water vapor created as byproduct. Hydrogen is stored on-board the vehicle as a

17 https://h2tools.org/bestpractices/hydrogen-compared-other-fuels.

18 During steam-reformation, water (as steam) reacts with natural gas (mostly methane) to produce carbon dioxide and hydrogen. Hydrogen is frequently used in the oil refining process to remove sulfur and nitrogen compounds from crude oil feedstocks.

19 Senate Bill 1505–Fuel: Hydrogen Alternative Fuel, S. 1505, 2006 Leg. § Chapter 877 (Cal. 2006) www.leginfo.ca.gov/pub/05-06/bill/sen/sb_1501-1550/sb_1505_bill_20060930_chaptered.html

20 https://www.nrel.gov/hydrogen/hydrogen-production-delivery.html

Growing the Renewable Hydrogen Supply

Both BEVS and FCEVs create about half of the well-to-wheels emissions, using today's energy mix in California, when compared to a traditional gasoline vehicle today. By leveraging solar, wind, and renewable natural gas, these technologies are uniquely positioned to drive emissions to zero.

SB 1505 requires hydrogen to include a minimum of 33% renewable content. California hydrogen stations already exceed this at around 38%. In addition, the LCFS infrastructure credits program requires a minimum of 40% renewable content to qualify.

Moreover, hydrogen is not just for transportation. It can be used to lower carbon intensity across our energy system in numerous other applications, including power generation and grid balancing, energy storage, building water and space heating, and decarbonized heat in industrial processes.

Electrolyzers provide the opportunity to generate low-cost renewable hydrogen during times of the day when there is an over production of renewable energy. This can help reduce or eliminate curtailment and hydrogen generated can be stored to help balance short-term (daily) or longer-term (seasonal or annual) energy demand.

The transition will be enabled by policies that encourage vehicle adoptions (ZEV mandate), renewable fuels and energy sources, and private investment to enable infrastructure to grow to scale. This investment is already underway. In September 2018, the Hydrogen Council (comprised of CEOs of the leading industrial players in the hydrogen market) committed to delivering 100% decarbonized hydrogen to the mobility markets by 2030, dependent on a supportive regulatory environment.* It is an ambitious goal, putting hydrogen on a fully renewable pathway many years sooner than the electric grid, and backed by the industry leaders who will be making the investments in to this new hydrogen production and supply chain.

*** http://hydrogencouncil.com/our-2030-goal/**

compressed gas, like compressed natural gas but at a higher pressure. Light-duty FCEVs take between three and five minutes to fill at a hydrogen station and have a range similar to gasoline vehicles (300+ miles). Heavy-duty FCEVs take 6-20 minutes to fill with a resulting driving range sufficient to meet their typical daily operational needs. In addition to zero tailpipe emissions, a hydrogen-powered FCEV is 2-to-3 times more efficient in producing usable energy, compared to gasoline in a conventional internal combustion engine vehicle.

FCEVs are as safe as other vehicles on the road and meet all Federal Motor Vehicle Safety Standards, including identical crash tests as gasoline fueled vehicles. FCEVs are closed systems and will not emit any hydrogen. In the event of an accident, leak and crash detectors will respond by automatically isolating the hydrogen in the storage tank. Hydrogen tanks themselves—constructed from carbon-fiber-reinforced material—have undergone rigorous testing to ensure their durability, including crashing, dropping, shooting, as well as placing the tank in a bonfire.[21, 22]

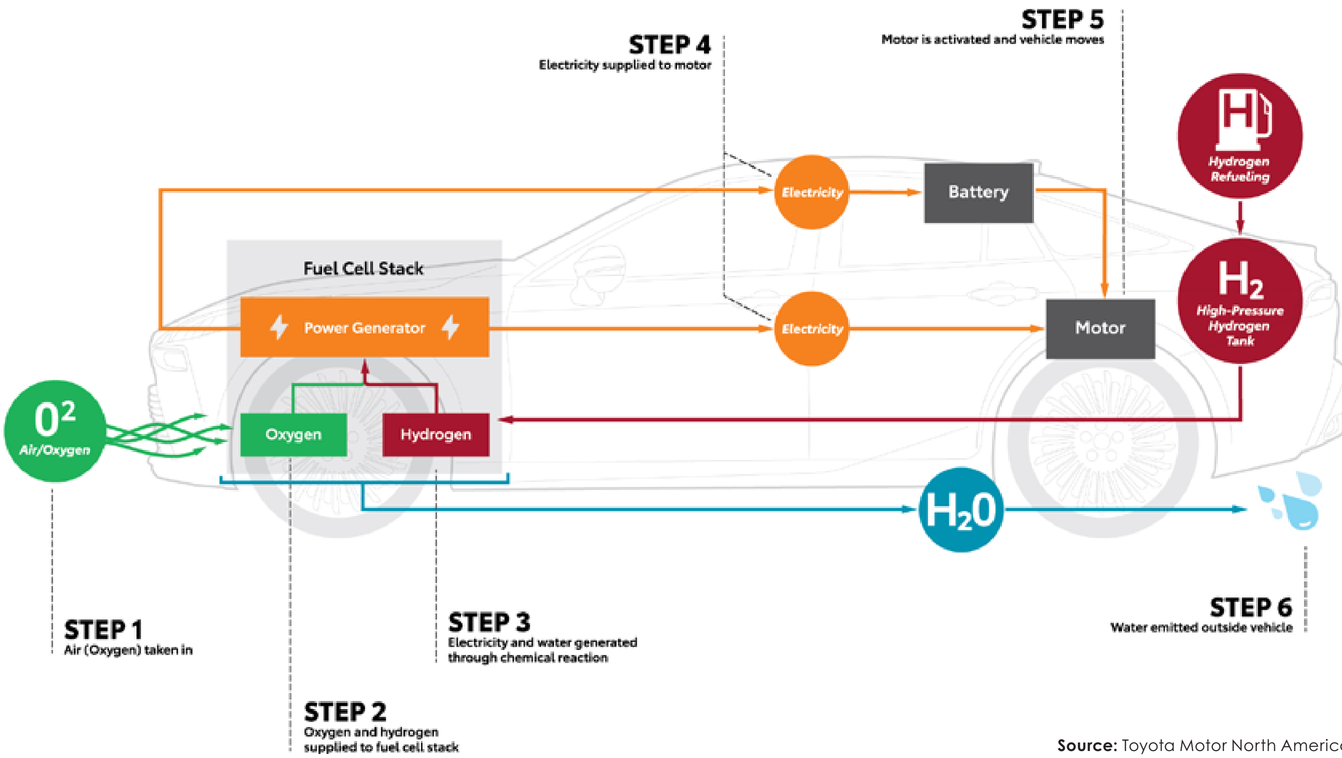
Should a FCEV be subject to extreme, high temperatures, such as from a fuel fire from another vehicle, the tank system has a temperature activated pressure relief device (TPRD) that is designed to safely release the hydrogen, which prevents over-pressurization of the tanks (discharging a full passenger car tank system takes approximately three minutes).[23] The rapid release of hydrogen also aids the removal of the hydrogen from the crash site because hydrogen is lighter than the surrounding air, unlike leaked liquid gasoline, which pools under a vehicle and continues to burn. Figure 1 provides an overview of how a FCEV works.

21 Tanks are tested to American National Standards Institute (ANSI) NGV 2 Standards.

22 Ben C. Odegard, Jr and George J. Thomas, Testing of High Pressure Hydrogen Composite Tanks (Livermore, CA: Sandia National Laboratories, n.d.)

23 California Fuel Cell Partnership, Fuel Cell Electric Vehicle Safety Systems (West Sacramento, CA: n.p., 2014), www.cafcp.org

Figure 1: Overview of How a FCEV Works



Source: Toyota Motor North America

Well-to-Wheel Emissions

As mentioned before, FCEVs have zero tailpipe emissions and provide significant air quality and climate benefits. As with any fuel generated from a variety of sources, some pollution and emissions are associated with the upstream fuel production and distribution. When these are added to vehicular emissions (e.g., from tailpipe) to obtain total emissions, this total reflects "well-to-wheel" impacts. The impact of FCEVs is comparable to BEVs, depending on the source of electricity. BEVs and FCEVs both have the potential to reach zero emissions on a well-to-wheel basis.

The four major air pollutants (commonly called "criteria pollutants") in California are volatile organic compounds (VOCs), carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter (PM). Because most criteria pollutants from vehicles are related to on-board combustion, FCEVs have almost zero air pollutants from well to wheels.

In addition to reductions in criteria pollutants, ZEVs provide significant well-to-wheel reductions in greenhouse gas emissions (GHGs). In 2017, California emitted 424 million metric tons of carbon dioxide equivalent (MMTCO2e). This is 5 MMTCO2e lower than 2016 levels and 7 MMTCO2e below the 2020 GHG limit of 431 MMTCO2e. Notably, these decreases have occurred while California's economy continued to grow. From 2016 to 2017, the state's GDP grew 3.6 percent while the carbon intensity of our economy declined by 4.5 percent.[24] Transportation is the largest source of emissions in California, accounting for 40 percent. On average, FCEVs provide a 62.5 percent well-to-wheel GHG reduction compared to gasoline-powered vehicles, with the potential to get to 100 percent.

For additional information about the well-to-wheel impacts of FCEVs, including efficiency, water, and energy security statistics, please see the California Fuel Cell Partnership's report.[25]

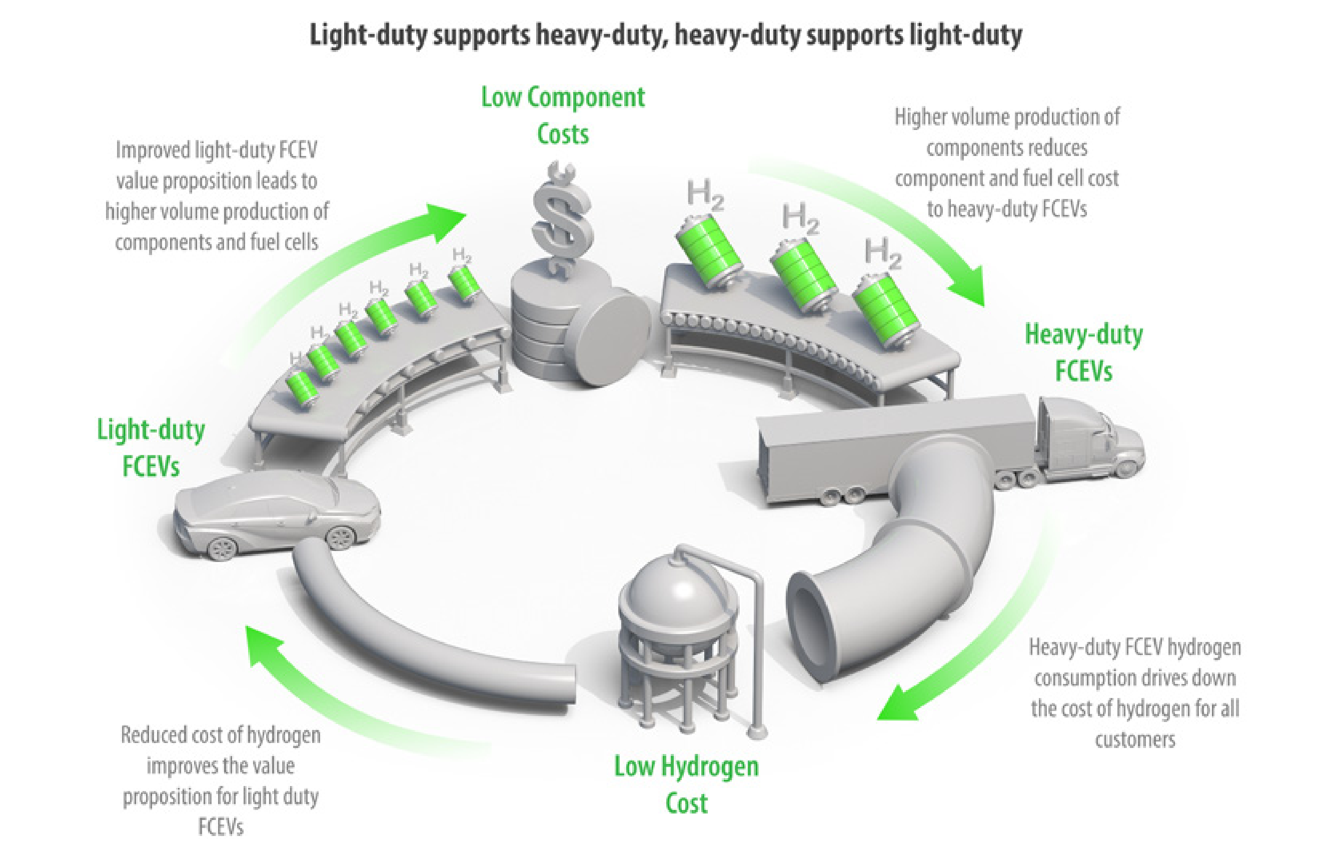
24 California Air Resources Board, 2019 Edition, California Greenhouse Gas Emission Inventory: 2000-2017. https://ww2.arb.ca.gov/ghg-inventory-data.

25 California Fuel Cell Partnership, Air Climate Energy Water Security: A guide to understanding the well-to-wheels impact of fuel cell electric vehicles (West Sacramento, CA: 2014), www.cafcp.org.

Realizing Greater Benefits with Medium—and Heavy-Duty

While much of this guidebook focuses on light-duty passenger cars, the medium- and heavy-duty fuel cell vehicle market is rapidly expanding. Buses are commercially available and announcements for new trucks are becoming more frequent. These vehicle classes offer significant opportunities to scale the market and address emissions issues in some of the most impacted areas in the state:

- **Synergies between the light-duty and medium/heavy-duty sectors:** The light-duty market advances the development of components, consistently improving hydrogen and fuel cell technologies that are applicable for larger applications while also decreasing costs. The medium- and heavy-duty sector represents much larger, more consistent, and more predictable per-vehicle hydrogen consumption rates. This offers the potential for large, rapid expansion of hydrogen demand. Consistent fuel throughput expectations and attractive station development economics fosters faster and greater hydrogen production investments to further support market expansion. Moreover, hydrogen and fuel cells offer distinct advantages as they scale in size; range and payload capacity can be added while adding relatively little weight to the vehicle. Together, these sector interactions create an opportunity for greatly increasing demand and reducing costs, enabling conditions to scale the market.
- **Co-Location Opportunities:** In addition to dedicated fueling networks for light- and heavy-duty fuel cell vehicles, the market can also support multi-use hydrogen stations with separate light-duty and heavy-duty dispensers that service both types of vehicles at the same station (in strategically selected locations), much like the conventional travel plazas throughout the country. While this type may be in the minority, these stations will support heavy-duty fleets and enable car owners to use these locations as their local fueling station or as a statewide connector and destination station for long-distance travel.



Source: National Renewable Energy Laboratory

- **Air Quality:** Medium- and heavy-duty fuel cell vehicles provide scalable solutions to replace the highest polluting vehicles in our state. In many cases, the areas of greatest freight and public transit activity overlap with the regions and communities most in need of air quality improvement. The majority of conventional heavy-duty fueling demand is along the state's freight corridors, including the Central Valley, where trucks bear the dominant load of moving cargo between the major metropolitan areas of California and neighboring states. Deploying clean, heavy-duty zero-emissions fuel cell vehicles and hydrogen stations along freight corridors will support goals outlined in *The California Sustainable Freight Action Plan* and capture significant air quality improvements in the areas that suffer most.

Fuel cell electric buses (FCEBs) have been in use in California since 2000[26] and are now widely available for commercial use. As of September 1, 2020, there are 48 FCEBs in operation in California — with more than 4,600,000 miles of operational service — and 7 more buses (as well as four shuttles) expected on California's roads soon.[27] FCEBs provide a one-to-one replacement to conventional bus fleets with excellent power, acceleration, and range performance in all climates—creating a rider experience that is smooth, quiet, and emission-free.

Recently, there has been an acceleration on the development of first-and-last-mile delivery trucks as well as drayage and long-haul trucks. As these platforms become more commercially available, infrastructure must be strategically located in order to capture the economic and environmental benefits of a zero-emission freight sector.

Many of the infrastructure needs and requirements are similar or the same as light-duty infrastructure. However, there are key differences that must be considered primarily in the development of some medium/heavy-duty specific codes and standards and fueling protocols, which are underway. Considerations must also be made for station location and size, which typically do not align with light-duty passenger fueling needs— just like conventional gasoline infrastructure and heavy-duty vehicle fueling.

Technology Advancement is Creating New Opportunities

As technology continues to advance, new lighter weight pressure tanks are being developed and approved for hydrogen ground storage in California.* Not only does this expand the supply chain, it also enables more compact station configurations, and increases station location options, by allowing placement of storage on top of the hydrogen compression equipment, the convenience store, or the gas island canopy — this is especially useful in densely populated urban areas where space is very limited.

**** For example, Hexagon's ultra-high pressure (15,000 psi) hydrogen storage tanks were approved for use in California by CalOSHA in September 2019. https://www.hexagongroup.com/***

Photo credit: Toyota Motor North America

26 Three transit agencies and one university currently operate FCEBs in California: Alameda-Contra Costa Transit District (AC Transit), SunLine Transit Agency, and Orange County Transportation Authority (OCTA), and University of California Irvine. https://cafcp.org/sites/default/files/2019-CaFCP-FCEB-Road-Map.pdf.

27 California Fuel Cell Partnership https://cafcp.org/by_the_numbers.

Hydrogen Stations

Typical Station Components

The functional components of hydrogen fueling stations are primarily the same, regardless of the dispensing capacity; be it 100 kg/day or 1000 kg/day. Stations will have different designs depending on if the hydrogen is produced on-site or delivered as gas or liquid, and where the station is located.[28] Hydrogen fueling stations may be integrated into an existing fueling station, such as a gasoline or compressed natural gas station, or constructed as a stand-alone project such as a forklift or heavy-duty truck fueling station. In either case, the intent is to provide FCEV drivers with a similar experience to gasoline or diesel with respect to fueling, dispenser operation, fill time, and payments. As such, the stations have the familiar look and feel of gasoline and diesel stations with similarly convenient locations to neighborhoods and main transportation corridors. Because the station is filling the vehicle with a compressed gas, the behind the wall equipment is different for hydrogen than for gasoline and diesel. Pressurized gas storage vessels, compression, cooling, and temperature control are all specific to the needs of hydrogen. Figure 2 provides schematics of gaseous and liquid hydrogen station layouts.

