CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Fuel Cell Electric Vehicle and Hydrogen Fueling Station Development for San Francisco

Prepared for: California Energy Commission

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-14-603 to support new and existing planning efforts for plug-in electric vehicles and fuel cell electric vehicles. In response to PON-14-603, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards January 16, 2015 and the agreement was executed as ARV-14-043 on April 17, 2015.

ABSTRACT

This report summarizes an investigation for the potential for hydrogen refueling station development in San Francisco, in addition to the currently operational hydrogen station in South San Francisco. This work also includes evaluating the potential for adoption of hydrogen fuel cell electric vehicles into San Francisco and County of San Francisco fleets. The use of fuel cell electric vehicles is being explored along with the use of plug-in electric vehicles in the region.

Keywords: Hydrogen refueling station, San Francisco, fuel cell electric vehicles, plug-in electric vehicles

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EXECUTIVE SUMMARY

In May 2017, the City of San Francisco passed an ordinance mandating that 100 percent of its city fleet vehicles must be zero-emission by the December 31, 2022. The City of San Francisco operates a fleet of approximately 7,500 vehicles, leaving the procurement of new zero-emission vehicles directly to each city department. The commercial development of hydrogen fuel cell electric vehicles made them a possible option for San Francisco, although the limited hydrogen fueling station development in San Francisco is a vital factor in fuel cell electric vehicle procurement.

There were 31 hydrogen fueling stations in the state of California in September 2017, with only 1 of these locations being in the San Francisco region. On February 17, 2017, the Notice of Proposed Awards was released for the California Energy Commission's GFO-15-605 which funded 16 new hydrogen fueling stations in California, including 3 additional stations in San Francisco. These locations in San Francisco are centrally located in the most heavily trafficked areas to best serve a potential hydrogen fleet.

In addition to California Energy Commission hydrogen station funding in San Francisco, there are two other potential sources of proposed funding. These are the Volkswagen Settlement programs as well as funding offered through the Bay Area Air Quality Management District. The Volkswagen Settlement Program offers up to 800 million dollars for advanced vehicle fueling infrastructure in California. The Bay Area Air Quality Management District has also allocated 2.2 million to be invested into Bay Area hydrogen fueling infrastructure.

Hydrogen at fuel cell electric vehicle purity is produced by 4 companies in the Bay Area. (Air Products and Chemicals, Inc., Linde, Praxair, and Air Liquide). Hydrogen fuel is not produced in large amounts in the San Francisco Bay Area. The Energy Commission grant requires that the production of hydrogen from these stations be at least 33 percent renewable. Sourcing this renewable hydrogen creates complexity for station developers but helps to approach the carbon output of plug-in electric vehicles in the state.

There are several other concepts that are beginning to emerge around hydrogen refueling. These include hydrogen energy stations, small scale fueling including mobile refuelers, and hydrogen fuel cell ferry refuelers, which would be located at the San Francisco Pier.

This study finds that the Fleet of San Francisco has interest in hydrogen fuel cell electric vehicles, but the lack of hydrogen refueling infrastructure coupled with the limited commercial fuel cell vehicle offerings make hydrogen vehicles currently less viable than other zero-emission vehicles.

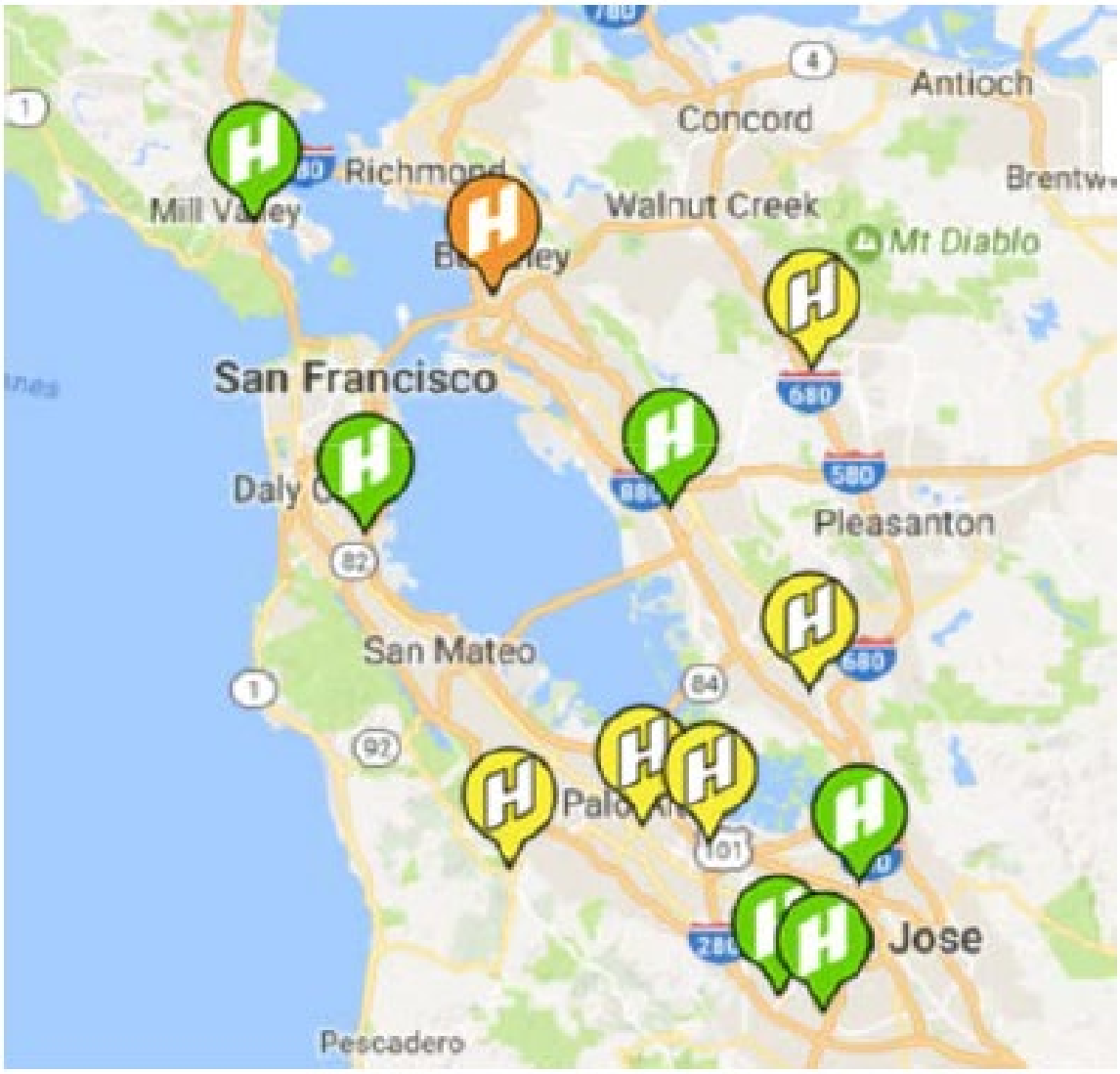
Chapter 1: Introduction

In May 2017, San Francisco passed an ordinance that 100 percent of light-duty passenger vehicles in San Francisco fleet are to be zero-emission vehicles by December 31, 2022, excluding public safety and emergency response vehicles. For vehicles parked on city-owned facilities at least 75 percent of these vehicles are to be zero-emission vehicles and another 25 percent can be plug-in hybrid electric vehicles.[1] Both battery-electric vehicles and Fuel Cell Electric Vehicles (FCEV) would qualify toward meeting the 75 percent Zero-Emission Vehicle requirement.

Hydrogen FCEVs are currently being commercialized by major automakers as a type of alternative fuel vehicles that offers high operational efficiency and low emissions along with fast refueling. These vehicles operate on a pure grade of hydrogen that is stored in pressurized tanks onboard the vehicle. Approximately 31 hydrogen stations are currently operational in California, and many more are in various stages of construction, permitting, or planning. As shown in Figure 1, hydrogen stations in the San Francisco Bay Area are still relatively sparse, particularly in the North end of the Bay Area. The closest hydrogen station to San Francisco is located in South San Francisco, near the San Francisco Airport.

1 "Zero Emission Vehicle Requirements for City Fleet," May 16, 2017, File Number 170210.

Figure 1: Bay Area Hydrogen Station Map – February 2017 Status



Note: Green = Retail Stations; Yellow = Under Construction; Orange = Transit Bus
Source: California Fuel Cell Partnership

Figure 2: Commercial Fuel Cell Vehicles

Note: Left: Toyota Mirai, Center: Hyundai Tucscon, Right: Honda Clarity
Source: Toyota, Hyundai, and Honda

Table 1: Technical Specifications of Commercial FCEVs

	Toyota Mirai	Hyundai Tucson Fuel Cell	Honda FCX Clarity
Driving Range (stated)	312 miles 502 kilometers	265 miles 426 kilometers	366 miles 580 kilometers
Fuel Cell/ Battery	Polymer Electrolyte Fuel Cell + Nickel Metal Hydride battery	Polymer Electrolyte Fuel Cell + Lithium-Polymer battery	Polymer Electrolyte Fuel Cell + Lithium ion battery
H2 Storage Capacity	~5.0 kilograms	5.63 kilograms	5.46 kilograms
Refuel Time	~5 minutes	~5 minutes	~5 minutes
Peak Torque	247 pound*foot 348 newton*meters	221 pound*foot 300 newton*meters	221 pound*foot 300 newton*meters
Peak HP	153 horsepower 114 kilowatts	134 horsepower 100 kilowatts	174 horsepower 130 kilowatts
0-60 Time	9.0 seconds	12.5 seconds	8-9 seconds (preliminary)
Top Speed	111 miles per-hour 179 kilometers per-hour	99 miles per hour 159 kilometer per hour	Not determined Not determined
Curb Weight	4080 pounds. 1851 kilograms	4101 pounds 1860 kilograms	4134 pounds 1879 kilograms
MSRP	$57,500	$50,895	$57,000
Notes	$350/month lease for 36 months, $3649 due at signing, lease includes up to $15,000 of fuel	$500/ month lease for 36 months, $3000 due at signing, lease includes up to $15,000 of fuel	$369/ month lease for 36 months, CA only (LA area), $2,868 due at signing, lease includes up to $15,000 of fuel

Note: MSRP refers to full retail price – special fleet pricing may be available. At present the Hyundai Tucson and Honda Clarity are available through vehicle lease only.
Source: Toyota, Hyundai, Honda

Hydrogen fueling station development in San Francisco is a key under-pinning to potential procurement of FCEVs for San Francisco's fleets. Such procurement is largely driven by the needs and requests of specific departments, but with oversight and procedures from San Francisco Administrator's Office via the Fleet Management Department at Central Shops.

San Francisco fleet policy is guided by San Francisco's climate action goal known as Ordinance 81-08, which pledges a reduction of greenhouse gas emissions 80 percent from 1990 levels by 2050, in alignment with the state's climate action targets.