Every hydrogen station includes, at minimum:

1. **Hydrogen ground storage**
   All fueling stations store gaseous hydrogen. Variation comes in with the source of hydrogen which can be a gaseous or liquid supply. Larger stations, (1,000kg+/day dispensing) may store cryogenic liquid hydrogen (-423°F) in a single large double-walled vacuum-insulated tank to be gasified downstream. Other stations may get gas deliveries by swapping out tube trailers or refilled from a higher pressure tube trailer. All stations feature high pressure compressed gaseous hydrogen cylinders for direct dispensing to the vehicles. All hydrogen storage vessels are constructed from hydrogen-compatible materials. Storage systems contain redundant safeguards such as pressure and temperature relief and safe-venting.

2. **Compression**
   Hydrogen flows from the lower pressure storage to the high-pressure compressor(s), which reduces the volume and increases the pressure, preparing the hydrogen for fueling at either 350 bar (5,000 psi) or 700 bar (10,000 psi). Large capacity stations feature multiple compressors or cryo-pumps. Every station type also contains real-time monitoring controls and pressure relief systems.

3. **Chiller**
   After leaving the compressor and prior to dispensing, hydrogen typically enters a closed-loop cooling system to chill the molecules to a predetermined temperature appropriate to the fueling protocol used at the station. The chiller compensates for heat of expansion[29] and enables high-pressure, fast fills.

4. **Dispenser**
   Hydrogen dispensers are designed to appear very similar to typical gasoline, CNG, or diesel dispensers. To fuel, a driver places the dispenser nozzle onto the FCEV fuel receptacle, squeezes the trigger and locks the lever in the "fill" position — the dispenser manages the fill once the nozzle is properly connected. After filling, the driver removes the nozzle, places it back onto the dispenser, closes the fueling door, and drives away.

   Dispensing equipment can be placed under the existing fueling canopy or under a separate canopy, depending on the specific agreement between the existing fuel station owner/operator and the hydrogen station developer.

Delivered Hydrogen

Hydrogen fuel delivery methods (as opposed to being created on-site), depend on the physical state of the hydrogen- liquid or gas-and the station infrastructure. A hydrogen provider and station operator negotiate a contract and arrange a delivery schedule. The station layout/footprint is also optimized for ingress/egress of larger hydrogen delivery vehicles.

- **Gaseous hydrogen** is typically delivered using one of two approaches:

  1. High-pressure delivery is similar to today's gasoline deliveries in that hydrogen is transferred by hose from a specialized delivery trailer into on-site storage vessels. This process typically takes approximately 30 minutes, depending on-site logistics and quantity of hydrogen exchanged. Depending on volumes

28 Please refer to "H2FIRST Reference Station Design Task, Project Deliverable 2-2" (April 2015) for a detailed explanation of common hydrogen station designs, components and layouts: http://www.nrel.gov/docs/fy15osti/64107.pdf

29 This is due to the reverse Jewel-Thompson effect of hydrogen. It heats on expansion, thus the reason for pre-cooling (to avoid reaching the 85 degree Celsius threshold of the vehicle cylinders).

and station need, a high-pressure delivery truck can fill or top-off multiple stations.

2. Swapping involves changing out transportable bulk hydrogen storage when the hydrogen is depleted. For this type of delivery system, compressed gas storage tube trailers or Multi-Element Gas Connectors (MEGC) are used. The gas delivery driver opens the gate at the storage area, disconnects and removes the depleted trailer or MEGC, then installs a full trailer or MEGC and connects it to the hydrogen station. The empty bulk hydrogen container is then taken away and refilled at a central facility. Swapping trailers can take between 10 minutes and an hour, depending on site logistics. Some of the original stations in the network use trailer swapping, but it is uncommon in newer stations and those under development.

New Trends in Hydrogen Stations: Larger Capacity and Liquid

The early market hydrogen stations were typically small (less than 200 kg/day) with gaseous delivery. Nearly as soon as they these stations were built, hindsight taught us they should have been larger.

Incorporating those lessons learned, stations under development and opening today are substantially larger (~400-1200 kg/day) and increasingly supplied by delivered liquid hydrogen. These changes are enabling stations to serve more cars with fewer hydrogen deliveries at a substantially lower cost — all of which translates to an improved driver experience.

Initial draft findings of research being performed by CARB indicate that large stations, between 600-2000 kg/day, show the most promise for self-sufficiency and generating attractive returns, whereas smaller stations (below ~400 kgs/day) have a difficult time turning a profit, especially without State funding (CapEx and OpEx cost reductions may help enable a small rate of return). However, large stations may not be appropriate for all locations, such as in remote areas, and may add unnecessary costs if overbuilt.

As station developers plan their fueling networks, they consider individual station profit potential as well as their overall network potential. Stations in busy, urban centers with high demand can help minimize thin or breakeven profits of smaller or low-utilization stations.

The average dispensable capacity of the first 25-30 gaseous delivered stations designed for passenger vehicles was just under 200kg per day, which is enough to fill approximately 50 light duty vehicles per day.[30] Newer light-duty stations being built and opened today average 400-1200 kg/day or more and feature multiple fueling positions and dispensers. Depending on fleet size, fuel cell bus and heavy-duty truck stations will be designed to dispense in excess of 1,000 kg/day using multiple dispensers as well.

- **Liquid hydrogen** is delivered by a tanker truck and is a standard industrial gas procedure. The driver connects the hose from the truck to a valve on the storage tank and offloads liquid hydrogen. Because liquid hydrogen is at a cryogenic temperature, a vapor cloud forms around the transfer point. Venting through a vent stack either off the truck or the station is also a standard procedure. Filling the storage tank can take between 30 minutes and more than an hour, depending on the size and status of the tank. Today's light-duty, liquid hydrogen stations typically can dispense between about 400-1200 kg per day (about 100-300 light duty vehicles per day).
- **Pipeline hydrogen** may be available in some situations. If available, a station can draw from a nearby hydrogen pipeline, then purify, compress, and dispense the hydrogen on-site.[31] The Torrance Pipeline Station (2051 West 190th Street, Torrance, CA 90504) connects to a hydrogen pipeline that carries hydrogen from the neighboring production plant to oil refineries for use in the refining process. Pipeline stations are expected to be economically attractive at high throughput levels and could play a significant role in future stations.

On-site Generated Hydrogen

There are multiple technologies that can produce hydrogen on-site. If fuel is created on-site, all the necessary production equipment is located on the same property or nearby. Currently, the primary technologies for on-site hydrogen production are:

- **Steam reformers** produce hydrogen from natural gas or biogas and can be sized according to expected station throughput. The reformer may be

30 Assumes approximately 4 kg per fill. This is also the full fill amount used in the Hydrogen Station Capacity Evaluation Tool (HySCapE) calculations.

31 Hydrogen purity is crucial, as fuel cells are generally sensitive to contamination. Most pipeline hydrogen is used for oil refining, which does not require the same purity as automotive fuel cells.

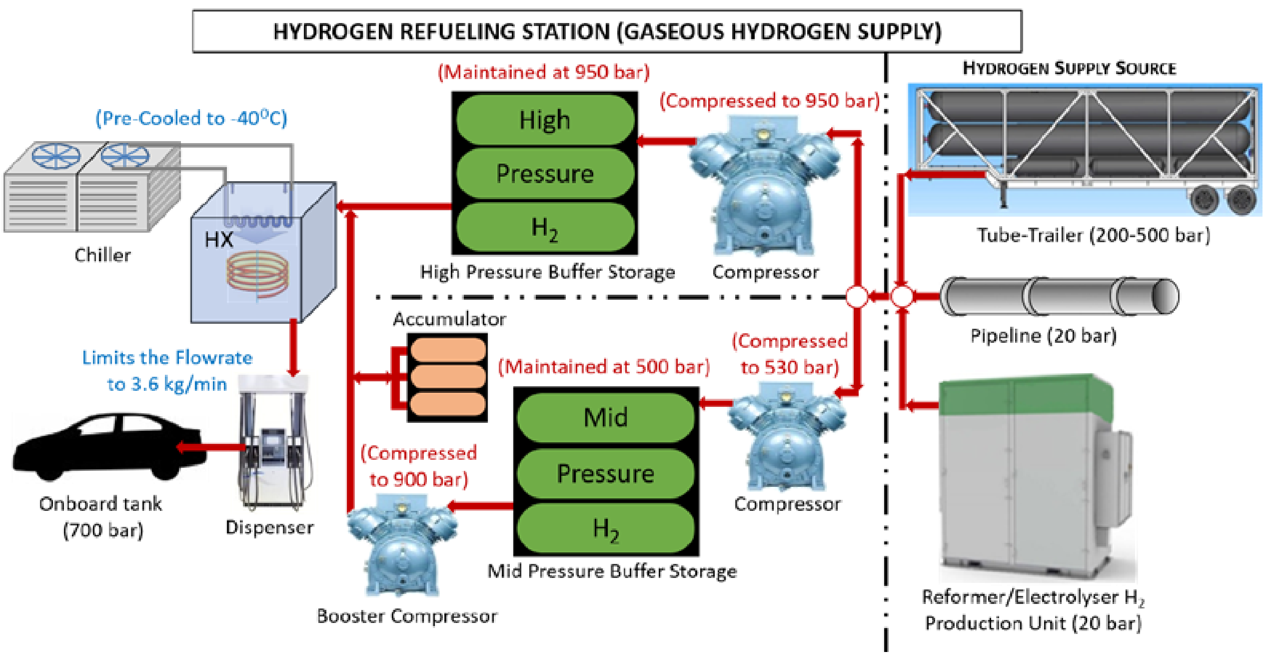
housed in a small building (or shipping container) or may not be enclosed at all, depending on the layout of the station. Additional equipment to compress and store the hydrogen would be located nearby, often on the same equipment pad, and certainly within the same equipment enclosure.

- **Electrolyzers** use electricity to produce gaseous hydrogen by splitting water molecules into their component elements—hydrogen and oxygen.[32] One or more packaged electrolyzer systems[33] using small quantities of feed water can be powered by several electricity supply arrangements: direct connection to the electrical grid, often leveraging renewable power purchase agreements, and /or direct connection to adjacent solar panels or wind generators.[34]

- **Co-generation by high temperature fuel cell systems** generate heat and electricity from natural gas or biogas. Tri-generation systems add hydrogen as a production product.[35, 36] These systems can generate the electricity to power the station or adjacent buildings, heat to support any number of industrial processes, and hydrogen for fueling.

Hydrogen ready for fueling, in its compressed gas form, is currently stored above ground in approved steel or composite pressure vessels, manufactured in accordance with American Society of Mechanical Engineers (ASME) standards.[37, 38] In the future, underground storage of hydrogen may become an economically viable option.

Figure 2: Gaseous and Liquid Hydrogen Supply Station Configurations



Source: Argonne National Laboratory

32 https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

33 Electrolyzing 9 liters (2.4 gallons) of water will yield 1 kilogram of hydrogen. By comparison it takes approximately 3-7 gallons of water to produce one gallon of gasoline (M. Wu et al., *Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline,* Chicago, IL: Energy Systems Division, Argonne National Laboratory, 2009).

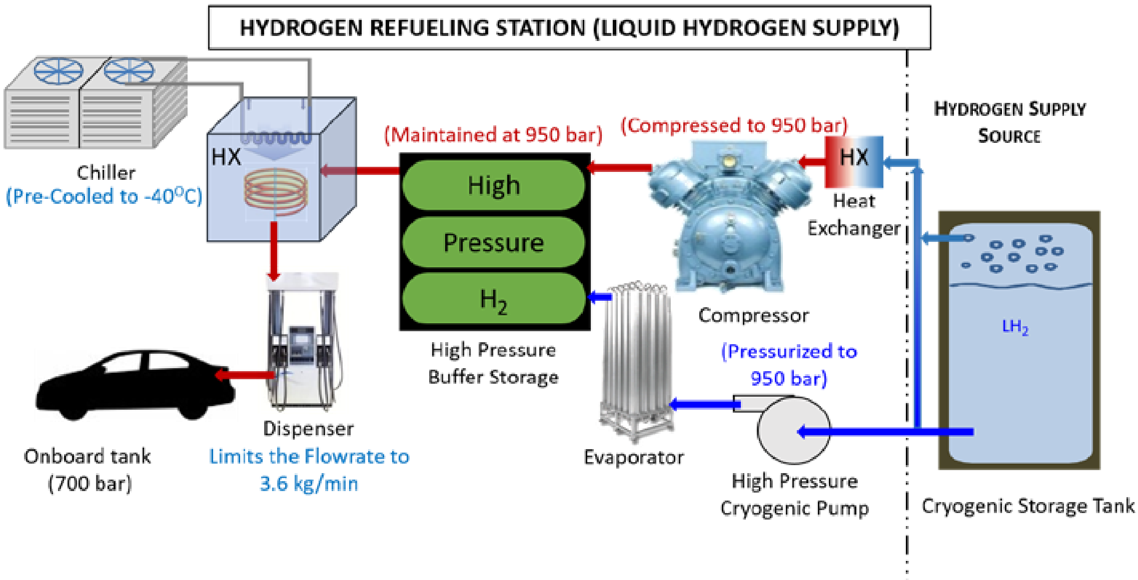
34 https://nelhydrogen.com/market/power-to-gas/.

35 University of California Irvine, "Tri-Generation from Biogas," Advanced Power and Energy Program, http://www.apep.uci.edu/3/research/partnership_TRI-GEN.aspx.

36 In 2011, the world's first tri-generation unit was demonstrated at the Orange County Sanitation District in Fountain Valley. In 2018, Toyota and Shell (along with an $8 million state grant) kicked off a tri-generation facility project at the Port of Long Beach. This facility is expected to come online in 2020 and will use 100% renewable biogas. It will supply all fuel cell vehicles moving through the port, including deliveries of Toyota's Mirai sedan and its Project Portal heavy duty class 8 trucks.

37 "Pressure Vessels," American Society of Mechanical Engineers, last modified 2013, https://www.asme.org/shop/standards/new-releases/boiler-pressure-vessel-code-2013/pressure-vessels.

38 Underground storage could be proposed and approved in California, neither of which has occurred at the time of publication.



Source: Argonne National Laboratory

How to Fuel

Hydrogen dispensers are designed as a self-service operation. Vehicle operators (or vehicle owners) may receive a fueling orientation from their dealership, if needed, and then are ready to fill at a hydrogen station. Filling with hydrogen is fast, easy, and safe. Throughout the fueling process, the system performs leak checks to ensure a secure seal as prescribed by the fire code. A full tank of hydrogen for a passenger vehicle (3 to 6 kilograms) typically fills in 3-5 minutes. Fuel cell buses have larger tanks—40 kg or more—and fill in 6 to 20 minutes, similar to filling a diesel bus.

A hydrogen station has several different safety systems that work together to keep vehicle operators safe while fueling. If flame detectors or gas sensors detect a fire or leak, redundant safety systems automatically stop hydrogen flow, seal storage tanks, and/ or, safely vent the hydrogen if required. Strategically placed emergency stops are designed to automatically shut down hydrogen equipment and isolate the gas supply, if activated. Separation walls and equipment setbacks are designed into the site plan to maximize safety. In addition to physical safety systems, hydrogen fueling stations also have logic systems that use sensors to detect illogical patterns or flows. If a sensor detects an off-normal condition the system will shut down if necessary.

Hydrogen is dispensed as a gaseous fuel to fill at either 35 MPa (5,000psi) or 70 MPa (10,000psi) pressures (referred to as H35 or H70, respectively).[39] A hydrogen dispenser looks similar to a retail gasoline dispenser and has dedicated hoses and nozzles—much like gasoline and diesel—for each pressure (H35 and H70). The newer stations (beginning around 2019) have two H70 hoses and nozzles available, with or without a H35 hose. Future stations are expected to be even larger with upward of four or more dedicated hoses and nozzles. Vehicle operators cannot attach a higher-pressure nozzle to a lower pressure vehicle receptacle, in the same way that a diesel nozzle will not fit into a gasoline receptacle.

Like gasoline dispensers, hydrogen dispensers can have two sides, each with identical user interfaces.[40] The dispensers are designed to accept credit cards and display sales information in accordance with state regulatory weights and measures requirements.[41] The quantity of fuel dispensed (units of measurement) is displayed in kilograms (kg).[42]

When a vehicle operator activates the dispenser, hydrogen flows from the storage tanks to the dispenser and through the nozzle into the vehicle

39 5,076 PSI = 35 MPa = 350 bar, 10,153 PSI = 70 MPa = 700 bar

40 All pre-2019 are one-sided. While many newer hydrogen stations remain one-sided, some station developers are beginning to install two-sided dispensers.

41 California Code of Regulations, Title 4. Business Regulations, Division 9. Chapter 1. Article 1 Sections 4001. Exceptions and 4002. Additional Requirements, Subsection 4002.9. http://www.cdfa.ca.gov/dms/regulations.html.