Each major city department is responsible for its own Climate Action Plan and fleet procurement goals. Enterprise departments, such as the San Francisco Municipal Transportation Agency, the San Francisco International Airport, the San Francisco Public Utilities Commission, and the Port of San Francisco, and well as public safety agencies and the General Services Agency (for non-Enterprise departments), have differentiated responsibility for fleet vehicle procurement and maintenance.

In addition to San Francisco's greenhouse gas reduction goal, San Francisco's Clean Air Plan, implemented in 2004, identifies a 100 percent zero emissions City fleet as a goal for 2020. Produced jointly by San Francisco Municipal Transportation Agency and San Francisco's Department of the Environment, San Francisco's Clean Air Plan aligns with the San Francisco Climate Action Strategy goal to expand access to clean vehicles and fuels.

The City of San Francisco recognizes that there are not viable zero-emission vehicle types in every vehicle category needed to meet San Francisco's needs; therefore, a process is in place to grant waivers for "non-zero emission vehicle" fleet procurements. This process is managed by the Fleet Management Department, in alignment with San Francisco's Healthy Air and Clean Transportation Ordinance, available at https://sfenvironment.org/policy/environment-code.

The Healthy Air and Clean Transportation Ordinance is part of San Francisco's Environmental Code and includes three elements of policy guidance for fleet management:

- Transit First
- Fleet Replacement Using the Cleanest Vehicles Possible
- Fleet Reduction

The Fleet Replacement Policy affirms that City departments must use the cleanest vehicle possible, with exemptions that reflect the unique operational requirements of Enterprise divisions and the public safety agencies. The Vehicle Selector List, managed by the Fleet Management Division, includes the cleanest vehicles in each relevant vehicle category, and applies to light-duty vehicles of 8,500 pounds or less gross vehicle weight rating. Departments that do not select the cleanest vehicle available must submit a waiver request, including the economic and emissions tradeoffs, with an explanation for the requested variance.

In 2015, San Francisco joined the Pacific Coast Collaborative-West Coast Electric Fleets initiative, which is made up of over 26 partners, including the states of California, Oregon, Washington and, the Province of British Columbia and the cities of Los Angeles, Portland, Seattle, Olympia, Oakland, and Vancouver, BC. Members of this partnership pledged to purchase at least 10 percent electric of its annual vehicle procurements. For San Francisco, this includes FCEVs.

In May 2017, San Francisco passed an ordinance that 100 percent of light-duty passenger vehicles in San Francisco fleet are to be zero-tailpipe emission vehicles by December 31, 2022, excluding public safety and emergency response vehicles. The following sections of this report presents key details learned from San Francisco departments and officials regarding various aspects of potential adoption of hydrogen fueling infrastructure in San Francisco. The focus of this report is on the potential for hydrogen station development to support public and private fleet adoption of FCEVs by San Francisco departments. The issue of hydrogen fueling support infrastructure in San Francisco, a key constraint given the geography and physical constraints from the built environment, is also addressed.

Chapter 2:
City of San Francisco Vehicle Fleet

The fleet of vehicles operated by various departments in San Francisco includes approximately 7,500 vehicles of various types based on a recent inventory. In addition to cars, vans, lighter and heavier pickup trucks, and heavy-duty vehicles, the inventory also includes trailers, carts, small off-road vehicles, and motorcycles. Table 2 shows the breakdown of the fleet by vehicle type and what vehicle types are eligible for FCEV use based on current market offerings. Police patrol vehicles are not eligible because they must be pursuit rated, and there is no zero-emission option available.

Table 2: Vehicle Count by Fuel Type

Vehicle Category	Total Vehicle Count	Vehicle Count by Fuel Type									
		Diesel	Gas	Hybrid	All-Electric	Plug-In Hybrid	Hydrogen	CNG	Propane	Unknown	Notes
Cars	1,271		560	530	37	15		129			Eligible for FCEV use
SUV	209		136	65	8						Eligible for FCEV use
Pickup Trucks	1,750	140	1,421	4				185			
Trucks	782		106					13			Eligible for FCEV use
Vans	709	54	533	2	1			118		1	
Buses	54	48	5					1			Eligible for FCEV use
Motorcycles	151		151								
Carts	577	3	468		106						
Small Off Road	542	161	227	13	72			3	57	9	
Trailers and Misc.	914	197	104	2	31		2			578	
Heavy Equipment	174	133	30						10	1	
Cars-Patrol	270		270								
SUV-Patrol	91		91								
Total	7,494	736	4,102	616	255	15	2	449	67	589	

Source: San Francisco Department of the Environment, 2016

Hydrogen Fuel Cell Vehicles for San Francisco Fleets

Vehicle procurement for City fleets is conducted on an annual basis, based on requests from specific departments, by the San Francisco Administrator's Office. Departments may request vehicles from the Vehicle Selector List, which includes zero and low-emission vehicles.

The following sections of this report presents key details learned from City departments and officials regarding various aspects of potential adoption of hydrogen FCEVs and fueling infrastructure in San Francisco. The focus of this report is on the potential for fleet adoption of FCEVs by City departments along with the critical issue of hydrogen fueling support infrastructure in San Francisco. This fueling infrastructure question is a key constraint given the geography and physical constraints from the built environment in San Francisco.

San Francisco Fleet Administration, Central Shops

The Fleet Administration Department at Central Shops provides fleet services to over 70 City departments, with a combined fleet of about 7,500 vehicles of various types. The department operates five maintenance and repair facilities and also provides fleet management, vehicle leasing, motor pools, alternative fuel programs, and fueling services.

A meeting was held with Fleet Administration staff on June 6, 2016 to discuss aspects of potential hydrogen FCEV adoption by City fleets. Present at the meeting were Tom Fung, Don Jones, and William Zeller from Fleet Administration; Suzanne Loosen from San Francisco Department of the Environment, and Timothy Lipman (consultant). Topics discussed include procedures for procurement of new vehicles for City fleets, including alternative-fuel vehicles, previous experiences with alternative fuel vehicles, the recent test experience with the Toyota Mirai FCEV (as part of a Toyota fleet demo program), and concepts for hydrogen refueling infrastructure within San Francisco.

A key outcome of the meeting was a clear understanding of fleet procurement procedures and guidelines. A typical request for a clean fuel vehicle by an S.F. department could proceed as follows:

1. Department makes vehicle purchase request to Central Shops showing department director approval;
2. If special fueling infrastructure needed (e.g. electricity, compressed natural gas, or hydrogen) then an infrastructure plan is requested;
3. Information is provided for life cycle cost and emissions assessment using Central Shops calculator spreadsheet;
4. Vehicle bid specifications are developed;
5. Approval is granted for alternative fuel vehicle purchase (if appropriate);
6. Vehicles are procured based on satisfactory vendor bids.

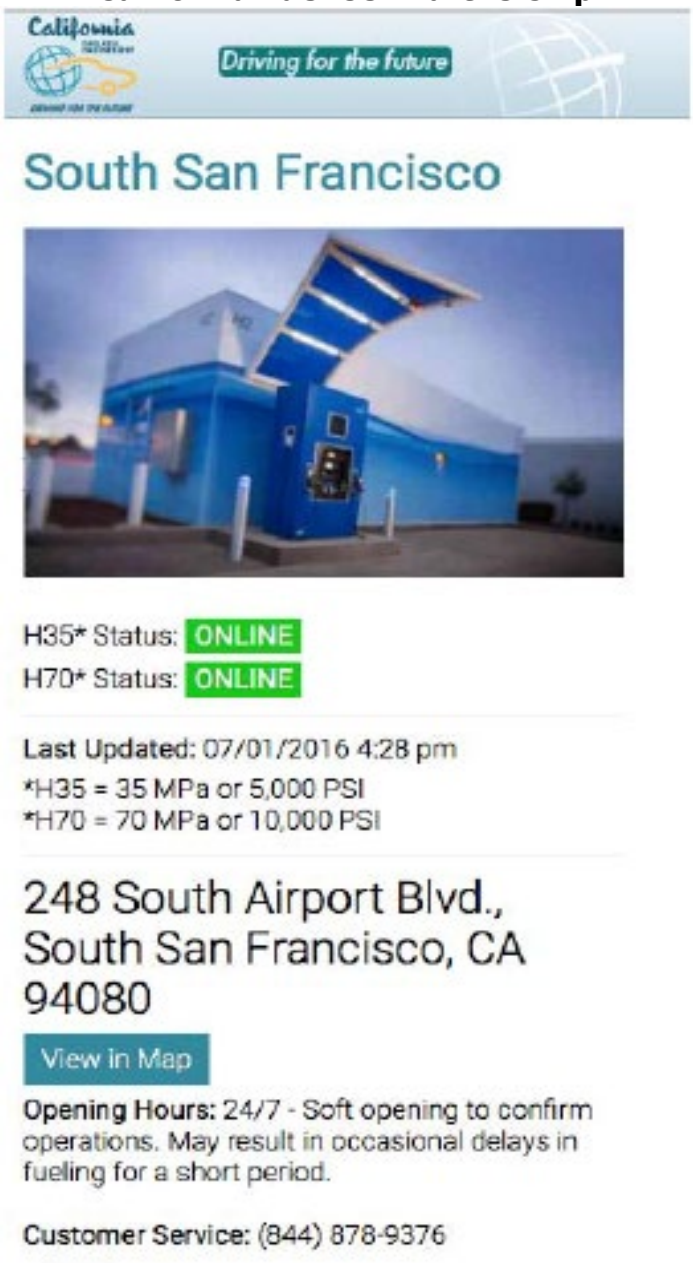
A follow up item from the meeting was for Fleet Administration to provide their template for assessing life cycle cost trade-offs with vehicle purchases. This was subsequently provided, and a Toyota Mirai FCEV sedan case was added to the spreadsheet calculator by project staff for purposes of comparison. See the section below for the results of this Toyota Mirai comparison calculation.

San Francisco International Airport

The airport operates vehicles for airport ground support as well as for the San Francisco Fire Department. Various types of vehicles are included in the onsite fleet, including baggage handling vehicles, sedans, and SUVs.

The South San Francisco hydrogen station, operated by First Element Fuel, provides convenient hydrogen refueling for the San Francisco International Airport site at pressure levels of 350 and 700-bar (5,000 and 10,000 pounds per square inch). The station is located at 248 South Airport Blvd., approximately 1 mile from the airport terminals. The current price at the station is $16 per kilogram of hydrogen fuel, and it is "full retail" (i.e., credit card) access. Figure 3 depicts the station and its key characteristics, as shown on the California Fuel Cell Partnership "Station Operating Status System" website.

Figure 3: South San Francisco Hydrogen Fueling Station Status Monitor Through California Fuel Cell Partnership



Source: California Fuel Cell Partnership

A meeting was held with San Francisco International Airport managers on April 21, 2016. Attendees included Roger Hooson, David Mondani, and Derek Fliess from San Francisco International Airport, Suzanne Loosen from San Francisco Department of the Environment, and Timothy Lipman (consultant).