42 A kg of hydrogen carries approximately the same chemical energy content as a gallon of gasoline.

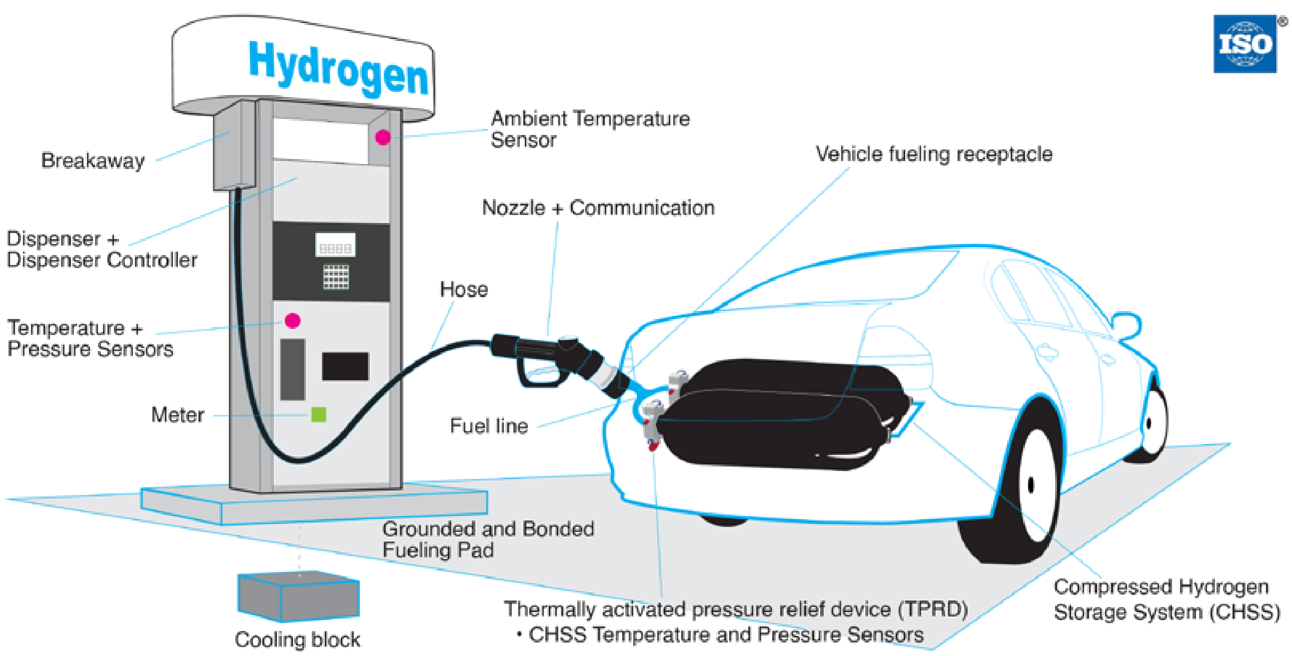
in a closed system. If filling with H70 (70 MPa), the hydrogen either passes through a booster compressor or is dispensed from high pressure buffer storage tanks before passing through a gas chiller and entering the dispenser. The hydrogen dispenser conducts brief pressure safety checks of the fuel hose, breakaway, nozzle, and FCEV receptacle before and during the fill. For example, if the nozzle is not correctly attached to the FCEV receptacle and fails the initial pressure test, fueling will not start.

During the fill, the dispenser conducts one or two pressure integrity checks where it momentarily stops the flow of hydrogen.[43] These pauses will last for at least five seconds, after which the fill resumes. The H70 dispenser communicates with the FCEV using infrared communication built in to the dispenser nozzle and vehicle receptacle. FCEV hydrogen storage pressure and temperature data are used by the dispenser controller to optimize the fill for both fueling time and amount of fuel dispensed.[44]

Refueling times are dependent on the ambient temperature and the pre-cooling ability of the station. The optimal station is an H70, T-40 meaning that it can pre-cool the hydrogen to no colder than -40°C resulting in refueling times of approximately 3 to 5 minutes under most ambient temperature conditions.[45]

Selling Hydrogen in California

California has taken important steps to enable the retail sale of hydrogen. The California Department of Food and Agriculture's Division of Measurement Standards (DMS) adopted market enabling hydrogen gas measuring devices regulations on June 16, 2014, and updates to the regulation were approved and enrolled on January 23, 2020. The updated regulation was made effective upon enrollment.[46] These regulations established realistic, near-, mid-, and long-term targets for measuring the mass of hydrogen delivered, given the current and expected



43 NFPA 2: Hydrogen Technologies Code, Edition 2020.

44 SAE J2799: Hydrogen Surface Vehicle to Station Communications Hardware and Software, Edition 2014-09.

45 SAE J2601: Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles, Edition 2016-12.

46 The 2020 update includes all tolerances (2.0, 3.0, 5.0, 7.0, and 10.0) without sunsets, and the 7.0 harmonizes with the NIST HB 44. California Code of Regulations, Title 4. Business Regulations, Division 9. Chapter 1. Article 1 Sections 4001. Exceptions and 4002. Additional Requirements, Subsection 4002.9. http://www.cdfa.ca.gov/dms/regulations.html.

status of hydrogen measurement technology. Once a dispenser passes DMS inspection and is type certified, hydrogen can legally be sold by the kilogram unit, through that dispenser (and dispensers that are the same model) to consumers. When the equipment is placed at the site, the device must pass field testing by the county sealer of weights and measures. Note that in practice, the tests are typically done by a registered service agency and witnessed by county officials.[47]

Hydrogen prices are determined by the businesses retailing the fuel. In the early phases of the market, most industry experts expect costs to the consumer to be competitive with gasoline on a per mile basis. As with all fuels, hydrogen prices are associated with the quantity sold. Over time, as demand for hydrogen fuel increases, the price of hydrogen is expected to decline to below parity with gasoline.[48, 49, 50]

There are two notable changes in the way hydrogen fuel is sold to the public compared to gasoline. First, all hydrogen dispensers are marked in mass units, e.g., kilograms instead of gallons. Second, DMS endorses the U.S. national method of sale regulation for hydrogen in the National Institute of Standards and Technology Handbook 130, which stipulates that street sign pricing be shown in terms of whole cents (e.g., $9.50 per kg, not $9.499 per kg).[51]

Safety is Required for State-Funding Eligibility

The majority of retail hydrogen stations open and in development today are substantially supported by state funding for capital expenses, and operations and maintenance costs (GFO-19-602 does not provide O&M funding). CEC's Clean Transportation Program grant funds are greatly oversubscribed and have a rigorous application and scoring process whereby only the highest of the top-ranking applications will receive awards.

By the time a station gets to the local jurisdiction to begin the permitting process, it has already undergone significant scrutiny to ensure state-of-the-art stations are built in the right locations, with robust safety and management plans, and by developers with demonstrated experience in building and operating hydrogen fueling stations. This enables AHJs to focus on their city's specific development requirements once the project begins local level permitting and development processes.

47 https://www.cdfa.ca.gov/dms/programs/rsa/rsa.html.

48 "Fuel Cell Technologies Office: Accomplishments and Progress," Office of Energy Efficiency and Renewable Energy, http://energy.gov/eere/fuelcells/accomplishments-and-progress.

49 https://cafcp.org/sites/default/files/path-toward-competitive-refueling-infrastructure-for-hydrogen-brochure.pdf.

50 Reed, Jeffrey, Emily Dailey, Brendan Shaffer, Blake Lane, Robert Flores, Amber Fong, G. Scott Samuelsen. 2020. Roadmap for the Deployment and Buildout of Renewable Hydrogen Production Plants in California. CEC. Publication Number: CEC-600-2020-002. https://efiling.energy.ca.gov/GetDocument.aspx?tn=233292&DocumentContentId=65781

51 "NIST Handbook 130," Physical Management Laboratory, 2019 (current edition). https://www.nist.gov/pml/weights-and-measures/publications/nist-handbooks/other-nist-handbooks/other-nist-handbooks-1

Photo credit: Nikola Motor Company

Photo credit: Air Liquide

Photo credit (top & bottom): Iwatani Corporation of America

PART 03:

Station Development

Developing a hydrogen fueling station can be time intensive, especially for the first station in a community. Permitting requirements will differ from station to station depending on the site characteristics, station type, and the local jurisdiction's unique processes. In California, local governments have the ultimate authority to approve (or deny) any project. A design approved in one community does not guarantee approval of the same design in another community (although it often helps). This section of the Guidebook is designed to minimize the research required to permit a station from both the authorities having jurisdiction (AHJs) or reviewing entities (often a city or county) and station developer perspective, offering insight and tools from past experiences and general recommendations for streamlining the permitting process.[52]

A major piece of the station permitting process is dedicated to ensuring stations are built to meet current codes and standards. The following text provides references to California codes and guidance, which can be amended by local jurisdictions in certain circumstances. The California Building Code gives authority to each AHJ's Chief Building Official to be the final authority on the code interpretation in their jurisdiction. Previous experiences have shown that code requests can vary widely with different interpretations from one AHJ to another.

Given this reality, the California Building Standards Code, Title 24, can generally be used to plan a permit strategy that is applicable statewide. However, as discussed in the Pre-Application Outreach section below, it is important for station developers to meet early in the process with local authorities to ensure projects are designed in compliance with local interpretations of codes and standards.

Before proceeding through the detailed information in this section, the reader should be aware that there are numerous opportunities to flood or overwhelm the hydrogen station development process with information. A complex permit application may address any questions that could arise, but also greatly increases the amount of time required to review and approve a package. Each jurisdiction is different, but as a rule of thumb, the best permit applications are concise but complete, including enough information to make each department's review as simple and straightforward as possible.

State Code Requirements

Code requirements are developed and implemented to provide for the safety of people and property, as well as minimize the environmental impacts associated with project development. The California Building Standards Code provides uniform requirements for buildings throughout the state. These requirements are contained in Title 24 of the California Code of Regulations (CCR). The CCR is divided into 28 separate titles based on subject matter or state agency authority. Title 24 is reserved for state regulations that govern the design and construction of buildings, associated facilities, and equipment. These regulations are also known as the "State Building Standards."

52 Note that a "station developer" might be the same as the station owner or station operator. In other cases, each of these may be different. In this Guidebook, we will use the term "station developer" to represent all of these variations.

Title 24 applies to all building occupancies and related features and equipment throughout the state. It contains requirements for a building's structural, mechanical, electrical, and plumbing systems, in addition to measures for energy conservation, sustainable construction, maintenance, fire and life safety, and accessibility. Specific areas within Title 24 directly relate to hydrogen stations, such as the California Fire Code, California Electrical Code, and California Building Code.

State regulations should not be confused with state laws enacted through the legislative process. State regulations are adopted by state agencies to implement, clarify, and specify requirements of state law. The California Building Standards Commission (CBSC) and other state agencies (both adopting and proposing) review the codes and update Title 24 as appropriate. Title 24 is updated every three years or, if needed, during an intervening code adoption cycle. The latest edition of the California Building Code was published July 1, 2019, with an effective date of January 1, 2020.

Several portions of Title 24 govern installation of a hydrogen station:

- California Building Code, Part 2, Title 24
- California Electrical Code, Part 3, Title 24
- California Energy Code, Part 6, Title 24
- California Fire Code, Part 9, Title 24

The intent of this guidebook is to provide consistent application of these Title 24 requirements throughout the state, as they relate to hydrogen stations. This guidebook is not intended to create, explicitly or implicitly, any new requirements. Updated information regarding new code requirements, as well as the code updating process, is available on the CBSC website.

Local Government Modifications

Cities and counties in California are required by state law to enforce Title 24 building standards. However, cities and counties can, and regularly do, adopt local laws (also called "ordinances") to modify these state building standards to address local climatic, geological, or topographical conditions, and generally are more restrictive. This means that a city or county may have local ordinances that modify or add to the provisions of Title 24 for any section that impacts hydrogen stations. The California Building Code (Sections 1.1.8 and 1.1.8.1) outlines the specific findings that a city or county must make for each amendment, addition, or deletion to the state building codes and be expressly marked and identified to which each finding refers.[53]

Cities, counties, and local fire departments file these local amendments to the state building code with the CBSC. Findings that are prepared by fire protection districts must be ratified by the local government and are then filed with the California Department of Housing and Community Development (refer to Health and Safety Code Sections 13869.7, 18941.5 and 17958.7).[54]

Additionally, changes made by a city or county to the California Energy Code, Part 6, Title 24 relevant to energy conservation or energy insulation must be submitted to the California Energy Commission for approval pursuant to the Public Resources Code, Section 25402.1.[55]

Many communities are already familiar with hydrogen and relevant safety codes and standards, through traditional industrial applications, such as food processing, petroleum refining, and the semiconductor industry. Hydrogen is also increasingly used in fuel cell powered forklifts and cell-tower backup applications. Moreover, several cities in the state have permitted or are in the process of permitting a hydrogen station, leading to a growing pool of planners experienced with hydrogen fueling infrastructure, and many of whom are happy to share their knowledge and experiences with other jurisdictions. Additionally, a wide variety of other resources are available to support AHJs as they prepare to apply codes and standards to hydrogen fueling stations.[56]

53 California Building Code, California Code of Regulations, Title 24, Part 2, Volumes 1 and 2, 2019. https://www.dgs.ca.gov/BSC/Codes

54 California Health and Safety Code. http://www.leginfo.ca.gov/.html/hsc_table_of_contents.html.

55 California Public Resources Code. http://www.leginfo.ca.gov/.html/prc_table_of_contents.html.

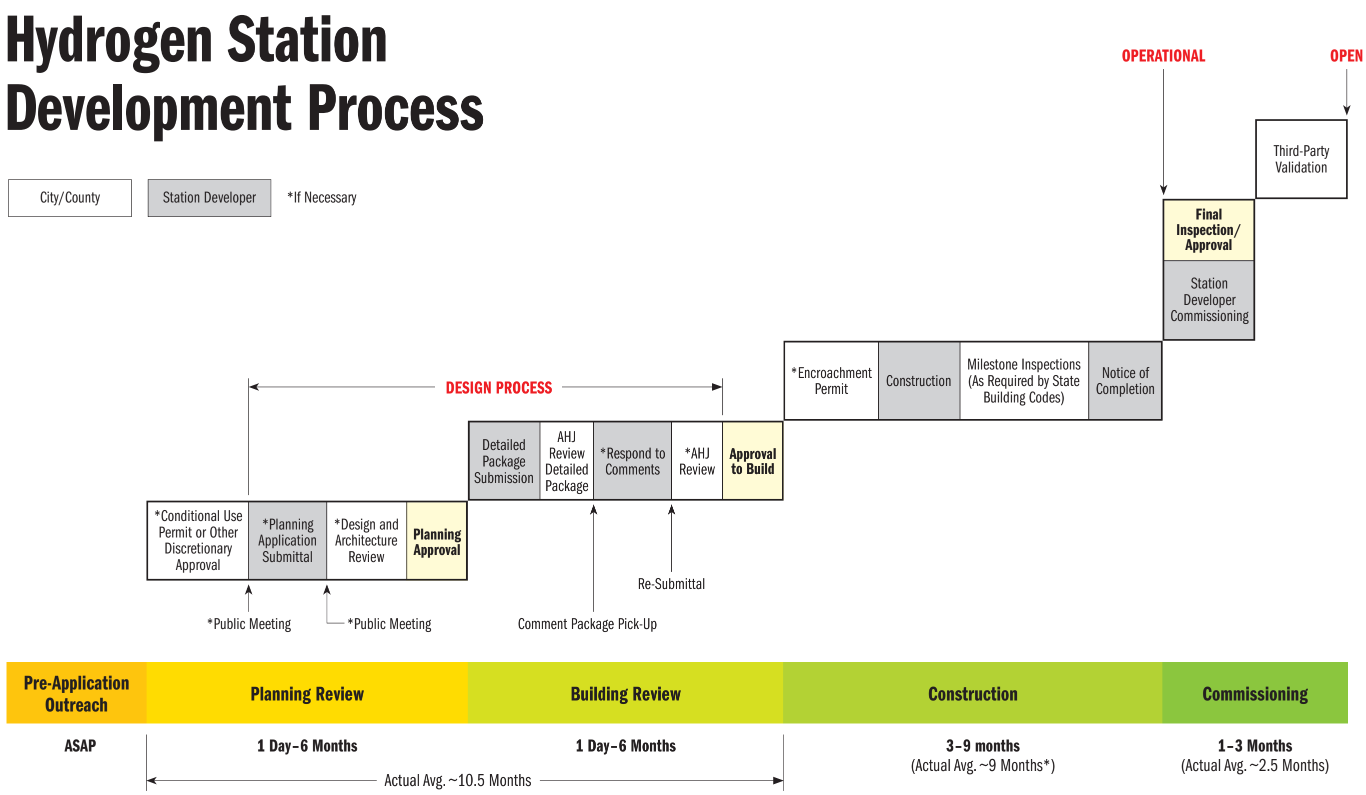
56 In addition to station developers themselves, CaFCP is positioned to connect AHJs to a variety of public (federal, state and local) and private hydrogen experts. Please refer to www.cafcp.org or send inquiries to info@cafcp.org.

The overall local permitting process and code review can be divided into five main phases, each of which are described in greater detail in this section:

1. **Pre-Application Outreach**
2. **Planning Review**
3. **Building Review**
4. **Construction**
5. **Commissioning**

It is important to remember that the design and permitting processes are interrelated, as multiple permits and approvals may be required in different stages of the process. The "Hydrogen Station Development Process" diagram (Figure 3) outlines the processes involved and includes a range of estimated timelines. Overall, development timeframes have decreased since the first retail stations in the state were built, from more than four years to complete to just over two years.[57] This trend should continue as local authorities become increasingly familiar with hydrogen station permitting, more entities enter the supply chain, and economies of scale are achieved.

Figure 3: Hydrogen Station Development Process



* Average of actual time across all CEC awarded solicitations: PON-09-608, PON-12-606, PON-13-607, GFO-15-605.
While development timelines have reduced overtime, further streamlining to accelerate station development remains high priority.

57 Change in development time between PON-09-608 and GFO-15-605. Source: Baronas, Jean, Gerhard Achtelik, et al. 2019. Joint Agency Staff Report on Assembly Bill 8: 2019 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California. California Energy Commission and California Air Resources Board. Publication Number: CEC-600-2019-039. https://ww2.energy.ca.gov/2019publications/CEC-600-2019-039/CEC-600-2019-039.pdf.

Phase 1: Pre-Application Outreach

A city or county planning agency is often the most effective place to first engage a local authority. Ultimately, the planning agency will ensure a project meets zoning requirements, complies with the California Environmental Quality Act (CEQA), and fits within the jurisdiction's General Plan. This includes considering impacts to parking, aesthetics, on-site circulation, and traffic flow. Planning departments will connect applicants with other relevant departments as appropriate. During this phase, community outreach is also important. This will be more crucial in some areas than others, and it is important for station developers to understand community dynamics when developing an outreach plan. Planning departments can often provide insight into the community's willingness for or resistance to development and other potential concerns specific to the communities they represent.

Above all else, two of the most important steps in the hydrogen station development process occur during the Pre-Application Outreach phase, before a permit application is submitted:

1. **Secure site control.** Seamless communication between the station developer, site owner, and site operator is vital in securing the station site.[58] Site owners and operators must be fully committed to the proposed station arrangement and remain part of the process to quickly enable any necessary changes along the way.
2. **Establish communication and a permitting pathway.** Most communities welcome pre-application meetings with the applicant, key AHJ staff, and the site owner. These meetings can help the applicant ensure their application provides all the information a jurisdiction needs to approve the station, saving time and resources for both the developer and AHJ staff.

Pre-application meetings can uncover potential issues upfront and may be a required criterion for state grant funding. They provide an excellent opportunity to bring AHJs up to speed with the broad effort to deploy hydrogen-powered FCEVs. These early meetings can open a dialogue about items that could delay the permitting process or lead to the denial of an application, such as:

- Problems with the proposed site—parking, circulation, right-of-way, or clearances;
- Specific city requirements the project must meet to achieve approval like aesthetics or local ordinances, and ways to streamline the approval process;
- Issues with similar projects in the jurisdiction;
- Neighborhood concerns.