The focus of the meeting was potential adoption of FCEVs for San Francisco International Airport operations, based on the current availability of the South San Francisco hydrogen station. Vehicle fleet needs and procurement procedures were discussed, along with current fleet inventory and replacement needs. San Francisco International Airport has about 2,000 "ground support equipment" vehicles, including approximately 400 road vehicles. Of the overall fleet including baggage handling, approximately one-third operates on diesel fuel, approximately one-third operates on compressed natural gas or liquefied petroleum gas, and approximately one-third is electric. The San Francisco Fire Department operates additional vehicles at San Francisco International Airport, including sedans and SUVs.

San Francisco Public Utilities Commission, Department of Water and Power

A meeting was held with fleet managers of the San Francisco Public Utilities Commission, Department of Water and Power on (April 2016). Attendees included Napoleon Campbell and Michael Gray from San Francisco Public Utilities Commission, Suzanne Loosen from San Francisco Department of the Environment, and Timothy Lipman (consultant). The meeting focused on potential use of FCEVs among the fleet operated by San Francisco Public Utilities Commission, with approximately 1,000 vehicles in the department fleet.

Key findings from the meeting include that the department has mixed luck with previous compressed natural gas vehicles, based partly on "educational issues" around the vehicle characteristics, and that the department is currently experimenting with two Toyota Prius plug-in hybrid electric vehicles. Furthermore, renewable diesel fuel is being used as a replacement for fossil diesel in diesel vehicles, with good results so far. Additional information gleaned includes that there are various municipal sites where fuel is dispensed (of possible interest for adding hydrogen fueling infrastructure) and also that Fleet Administration/ Central Shops maintains a clean vehicles list for use by City departments. A list of City refueling sites was obtained as a follow-up to the meeting.

San Francisco Municipal Transportation Agency

San Francisco Municipal Transportation Agency has previously examined the potential for adoption of hydrogen fuel cell buses, noting the use of hydrogen fuel cell buses by Alameda Contra Costa Transit in the East Bay for many years. The Alameda Contra Costa Transit hydrogen refueling station in Emeryville, also offering relatively low-cost fuel compared to other stations because the agency is not currently raising any profit from hydrogen sales to light-duty vehicles. San Francisco Municipal Transportation Agency has no immediate plans to purchase fuel cell buses and thus there are no immediate opportunities for synergy with efforts to deploy light-duty FCEVs, e.g., for a combined use hydrogen fueling station such as that in Emeryville.

Mirai FCEV Fleet Lifecycle Cost Calculation

Based on the calculation framework provided by Fleet Administration, a calculation was developed for the lifecycle cost of the Toyota Mirai FCEV. Based on the assumptions shown in Figure 4, the Toyota Mirai has a lower full life cycle cost than the "Ford Focus – Gasoline," and the "Honda Compressed Natural Gas" vehicles, but the "Average Replacement Sedan," "Ford Focus – Gasoline," "Nissan Leaf," "Prius Hybrid" and "Prius Plug-in Hybrid Electric Vehicle"

have lower life cycle costs. However, only the Nissan Leaf has lower lifecycle greenhouse gas emissions than the Toyota Mirai FCEV. Fleet Administration considers the greenhouse gas emissions of the Nissan LEAF to be minimal because of they receive greenhouse gas-free electricity from San Francisco Public Utilities Commission ’s Hetch Hetchy Reservoir. Also note that the driving range of the Leaf is approximately 80-90 miles, while the Mirai offers an approximate 250-mile driving range.

The Toyota Mirai fleet purchase economics were considerably better in 2016 when California offered a $15,000 incentive for purchase of fleet-based FCEVs. However, the incentive dropped to $5,000 per vehicle in 2017, reflecting the economics shown in Figure 4.

Figure 4: Life Cycle Assessment Cost of San Francisco Fleet Sedan Vehicles

Life Cycle Costs	Average	Ford Focus		Nissan Leaf	Prius			Honda CNG	Mirai	
Fuel/Drive	Replacement	Gasoline		BEV	Hybrid	PHEV		CNG	FCV	
	Sedan (1)					Electric	Gasoline			
Capitalization Cost (2)	$ 20,773	$ 13,416		$ 35,430	$ 22,035	$ 31,109		$ 26,424	$ 40,800	DGS fleet pricing
Incentives (3)				$ (20,000)	$ -	$ (8,750)		$ -	$ (7,500)	Assumes $5K CVRP
Maintenance (4)	$ 16,446	$ 26,300		$ 3,628	$ 14,510	$ 14,510		$ 18,200	$ 3,628	
Life Cycle Fuel Cost (2)	$ 8,631	$ 19,715		$ 3,006	$ 9,095	$ 1,760	$ 5,290	$ 3,283	$ 13,536	3 years fuel incl.
Fueling Labor Cost (5)	$ 26,366	$ 30,284		$ 5,863	$ 14,558	$ 5,863	$ 9,506	$ 46,298	$ 30,284	same as gasoline
Accident Loss (6)	$ 2,234	$ 2,234		$ 2,234	$ 2,234	$ 2,234		$ 2,234	$ 2,234	
Full Life Cycle Cost	$ 74,450	$ 91,949		$ 30,161	$ 62,432	$ 61,523		$ 96,439	$ 82,982	
Life Cycle Cost Savings (vs Baseline)	N/A	$ (17,499)		$ 44,289	$ 12,018	$ 12,927	N/A	$ (21,989)	$ (8,532)	
Life Cycle GHG Emissions (Tonnes*)	49.9	$ 73		$ -	$ 53	$ 31	N/A	$ 34	$ 25	

Cost/Mile	$ 1.00	$ 1.01		$ 0.33	$ 0.69	$ 0.68		$ 1.06	$ 0.92
Cost/Mile W/O Fueling Labor	$0.65	$0.62		$0.24	$0.48	$0.52		$0.50	$0.53

Note: Based on a Life Cycle Assessment Calculator Developed by San Francisco Fleet Administration
Source: San Francisco Fleet Administration

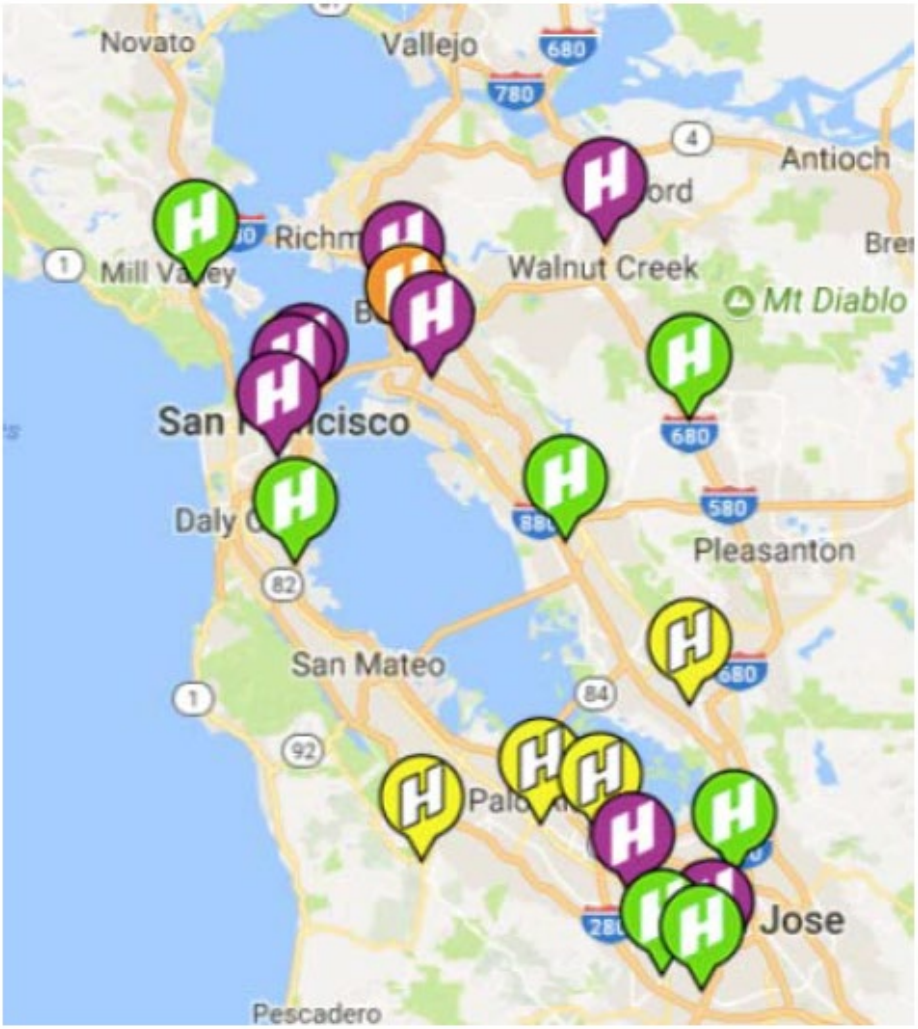
Chapter 3:
Hydrogen Fueling Infrastructure

Current Hydrogen Fueling Status in California

As of September 2017, there are 31 open "retail" stations and several other restricted access stations operating in California, mostly offering both 350 and 700 bar (5,000 and 10,000 pounds per square inch) fill pressures. All of the currently available commercial light-duty FCEVs accept hydrogen fuel at 700 bar of pressure, and typically with the fuel pre-cooled to -40 F. (-40 C.) just prior to vehicle fueling to avoid heating of the vehicle storage tanks at the end of the fueling process. Some other fleets such as the hydrogen buses operated by Alameda Contra Costa Transit in the Oakland/Berkeley area refuel at 350 bar.

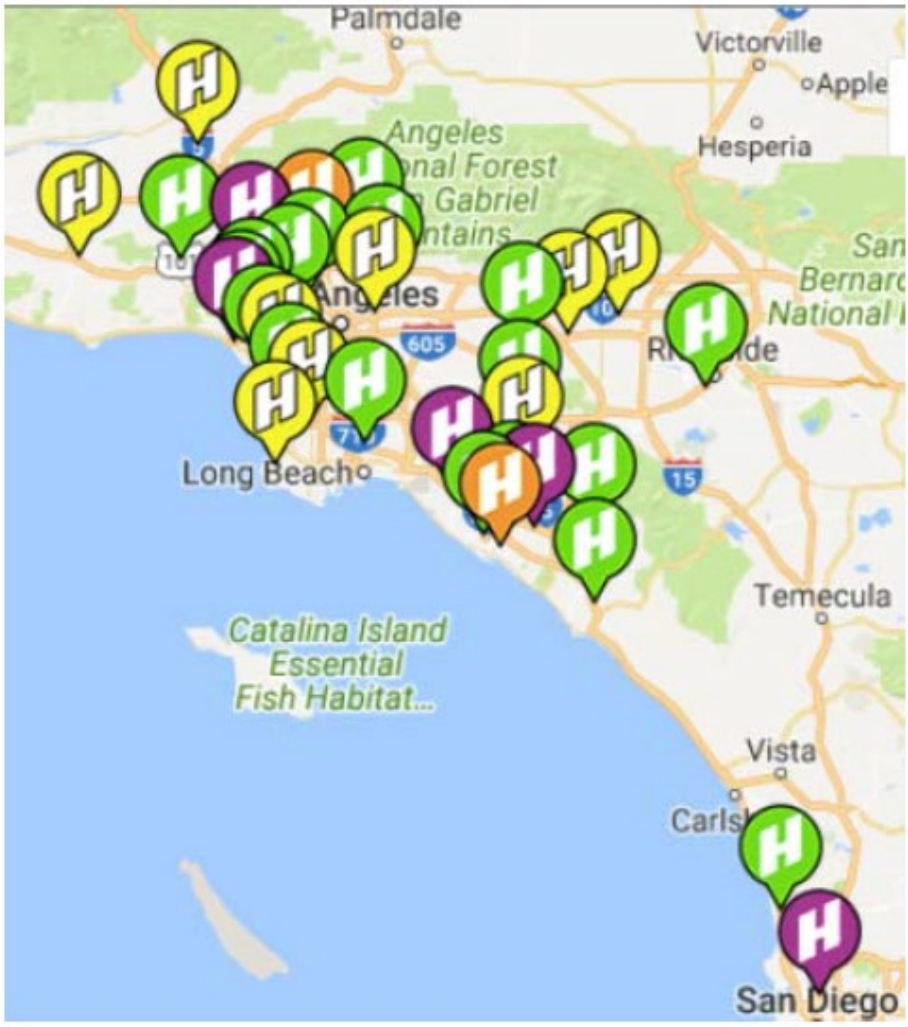
Figures 5 through 8 show the current layout of hydrogen fueling stations in California, now including a "connector" station in Coalinga that allows for travel between Northern and Southern California in the latest 250-300-mile range FCEVs. Shown in the figures are green dots for open retail stations, yellow dots for stations under development, orange dots for combined bus and light vehicle fueling stations, and purple dots for planned stations.

Figure 5: San Francisco Bay Area Hydrogen Station Development Status



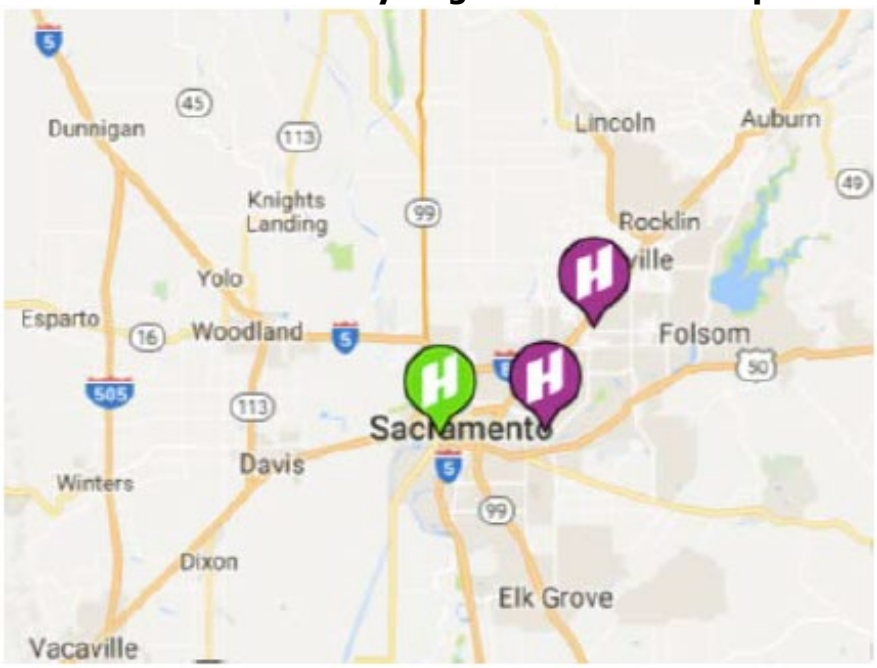
Source: California Fuel Cell Partnership

Figure 6: Southern California Hydrogen Station Development Status



Source: California Fuel Cell Partnership

Figure 7: Sacramento Area Hydrogen Station Development Status



Source: California Fuel Cell Partnership

Figure 8: Central California Hydrogen Station Development Status

Source: California Fuel Cell Partnership

Figure 9 depicts a typical new hydrogen station layout, in this case for the South San Francisco Station near San Francisco International Airport. Here the hydrogen-fueling pump is co-located with a gasoline station location but typically set in a side location adjacent to the main gasoline/diesel pump canopy. The California Fuel Cell Partnership 's real-time "station operating status system" website allows FCEV drivers to access current information about station status, available at https://cafcp.org/stations.

Figure 9: South San Francisco Hydrogen Fueling Station

Source: California Fuel Cell Partnership

Hydrogen Station Awards Under CEC GFO-15-605

In a major development for hydrogen fueling stations in the state, the California Energy Commission announced "Notice of Proposed Awards" on February 17, 2017 for 16 additional hydrogen stations in California for a total of $33 million in new state funding under GFO-15-605. The award notice is titled "Light Duty Vehicle Hydrogen Refueling Infrastructure."

The awards include three stations within the City of San Francisco, all to be built and operated by Equilon Enterprises LLC, a division of Shell Oil Products U.S. The awards also include one station for Berkeley (Equilon), one for Oakland (FirstElement Fuel), one for Walnut Creek (Equilon), one for Sunnyvale (FirstElement Fuel), and one for Campbell (FirstElement Fuel) in

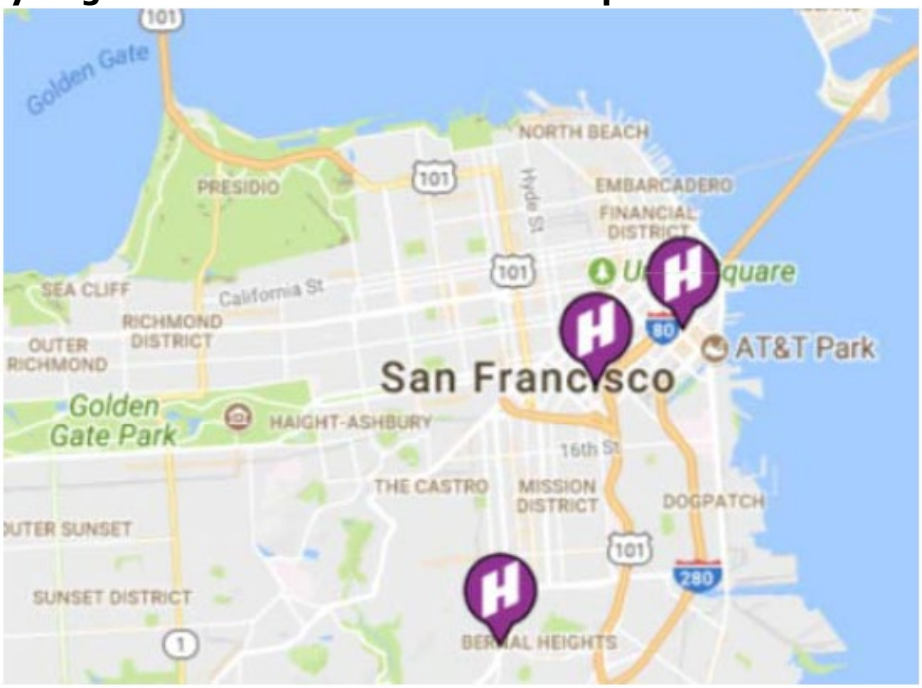
the Bay Area, and several for Southern California. In total, eight of the sixteen awards went to FirstElement Fuel, seven to Equilon, and one to Air Liquide for a "connector" station in Santa Nella, California, to the East of San Jose.

The San Francisco locations are shown in the map in Figure 10; all will be co-located with existing Shell gasoline stations. The exact locations identified in the Notice of Propose Awards are:

- 551 Third St. (South of Market Street)
- 3550 Mission St. (Mission/Bernal Heights District)
- 1201 Harrison St. (South of Market Street)

These central locations appear ideal to support the initial rollout of 700-bar (10,000 pounds per square inch) hydrogen refueling in San Francisco, located close to the most heavily trafficked locations and corridors in San Francisco. Future stations could be located along the Hwy 1 corridor in the western area and in the Golden Gate Park area, and in the Northern area of San Francisco (Fisherman's Wharf/Lombard Street), to provide more complete coverage.

Figure 10: Hydrogen Stations from "Notice of Proposed Awards" in San Francisco



Source: California Fuel Cell Partnership

Progress toward completion of these stations will be tracked over time by the California Fuel Cell Partnership and the Governor's Office of Business and Economic Development. These organizations have developed a helpful "Hydrogen Station Permitting Guidebook" for use by local municipalities.

Appendix B includes further details of the GFO-15-605 Notice of Proposed Awards released in February 2017, including award amounts and site match funding, as well as the awardees and locations.

Outreach Efforts for Hydrogen Fueling Stations in San Francisco

Several meetings have been held with City departments related to these project efforts, including those focused on adoption of FCEVs by San Francisco as well as hydrogen station

development efforts. Following is a brief synopsis of key meetings related to hydrogen station development planning and facilitation.

San Francisco Mayor's Office

A meeting was held with the San Francisco Mayor's office on June 21, 2016. Meeting attendees included Tyrone Jue (Senior Advisor on the Environment, Office of Mayor Edwin M. Lee); John Updike (Director of San Francisco's Real Estate Division); Suzanne Loosen (San Francisco Department of the Environment); Michael Parks (Director, Business Council on Climate Change); Timothy Lipman (consultant); and Geri Yoza, Rommel Momen, Jeff Sievers, and Jay Turmell (Toyota North America).

Discussed at the meeting were hydrogen FCEV adoption by City fleets and hydrogen refueling station locations and plans. Representatives from Toyota explained the company's commitment to commercializing the Mirai FCEV and their willingness to work with San Francisco on both vehicle adoption and hydrogen station concepts to help meet City and statewide environmental and energy goals. City staff explained their general receptiveness to hydrogen station concepts, but the "real world" constraints faced in San Francisco with regard to setback requirements, local community concerns, and potential "community enhancement" aspects as part of potential station developments. One potential avenue for making City land available for a lease for a hydrogen refueling station would be a "public benefits statement" that could potentially allow the land to be leased at a reduced rate. At the end of the meeting a Toyota Mirai FCEV was displayed in front of City Hall and offered for "ride-and-drives" after the meeting.

Hydrogen Fuel Cell Ferry Refueling Station

One concept for hydrogen fueling facility development for San Francisco is an idea proposed by Red and White Fleet, a tenant of the Port of San Francisco, for a hydrogen fuel cell-powered ferry that would operate in and around San Francisco, fueled with cryogenic liquid hydrogen. A hydrogen fueling depot would supply liquid hydrogen to the ferry boat (partly through a fuel "bunkering" scheme) in quantities of approximately 1,000 kilograms per day. Such a station could also be designed to provide 700-bar gaseous hydrogen fueling for light-duty vehicles as well as potential for bus and delivery truck fueling.