The pre-application meeting can take place any time before the permit package is submitted, but earlier in the process is typically better, even if a very rough general arrangement document or aerial photo of the site are the only design documents available. During the pre-application meeting, the applicant should layout the plan, describe the proposed path forward, learn what permits or approvals will be required to complete the project, and gain a clear understanding of the level of detail each department would like to see in the permit application submittal package.[59]

During Pre-Application Outreach, developers and AHJs can leverage a variety of resources to help with community outreach and education, including (but not limited to) vehicle manufacturers, the California Fuel Cell Partnership, the California Energy Commission, the California Air Resources Board, the Governor's Office of Business and Economic Development, and local Air Pollution Control or Air Quality Management Districts. Contact information for these resources can be found in "Additional Resources" section, page 57.

Phase 2: Planning Review

Planning Review is a required part of the permitting process that ensures that a proposed station fits within a community's zoning codes, General Plan and overall aesthetics. Experience has shown that gaining planning approval can be the most time-consuming portion of the permitting process, underscoring the importance of early engagement with the planning department.

Depending on the community and proposed project site, the planning process can be as simple as checking a box if the chosen location is zoned to accept more fueling, or as complex as CEQA analysis

58 In some cases, the site owner and site operator are the same entity, in other cases they are separate. Additionally, there may be other parties involved, such as a property management company, leasing agency, trustee, or other, that can delay or inhibit the process. It is important for station developers to understand the ownership structure of the property and to engage all parties with a stake in decision-making around the use of the site.

59 Please refer to the Pre-Application Checklist, located in the "Additional Resources" section, page 45, for a starter list of questions that should be asked/answered prior to application submittal.

coupled with multiple architectural review and planning commission hearings. If an item needs to be heard by any public body, agenda requests should be made as soon as possible, as some communities may have protracted processes and/or a back-log of actions that require a public meeting.

The involvement of the city or county planning agency will vary by jurisdiction and station location. In the simplest case, a proposed station will fit within the parameters designated by a jurisdiction's zoning code and General Plan (a local jurisdiction's plan for long-term development), and not displace any parking spaces, or trigger the need to upgrade facilities to comply with the Americans with Disabilities Act (ADA), for example. However, many sites are geographically constrained and require special consideration from the local planning agency.

What to Prepare for: Zoning, Architectural Review, CEQA, Fire, and Utility Connection

The Planning Review process typically does not require detailed engineering drawings. However, any required general arrangement or architectural drawings should take code compliance into account.[60] Interpretation of codes can vary by jurisdiction, underscoring the importance of early fire and building department engagement. For example, if a fire wall will be required as a mitigation measure, it needs to be included for Planning Review to avoid needing to backtrack through the process.

1. Zoning

An AHJ cannot permit a hydrogen fueling station without proper zoning approval. In California, local jurisdictions are responsible for writing or adopting their own zoning ordinances. As such, the rules that govern the siting and construction of hydrogen stations may differ substantially from one jurisdiction to another.[61] For example, jurisdictions may have specific language that covers hydrogen stations in an industrial zone, but not in a commercial zone. Others may simply group hydrogen in with all motor vehicle fuels and, therefore, may allow it in commercial zones. Some jurisdictions may require design reviews or specific discretionary approvals to proceed, while in others, hydrogen dispensers may be installed in existing fueling stations by right or entitlement.

Applicants should refer to a community's General Plan to help make an initial zoning compatibility assessment. In some cases, a location may be covered by a Specific Plan, which provides a more nuanced and detailed land-use description.

Typical Planning Approval Requirements

While each jurisdiction varies slightly, hydrogen stations typically need to satisfy local requirements in each of these four areas to obtain planning approval: Zoning, CEQA, Architectural Review, and an initial Fire Department Review. In addition, utility connection plans should be arranged as early as possible to ensure they do not impact planning approval.

Plan for Noise

Hydrogen stations can make relatively loud and unfamiliar sounds (day and night). Planning to address noise upfront with mitigation practices can save time and money, and help reduce potential for noise complaints.

Taking a baseline sound reading can be a helpful data point if issues do arise. Station developers should also clearly understand local requirements and incorporate them into the station design. Working with a sound consultant may add costs but could be substantially less than the cost of mitigation.

Conditional Use Permits and Variances

In the simplest case, the selected project site will already be zoned for vehicle fueling and allowed to add additional fuel "by right," which is one reason most hydrogen stations are proposed at existing gasoline facilities. However, in many cases the station developer or property owner will need to obtain a Conditional Use Permit (CUP) or variance before pursuing approval to build. A CUP defines how a site can be used (e.g., hours of operation, delivery timing,

60 In many cases, planning departments will ask for elevation drawings to understand visual impacts of the station.

61 The National Association of Convenience Stores (NACS) created a guide to help convenience and fueling retailers navigate local zoning processes: https://www.convenience.org/Topics/CommunityToolkit/Site-Approval-Toolkit.pdf

etc.).[62] A variance is a request for a deviation from local zoning code (e.g., eliminating parking spots, building height).

Consideration of a CUP or variance is a discretionary act of the AHJ, and if approved, is generally subject to pertinent conditions of approval and mitigation requirements. CUPs and variances typically involve a public meeting by a board of zoning, the planning commission, or a zoning administrator.

Rezoning

In some cases, a site may need to be re-zoned by the relevant city or county. This process requires public meetings by the local planning commission, city council or county board of supervisors. The council or board is not obligated to approve requests for rezoning and, except in charter cities, must deny such requests when the proposed zone conflicts with the General Plan.

2. Architectural Review

Some communities have design review bodies chartered to review and approve the aesthetics of development plans. These committees play a crucial role in project approval, and approval often needs to occur prior to a project being heard by a planning commission.

Generally, an architectural or design review board works to ensure that projects fit the local aesthetic. They may ask for unique roofing, landscaping, or painting to help a station blend in or make a visual statement. These requests can lead to negotiations between the board and project proponents—leading to a mutually agreeable solution.

At times, aesthetic driven requests conflict with codes and standards—in this case, it often falls to the project proponent to articulate why suggested changes cannot be implemented. Local building officials can often also help identify and support a path forward.

3. CEQA

The California Environmental Quality Act (CEQA, Res. Code §21000 et seq.) was promulgated in 1970 to notify the decision makers and public of any potential adverse environmental impacts of projects. The act is implemented through the CEQA Guidelines which are regulations that explain and interpret the law. They are found in CCR Title 14 Chapter 3. CEQA projects are generally construction projects, but also include programmatic or policy changes that could result in an environmental impact.

CEQA applies to projects undertaken by state and local agencies or private entities which require some discretionary approval. For example, adding a piece of equipment that requires a permit from a local Air Pollution Control District would be considered a "project" under CEQA.

In many jurisdictions, installing a hydrogen station fits the definition of a project under CEQA. However, some jurisdictions consider the addition of hydrogen to an existing gasoline station a ministerial, non-discretionary, action that does not trigger an extensive CEQA review.

Several local governments that have determined a project fits under CEQA have filed a categorical exemption or prepared a negative declaration. Most open retail hydrogen stations on existing fueling sites have used categorical exemptions. It is important to note that the use of hydrogen does not trigger any special CEQA considerations, and that these are common exemptions, based on the scope of the project.

Commonly filed exemptions for hydrogen stations on existing fueling sites are:

- 15301 (Class 1) for Existing Facilities
- 15303 (Class 3) for Small Structures
- 15304 (Class 4) for Minor Alterations to Land

In the infrequent case that a CEQA review is required, it is important to identify the need as soon as possible, as CEQA analyses can be time consuming. Interested agencies can check CEQA Net for references to other hydrogen fueling station CEQA determinations.[63, 64] CEQA Net lists the CEQA categorical exemptions filed by the CEC to encumber funds for hydrogen fueling stations. Local jurisdictions have the discretion to defer to the CEC's determination or conduct their own CEQA analysis.

62 Many gas stations operate with an existing CUP. In this case, a proposed hydrogen station would trigger the need to modify the existing CUP.

63 http://www.ceqanet.ca.gov/. The database is incomplete, as local governments are not required to submit CEQA documentation. However, the State of California is actively collecting CEQA determinations, and will update the database as possible.

64 The California Fuel Cell Partnership maintains updated station maps on their website. This is a reliable source for communities looking for jurisdictions that have approved, or are reviewing, hydrogen station proposals. http://cafcp.org/stationmap.

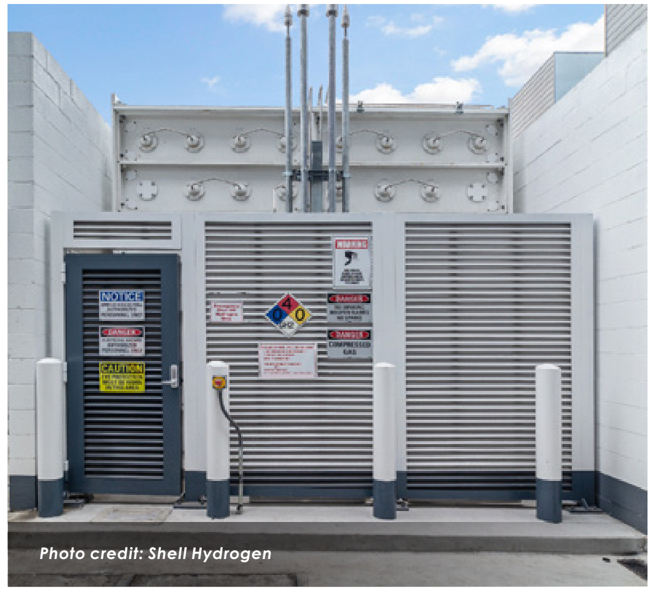


Photo credit: Shell Hydrogen

4. Fire Department Approval

The timing of a fire department's review of a project varies by jurisdiction and project. Some fire departments will engage early in the process (in parallel with planning review), others will begin their review once a project has Planning Approval. As with all permitting, early engagement is critical, especially if the project is likely to require mitigation measures, as these measures (e.g., a fire wall) can impact the Planning Review.

Hydrogen station designs need to comply with the California Building Code (Part 2) and the California Fire Code (Part 9) of the California Building Standards Code (Title 24), the California Code of Regulations and/or the local amendment of the California Building and Fire Code. The code ensures proper setback distances, equipment and mitigation measures for fueling, infrastructure and storage.

Any hydrogen station design must demonstrate code and standards compliance through plans, notes, and calculations throughout the Planning Approval phase. These notes and calculations should clearly identify the codes the project will be designed to, and demonstrate how the project is proposed to meet the codes. The primary means of resolving any questions relating to code compliance is through the plan check process.[65] However, in some cases, it will make sense to have an application requirements meeting when submitting the application. If an AHJ offers such a meeting, station developers should be prepared to give a complete description of each code section the proposed project addresses and how the project will meet or exceed all code requirements.

In July 2014, California became the first state in the nation to adopt and approve the 2011 edition of National Fire Protection Association 2 (NFPA 2 Hydrogen Technologies Code), which stems from considerations in the more familiar NFPA 52 and 55. NFPA 2 is a science-based code that provides fundamental safeguards for the generation, installation, storage, piping, use, and handling of hydrogen in compressed gas or liquid form. It has undergone significant industry examination and engineering peer review through the rigorous NFPA adoption process. The 2016 California Fire Code adopted by reference the 2016 Edition of NFPA 2. California previously adopted the 2018 International Fire Code as the 2019 California Fire Code, which was effective January 1, 2020. The 2020 Edition of NFPA 2 was adopted by the California Building Standards Commission in August 2020 and will be included as a 2019 Intervening Code Supplement, which is scheduled for publication on or before January 1, 2021, with an effective date of July 1, 2021.[66]

5. Utility Power Considerations

Obtaining approval for electrical systems at a hydrogen station is a two-part process:

- **Connecting to the Local Utility.** The level of utility involvement in a station is site and design specific. In the simplest case, the utility company can pull power from adjacent power lines that have excess capacity for the station to access. Project timelines and complexity increase with wider power demand and expansion requirements, which might entail an upgrade to the distribution infrastructure near the project area.
- **Obtaining Building Department Approval.** The local building department will ensure electrical plans comply with relevant codes. Details are included in the following "Phase 3 Building Review" section.

65 During the plan check process, the project is reviewed by multiple local agencies to ensure compliance with particular regulations, codes, etc.

66 Title 24 is updated every three years or, if needed, during an intervening code adoption cycle. The latest edition of the California Building Code was published July 1, 2019, with an effective date of January 1, 2020. https://codes.iccsafe.org/content/CAFC2019

Special Focus: Connecting to the Grid

Grid connection describes the process by which hydrogen stations are connected to the electrical grid through the local utility. This process can be complex and can significantly lengthen a project timeline, especially because each site is unique and may follow a different process for setting up new service. By engaging with the local utility early in the process, station providers can gain a clearer understanding of the development timeline, costs, and specific requirements. Utility approval to begin the grid connection process is a separate and distinct approval process from an AHJ permitting process, although the processes may be more closely linked in areas with a municipal utility.

Understanding Grid Connection

Usually, similar to any other commercial customer, the station developer will be responsible for some of the work of connecting to the grid. The delineation of responsibilities between a developer and the utility varies by territory. Most utilities provide a breakdown of rules and responsibilities for all involved. It is important to clearly understand the specific steps that must be followed and potential pitfalls for a project and site as these can affect the budget and timeline. For example, if underground lines are being installed, easements must be attained by the developer. This can create a barrier if the site host is unwilling to provide an easement or lacks the legal authority to do so. Understanding these details upfront can reduce project delays.

The scope and scale of grid connection differs based on the size of the project and available electrical capacity. In the best-case scenario, sufficient capacity will exist in the existing transformer to accommodate the addition of the hydrogen station. In other cases, a transformer upgrade will be needed, which could involve adding a new transformer or upgrading the existing transformer. This can be an expensive task, underscoring the importance of understanding your project's unique demands and needs—and communicating them to your utility—early in the process.

Timeline for Communicating with Your Utility

As a rule of thumb, station developers should engage utilities as early in the process as feasible. The extensive construction that may be needed to get power to the site can take 10-12 months and station developers report that sometimes internal utility deadlines are missed due to myriad factors. Early engagement can shave weeks or months off a project timeline. To expedite the process, station developers should contact their utility to ensure they understand what components a utility will require for an application to be deemed "complete."

Page 54 in the "Additional Resources" section provides more information on how the process varies at different major utilities in the state. These five utilities (three investor-owned and two publicly-owned) are the most prominent in the state and represent the majority of California's population, although there are 59 utilities that cover the whole of California's needs.[67]

Permit Fees

Current state law requires that fees charged by a local enforcing agency for permit processing and inspection cannot exceed the reasonable cost of providing the service for which the fee is charged. In other words, fee revenue must only be used to defray the cost of permit processing and enforcement and cannot be used for general revenue purposes. These requirements are contained in Government Code Section 66016 and State Health and Safety Code Section 17951.[68] Permit fees will vary by jurisdiction.

Planning Review Tips, Best Practices, and Resources

Planning Approval Tips

Early engagement. Early AHJ engagement can have tremendous benefits, saving both developers and AHJs considerable time. A general arrangement schematic, if available, can help calibrate this initial discussion and subsequent path forward. This general arrangement can facilitate a discussion about key constraints on many sites, such as parking spaces and traffic flow. It can also help shed light on items such as design expectations or requirements (e.g., landscaping, building aesthetics, etc.) that can help minimize rounds of feedback in the permitting process. It is also important for both AHJs and station developers to be thoughtful and transparent about

67 This includes investor-owned utilities, electric load serving entities (including publicly-owned utilities), rural electric cooperatives, and community choice aggregators. See CEC Load Servicing Entities in California.

68 California Government Code. http://www.leginfo.ca.gov/.html/gov_table_of_contents.htm.

California Health and Safety Code. http://www.leginfo.ca.gov/.html/gov_table_of_contents.html.

potential issues (e.g., city ordinances, sound impacts, space constraints, etc.) that might arise that could delay or even kill a project down the road.

Thorough and Concise Interactions with Planning Departments. Station developers can create positive baseline impressions early on in a project by initiating interactions with planners that are organized and efficient. Providing planners with everything they need, while not overloading them with unnecessary information can go a long way in streamlining the permitting process and building rapport with AHJs.

Parking. Parking spaces fall into one of two categories: general parking and disabled access parking. Both are incredibly important for the local planning process and can significantly impact station design. General parking requirements are typically governed by the jurisdiction's General Plan and zoning requirements. Disabled access spots are determined by the local jurisdiction's interpretation of the ADA, which prohibits discrimination against people with disabilities in employment, transportation, public accommodation, communications, and governmental activities. Care should be taken to incorporate parking requirements and opportunities into the station design as early as possible. If a site has flexibility, AHJs can help the process by informing the station developer, often resulting in a better design overall.

Traffic Flow and Site Circulation. Adequate traffic flow and circulation is fundamental to the planning approval and long-term viability of the site. Early engagement and a clear understanding of a site's dynamics and user behavior can help facilitate productive discussions with AHJ staff and planning commissions. This is especially true if the proposed project can improve traffic flow on-site. Station developers should also consider how flow and circulation patterns may change with an increased influx of vehicles. Heavily utilized hydrogen stations can result in long fueling queues with cars waiting in line for considerable lengths of time. Appropriately sizing the station capacity and the number of fueling positions to meet anticipated demand can help.

Hydrogen Supply Strategy. For delivered hydrogen based stations, delivery schedules are likely to be governed by site dynamics and property owner wishes. However, local ordinances, such as limiting nighttime deliveries, may also impact the schedule. Any delivery restrictions should be understood early in the process so that challenges can be addressed.

Aesthetics. A well-engineered station is often only part of the equation. To facilitate quick local approval, a station should be designed to fit the visual landscape as much as possible and should be compliant with the AHJ's published design standards. Designing a station to meet the local aesthetics can save time, money and help gain community support.[69] Hiring a local architect who understands local nuance can help seamlessly integrate the station into the existing visual landscape, and minimize potential back and forth between the developer and AHJ. Overall flexibility and a willingness to work with the AHJ on design and local preferences can help the process go smoothly.

General Plan Considerations. Some General Plans specifically state that fueling stations can dispense gasoline or diesel fuel. Communities that want to attract hydrogen fueling stations should ensure their General Plans recognize all fuels, not just gasoline and diesel. A General Plan may also make reference to hydrogen dispensing as a way to meet local sustainability goals and clean air standards.