The ferry operator Red and White Fleet has expressed continued interest in the project, first proposed in 2014. The project team attended a meeting on April 7, 2016 at Red and White offices in San Francisco with top company officers, including Tom Escher, Richart Berman from the Port of San Francisco, and Lenny Klebanoff and Joe Pratt from Sandia National Laboratory, which is conducting a feasibility study of the proposed ferry. The goal of the meeting was to discuss and elaborate on these ideas and plans as the Sandia National Laboratory study was being conducted. Discussed were the potential sites for refueling facilities; tie-ins with potential light-duty and transit bus fueling; potential connections to the "Chase Center" (future home of the Golden State Warriors); codes, standards, and permitting considerations along with potential support from City agencies; and hydrogen fuel supply considerations. Additional details about the proposed hydrogen-powered ferry boat and fueling station concept are presented later in this report.

Pre-Application Meeting for Proposed Hydrogen Station

In preparation for submitting a proposal for funding under GFO-15-605, San Francisco Department of the Environment, in collaboration with the Center for Transportation and Environment, organized a "pre" preapplication meeting for hydrogen station applicant, Shell,

and our city permitting, zoning, and inspection stakeholders on July 12, 2016 (an official pre-application involves fees). In the meeting, we discussed roles and responsibilities, identified the planning project lead, and laid out an expedited permitting pathway for hydrogen fueling to be added to three existing gasoline service stations. The developer proposed three stations to strengthen the possibility of winning the two that were planned for this funding cycle.

Meeting Participants:

- San Francisco Department of Environment
- San Francisco Planning Department
- Department of Building Inspection
- Bureau of Fire Prevention – Fire Plan Check Section
- UC Berkeley Transportation Sustainability Research Center
- Station Developer (Shell)
- Center for Transportation and the Environment (Developer's Consultant)

During the post-meeting debrief, San Francisco Department of the Environment recommended that the station developer consider procuring 100 percent renewable electricity from CleanPowerSF to provide power at these new hydrogen stations, including the existing gas pumps and c-stores.

CleanPowerSF is a community choice aggregation program managed by the San Francisco Public Utilities Commission. This commitment strengthened the Shell/Toyota CEC application, which beat two other applicants. Shell's proposal for San Francisco stations scored at the top of the selection criteria and resulted in the award of three stations versus the anticipated two.

Norwegian Delegation from Akershus County

Representatives from the San Francisco Department of the Environment, the California Fuel Cell Partnership, and Air Liquide met with a Norwegian hydrogen delegation on February 15, 2017 in San Francisco. The group represented Akershus County, which surrounds the Capital City of Oslo, and was led by Mayor Mrs. Anette Solli. For the meeting agenda, Ms. Jessie Denver from San Francisco Department of the Environment presented an overview of San Francisco city sustainable transportation efforts. Dr. Timothy Lipman provided an overview of the latest U.S. and California developments with regard to hydrogen fuel cell vehicles and fueling stations, as well as an overview of environmental considerations for hydrogen production. Mayor Solli then presented information on the latest efforts in Norway to promote hydrogen fuel cell vehicles as well as plug-in electric vehicles for both lighter and heavier duty applications, especially taxis and buses.

Discussions were then held with regard to comparative hydrogen infrastructure development activities in the two regions, FCEV adoption status, and policy and regulatory considerations. The Norwegian team reported that their program was proceeding in two phases, one from 2014-18 and a second one from 2019-2025. The objective by 2018 is to have seven to eight high capacity hydrogen stations in the region (versus one at present), 25 buses (versus five at present), 350 FCEVS (versus about 50 at present), and 100 FCEV taxis. By 2025 the goals are to have 10,000 FCEV passenger cars, 500 taxis, and 100 buses. These goals are driven by strong Norwegian national directives to make all new cars, buses, and light vans zero-emission (from the tailpipe) by 2025.

FCEVs and other EVs are expected to become increasingly important in the Akershus region, given Oslo's recent two-day ban of diesel vehicles on municipal roads because of severe pollution from a winter inversion layer.

Berkeley Energy Commission

On May 24, 2017, Dr. Timothy Lipman was invited to attend and present at a meeting of the Berkeley Energy Commission. The invitation was pursuant to the Commission hearing about the CEC award for the proposed Equilon, LLC hydrogen station at a location on University Avenue in Berkeley. The Commission requested an update on the current status and plans for hydrogen refueling infrastructure in California, particularly in the Bay Area, along with the commercial status of FCEVs, an overview of electric vehicle charging infrastructure programs, and the CEC "NorthCAT" project for alternative fuel vehicle outreach and training. Berkeley City staff also provided an update to the Commission with regard to development of electric vehicle charging infrastructure in the City of Berkeley.

With regard to hydrogen fueling stations and FCEVs, the following topics were covered:

- Commercialization status of FCEVs;
- Current status of hydrogen fueling infrastructure in California; and
- Hydrogen system permitting and safety considerations.

The session concluded with questions and answers with Commission members and additional exchange of information. One issue that came up is that permitting of a hydrogen fueling station for the selected Berkeley site on University Avenue may be somewhat of a lengthy process because the environmental and building permit processes are not able to be conducted concurrently.

Additional Hydrogen Station Funding Opportunities for San Francisco

In addition to the primary hydrogen station funding mechanism from the Energy Commission under the Clean Transportation Program, there are two other funding mechanisms that may be available for San Francisco sites. These are: 1) the Volkswagen Settlement program, and 2) programs offered by the Bay Area Air Quality Management District.

The $2 billion U.S. Volkswagen Settlement agreement was announced in 2016; up to $800 million will be available for advanced vehicle fueling infrastructure in California under the "Electric Vehicle Infrastructure Investment Plan." The settlement results from the sale of about 70,000 Volkswagen vehicles in California that were equipped with diesel engine and emission control systems that were designed to bypass the goals of vehicle emission certification programs. The funds will be programed in 30-month cycles. Applications for the first phase of the California program were accepted beginning in December 2016.

The infrastructure defined as eligible under the Electric Vehicle Infrastructure Investment Plan specifically allows for the development of stations to dispense "hydrogen for fuel cell vehicles." The specific language in the Plan guidance from the California Air Resources Board is:

> Hydrogen used as a transportation fuel is important in California. VW is strongly encouraged to include hydrogen investment; if not now in a subsequent 30-month investment plan. In this way, VW and California will promote zero-emission vehicles but remain technology neutral. Hydrogen fuel has attributes that may mitigate grid supply and demand inequities, be applicable to medium and heavy-duty transportation, and

> provide long-range refueling as quickly as gasoline or diesel. Although VW has expressed more interest in plug in technologies, California has many opportunities to invest in the early development of the hydrogen refueling station network. Establishment of an efficient, reliable and accessible fueling network will open up the market for fuel cell vehicles and provide an opportunity for a more renewable transport sector, opening new opportunities for car makers including Volkswagen to successfully market zero emission vehicles fueled by zero emission sources of energy.

So although the initial 30-month period does not include a focus on hydrogen fueling stations and is instead completely focused on electric vehicle charging infrastructure, there is a strong sense that the California Air Resources Board would like to see complementary investments in hydrogen moving forward.

The Bay Area Air Quality Management District has also released grant opportunities for hydrogen station projects, most recently in early 2016. In the latest program, $500,000 was available for fiscal year 2016 as part of a $2.2 million investment to be allocated to the development of Bay Area hydrogen stations. However, no announcements were made about awards in 2016 and it appears that there were no successful applicants. This is potentially because the California state program through the Energy Commission offers higher allowable "capital expense" costs and was a more attractive opportunity.

Hydrogen Fuel Supply for the San Francisco Bay Area

Hydrogen at the level of purity required for FCEV applications is provided in the San Francisco Bay Area by four major fuel providers. These include Air Products and Chemicals, Inc., Linde, Praxair, and Air Liquide. A company called First Element Fuel is also in the business of sourcing hydrogen for hydrogen fueling stations that it designs and constructs, working most closely with Air Products and Chemicals, Inc.

Hydrogen fuel is not produced in large amounts in the San Francisco Bay Area except as "captive" production by the region's major oil refineries. As refinery blends are changing over time, an increasing amount of hydrogen is needed for refinery "hydrocracking" and "hydrotreating" processes. Refineries in the area are upgrading their hydrogen production facilities and/or sourcing merchant hydrogen from the above providers to help meet their growing demands.

Hydrogen for the Alameda Contra Costa County Transit Emeryville station is supplied by Praxair. The fuel is typically trucked from Long Beach in Los Angeles in liquid form. Air Products has a hydrogen production and liquefaction facility in Sacramento that is also capable of delivering high purity hydrogen to the San Francisco Bay Area.

The Energy Commission grant program requires hydrogen stations to be at least 33 percent powered by renewable feedstocks, including both the hydrogen gas throughput and electricity use of the refueling station. An associated "well to wheels" analysis is required to be included in each proposal. Stations can receive higher scores by increasing that value above 33 percent. In practical terms with current technologies, this necessitates station developers to either: 1) source biogas to be reformed into hydrogen, and/or 2) derive hydrogen from electrolysis of water using renewable sources of electricity and the use of "electrolyzer" devices.

The specific language in the latest GFO-15-605 solicitation was:

> Proposed projects must dispense a minimum renewable hydrogen content of at least 33 percent renewable hydrogen (on a per kilogram basis) either 1) at each, individual

hydrogen refueling station or 2) as an average of hydrogen dispensed across a collection of a grant recipient's hydrogen refueling stations receiving capital expenditure funding under this solicitation. Hydrogen refueling stations not receiving capital expenditure funding under this solicitation cannot be used to meet the minimum renewable hydrogen content requirements under this solicitation. Proposed projects committing to dispense more than the required 33 percent renewable hydrogen content will score higher in accordance with the Evaluation Criteria in this solicitation.

Eligible renewable feedstocks include:

- Biomethane or biogas such as: biomass digester gas, landfill gas, sewer gas, or municipal solid waste gas.
- Other feedstocks may be eligible if the Application demonstrates that the proposed feedstock is sustainably produced, reduces greenhouse gas emissions compared to the petroleum baseline, and achieves the Clean Transportation Program sustainability goals contained in 20 CCR 3101.5.