Understanding Site Ownership. Fully understanding the ownership structure, lot lines, easements, and any deed restrictions on the proposed property can save time throughout the permitting process. If the site has multiple owners, all owners should agree upon, or have an agreement on, the proposed general arrangement drawings before initiating the design process. If a site has multiple lots tied together, the city or county may require a covenant to tie the properties together. Station owners often rent the space to host their station and may not be fully aware of title restrictions on the property, even if they sign an agreement with a hydrogen station developer. Researching the title can avoid potential issues upfront and save time in the long run.

Fire Approval Tips

The importance of fire approval, or an identified pathway to fire approval — cannot be over-stressed, especially in communities new to hydrogen fueled transportation. While no un-safe hydrogen project would survive the permitting process, the *perceived* risk of hydrogen can be high for those who have not been exposed to the technology. Experience shows

69 Some communities have architectural or design review boards that will review projects before they receive planning approval. Others allow planning review in parallel with the building review process.

that in those cases, fire official engagement gives decision makers the transparency they need to be assured enough to approve a proposed station. In general, local fire officials have been very supportive of the State's effort to deploy hydrogen fueling stations once they gain comfort that safety codes and standards exist and that stations comply with them.

Hiring an experienced fire protection engineer with an understanding of the local AHJ's approach to code application can help minimize the back and forth associated with the station approval process. A fire protection engineer can succinctly communicate compliance with relevant codes and standards, saving fire marshals time and effort.[70]

Early AHJ engagement. Some fire department workflows are set up to wait for planning approval prior to reviewing projects. However, given the novelty of retail hydrogen use in some communities, out of order processes may be required to establish the comfort needed to gain planning approval. Conceptual approval or a willingness to engage on a project early can be the difference between a project stalling and gaining planning approval at the first hearing.

Safety system innovation and understanding is evolving as the retail hydrogen fueling market is developing. Nevertheless, if a new approach is to be considered in a community, resources are available to help ensure appropriate risk mitigation, such as the Hydrogen Safety Panel.

Utility Connection Tips

Early outreach to the local utility is crucial to ensure the utility has sufficient time to provide a new service and deliver any additional power requirements to the site. This early engagement enables project proponents to incorporate utility specs into site drawings.[72]

Hydrogen Safety Resources

The Hydrogen Safety Panel (HSP) was formed in 2003 to support the U.S. Department of Energy Hydrogen and Fuel Cells Program and represents almost 500 years of combined industry and hydrogen experience. The 17-member panel is comprised of a cross-section of expertise from the commercial, industrial, government, and academic sectors. They meet regularly to identify safety-related technical data gaps, best practices, and lessons learned, and to help integrate safety planning into hydrogen and fuel cell projects to ensure that the appropriate safety practices are addressed and incorporated. This HSP also reviews safety plans and hydrogen fueling station designs as part of the CEC competitive grant funding. The HSP is a fee-for-service organization and can be consulted to review innovative projects and provide feedback and insights to both station developers and AHJs through the Center for Hydrogen Safety.

The Center for Hydrogen Safety (CHS)[71] is a global, neutral and nonprofit resource that supports and promotes the safe handling and use of hydrogen across industrial and consumer applications in the energy transition. The CHS facilitates access to the HSP; develops comprehensive safety guidance, outreach and education materials; incident response resources and provides a forum to partner on world-wide technical solutions. CHS is a membership organization that provides assurance that groups of experts have a common communication platform with a global scope to ensure safety information, guidance, and expertise is available to all stakeholders.

The Hydrogen Tools Portal (http://h2tools.org) supports implementation of the practices and procedures that will ensure safety in the handling and use of hydrogen in a variety of fuel cell applications. The Portal brings together and enhances the utility of a variety of tools and web-based content on the safety aspects of hydrogen and fuel cell technologies to help inform those tasked with designing, approving, or using systems and facilities, as well as those responding to incidents.

70 https://www.fireprotectionengineering-digital.com/fireprotectionengineering/2019_q4/MobilePagedReplica.action?pm=2&folio=42#pg44

71 Additional information on the HSP and Center for Hydrogen Safety can be found at www.aiche.org/chs.

72 Some AHJs will want to see the detailed engineering plans for utility service. Others accept drawings without that detail (e.g., the plans would show any additional footprint added to the site, but not the internal electrical design).

Conduct Thorough Pre-Application Discovery. Quickly establishing the available power on a connection or nearby transformer is essential to understand the type and size of upgrades that will be required, if any. Utilities providing this information without the need for detailed site plans or drawings enables station developers to explore possible sites and, when appropriate, adapt design and layout to minimize utility costs.

Engage in Service Representative Consultation. Local site knowledge can supersede plans approved by utility plan checkers. Early consultation with the utility service representative (in addition to utility plan checker) can save time and effort later in the process.[73]

Understand Electrical Load Requirements. Load requirements can vary widely between station designs. For example, given the same hydrogen throughput, on-site electrolysis typically consumes much more electricity than delivered hydrogen, or delivered liquid hydrogen based stations may have a higher energy demand than delivered compressed gas based stations. These differences may impact local building department review strategies.

Consider Establishing Separate Service. If a station is being installed at an existing fueling site, but requires a separate utility meter, a separate address may need to be obtained from the city or county. This is generally a simple process not involving any underlying property changes (for example, 1 Hydrogen Way would become 1A Hydrogen Way for the new meter and 1A would be removed if the meter were to be removed). It is important to engage utilities early to understand how they prefer to handle their accounts.

Understand Evolving Standards. Electrical requirements evolve over time. Depending on code cycle and project development timelines, a project may straddle code changes. An early check-in with the local jurisdiction as well as review of the California Building Standards Code (Title 24) can avoid surprises during the permitting process. In the context of electrical permits, Title 24, Part 3 of the California Energy Code should be given particular attention by developers who also work outside of California. Part 3 is adopted by the CEC and approved by the CBSC for inclusion in Title 24, and is not based on a model code.

Collaborate to Plan and Prepare for installation. Some stations have suffered delays from a lack of capacity or availability of utility parts. Effort should be made to help utilities plan their resource allocation to the project as early in the process as possible. AHJs can share information about the number of installations under review and when they are likely to be approved. For example, Southern California Edison has regular meetings with proactive cities in its territory to share information and discuss existing and upcoming projects. This can eventually help utilities start their processes before AHJ approval so they can get the right resources and parts in place to minimize the time between permit approval and interconnection.

Provide Timeline Transparency. A lack of understanding of the timeline to add new electrical service can doom a project and frustrate the station developer and AHJ involved. By providing timely and realistic estimates of the timeline to develop a site and complete construction, utilities can help station developers plan and develop projects as planned. Equally important is meeting those timelines in a realistic manner. A number of factors can extend timelines, including utility workload. Some utilities allow developers to engage third party contractors to complete portions of the work, which can help shorten utility connection timelines.

Offer Clear Rate and Demand Charge Structure. Unpredictable electricity costs can be one of the greatest obstacles to station deployment. Utilities can help address cost uncertainties by proactively educating station developers on the range of electricity rate options, charges they can anticipate, and strategies to mitigate costs.

Ensure Clear Understanding of Roles and Responsibilities. It is not always clear to station developers the delineation of grid connection responsibilities between the utility and the station developer. Providing clear and up-front guidance is helpful and allows station developers to better plan and reduce the potential back-and-forth between the utility and developer.

73 Many utilities have staff who focus on service requests and/or site inspections within a general geography. Inspector approval is needed to power up and operationalize a station—early engagement can minimize the potential for costly changes.

Phase 3: Building Review

In some jurisdictions, the building department serves as the central clearinghouse for project approval.[74] In others, the building department simply conducts a building plan check once a project has been cleared by the planning department. In either case, building departments review complete, fully detailed plans to ensure that projects comply with applicable requirements of the California Building Standards Code (Title 24) and local ordinances. These detailed plans include structural, mechanical, and electrical information.

Electrical approval is one of the key milestones. An electrical engineer will check the plans against the California Electrical Code (Title 24, Part 3), California Energy Code (Title 24, Part 6), and local ordinances, which may be more stringent than the California Building Standards Code, Title 24.[75] These codes ensure proper electrical installations, efficiency measures, and load management.

The building department will use its interpretation of the California Building Standards Code to ensure a project is set up for safe installation and operation, with a focus on safety, structural design, and layout. It may issue separate permits for demolition, site grading, and construction. Final construction plans must incorporate all of the Planning Agency's conditions of approval. When the project is approved, the AHJ will issue the approval to build.

Building Approval Tips, Best Practices, and Resources

Balance Detail with Simplicity

Station developers should note that providing too much information could inundate the plan-check process. The ideal permit application demonstrates department specific compliance with all relevant codes—nothing less and nothing more. Each department's plan checker (building, electrical, fire, etc.) should be able to quickly assess what section(s) they needs to review. They should not have to hunt through pages of calculations to find the relevant sections. Depending on the AHJ, the best approach may include packages tailored to each department, or one set of clearly indexed plans. This can be determined during the pre-application outreach meeting.

Provide Full and Complete Responses

As the AHJ reviews the application, it will often provide feedback including questions or comments and definition of changes needed for approval. Station developers should receive full and complete comments from all agencies of the AHJ. Adjustments in the permit application may be required based on staff input. Applicants should clearly and succinctly address all issues raised by the AHJ, and resubmit the modified package as soon as possible.

Nationally Recognized Testing Laboratory (NRTL) Approval

In an established market, building designs can incorporate off-the-shelf NRTL certified components and designs, simplifying the engineering review process. However, NRTL certified components often do not exist for early market products. Hydrogen fueling stations are no exception.[76] Given this, the onus falls on the station developer to provide information to AHJs so that station designs can be approved. Fortunately, the number of approved and safely operating stations continues to grow globally. As the market expands, the expectation is that certified components or systems will be available for station developers, simplifying infrastructure approval and deployment.

Maintain Consistency in the Inspection Process

Past experience has illuminated the potential for misalignment between plan check and equipment inspection, as plan checkers and inspectors are often different people. These discrepancies can arise from miscommunication at a variety of process points. To the extent possible, both AHJs and station developers should actively work to ensure inspection requirements are fully understood. This will help stations move from construction to operation as quickly as possible.

Utilize Third Party Resources

If staff has questions or concerns regarding a project, a number of third-party resources are available to

74 The City of Los Angeles' building department is an example of this arrangement.

75 Local ordinances can often be found on an AHJ's website and should be confirmed at the pre-submittal meeting.

76 https://h2tools.org/hsp/certification-guide.

share insights or connect resources, free of charge. The California Fuel Cell Partnership serves as an information clearinghouse that can connect project participants to industry and government experts, in addition to knowledgeable staff.[77] The "Additional Resources" section (page 57) provides a list of organizations and contact information.

Phase 4: Construction

After the AHJ issues the final approval to build, construction can begin. During and at the completion of construction, the station is subject to inspections and final approval by the local authorities. The purpose of inspections is to ensure that project developers build their projects in compliance with the specifications agreed upon in previous phases of the process. Work in progress (WIP) inspections are strongly recommended to help avoid potentially costly interpretation misunderstandings and help ensure a station opens on time. When construction is complete, the station developer will file a notice of completion and begin commissioning the station.

Timely Construction Tips and Best Practices

Inspection processes can vary from jurisdiction to jurisdiction. The local process should be fully understood before commencing construction. Many jurisdictions will require multiple inspections, others a single inspection upon project completion. Either way, inspections should be worked into the project plan and scheduled as soon as possible to avoid long lead times.

Encroachment Permits must be obtained prior to doing any work that may impact a city or county right of way. These permits are typically obtained by the contractor responsible for installing the station and generally require a performance security (e.g., cash deposit, performance of bond, letter of credit) to ensure completion of work. Applicants should work with the building department to ensure they are prepared to secure all potential encroachment permits. If work needs to be done on a state highway, an encroachment permit from the California State Transportation Agency will be required. More information on obtaining an encroachment permit for areas under the State highway rights of way can be found on the Caltrans website.

Phase 5: Commissioning

Once a station has been fully constructed and a notice of completion by the station developer has been submitted, final commissioning begins. Once commissioning is completed, the station can be opened to the public. An "open" retail station can accept any FCEV driver with a credit card or fleet fueling card.

Currently, final retail station commissioning involves five key parties: the station developer, local AHJ, CARB, auto manufacturers, and DMS. The following steps are general milestones and not meant to serve as a complete commissioning checklist. This process will continue to evolve as the market matures. For example, the State of California (led by CARB) and industry are collaborating on a process to help move station confirmation towards a more traditional NRTL listing and approval process with the State offering oversight and compliance spot checks, for example. This process is underway and input is actively being solicited.

1. **Station Developer Commissioning.** The station developer is responsible for constructing the station to the plans and specifications approved by the AHJ. The developer will also fill the system with hydrogen and administer a series of tests to ensure the station performs as expected. Once construction and verification has been completed, the developer will schedule a final inspection by the AHJ to approve the station for operation.

2. **Hydrogen Fuel Quality Testing.** The hydrogen station, including the dispenser, must be tested to ensure it complies with the hydrogen quality requirements in CCR Title 4, Division 9, Chapter 6, Article 8, Sections 4180 and 4181 which adopts SAE J2719 "Hydrogen Fuel Quality for Fuel Cell Vehicles." This step is typically required prior to step 3, fueling protocol confirmation. Thereafter, hydrogen quality reading should be taken regularly, at a minimum of every three months if the retail station received funding from the State of California. Hydrogen quality should also be retested after any event in which the hydrogen lines are potentially exposed to contamination due to maintenance or other activities. Additionally, DMS spot checks hydrogen retail stations periodically to ensure the station adheres to SAE J2719.

77 For contact information, refer to http://cafcp.org/aboutus/contactus

3. **Fueling Protocol Confirmation.** Currently, station developers and the CARB's HyStEP (Hydrogen Station Equipment Performance) testing team works closely with station developers to ensure new stations fill FCEVs according to industry agreed upon fueling protocols (SAE J2601 "Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles"). Once successful testing (ANSI/CSA HGV 4.3 test matrix) is complete, automakers perform final test fills confirm that the station fills according to their satisfaction. A CARB rulemaking process is being explored in the effort to help move station confirmation towards factory approval through a NRTL, with the State providing compliance oversight and enforcement, for example. Other goals for a regulation are to remove the vehicle OEMs from testing each station, and to make the entire process of opening a station more of an industry standard than a specialized process.

4. **Commercial Testing.** Prior to approval of retail sales, a station must be certified by DMS to ensure that: a kilogram of hydrogen sold is a kilogram of hydrogen received, that the point of sale system functions properly, and that hydrogen dispensed meets the purity requirements for use in a FCEV (the fuel quality tests take place in Step 1 and can be done by a commercial lab).[78] As previously noted, the station must pass field testing by the county sealer of weights and measures. Typically, these tests are performed by a registered service agency and witnessed by county officials.[79]

5. **Opening the Station for Public Use.** Currently, a station will be open to FCEV drivers when each of the following steps have been completed:

   a. The AHJ has issued the final occupancy permit to the station developer;

   b. The dispenser has been certified to sell hydrogen by the kilogram (pursuant to CCR Title 4, Division 9, Chapter 1);

   c. Fueling protocol has been confirmed by HyStEP or a recognized NRTL/third-party system, and at least two automakers have confirmed the station meets protocol expectations, and their customers can fuel at the station;

   d. The station has a functional point of sale system;

   e. The station is connected to the Station Operational Status System (SOSS), maintained by CaFCP; and

   f. The station developer declares the station is ready to serve the public.

In the near-term, the State of California, led by GO-Biz's Zero Emission Vehicle Market Development Unit, in collaboration with CaFCP, works with stakeholders to facilitate the steps each party takes to "open" stations to FCEV drivers. Station status is publicly communicated and displayed on the CaFCP website. Longer term, we expect a technical third party (public or private) to verify the station and the station developer to officially declare the station open to the public.

State of California representatives are actively working with stakeholders to improve the commissioning process so that developers and local jurisdictions across the globe can seamlessly open to the public. Improvements will be collected and shared through state, local, and industry relationships.

Hydrogen Fueling Highway Signage

When advertising the presence of the station, hydrogen stations that are accessible to the public 16 or more hours per day and located within three miles driving distance of a state highway are eligible for free highway signage, providing the station developer purchases and installs directional signage from the freeway to the site (also known as trailblazer signs) on the local streets and roadways. Additional details on signage requirements can be found in section 21.03 of the Caltrans Manual on Uniform Traffic Control Devices (MUTCD).

Encroachment permits and installation costs for trailblazer signs are the responsibility of the station developer. However, the purchase and installation of highway signage will be covered by Caltrans at no cost to the station developer.

78 Refer to "Selling Hydrogen in California" on page 17 for more information.

79 https://www.cdfa.ca.gov/dms/programs/rsa/rsa.html

Photo credit: Gia Brazil Vacin

Photo credit: FirstElement Fuel Inc.

PART 04:

Additional Topics

Safety Planning

Ultimately, communities will define the success of hydrogen stations and FCEVs. A thoughtful permitting process will help ensure that hydrogen stations are as safe, or safer, than conventional fuel stations. However, the concept of hydrogen as transportation fuel remains new to many. A smooth permitting process can hinge on neighbors being educated and exposed to the technology, with misconceptions actively dispelled. Extensive and ongoing outreach to the general public—especially local elected officials, businesses and residents—in the local area has proven to be advantageous for projects in California. The HSP can provide outreach to authorities having jurisdiction (code officials, stakeholders, etc.) on hydrogen safety via a request to the CEC. The CaFCP also works with the Center for Hydrogen Safety to deliver a robust education and outreach program—project and community leaders should leverage this resource and expertise to help introduce communities to hydrogen FCEVs and their benefits.

As with any project that could impact the health and safety of a community, a hydrogen station operator should develop a project safety plan to addresses potential risks and impacts to personnel, equipment and the environment. The plan should describe how project safety is communicated and made available to the operating staff, neighboring occupants, and local emergency response officials. A communication plan that employs regular dissemination of safety procedures and practices is critical to avoiding potential safety incidents and assure proper incident response.[80]

Hydrogen Station Safety is a Priority

CEC Grant Funding Opportunities require all stations applying for state grant funds to develop and submit a thorough safety plan as part of their application. The plans were reviewed by a third-party team of experts, the Hydrogen Safety Panel. Applications with incomplete or insufficient safety plans were disqualified from the competitive grant process for that funding cycle.