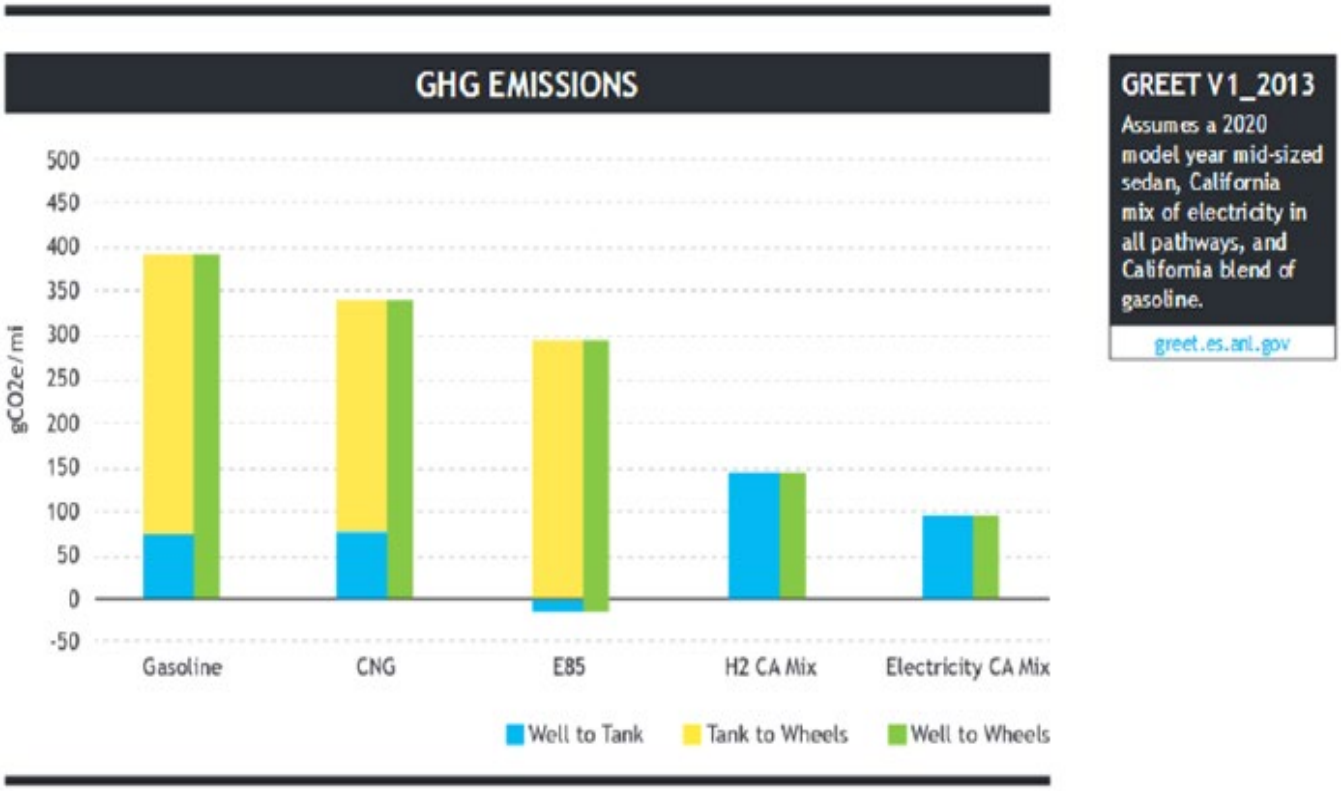
Eligible renewable electricity sources include facilities that use the following:

- Fuel cells using renewable fuels
- Geothermal
- Small hydroelectric (30 megawatts or less)
- Ocean wave
- Ocean thermal
- Tidal current
- Photovoltaic
- Solar Thermal
- Biomass digester gas
- Municipal solid waste conversion (non-combustion thermal process)
- Landfill gas
- Renewable Energy Credits
- Wind[2]

Sourcing this renewable hydrogen component provides additional complexity for station developers but improves the "carbon footprint" of the dispensed hydrogen because of the blending in of low-carbon renewable feedstocks. As shown in Figure 11, using this 33 percent renewable and 67 percent natural gas steam reforming "California mix" approaches the level of greenhouse gas emissions from plug-in electric vehicles in California and significantly improves upon the combustion-based options using gasoline, natural gas, or ethanol.

2 California Energy Commission (2016), "Light Duty Vehicle Hydrogen Refueling Infrastructure Application Manual," Alternative and Renewable Fuel and Vehicle Technology Program, GFO-15-605, July.

Figure 11: Fuel Cycle Emissions Implications of Hydrogen FCEVs in California



Source: California Fuel Cell Partnership

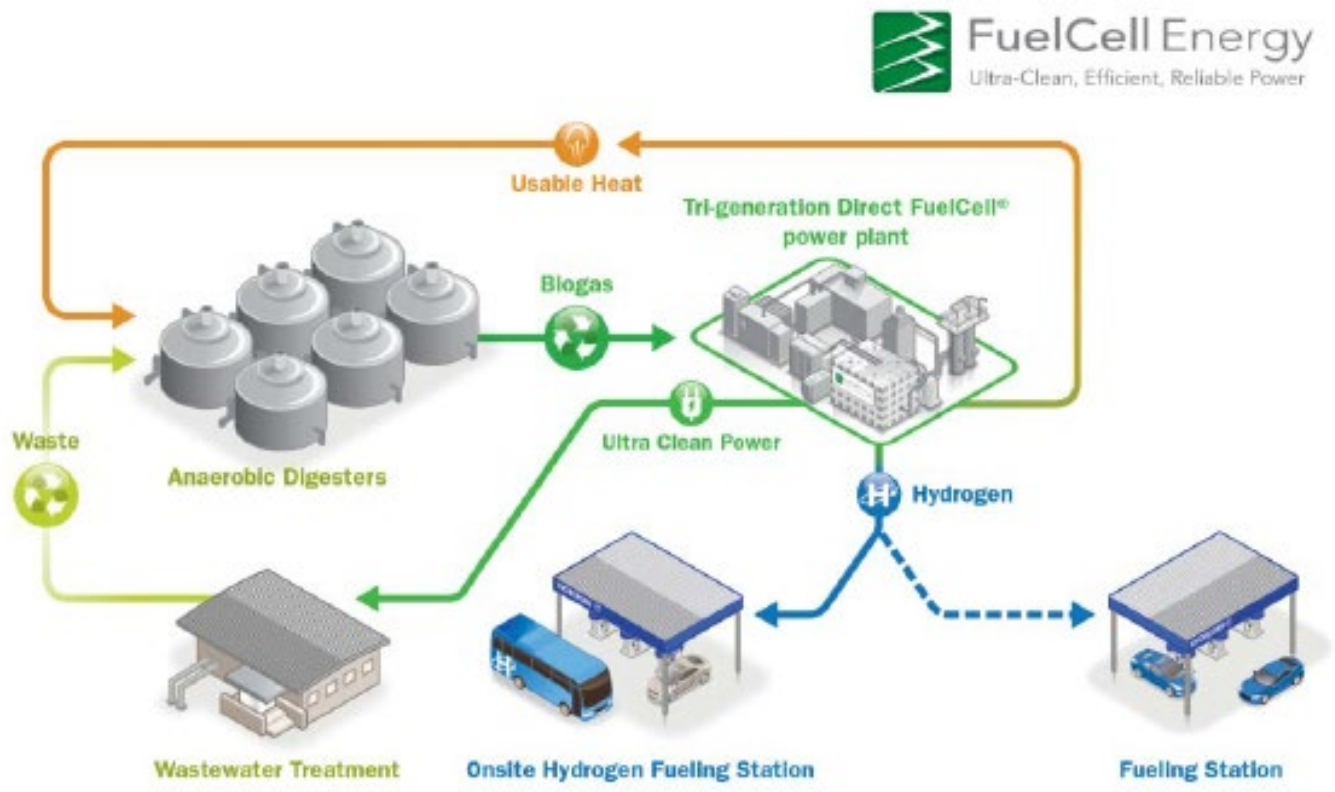
Hydrogen Energy Stations

The concept of hydrogen energy stations has been investigated and tested in various configurations over many years but still in a pre-commercial phase. The basic idea is production of electricity using stationary fuel cell systems, along with purified hydrogen for vehicle fueling, and waste heat for local uses. This is sometimes called "tri-generation" or "polygeneration" as a further advance from the more conventional "co-generation" of electricity and waste heat.

Hydrogen energy stations can be based around two main concepts: 1) dual use of a natural gas reformer to produce both hydrogen for vehicle fueling and for operation of low-temperature proton-exchange membrane stationary fuel cells; or 2) use of a high temperature molten carbonate or solid-oxide fuel cell to "internally reform" natural gas for both electricity and hydrogen "anode tail gas" production. In fact, such systems also typically employ some level of "external reforming" using a steam-methane reformer, for thermal balance reasons. But much of the breakdown of natural gas to hydrogen and carbon monoxide/dioxide can be done directly inside the fuel cell stack, owing to the high (800-1,000 Celsius) temperatures of this class of high temperature fuel cells.

Purified hydrogen for vehicle refueling can be produced through these systems by running excess natural gas (or biogas) through the system and recovering the hydrogen from the anode exhaust stream, before purifying it (typically with a "pressure swing adsorption" device) for compression and dispensing. Figure 12 shows the "tri-generation" concept employed by FuelCell Energy as it would be implemented using biogas at a wastewater treatment facility.

Figure 12: Electricity, Hydrogen, and Waste Heat "Tri-generation" System Using Biogas

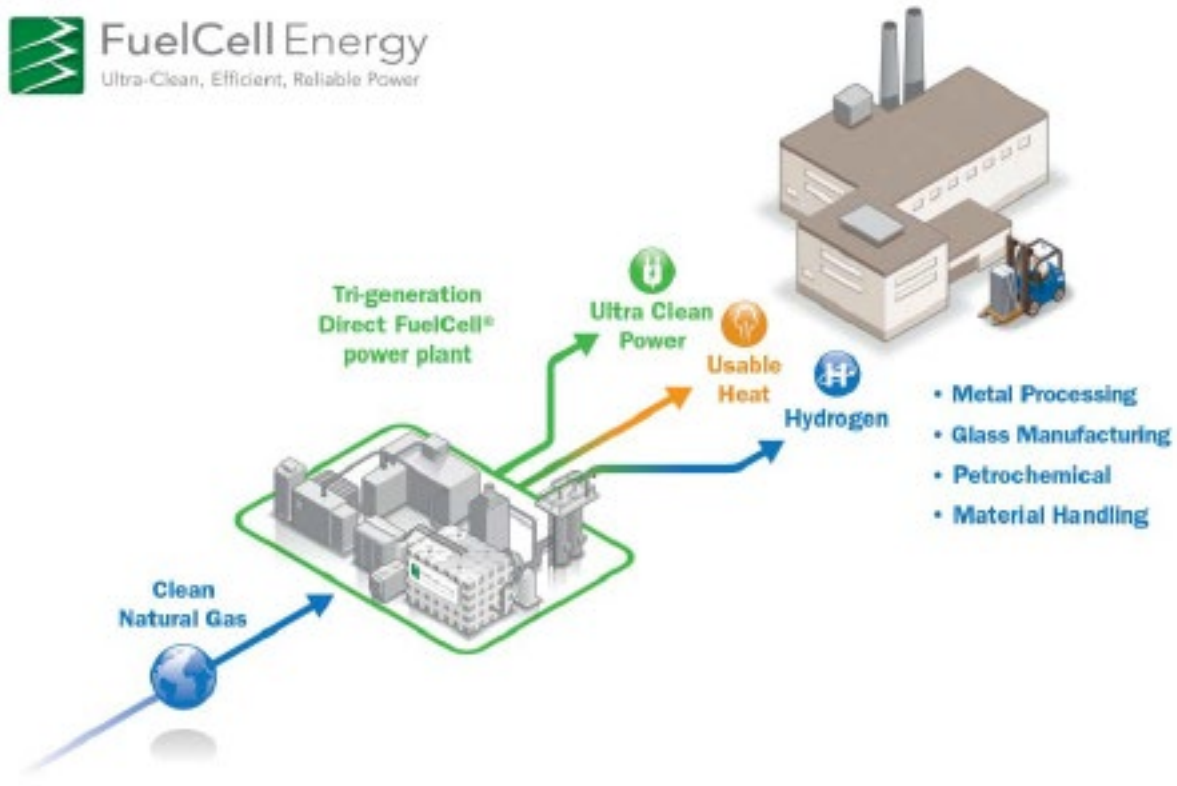


Source: FuelCell Energy

Talks with FuelCell Energy have revealed that approximately 1,000 kilograms of hydrogen per day could be produced, helping to meet the 33 percent renewable requirements for local Bay Area hydrogen stations. This could be accomplished with a single fuel cell installation also producing about 1 megawatt of electrical power. This concept is being explored further for potential sites in the Bay Area, but a key issue remains the relatively high cost of the fuel cell powerplant, necessitating relatively low biogas feedstock costs to make the project economics pencil out.

A further concept is natural gas-based tri-generation, potentially for industrial sites, where vehicle refueling could also be integrated. FuelCell Energy has an installation of the type depicted in Figure 13 at its North American manufacturing facility in Torrington, Connecticut. The system provides clean onsite power, waste heat for manufacturing processes, and industrial grade hydrogen for metals and glass processing.

Figure 13: Electricity, Hydrogen, and Heat "Tri-generation" System Using Natural Gas



Source: FuelCell Energy

Small-Scale Fueling Solutions

Another emerging concept is the idea of a small-scale (household or community) hydrogen production and dispensing solution or dispensing only through "mobile refuelers." Mobile refuelers are trailer-type devices that can be filled with compressed hydrogen at a production facility and then dispatched to specific locations for vehicle fueling. When the trailers run low on fuel, telemetry systems onboard the trailers alert the distributor that it is time to swap the relatively empty trailer for a full one. Companies pursuing mobile refueler technology include Air Products (Pennsylvania), Linde (Germany), and Powertech Labs (Canada).

In fact, there was a mobile refueler installed at Pacific Gas and Electric Company's parking lot at 18th and Harrison streets in San Francisco in 2006-2008 as a temporary demonstration. This installation shown in Figure 14 shows an earlier generation of mobile refueler technology that dispensed hydrogen at 5,000 pounds per square inch (350 bar) rather than the newer pressure level of 10,000 pounds per square inch (700 bar). The system was developed by Air Products and operated in San Francisco for approximately two years.

Figure 14: Mobile Hydrogen Refueler (350 Bar) at PG&E in 2006

Source: Timothy Lipman

Recently, a company called SimpleFuel responded to a U.S. Department of Energy challenge program called the "H-Prize" for small-scale fueling solutions. Their top-ranked system is capable of about 5 kilograms of fueling per day—enough for a few relatively full vehicle fills—or five one kilogram "top off" or "shot in the arm" type fills. The system was developed through collaboration among three companies: PDC Machines, Ivys, Inc., and McPhy Energy.

The system has a small footprint of 80 inches deep by 42 inches wide, and a height of 82 inches. The system uses standard utility hookups for electricity and water to produce hydrogen through electrolysis and then compress and dispense it. The system is shown in Figure 15 and is expected to cost $200,000 or less depending on factors such as the fueling rate and scale of production.

Figure 15: SimpleFuel Hydrogen Fueling Solution

2016 U.S. Department of Energy H-Prize Finalist

Source: SimpleFuel

Hydrogen Fuel Cell Ferry Boat Concept

An additional concept related to hydrogen fueling facility development for San Francisco is an idea proposed for a hydrogen fuel cell powered ferry boat that would operate in and around San Francisco, fueled with cryogenic liquid hydrogen. The hydrogen fueling depot that supplies liquid hydrogen to the ferry boat (partly through a fuel "bunkering" scheme) could also be designed to provide 700-bar gaseous hydrogen fueling for vehicles.

The concept was initially raised by the Red and White Fleet ferry operator in 2014 and has now been extensively studied by Sandia National Laboratory. Several potential fueling locations have been considered in waterfront locations that could accommodate a passenger ferry. One concept would be to install the station at Pier 54 in the Mission Bay area, shown in Figure 16, with a preliminary analysis included in the report that has now been released by Sandia National Laboratory.[3]

3 Joseph W. Pratt and Leonard E. Klebanoff (2016), "Feasibility of the SF-BREEZE: a Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry," Sandia Report, SAND2016-9719, September.

Figure 16: Potential Pier 54 Location for a Hydrogen Fueling Facility

Source: Sandia National Laboratories, 2016

As discussed above, the project team met with Red and White Fleet and Sandia National Laboratory in April 2016. Red and White Fleet has expressed continued interest in the project and the plan is still being pursued, but project economics are the principal barrier. The identified specifications are to have a 150-passenger ferry that would operate with zero emissions (from the boat itself), travel four 50-nautical mile trips each day, with 60 percent of the operational time at the top speed of 35 knots. The conceptual ferry has been named the "SF-BREEZE" for "San Francisco Bay Renewable Energy Electric vessel with Zero Emissions".[4]

Hydrogen Safety Resources for San Francisco Hydrogen Stations and Fuel Cell Vehicles

Extensive efforts have been made to develop and provide guidance and resources for municipalities and regions that are exploring the introduction or further development of hydrogen fueling stations and use of light and heavy-duty FCEVs. These have mostly been conducted by U.S. Department of Energy and its National Laboratories, National Fire Protection Association codes and standards activities, the Hydrogen Safety Panel, and the California Fuel Cell Partnership among others.

4 Sandia National Laboratories, 2016, "Feasibility of the SF-BREEZE: a Zero Emission, Hydrogen Fuel Cell High Speed Passenger Ferry," Report SAND2016-9719, September.

Key resources that are briefly summarized below include:

- H2 Tools (DOE and Pacific Northwest National Laboratory), available at https://h2tools.org
- Hydrogen Safety Panel, available at https://h2tools.org/hsp
- DOE HTAC Subcommittee Safety and Event Response Report, available at https://www.hydrogen.energy.gov/htac_reports.html
- Station Permitting Guides:
  - Guide to Permitting Hydrogen Motor Fuel Dispensing Facilities, available at https://www.nrel.gov/docs/fy16osti/64042.pdf

National Fire Protection Association Codes

National Fire Protection Association Codes have evolved greatly over the past 20+ years to more fully and appropriately cover the installation and operation of hydrogen fueling stations that either get hydrogen fuel delivered and stored onsite in gaseous or liquid form, and/or that also produce hydrogen onsite.

The current edition of the National Fire Protection Association Code that addresses hydrogen fuel is the "Hydrogen Technologies Code" in National Fire Protection Association 2 (2016). The purpose of the code is summarized by National Fire Protection Association as:

> The purpose of this code shall be to provide fundamental safeguards for the generation, installation, storage, piping, use, and handling of hydrogen in compressed gas form or cryogenic liquid form 1.3* Application. 1.3.1 This code shall apply to the production, storage, transfer, and use of hydrogen in all occupancies.

At the pre-application meeting with San Francisco Planning, Department of Building Inspection, and Bureau of Fire Prevention staff, it was very clear that the fire officials are familiar with these latest codes for hydrogen fueling station permitting and safety.

Hydrogen Tools Website

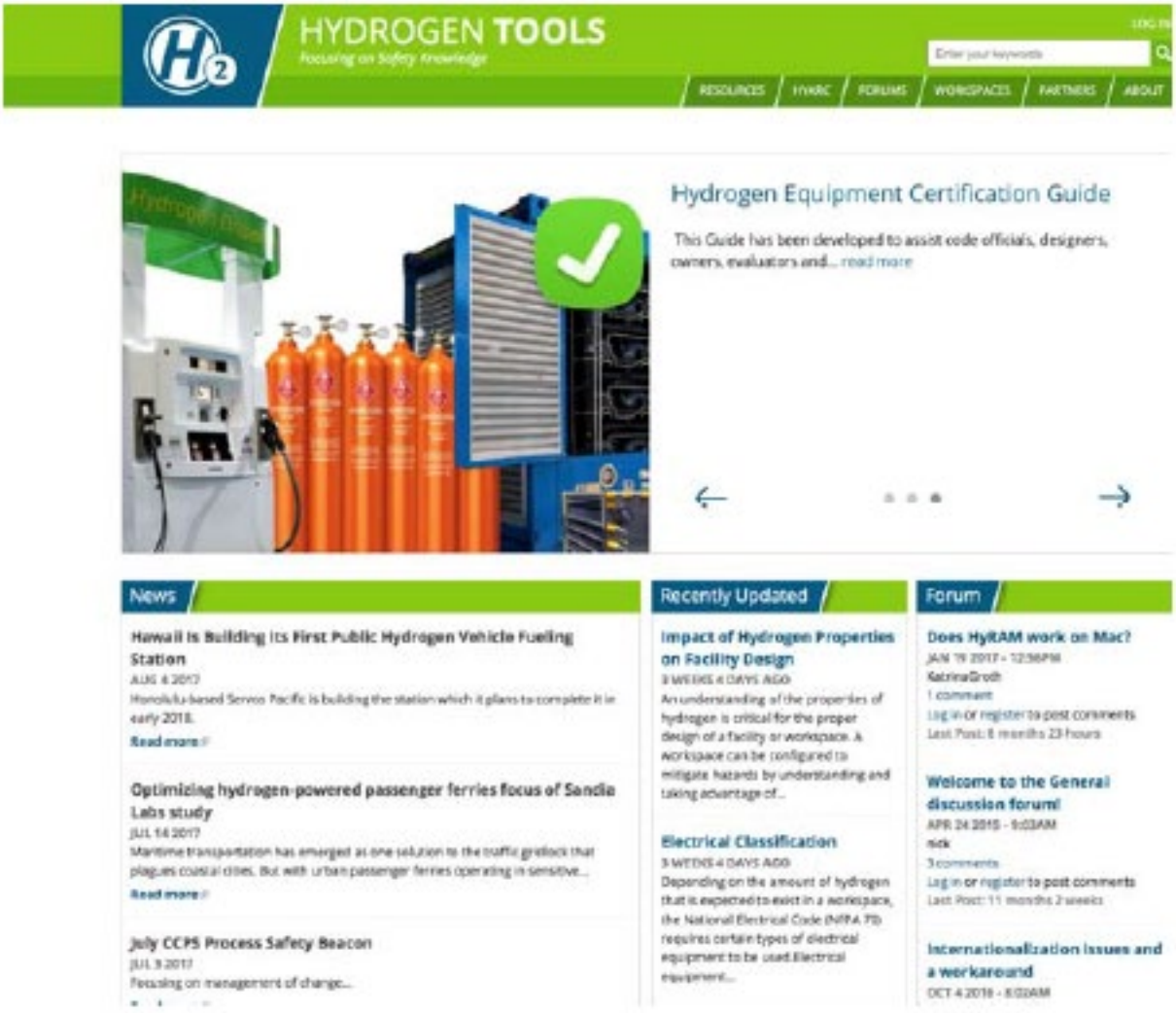
"H2 Tools" is an effort led by U.S. Department of Energy and Pacific Northwest Laboratory to develop a suite of hydrogen safety resources for code officials, local permitting officials, and other stakeholders. The Resources section of the H2 Tools website, available at https://h2tools.org includes the following topics:

- Best Practices
- International Conference on Hydrogen Safety Conference Papers
- Codes & Standards
- Lessons Learned
- Compatibility of Materials
- Properties & Calculators
- Contaminant Research Library
- Questions & Answers
- H2first
- Training Materials
- Hydrogen Safety Panel

- Videos
- Hydrogen Risk Assessment Model

The H2 Tools website front page is shown in Figure 17.