Interfacing with CUPAs

Certified Unified Program Agencies (or CUPAs) are consolidated local entities with jurisdiction over the management of hazardous materials and wastes in California. During the hydrogen station development process, both station developers and AHJs should be aware of the standard CUPA requirement to develop a Hazardous Materials Business Plan (HMBP).

HMBPs are overview documents that contain information on the location, type, quantity, and health risks related to hazardous material stored, used, or disposed of by businesses operating in

80 Additional guidance is provided in Hydrogen Safety Panel's Safety Planning for Hydrogen and Fuel Cell Projects, dated March 2016: https://h2tools.org/sites/default/files/Safety_Planning_for_Hydrogen_and_Fuel_Cell_Projects-March_2016.pdf.

the state. As with any fueling project, a hydrogen station operator is required to develop a HMBP.[81] The station's HMBP is kept on file with the AHJ, which is typically the local fire or environmental health department. The HMBP should include a complete inventory of all hazardous materials on-site, demonstration of compliance with the California Fire Code, emergency response plans and procedures, a training plan, and procedures for documenting compliance with training and inspection requirements. AHJs can provide clear guidance on what should be included in the HMBP and what level of detail is necessary to meet CUPA requirements.[82] State law required that these plans be filed within 30 days of the material being brought on-site.

Another related CUPA program is the California Accidental Release Program (Cal-ARP), which requires implementation of a risk management program and submission of a risk management plan to prepare for accidental releases of hazardous substances. This only applies if more than 10,000 pounds of hydrogen (4,536 kilograms) are stored or processed on-site at one time.[83] Current and planned light-duty hydrogen stations in California range from 130 to 5,300 pounds (60 to 2,400 kg) of hydrogen at one time and therefore are not required to participate in the Cal-ARP program at this time. Heavy-duty hydrogen stations are expected to range between 17,600 to 70,400 pounds (8,000 to 32,000 kg), which would trigger the requirement to prepare and submit a risk management plan.

There is an exclusion in the Cal-ARP regulations for flammable substances being used as fuel and held at retail facilities, "Flammable substances used as fuel or held for sale as fuel at retail facilities. A flammable substance listed in Section 2770.5, Table 2, is nevertheless excluded from all provisions of this chapter when the substance is used as a fuel or held for sale as a fuel at a retail facility."[84] Therefore, in most cases, light-duty hydrogen stations regarded less of size, and future retail heavy-duty stations would be exempt from this requirement.

Cal-ARP enforcement officials can contact California Office of Emergency Services for further information on the program and requirements.[85]

Air Quality Permits

Local air quality improvement is a fundamental motivation for pursuing hydrogen and FCEV deployment. As such, most hydrogen fueling station arrangements will not require an air district permit to construct or operate, since local emissions will not increase from the sources subject to air district review. This is true for both delivered hydrogen and electrolysis stations. In many cases, on-site generation using natural gas or biogas as the feedstock will also be exempt from obtaining an air quality permit. However, this presumption should be verified with the local air district. Regardless of whether or not a permit is required, the project may need to be formally registered with the local air district.[86]

Permitting Temporary Fuelers

This section provides a very brief overview of a more complicated topic. AHJs and developers should utilize additional resources and reference applicable codes to ensure a full understanding of the requirements if intending to obtain a permit or utilize a temporary fueler.

As more FCEVs take the road and the hydrogen station network expands, temporary fuelers will be able to provide additional capacity on a temporary basis to support high use areas, remote areas, or as a backup for outages. Temporary fuelers have capability to travel to designated locations throughout the state and placed as a temporary fueling station to fill vehicles. Their designs can vary; as some are as simple as storage tubes and a dispenser, while others include compressors, generators, and cooling equipment. All are on trailers hauled by trucks, parked/placed in a specific location for vehicles to come to them and get fuel: a temporary station.

In order to convey hydrogen on public roads, temporary fuelers are required to meet US

81 "Hazardous Materials Business Plan," California Governor's Office of Emergency Services, last modified 2016, https://www.caloes.ca.gov/cal-oes-divisions/fire-rescue/hazardous-materials/hazmat-business-plan.

82 It is also important to note that hydrogen is not an "Extremely Hazardous Substance," so it will not be subject to additional reporting requirements for this category (Appendix A, 40CFR, Part 355).

83 "California Accidental Release Prevention (Cal-ARP)," California Governor's Office of Emergency Services. https://www.caloes.ca.gov/cal-oes-divisions/fire-rescue/hazardous-materials/california-accidental-release-prevention.

84 19 CCR § 2770.4.1, § 2770.4.1. Exclusion. https://govt.westlaw.com/calregs/Document/IF046735CD9F1441987D3F032881E482A?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).

85 "Cal OES Contacts," California Governor's Office of Emergency Services. https://www.caloes.ca.gov/cal-oes-divisions/about-cal-oes/cal-oes-contacts.

86 California Air District websites can be found here: http://www.arb.ca.gov/capcoa/dismap.htm.

Department of Transportation (DOT) Standards for transporting flammable gases (see 49 CFR).[87, 88]

The Compressed Gas Association TB25 "Design Considerations for Tube Trailers," which has been incorporated by reference into 49 CFR 173.01, offers a solid starting point for planning to comply with DOT regulations. It should be used for performing analysis or performance testing. For composite cylinders used to store hydrogen, DOT standards will require a full range of testing to verify integrity. Prior to testing, it is recommended that manufacturers of mobile fuelers contact the Pipeline and Hazardous Materials Safety Administration (PHMSA) at DOT to ensure tests and methods meet all requirements.

In general, when temporary fuelers are placed, they must meet the same requirements as fixed stations, except in specific applications. Manufacturers and users of mobile fuelers should review NFPA 2 to ensure project compliance.

FCEV Repair Facilities

NFPA 2: Hydrogen Technologies Code Chapter 18 addresses repair garages. The 2019 California Fire Code Chapter 23 addresses repair garages for vehicles fueled by lighter than air fuels. Section 2309 "Hydrogen Motor Fuel-Dispensing and Generating Facilities" provides additional detail.

Human Resources

Local AHJs, station developers, and consultants gain hydrogen permitting experience in California and elsewhere every day. Outreach to communities statewide has confirmed that local permit authorities are more than willing to share lessons learned and insights with other permit authorities. Challenges are often similar across jurisdictions and sharing information can significantly improve the overall development process. However, identifying the right person to connect with and beginning a dialogue can take time. With this in mind, the State continues to work with local jurisdictions and professional associations to maintain a list of key contacts that have played a role in the permitting of a hydrogen fueling station. GO-Biz frequently updates a contact list and welcomes the opportunity to provide key connections. Interested parties should contact GO-Biz at zev@gobiz.ca.gov for more information.

In addition to local contacts, state and federal governments, academia, and non-profit organizations house considerable knowledge on the hydrogen station permitting process. While they cannot make local decisions, they can help jurisdictions work through potentially complex issues. For example, the Hydrogen Safety Panel, highlighted in the permitting section, could provide unique hydrogen projects recommendations for strategies to improve (or maintain) its safety profile. The "Additional Resources" section (page 57) provides a table listing organizations, their purpose as it relates to hydrogen, and contact information.

Photo credit: 2016 Andrew Hill

87 https://www.fmcsa.dot.gov/regulations/hazardous-materials/how-comply-federal-hazardous-materials-regulations

88 49 CFR 173.301 "General requirements for shipment of compressed gases and other hazardous materials in cylinders, UN pressure receptacles and spherical pressure vessels." This regulation incorporates CGA – TB25 "Design Considerations for Tube Trailers" by reference, highlighted here for its direct application to mobile fuelers.

Photo credit: Toyota Motor North America

Photo credit: Nikola Motor Company

PART 05:

Looking Forward

The State of California is firmly committed to the success of zero-emission vehicles. Too much is at stake to fail. Regions of California suffer from the worst air quality in the nation and the transportation sector stubbornly continues to be the largest source of our greenhouse gases.

Since the commercial launch of FCEVs, the question of whether this technology and market can work has been answered with a resounding yes. As we look to the future, the question now before us is whether we can scale the market in time to meet our climate and health targets. This necessary scale hinges on establishing business cases that attract growing private investment—minimizing permitting uncertainty is fundamental to success.

While the state can write laws, set targets, invest in stations and vehicles, and dedicate staff to the cause, the mission to replace internal combustion vehicles with zero-emission vehicles depends on focus at the local level–deploying groups of stations and vehicles community by community. This local leadership is crucial for a host of reasons. Nobody knows a city or county's permitting processes, constraints, and opportunities like city and county staff. They know how to avoid red flags and get projects through the permitting process faster. Cities and counties willing to work with station developers to streamline processes create opportunities for statewide improvement. A process breakthrough in one city can open the door for improvement in another. This local momentum often turns into regional momentum, which feeds state momentum, and leads to national momentum, all of which benefits our shared resources— natural and man-made.

With a supportive government backdrop, industry can and must work to build more and bigger stations faster, provide a reliable experience that is better than gasoline, continue to bring FCEVs to the California market at an accelerated pace, and to expand model offerings. A growing number of players need to continue to enter the market to strengthen and diversify the supply chain.

Together, we must continue to actively collaborate to overcome barriers and take tangible steps to accelerate the hydrogen and fuel cell market. We must devote attention to growing the medium- and heavy-duty vehicle market, to increasing the production of renewable hydrogen, and to cultivating opportunities to diversify the hydrogen and fuel cell portfolio to other applications. We must also harness the global momentum in technology and market advancements. In doing so, we can unlock clean mobility options for millions of drivers and riders, create a self-sustaining market, and generate high-quality, green jobs. As a result, all Californians will breathe cleaner air.

Hydrogen and fuel cell technology is an essential aspect of our clean energy transition and GO-Biz is committed to helping realize its potential. We are always looking for ways to improve. If you have insights or ideas that can help improve station development processes, please share them with the GO-Biz ZEV team (zev@gobiz.ca.gov) and anyone who has a role to play in the station development process. The keys to success are in all our hands.

Photo credit: Hyundai Motor America

PART 06:

Additional Resources

Acronyms

A

ADA: Americans with Disabilities Act

AHJ: Authorities Having Jurisdiction

ASME: American Society of Mechanical Engineers

B

BEV: Battery Electric Vehicle

C

CaFCP: California Fuel Cell Partnership

Cal-ARP: California Accidental Release Program

CARB: California Air Resources Board

CBSC: California Building Standards Commission

CCR: California Code of Regulations

CEC: California Energy Commission

CEQA: California Environmental Quality Act

CHS: Center for Hydrogen Safety

CHSS: Compressed Hydrogen Storage System

CNG: Compressed Natural Gas

CUP: Conditional Use Permit

CUPA: Certified Unified Program Agencies

CVRP: Clean Vehicle Rebate Project

D

DMS: California Department of Food and Agriculture, Division of Measurement Standards

DOT: US Department of Transportation

F

FCEB: Hydrogen Fuel Cell Electric Bus

FCEV: Hydrogen Fuel Cell Electric Vehicle

G

GFO: Grant Funding Opportunity

GH2: Gaseous Hydrogen

GHGs: Greenhouse Gas Emissions

GO-Biz: Governor's Office of Business and Economic Development

H

HMBP: Hazardous Materials Business Plan

HSP: Hydrogen Safety Panel

HVIP: Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project

HySCapE: Hydrogen Station Capacity Evaluation Tool

HyStEP: Hydrogen Station Equipment Performance

L

LADBS: Los Angeles Department of Building and Safety

LADWP: Los Angeles Department of Water and Power

LCFS: Low Carbon Fuel Standard

LCFS HRI Program: Low Carbon Fuel Standard Hydrogen Refueling Infrastructure Program

LH2: Liquid Hydrogen

M

MEGC: Multi-Element Gas Connectors

MMTCO2e: Million Metric Tons of Carbon Dioxide Equivalent

MUTCD: Caltrans Manual on Uniform Traffic Control Devices

N

NACS: National Association of Convenience Stores

NFPA: National Fire Protection Association

NREL: National Renewable Energy Laboratory

NRTL: Nationally Recognized Testing Laboratory

P

PG&E: Pacific Gas and Electric Company

PHMSA: Pipeline and Hazardous Materials Safety Administration

S

SCE: Southern California Edison

SDG&E: San Diego Gas & Electric

SMUD: Sacramento Municipal Utility District

SOSS: Station Operational Status System

T

TPRD: Temperature Activated Pressure Relief Device

T

ZEV: Zero-emission vehicle

Hydrogen Station Permitting Checklist

Prior to beginning development of a hydrogen fueling station, station developers should consider key questions related to siting, as outlined in the series of questions below. Corresponding page numbers and section headings will lead you to a more in-depth discussion of these topics in the main body of the Hydrogen Station Permitting Guidebook.

Preliminary Checklist for Station Developers

1. Is the property owner committed to the project? (Page 24: "Securing Site Control")

   ☐ **Yes**

   ☐ **No:** Get commitment from property owner.

2. Is the proposed site properly zoned for hydrogen fueling? (Page 25: "Zoning")

   ☐ **Yes**

   ☐ **No:** During pre-application meeting, ask City or County Planning Department if a zoning variance could be obtained (or if the site could be re-zoned).

3. Can the fueling equipment fit on-site and accommodate relevant setback distances? (Page 27: "Fire Department Approval," page 49: "Additional Resources")

   ☐ **Yes**

   ☐ **No:** Can mitigation measures reduce the setback distance required? If yes, establish a proposal, raise in pre-application meeting and review with the local fire marshal. If not, find a new site.

4. Do any local ordinances impact the ability to add hydrogen to the property? (Page 22: "Local Government Modifications")

   ☐ **No**

   ☐ **Yes:** During pre-application meeting, ask City or County Planning Department if a Conditional Use Permit or variance could be obtained.

5. Is there potential for California Environmental Quality Act (CEQA) related concerns to develop? (Page 26: "CEQA")

   ☐ **No:** Most brownfield sites will fall into this category

   ☐ **Yes:** Determine if similar projects have been completed in California. If so, during the pre-application meeting, share how projects complied with CEQA with City or County Planning Department. Seek guidance from City or County Planning Department.

Once this initial assessment is complete, the station developer should secure a pre-application meeting with the local City or County Planning Department to review the potential station installation. Ideally, the station developer will prepare a rough general arrangement drawing to facilitate feedback.

Pre-Application Meeting Questions (Station Developer)

Pre-application meetings are highly recommended and provide an excellent opportunity for the station developer and local Authority Having Jurisdiction (AHJ) to have an early discussion about the proposed station and identify potential issues that may arise. Addressing the questions below during the pre-application meeting can often help save time and effort throughout the remainder of the process.

- Are there any site issues we (the station developer) should be aware of?
  (Page 24: "Pre-Application Outreach")
- How should a permit application be structured to make it as easy as possible for each department? What level of detail is expected?
  (Page 24: "Pre-Application Outreach")
- Can (should) an application intake meeting be scheduled with all relevant departments?
  (Page 24: "Pre-Application Outreach")
- Are there any steps that can be taken to reduce the permitting timeline? What can we (the station developer) do to help streamline review efforts?
  (Page 24: "Pre-Application Outreach")
- If a project will be heard by a political body (Planning Commission, City Council), can members be approached prior to the hearing?
  (Page 24: "Pre-Application Outreach")
- Is the location in an aesthetically sensitive area? If not, the station developer should focus on the engineering package, but keep in mind visual appeal is often crucial to planning approval. If yes, the station developer should consider hiring a local architect to help ensure the project reflects the local view-shed.
  (Page 29: "Aesthetics")
- How does the construction inspection process work? Is there anything we (the station developer) can do to get ahead of typical issues that may arise during inspections?
  (Page 33: "Phase 4: Construction")

Pre-Application Meeting Questions (AHJ)

Authorities Having Jurisdiction (AHJs) are the local planning experts. They know their processes, and what questions to ask, better than anyone else. Discussing the below questions early in the process can help avoid common permitting pitfalls.

- How will the station be supplied with hydrogen?
  (Page 29: "Hydrogen Supply Strategy")
- How do you expect traffic to flow through the site?
  (Page 29: "Traffic Flow and Site Circulation")
- What codes and standards do you plan to design to?
  (Page 21: "State Code Requirements," page 47: "Additional Resources," H2Tools.org)
- How do you plan to meet relevant set-back distances?
  (Page 27: "Fire Department Approval," page 49: "Additional Resources")
- What do you expect the station to look like?
  (Page 26: "Architectural Review," Page 29: "Aesthetics")
- Have you engaged the local utility?
  (Page 27: "Utility Power Considerations," Page 28: "Special Focus: Connecting to the Grid")

Application Checklist

Submitting a complete, yet simple application is essential to help streamline the permitting process and ensure the AHJ has all information required for review. The checklist below identifies key components of a complete application.

- Is the application appropriately tailored to each department?
  (Page 32: "Balance Detail with Simplicity")
- Does the application clearly spell out the codes and standards it has been designed to meet?
  (Page 32: "Balance Detail with Simplicity," page 47: "Additional Resources")
- Does the application address relevant ordinance and zoning constraints?
  (Page 25: "Zoning")
- Have all pre-application meeting questions been answered?
- Has the station's safety plan been clearly articulated?
  (Page 37: "Safety Planning")

Regulation, Codes, and Standards

As with any development project, ensuring compliance with relevant regulations, codes, and standards is critical to obtain approval and successfully construct a project.

The list that follows is California centric but does include some national and international standards. It is informational and reasonably comprehensive. However, it does not list every regulation, code, and standard that may be used in every jurisdiction or for every hydrogen station. Station developers and AHJs should ensure they use the most recent version of the listed regulations, codes, and standards.

In addition to the list below, H2tools.org offers a centralized codes and standards database. The database is maintained by the Pacific Northwest National Laboratory Department, through US Department of Energy support. This resource will help ensure all relevant codes and standards are addressed when permitting a hydrogen fueling station.

California Codes[89, 90]

- California Fire Code (International Fire Code and Uniform Fire Code)
- California Electric Code
- California Building Code (International Building Code)
- California Mechanical Code (International Mechanical Code)
- California Unified Program Agency (Cal/EPA certified CUPA)
- International Fuel Gas Code

National Hydrogen Specific Codes[91]

- NFPA1 Fire Code
- NFPA 2 Hydrogen Technologies Code
- NFPA 30A Motor Fuel-Dispensing Facilities and Repair Garages
- NFPA 55 Compressed Gases and Cryogenic Fluids Code

Federal Regulations

- OSHA Regulatyions 29 CFR 1920 Subpart H
- DOT Regulations including 40 CFR Part 68 Risk Management Plan (as applicable)

Component Design Standards

- ASME Boiler and Pressure Vessel[92]
- ASME B31.12-Hydrogen Piping and Pipelines
- ASME B31.1-Power Piping
- ASME B31.8-Gas Transmission and Distribution Piping Systems
- ASME B31.8S- Managing System Integrity of Gas Pipelines
- ASME B31.3- Process Piping
- CGA S Series -1.1-3 Pressure Relief Device Standards
- CGA-G-5.5 Hydrogen Vent Systems
- CGHA H Series of Standards
- SAE J2600-Compressed Hydrogen Surface Vehicle Fueling Connection Devices
- UL 2075 Standard for Gas and Vapor Detectors and Sensors
- NFPA 77/API RP 2003: Guidance on Grounding and static electricity (also API RP 2003)

Component Listing and Design Standards

At this time, there are very few existing listed and labeled components tested to listing standards implemented by a Nationally Recognized Testing Laboratory (NRTL). To bridge this gap, AHJs may allow the station manufacturer to provide technical information to prove that the compression, storage and dispensing components used are fit for service. As the market develops, the list of listed components (and systems) is expected to grow.[93]

89 Office of the State Fire Marshal, "Code Development and Analysis," Office of the State Fire Marshal, http://osfm.fire.ca.gov/codedevelopment/codedevelopment.php.

90 California Building Standards Commission, "Current 2013 Codes," California Building Standards Commission, last modified 2014, http://www.bsc.ca.gov/Home/Current2013Codes.aspx.

91 National Fire Protection Association, "Home Page," last modified 2015, http://www.nfpa.org/.

92 The American Society of Mechanical Engineers, "Home Page," ASME, https://www.asme.org/.

93 Example certification guidance documents: Intertek: http://www.intertek.com/WorkArea/DownloadAsset.aspx?id=49375; UL: https://www.ul.com/help/preparing-your-ul-mark-evaluation-us-and-canada

Station Developer Standards

(For informational use)

- ISO 17268, Gaseous Hydrogen Land Vehicle Refueling Connection Devices
- SAE J2600 Compressed Hydrogen Surface Vehicle Fueling Connection Devices
- SAE J2601, Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles
- SAE J2601-2, Fueling Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles[94]
- SAE J2799, Hydrogen Surface Vehicle to Station Communications Hardware and Software
- SAE J2719, Hydrogen Fuel Quality for Fuel Cell Vehicles
- HGV CSA Series Standards (Currently being updated)
- SAE/ISO/GTR, Heavy Duty Fuel Cell Truck Fueling Protocols under development

Additional Resources

United States Department of Energy:

- http://energy.gov/eere/fuelcells/safety-codes-and-standards
- http://www.afdc.energy.gov/uploads/publication/57943.pdf

NREL Permitting for Officials:

- http://www.nrel.gov/docs/fy13osti/56223.pdf

Sandia Technical Reference on Hydrogen Compatibility of Materials:

- http://www.sandia.gov/matlsTechRef/chapters/SAND2012_7321.pdf http://www.ca.sandia.gov/matlsTechRef/

94 SAE International, "Home Page," last modified 2015, https://www.sae.org.

Selecting a Workable Site—Setback Requirements

(appendix provided compliments of Sandia National Laboratories)

A variety of factors determine whether or not a piece of land is suitable for a hydrogen fueling station. These include two fundamental categories:

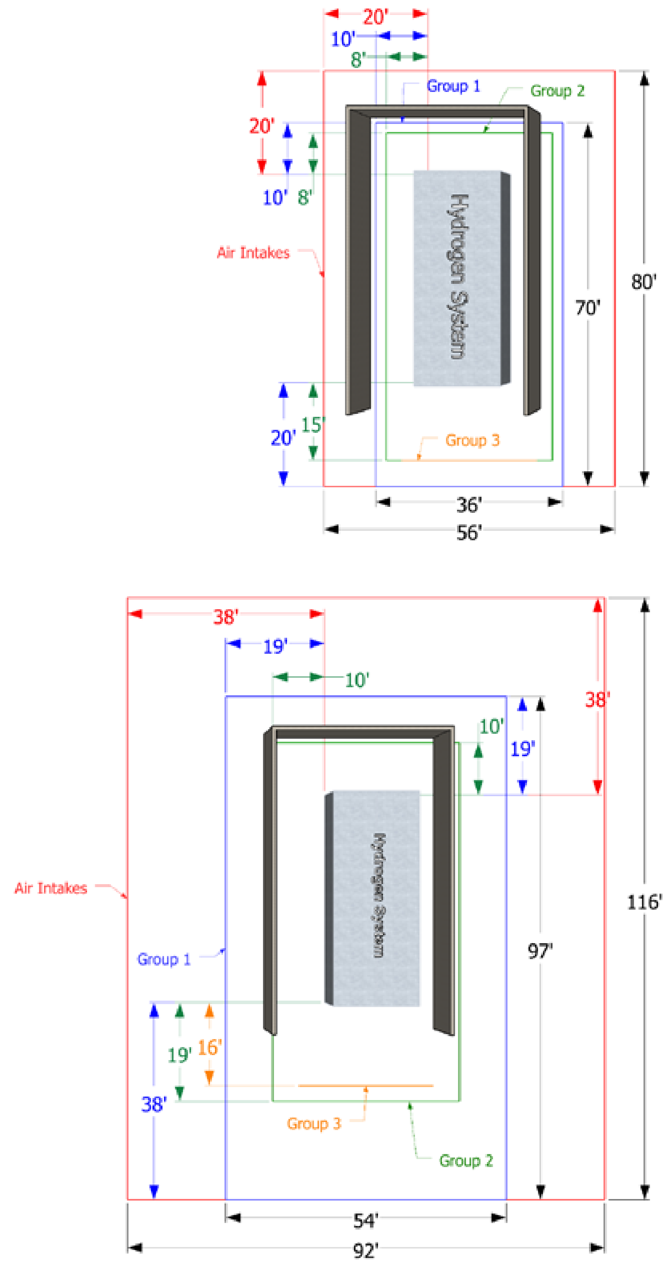
1. Social constraints: property ownership and structure, adjacent property owners, zoning, and planning issues (traffic flow, aesthetics, parking, etc.).
2. Physical constraints: equipment design/footprint and associated setback distances.

Many of the social factors are discussed in the main body of this guidebook. This appendix focuses on the physical aspects of adding a hydrogen dispenser to an existing gasoline/diesel station or other site. If fueling equipment cannot fit on the site, with or without mitigation measures in place, the project will not move forward.

Ultimately, the local fire marshal decides whether or not a site can physically host a proposed hydrogen fueling station. This decision is based on the fire marshal's review of proposed plans and interpretation of locally recognized fire code. Local interpretation of the code and on-the-ground realities can result in different solutions in different locations. However, information from NFPA 2, Hydrogen Technologies Code (2020 Edition) can and should be used to estimate a site's ability to host a hydrogen fueling station.[95]

The most recent 2020 Edition of the NFPA 2 code contains some changes for both gas and liquid hydrogen systems. One of the most significant changes in the 2020 Edition for gaseous systems is the reduction of some setback distances. Several factors contributed to the reductions, including a smaller leak size basis, different harm criteria, and the addition of a safety factor. Figure D.1 shows the reduction in setback distances for different exposures for an example system (more details below). The figure is taken from the Sandia National Laboratories report, "Hydrogen Refueling Reference Station Lot Size Analysis for Urban Sites" (hereafter referred as the Sandia H2 Reference Station Urban Sites Study).[96]

Figure D.1: Gaseous hydrogen system setback distances using the new NFPA 2 2020 Edition (left) and the previous NFPA 2 2016 Edition (right) requirements



95 The 2016 California Fire Code adopted by reference the 2016 Edition of NFPA 2. Efforts are underway to adopt the 2020 Edition of NFPA 2. The current draft proposal will be voted on by the California Building Standards Commission in June 2020 and the 2019 intervening code supplements will be published by January 1, 2021, with the regulation effective July 1, 2021.

96 B.D. Ehrhart, G. Bran Anleu, E. Sena, A.B. Muna, D. Ye, E.S. Hecht. C. Rivkin "Hydrogen Refueling Reference Station Lot Size Analysis for Urban Sites" Sandia National Laboratories. SAND2020-2796 (March 2020). https://www.osti.gov/biblio/1604872

The bulk liquid hydrogen separation distances did not change in the 2020 Edition of the NFPA 2 code, but there were some other changes that affect the separation distances. The significant changes are summarized in Table D.1, which is also from the Sandia H2 Reference Station Urban Sites Study.

Table D.1: Selection of significant changes in the 2020 Edition of the NFPA 2 code relevant to liquid hydrogen systems.

NFPA 2 Citation	Code Summary	Changes for NFPA 2 2020 Edition
8.3.2.3.1.6	Provides siting requirements for bulk liquid hydrogen systems.	For the point of delivery, distances in Table 8.3.2.3.1.6(A) Group 1 and 2 can be reduced to 50 ft. with specific active mitigations
8.3.2.3.1.6(2)	Allows for reduction in setback distances through adding fire barrier walls	Clarification that separation distances can be reduced to 0 ft. (0 m) by fire barrier walls
A.3.3.231.3	Clarifies the definition of a liquid hydrogen system to include gas/liquid hybrid systems	Number updated to A.3.3.231.3 and text updated in NFPA 55 to state that system can have two source vales for the purposes of determining separation distances.

Table D.1: Selection of significant changes in the 2020 Edition of the NFPA 2 code relevant to liquid hydrogen systems.

Sub-system	Maximum Pressure	Maximum ID	Group 1	Group 2	Group 3
1	50.0 MPa (7,250 psi)	9.07 mm (0.357 in)	5.0 m (16.0 ft.)	4.0 m (14 ft.)	4.0 m (13 ft.)
2	94.4 MPa (13,688 psi)	5.15 mm (0.203 in)	2 m (7 ft.)	2 m (7 ft.)	3 m (9 ft.)
3	94.4 MPa (13,688 psi)	7.925 mm (0.312 in)	6 m (20 ft.)	5 m (15 ft.)	4 m (15 ft.)

There are many different setback distances shown in the figures above; each of these distances applies to different exposures, such as lot lines, buildings, parking, or air intakes. These exposures and the different separation distances associated with them mean that there is no single setback distance or single land area requirements for a hydrogen system; there are many different considerations that must be assessed independently.

To illustrate this point, two example station layouts are described below, both taken from the Sandia H2 Reference Station Urban Sites Study. Both stations are sized for 600 kg/day dispensed hydrogen and four dispenser hoses (fueling positions).

The first system uses on-site storage of gaseous hydrogen both before and after the compressor, and a 2-hour rated fire wall for setback distance reduction. The calculated setback distances for this example are shown in Table D.2. Three different sub-systems are noted in this table. Gaseous setback distances are based on the pressure and inner diameter of the system piping, so setback distances are calculated for each portion of the system (with greater than 400 scf of hydrogen), and the largest setback distance for each group of exposures should be applied to the whole system (as specified in NFPA 2 Appendix E.1). This is an example system only, and different designs, operating pressures, or pipe sizes will lead to different calculated setback distances.

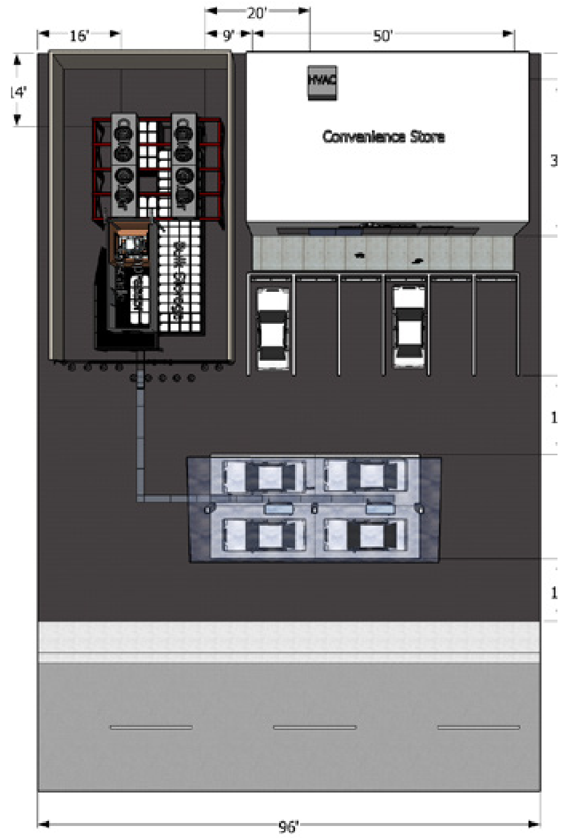
The example setback distances for gaseous hydrogen systems shown in Table D.2 are calculated for different groups of exposures. Group 1 exposures include lot lines, air intakes, ignition sources, and operable openings in buildings. Group 2 exposures include exposed persons (other than service technicians) and parked cars. Group 3 exposures include buildings, hazardous material storage, ordinary combustibles, and overhead utilities. A 2-hour fire rated wall that breaks the line-of-sight to the system can reduce Group 1 and Group 2 setback distances (except for air intakes) by half, and can eliminate Group 3 setback distances altogether. These reduced setback distances and the fire-rated wall are shown in Figure D.1 above.

Figure D.3 shows an example reference station layout from the Sandia H2 Reference Station for Urban Sites Study for an example system described above that meets the setback distances in Table D.2, including the setback distance reduction from the fire-rated wall.

Setback distances for liquid hydrogen systems are based on system storage volume instead of system pressure or pipe size. An example system which uses liquid hydrogen storage before the compressor and gaseous hydrogen storage in the cascade after the compressor uses both liquid and gaseous separation distances. These setback distances are then applied to the respective portion (gaseous or liquid) of the

Photo credit: Hyundai Motor America

Figure D.3: Example layout of hydrogen-only refueling system for gaseous hydrogen using NFPA 2 2020 Edition requirements.



system. Some of the calculated setback distances for an example system with 11,300 L (3000 gal) of liquid hydrogen are shown in Table D.3; gaseous setback distances for the cascade system which operates at 94.4 MPa (13,688 psi) with 7.925 mm (0.312 in) diameter piping in Table D.2 are used for the gaseous portion of the system.

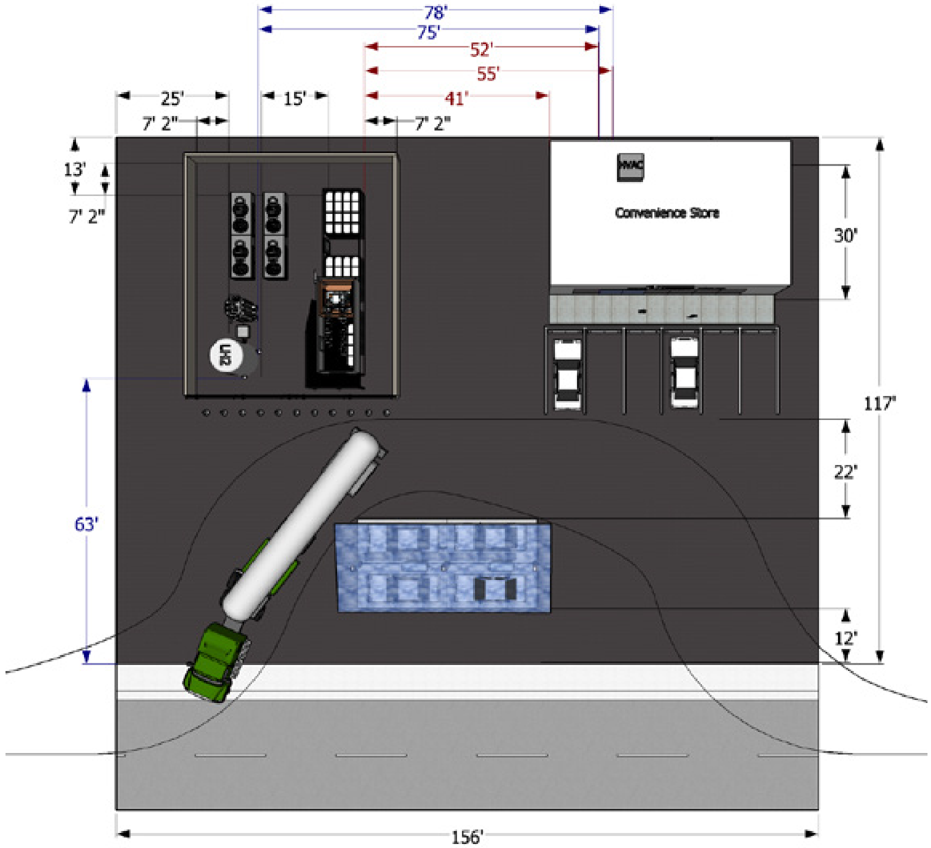
There are many other exposures with different setback distances for liquid systems noted in NFPA 2, only a selection is shown here. As shown in Table D.3, while the exposures are categorized into Groups 1, 2, and 3 (like the gaseous requirements), the separation distances are not defined per-group but rather for each individual exposure. This leads to an even more complex system siting assessment, since each exposure needs to be considered, rather than just the 3 groups. Furthermore, some (but not all) of the liquid setback distances may be reduced by insulation or by fire-rated walls; these include lot lines and flammable gas systems (other than H2) of the exposures shown in Table D.3 above.

Figure D.4 shows an example reference station layout from the Sandia H2 Reference Station for Urban Sites Study for an example system described above that meets the setback distances in Tables D.2 and D.3, including the setback distance reductions from the fire-rated wall.

Table D.3: Example setback distances from NFPA 2 2020 Edition for example system 11,300 L of liquid hydrogen storage.

Group	Exposure	Setback Distance
1	1 Lot lines	7.6 m (25 ft.)
	2 Air intakes	23 m (75 ft.)
	3 Operable openings in buildings	23 m (75 ft.)
	4 Ignition sources	15 m (50 ft.)
2	6 Parked cars	1.7 m (25 ft.)
3	7(a)(1) Sprinklered non-combustible building	1.5 m (5 ft.)
	8 Flammable gas systems (other than H2)	15 m (50 ft.)
	14 Inlet to underground sewers	1.5 m (5 ft.)
	15b Utilities overhead: other overhead electric wire	7.5 m (25 ft.)

Figure D.4: Example layout of hydrogen-only refueling system for liquid and gaseous hydrogen using NFPA 2 2020 Edition requirements.