Figure 17: Hydrogen Tools Website



Source: H2First

Hydrogen Safety Panel

The Hydrogen Safety Panel is operated in conjunction with the U.S. Department of Energy. The Panel's goal is to help to foster the safe use of hydrogen across various types of installations. The Panel works to identify safety gaps and to inform interested parties of relevant issues and best practices for the use of hydrogen. The Panel's work, available at https://h2tools.org/hsp includes:

- Participating in safety reviews
- Providing safety planning guidance
- Reviewing project designs and safety plans
- Sharing safety knowledge and best practices
- Presenting and recognizing safety as a priority
- Participating in incident investigations.

Hydrogen Fueling Station Permitting Guides

Hydrogen station permitting guides have been developed both for California and more generally for the U.S. The California version was released in November 2015 by the Governor's Office of Business and Economic Development. The document first reviews basic concepts such as the use of hydrogen as a vehicle fuel, current status of FCEVs, and an overview of California's hydrogen station development plan. The bulk of the guide then covers key permitting aspects including zoning, architectural reviews, California Environmental Quality Act considerations, fire department approvals, utility considerations, permitting fees, building reviews, and construction considerations. The guide can be found at the California Business Portal website link.

An additional hydrogen-station permitting guide was developed and released by the National Renewable Energy Laboratory in March 2016. The covered materials are similar to the California guide, including the basics of hydrogen as a fuel and hydrogen fuel dispensing facilities, requirements for facility installations, relevant codes and standards, and site considerations. The guide also includes a case study example of an actual hydrogen station installation process for the 700-bar hydrogen station that was constructed at National Renewable Energy Laboratory from 2013 to 2015.[5]

Hydrogen Safety and Event Response Report

A "Hydrogen Safety and Event Response" report was produced in early 2017 by the Hydrogen and Fuel Cell Technical Advisory Committee of the U.S. Department of Energy's Fuel Cell Technology Office. The report covers an overview of hydrogen as a fuel and hydrogen station development efforts, and then focuses on procedures for safety plans and preparation and incident response for hydrogen fueling stations. The report also includes a case study of an incident that occurred in 2012 at a California hydrogen station where there was a fire due to a safety valve malfunction. The case study reviews the incident and the safety procedures that were followed, as well as "lessons learned" from the incident.[6]

5 U.S. Department of Energy, 2016: Guide to Permitting Hydrogen Motor Fuel Dispensing Facilities, available at https://www.nrel.gov/docs/fy16osti/64042.pdf

6 HTAC Safety and Event Response Subcommittee Report (Forthcoming 2017).

Chapter 4: Conclusion

We find in this study that San Francisco fleet departments are interested in the potential use of FCEVs but are limited by the current lack of refueling infrastructure and to some extent by the limited FCEV model offerings. There are currently three commercial FCEV options, by Toyota, Honda, and Hyundai, with several others expected by 2020 from additional automakers. The overall lifecycle costs of FCEVs look fairly competitive with other clean fuel vehicle options, with fleet discounts and state level incentives. However, recent reductions in incentive levels have made the total cost of ownership more expensive than they were in 2016 when California state level incentives for fleet adoption were three times higher.

Furthermore, current efforts to develop hydrogen stations in San Francisco are expected to produce three stations that would become operational in the 2018 timeframe. These would be owned and operated by Equilon Enterprises LLC, a division of Shell Oil Products U.S. The Notice of Propose Awards issued by the Energy Commission in February 2017 under GFO-15-605 is very timely in the context of this project. Additional potential funding opportunities are available through the Volkswagen Settlement and programs offered by the Bay Area Air Quality Management District. The project team will spend the remaining effort on the project to help facilitate communication between the station developers and City staff and officials, to assist with initial community information efforts, and to help inform interested City agencies such as San Francisco Municipal Transportation Agency and the Fleet Management Department, as well as regional agencies such as the Bay Area Air Quality Management District.

Finally, as discussed above, the environmental impacts of FCEV use will depend on how and from what sources the hydrogen fuel is derived. The Energy Commission requires at least 33 percent renewable hydrogen production as part of grant-funded station implementation. As additional hydrogen refueling becomes available, particularly from low-carbon sources, the attractiveness of FCEVs for fleet adoption in San Francisco is expected to increase.

GLOSSARY

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The CEC's five major areas of responsibilities are:

1. Forecasting future statewide energy needs.
2. Licensing power plants sufficient to meet those needs.
3. Promoting energy conservation and efficiency measures.
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels.
5. Planning for and directing state response to energy emergencies.

Funding for the CEC's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account, and other sources.

FUEL CELL ELECTRIC VEHICLE (FCEV)—A zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

Appendix A:
Commercial Fuel Cell Electric Vehicles

Figures 18, 19 and 20 show advertisements for the 2016 Toyota Mirai, 2016 Hyundai Tucson and 2017 Honda Clarity fuel cell electric vehicles.

Figure 18: 2016 Toyota Mirai

Source: Toyota

Figure 19: 2016 Hyundai Tucson

Source: Hyundai

Figure 20: 2017 Honda Clarity

Source: Honda

Appendix B:
GFO-15-605 Notice of Proposed Awards

Figure 21 shows the California Energy Commission GFO-15-605 Notice of Proposed Awards, released on February 17, 2017.

Figure 21: California Energy Commission GFO-15-605 Notice Of Proposed Awards

California Energy Commission
Alternative and Renewable Fuel and Vehicle Technology Program
Solicitation GFO-15-605
Light Duty Vehicle Hydrogen Refueling Infrastructure
Notice of Proposed Awards
February 17, 2017

Proposal Number	Applicant	Station Address	Funds Requested	Proposed Award	Match Amount	Score	Recommendation
Proposed Award for I-5 Connector Station Competition Grant							
8	Air Liquide Advanced Technologies U.S. LLC	12754 State Highway 33, Santa Nella, CA 95322	$1,712,461	$1,712,461	$733,912	70.75%	Awardee
		Subtotal	**$1,712,461**	**$1,712,461**	**$733,912**		
		I-5 CONNECTOR STATION COMPETITION TOTAL FUNDING RECOMMENDED	**$1,712,461**	**$1,712,461**	**$733,912**		
Proposed Awards for Main Station Competition Grants							
California Hydrogen Infrastructure Tool (CHIT) Round 1							
3	Equilon Enterprises LLC (d/b/a Shell Oil Products US)	551 Third Street, San Francisco, CA 94107	$2,337,500	$2,337,500	$1,634,213	86.63%	Awardee
CHIT Round 2							
3	Equilon Enterprises LLC (d/b/a Shell Oil Products US)	3550 Mission Street, San Francisco, CA 94110	$2,337,500	$2,337,500	$1,634,213	86.63%	Awardee
CHIT Round 3							
3	Equilon Enterprises LLC (d/b/a Shell Oil Products US)	1250 University Avenue, Berkeley, CA 94702	$2,337,500	$2,337,500	$1,634,213	86.63%	Awardee
CHIT Round 4							
3	Equilon Enterprises LLC (d/b/a Shell Oil Products US)	1201 Harrison Street, San Francisco, CA 94103	$2,337,500	$2,337,500	$1,634,213	86.63%	Awardee
CHIT Round 5							
9	FirstElement Fuel, Inc.	14478 Ventura Boulevard, Sherman Oaks, CA 91423	$1,905,285	$1,905,285	$635,095	86.32%	Awardee
CHIT Round 6							
9	FirstElement Fuel, Inc.	1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087	$1,950,285	$1,950,285	$650,095	86.32%	Awardee
CHIT Round 7							
3	Equilon Enterprises LLC (d/b/a Shell Oil Products US)	2900 N Main Street, Walnut Creek, CA 94597	$2,337,500	$2,337,500	$1,634,213	86.30%	Awardee
CHIT Round 8							
9	FirstElement Fuel, Inc.	1866 Lincoln Boulevard, Santa Monica, CA 90405	$1,882,785	$1,882,785	$627,595	85.92%	Awardee
CHIT Round 9							
9	FirstElement Fuel, Inc.	350 Grand Avenue, Oakland, CA 94610	$1,972,785	$1,972,785	$657,595	85.58%	Awardee

Figure 21: California Energy Commission GFO-15-605 Notice Of Proposed Awards (cont'd)

Proposal Number	Applicant	Station Address	Funds Requested	Proposed Award	Match Amount	Score	Recommendation
		CHIT Round 10					
9	FirstElement Fuel, Inc.	16001 Beach Boulevard, Huntington Beach, CA 92647	$1,882,785	$1,882,785	$627,595	83.98%	Awardee
		CHIT Round 11					
9	FirstElement Fuel, Inc.	5494 Mission Center Road, San Diego, CA 92108	$1,875,285	$1,875,285	$625,095	83.98%	Awardee
		CHIT Round 12					
3	Equilon Enterprises LLC (d/b/a Shell Oil Products US)	3510 Fair Oaks Boulevard, Sacramento, CA 95864	$2,337,500	$2,337,500	$1,634,213	83.97%	Awardee
		CHIT Round 13					
9	FirstElement Fuel, Inc.	337 East Hamilton Avenue, Campbell, CA 95008	$1,972,785	$1,972,785	$657,595	84.65%	Awardee
		CHIT Round 14					
3	Equilon Enterprises LLC (d/b/a Shell Oil Products US)	6141 Greenback Lane, Citrus Heights, CA 95621	$2,337,500	$2,337,500	$1,634,213	82.97%	Awardee
		CHIT Round 15					
9	FirstElement Fuel, Inc.	5333 University Drive, Irvine, CA 92612	$1,897,785	$1,897,785	$632,595	82.25%	Awardee
		Subtotal	**$31,702,280**	**$31,702,280**	**$16,552,751**		
		MAIN STATION COMPETITION TOTAL FUNDING RECOMMENDED		**$31,702,280**			
		GRAND TOTAL FUNDING RECOMMENDED		**$33,414,741**			

Source: California Energy Commission