As noted previously, these example station layouts are for illustrative purposes only. Real-world stations will have many other factors to consider and may not have a simple rectangular lot available. Additionally, these examples are for a specific capacity and design; different design choices may result in different setback distances.

Setting up a Station for Success

The process of station siting is often a flexible, iterative process with local officials. As discussed above, Figures D.3 and D.4 meet the NFPA 2 specified setback distances, without mitigation measures beyond the passive fire-rated walls or insulation. In the simplest permitting scenario, setback distances would be fully supported by the sites as described above. However, a few constraints can likely be overcome by well-designed mitigation measures. Additional mitigation measures may include active measures (e.g. leak detection with isolation), obtaining setback credit from adjacent sites, and alternative designs.

Code Development

Hydrogen has been safely used in commercial applications for decades, a fact that is reflected in hydrogen codes and standards. The challenge is bringing this operational history into the retail environment, which generally offers less free space and untrained public access. There is substantial interest in increasing the flexibility associated with bringing hydrogen into retail environments while maintaining acceptable risk profiles.[97]

NFPA 2 demonstrates considerable progress towards safe and practical retail hydrogen deployment, and code officials will continue to learn through its application. As the above reference stations demonstrate, liquid hydrogen has a particular challenge: it is difficult to find sites with 75 feet separation between potential equipment placement and buildings/parking. This challenge is far from the end of the story. An active effort is underway to determine if lesser setback distances can be justified and codified for liquid hydrogen.

97 Risk exists for all fuels: gasoline, diesel, CNG, electricity, hydrogen, etc. Risk tolerance is subjective, but also quantifiable. The current codes and standards regime ensures that a hydrogen station is as safe, or safer, than a typical gasoline station.

Major Utility Grid Connection Processes

Each utility has a different grid connection process and will follow different intake, review, estimating, and construction processes. However, there are also many commonalities between them. If you install stations in multiple service territories, it is important to become familiar with the similarities and differences across the utilities.

It is also important to communicate early with your utility about who will be responsible for the cost of each component of the connection progress. Almost always, the customer will be financially responsible for the electrical work between the station and the meter, while the utility will be financially responsible for work done behind the meter up to a pre-defined allowance. When a service upgrade is necessary, utilities may cover some or all of the cost on the utility side of the meter based on anticipated cost recovery from ratepayers. This may vary based on site-by-site conditions, the scale of a project, and other variables.

Pacific Gas & Electric

The Pacific Gas and Electric Company (PG&E) requests customers submit an application through the standard application portal. Once received, it goes to a service representative who will check the application package to make sure all necessary materials are included, review for completeness, and request any additional or clarifying information. Next it goes to an estimator who looks at the request and the existing service available at the site and develops a cost and technical specifications package. The package then moves to a distribution planning team that evaluates any request for additional load to determine whether significant impact to the grid is anticipated, which typically adds time and cost to a project. Finally, the estimator compiles the whole package and sends it back to the customer with full specifications and cost estimates.

PG&E aims to deliver an estimate within three to four weeks, although developers report it can often take longer. The station developer should communicate to PG&E the anticipated length of construction, the target work completion date, the timeline for final inspection, and when they would like to begin new electrical service. Station developers may opt to begin their portion of the trenching and conduit before PG&E begins construction on its portion of the work. Designers and builders can consult the PG&E Greenbook Manual for the exact technical specifications required by PG&E.

The speed at which additional service can be connected depends on the size and scope of the project. If minimal involvement from PG&E is necessary, grid connection should take approximately one month. Larger projects, such as those requiring a new service drop, could take a month to schedule, with a week allotted to perform the work. Additional complexities, such as more undergrounding, right-of-way work, and more intensive service requirements, can push the process out to 3-5 months, or more. The most complex projects could take up to a year, including both the scheduling and completion of work.

An overview of the general process for adding electrical service, from application to service connection, can be found on the PG&E website.

At any point during the process, customers may track the project and review its status through the Customer Connection Online Portal. The portal gives detailed summaries of each step of review, showing when an application has been received and reviewed, when project planning is underway, when the contract has been mailed, and when construction is scheduled.

Southern California Edison

Southern California Edison (SCE) has a dedicated electric vehicle connection team, the Transportation Electrification Project Management (TEPM), which manages customers submitting multiple hydrogen station requests throughout the service territory. This team acts as the single point of contact for multi-site developers including government entities, fleets, and third party developers. SCE routes individual hydrogen station requests through their standard local planning districts and account managers via SCE Local Planning. SCE estimates an average 4-6 months for engineering review and planning once the customer has delivered a complete submittal to SCE. Customer construction timelines will vary based on project scope. Engineering technical review can be the most time-intensive part of the process.

The SCE process for developers, fleets, and other multi-site hydrogen station projects is described on their New Development Project Management page. For single hydrogen station projects or upgrades to existing service extensions, applicants can contact SCE Local Planning. These pages have a wealth of information, many FAQs and all of the forms needed to apply for service or upgrades to existing service extensions. Station developers are encouraged to refer to them when pursuing projects in SCE service territory.

San Diego Gas & Electric

San Diego Gas & Electric (SDG&E) assigns grid connection projects to a geographically close planner who already has familiarity with the area. The planner will gather information on the size of the job and look at their service maps to see whether enough power will be available for the project.

If a station developer is planning to develop multiple hydrogen stations in SDG&E's territory, they can work with one of the design firms with whom SDG&E contracts to ensure more consistency and efficiency than if each site were assigned a different regional staff planner. This list is dynamic and updated frequently. Station developers can request the latest version of the list from the Project Management Group in the geography where the new electric service is needed (there are three offices, provided at the bottom of the Request for Service form).

After this stage, planners are available to perform a site walk with the customer. SDG&E highly recommends the site walk, which often leads to fruitful conversations and highlights opportunities to slightly modify the plans to save money on grid connection costs. After the site walk, the planner will perform additional technical work, as required, such as conducting a fusing study, verifying connections in electrical vaults, and studying the electrical mapping system. This goes into designing the utility portion of the job which concludes in issuing a service order to the station developer with details and instructions for the contractor.

The service order will include a fee for the utility's work. An allowance, based on anticipated ratepayer recovery over the first year of station operation, will be applied to the fee to reduce it. This may result in no fee being charged due to the station developer and the utility bearing the full construction cost. In larger jobs, the fee will still carry a balance.

The customer is responsible for laying all conduit from the transformer to the meter pedestal, as well as connecting the pedestal to the station or stations. SDG&E is responsible for placing wire in the empty conduit between the meter pedestal and the transformer and for placing the meter into the socket. SDG&E may require that their trench inspectors review any trenching before the trenching can be refilled and paved.

After construction is complete, an SDG&E crew will visit the site, make transformer upgrades as needed, put wire through the conduit, connect the transformer to the meter pedestal, and set the meter, energizing the new service.

To minimize costs, SDG&E recommends several steps. Early engagement is key, although a customer will likely not be referred to a planner for a more detailed estimate until a project is reasonably planned out. Trenching, which can easily account for two-thirds of interconnection costs, should be minimized. Trenching through concrete is the most expensive, then trenching through asphalt, then through landscaping. Finally, SDG&E recommends taking a site walk with the assigned planner to discuss the particularities of the site and identify ways to reduce costs.

SDG&E anticipates about twelve weeks to deliver a service order with all information on the work that will be necessary.

More information is available on SDG&E's website as well as the new electric service request form.

Los Angeles Department of Water and Power

Los Angeles Department of Water and Power (LADWP) is the largest municipal water and power utility in the nation, providing service to 1.4 million electric customers in the region. The territory is broken into three service areas, Valley Service Planning, Metro West Service Planning, and Metro East Service Planning.

Before initiating a project, LADWP offers a feasibility study for the potential project site that provides information that may be used for evaluation of alternatives and conceptual estimates of new or upgraded installations. Once a site has been selected, to initiate a new service request, the station developer uses "Find The Right Person" to find the appropriate service planner and office, and provides complete plot plans and/or site plans, building profile and/or elevation plans, one line electrical diagram, load schedule and Service Planning Information Sheet. LADWP assesses the service request, performs an engineering plan review, and provides meter options in a written report. Note that if the project is a dedicated new service or upgrade, the developer must submit a complete submittal package to LADWP to proceed with engineering review and design work. LADWP then provides the service design and Commitment Letter.

For larger projects, such as a hydrogen station, a customer requirement plan is completed (the plan delineates work to be completed by the developer and LADWP). The typical timeline for this portion of the project is approximately 6-12 weeks depending on the size and complexity of the project. For new or existing services requiring conduit work, transformer work, or street resurfacing on public property, charges may be incurred. The Service Planning Engineer will calculate projected charges based on the submitted plans.

The station developer is responsible for scheduling a pre-construction meeting to confirm all requirements – review the service design, discuss inspection requirements, confirm the next steps to complete the installation, and sign any necessary documents. The developer is also responsible for obtaining required permits and final electrical approval from the Los Angeles Department of Building and Safety (LADBS) and installing electric service infrastructure as detailed in the service design.

Once the completion of the electrical service infrastructure is known, the developer arranges final inspections by LADBS and LADWP (via "Find the Right Person") and pays for service installations costs. LADWP then dispatches a crew to perform their portion of the work (typically 6-8 weeks lead time).

More information is available on LADWP's website.

Sacramento Municipal Utility District

Sacramento Municipal Utility District (SMUD) is one of the ten largest publicly owned utilities in the United States, providing electricity to Sacramento County and a small portion of adjacent Placer County.

To initiate a new service request, the developer submits an application with a site diagram, estimated power draw, and a $5,000 deposit (this is later applied to project construction costs). A Line Designer is assigned to the project and begins to create a "commitment drawing." This portion of the project usually takes approximately 60 days. The applicant is then responsible for adding their portion of the infrastructure to the drawing – conduits, boxes, subsurface infrastructure – and ensuring entitlements and other permit requirements are received. Once the developer-installed infrastructure is complete, the applicant and SMUD execute the final contract and the applicant pays the grid connection project costs in full. SMUD typically has a 4-6 week minimum lead time once the project is ready to move forward with construction. The entire process, from applying to having the grid connection complete, is approximately 4-6 months, assuming there are not hold-ups on the project developer side.

To minimize costs and project delays, the SMUD team recommends engaging with them early in the process and utilizing the site "due diligence" service. The SMUD Interconnection Information page outlines the interconnection process, and provides guidelines, applications forms, and other helpful information.

Organizations

Organization	Purpose (as it relates to hydrogen and FCEVs)	Website	Contact
State Government			
California Air Resources Board (CARB)	CARB adopts technology-advancing vehicle emission standards under California's Advanced Clean Cars program, aiming to improve public health and air quality. Specific to hydrogen, CARB issues an annual evaluation of FCEVs and station deployment, pursuant to AB8. The evaluation assesses the current and future FCEV vehicle numbers and current and future hydrogen stations and capacity. CARB also administers the LCFS HRI crediting program. In addition, CARB works with FCEV and hydrogen stakeholders to identify and proactively resolve potential impediments.	https://ww2.arb.ca.gov/our-work/programs/hydrogen-fueling-infrastructure	Andrew Martinez *Hydrogen Program Expert* (916) 322-8449 andrew.martinez@arb.ca.gov
California Building Standards Commission (CBSC)	CBSC is authorized by California Building Standards Law to administer the many processes related to the development, adoption, approval, publication, and implementation of California's building codes.	http://www.bsc.ca.gov/	Mia Marvelli *Executive Director* (916) 263-0916 mia.marvelli@dgs.ca.gov
California Department of Food and Agriculture, Division of Measurement Standards (DMS)	DMS regulates the quantity and quality of hydrogen fuel, to protect the public and ensure fair competition within industry. DMS certifies the accuracy of hydrogen dispensers, enforces fuel quality standards, and enforces advertising and labeling standards.	http://www.cdfa.ca.gov/dms/	Kevin Schnepp *Environmental Program Manager* (916) 229-3458 Kevin.schnepp@cdfa.ca.gov
California Department of Forestry and Fire Protection, Office of the State Fire Marshal (OSFM)	The mission of OSFM is to protect life and property through the development and application of fire prevention engineering, education and enforcement. In relation to hydrogen, OSFM provides guidance on the California Fire Code for station development and safe handling of materials. California was the first state jurisdiction in the nation to adopt NFPA 2 (in 2011), a code that provides fundamental safeguards for the generation, installation, storage, piping, use and handling of hydrogen in compressed gas or liquid form. It is in the process of adopting the 2020 version of NFPA 2.	http://osfm.fire.ca.gov/	Steve Guarino *Chief, Fire and Life Safety Division* (916) 568-2960 steve.guarino@fire.ca.gov
California Energy Commission (CEC)	Through the Clean Transportation Program the CEC invests up to $20 million annually in fueling infrastructure to grow the network of hydrogen stations in California. CEC also issues, with CARB, a joint annual assessment of the time and cost needed to attain 100 hydrogen fueling stations, pursuant to AB8.	http://www.energy.ca.gov/drive/technology/hydrogen_fuelcell.html	Miki Crowell *Advance Vehicle Infrastructure Office* (916) 653-0363 Miki.Crowell@energy.ca.gov

Governor's Office of Business and Economic Development (GO-Biz)	GO-Biz provides resources and assistance to accelerate the ZEV market. It works with FCEV and hydrogen stakeholders to overcome barriers and offers assistance with ZEV for infrastructure development and permitting processes.	http://www.business.ca.gov	Gia Brazil Vacin *Assistant Deputy Director* Zero Emission Vehicle Market Development (916) 319-9968 gia.vacin@gobiz.ca.gov
Local Government			
Bay Area Air Quality Management District (BAAQMD)	BAAQMD is the public agency entrusted with regulating stationary sources of air pollution in the nine counties that surround San Francisco Bay. BAAQMD also provides incentive funding for alternative fuel vehicle and infrastructure projects and is responsible for issuing necessary air quality permits for stations that conduct regulated activities.	http://www.baaqmd.gov/grants	Chengfeng Wang *Manager, Strategic Initiatives* (415) 749-8647 cwang@baaqmd.gov
South Coast Air Quality Management District (SCAQMD)	SCAQMD is the air pollution control agency for all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties. SCAQMD provides funding for hydrogen stations in the region, helping to promote the commercialization of fuel cell electric vehicles. In addition, SCAQMD is responsible for issuing air quality permits for certain types of hydrogen stations during the development process.	http://www.aqmd.gov/home/library/technology-research/projects	Lisa Mirisola *Program Supervisor* Science & Technology Advancement (909) 396-2638 Lmirisola@aqmd.gov
Federal Government			
U.S. Department of Energy (DOE)	Through the Fuel Cell Technologies Office (FCTO), DOE focuses on applied research, development, and innovation to advance hydrogen and fuel cells for transportation and diverse applications enabling energy security, resiliency, and a strong domestic economy in emerging technologies.	https://www.energy.gov/eere/fuelcells/fuel-cell-technologies-office	Laura Hill *Project Manager* Safety, Codes & Standards (202) 586-8384 laura.hill@ee.doe.gov
Pacific Northwest National Laboratory (PNNL)	PNNL works to advance the frontiers of science and address some of the most challenging problems in energy, the environment, and national security. PNNL provides research and engineering to advance fuel cell commercialization.	http://www.pnnl.gov/	Jamie Holladay *Sector Manager* Fuel Cell Technology Office (509) 371-6692 Jamie.holladay@pnnl.gov
Academia			
University of California, Davis (UC Davis)	Through the Transportation Sustainability Research Center (TSRC) at the Institute of Transportation Studies, UC Berkeley analyzes the real world and potential future performance of hydrogen fuel cell electric vehicles. TSRC research focuses on technical performance, economics, policy analysis, behavioral response and environmental impacts of fuel cell technology. TSRC works with automakers to assess infrastructure needs and analyze and test vehicles and fueling stations.	http://steps.ucdavis.edu/?energy-category=hydrogen	Joan Ogden *Professor, Environmental Science and Policy, and STEPS Director* (530) 752-2768 jmogden@ucdavis.edu

University of California, Irvine (UC Irvine)	UC Irvine is home to the National Fuel Cell Research Center, dedicated in 1998 by the U.S. Department of Energy and the California Energy Commission to accelerate the development and deployment of fuel cell technology, to provide an outreach to the market, to address market hurdles, and to provide leadership in the preparation of educational materials and programs throughout the country. In addition, UC Irvine's Hydrogen Program, a component of the Advanced Power and Energy Program, actively develops and demonstrates energy technologies that generate and utilize hydrogen.	http://www.nfcrc.uci.edu/3/research/keyInitiatives/hydrogen/Index.aspx	Jack Brouwer *Director* National Fuel Cell Research Center (949) 824-5468 gss@nfcrc.uci.edu
Membership-based Organizations			
California Fuel Cell Partnership (CaFCP)	The California Fuel Cell Partnership is a collaboration of organizations, including auto manufacturers, energy companies, fuel cell technology companies, and government agencies that work together to promote the commercialization of hydrogen fuel cell electric vehicles.	https://cafcp.org/	Jennifer Hamilton *Safety, Education, Codes & Standards Program Manager* (916) 267-4083 jennifer.hamilton@cafcp.org
California Hydrogen Business Council (CHBC)	The California Hydrogen Business Council is a member based trade association that works to advance the commercialization of hydrogen in the energy sector, including transportation, goods movement, and stationary power systems to reduce emissions and dependence on oil.	https://www.californiahydrogen.org/	Emanuel Wagner *Deputy Director* (310) 455-6095 x360 ewagner@californiahydrogen.org
Fuel Cell and Hydrogen Energy Association (FCHEA)	FCHEA is the trade association dedicated to the commercialization of fuel cells and hydrogen energy technologies. FCHEA represents the full global supply chain, including material component and system manufacturers, hydrogen producers and fuel distributors, government laboratories and agencies, trade associations, utilities, and other end users.	http://www.fchea.org/	Connor Dolan *Director of External Affairs* (202) 261-1331 cdolan@fchea.org
Other			
Hydrogen Safety Panel (HSP)	The HSP is a 15-member group having a broad cross-section of expertise from the commercial, industrial, government, and academic sectors. The HSP seeks to identify safety-related technical data gaps, best practices, and lessons learned, and to help integrate safety planning into hydrogen and fuel cell projects to ensure that the appropriate hydrogen safety practices are addressed and incorporated. The Panel's project-related activities include reviewing equipment and facility designs, risk assessments and safety plans, and conducting site safety reviews.	https://www.h2tools.org/hsp	Nick Barilo *Manager* Hydrogen Safety Program (509) 371-7894 nick.barilo@pnnl.gov

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