CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

California Energy Commission

Clean Transportation Program

**FINAL PROJECT REPORT**

# Scaling Up the True Zero Network

## Hydrogen Station – 1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087

**Prepared for: California Energy Commission**

**Prepared by: FirstElement Fuel, Inc.**

**Gavin Newsom, Governor**

**March 2024 | CEC-600-2024-032**

# California Energy Commission

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The construction of the Sunnyvale hydrogen refueling station has only been possible because of the substantial efforts and funds provided by a number of stakeholders.

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# PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology 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 Grant Funding Opportunity (GFO)-15-605, Light Duty Vehicle Hydrogen Refueling Infrastructure to provide grant funds to expand the network of publicly accessible hydrogen refueling stations that serve California's light duty fuel cell electric vehicles (FCEVs). In response to GFO-15-605, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards February 17, 2017, and the agreement was executed as ARV-16-036 on July 25, 2017.

# ABSTRACT

Per the terms of funding agreement ARV-16-036 between the California Energy Commission (CEC) and FirstElement Fuel, Inc. (FEF), FEF designed, engineered, permitted, constructed, and commissioned a hydrogen refueling station at 1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087. FEF plans to own and operate the hydrogen refueling station until at least 2025. The hydrogen refueling station consists of an enclosed compound, or building, that houses compressing and dispensing equipment, high pressure storage tubes, two dispensers each with two fueling positions, a customer payment interface, and canopy for one of the dispensers.

**Keywords**: California Energy Commission, FirstElement Fuel, Inc., hydrogen refueling station, hydrogen infrastructure, fuel cell vehicles

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# EXECUTIVE SUMMARY

Hydrogen fuel cell electric vehicles (FCEVs) and hydrogen refueling stations are expected to play key roles in California's commitment towards utilizing clean, alternative energy sources. As the state transitions to lower-carbon and zero-emission vehicle (ZEV) technologies, several areas in transportation sector—such as light-duty passenger vehicles, transit buses, and truck transport fleets—are expected to benefit. Numerous government regulations and policy actions identify FCEVs as a vehicle technology that will be available to meet the California Air Resources Board Zero Emission Vehicle Regulation and the Governor's zero emission vehicle mandate. The Governor's *Zero Emission Vehicle Action Plan* specifies actions to bring FCEVs to California markets.

Hydrogen fuel cell electric-drive technology has tremendous potential to be used across a wide range of transportation markets including one for light-duty passengers, medium to heavy-duty trucks, and buses**.** On a full tank of hydrogen, FCEVs can travel more than 300 miles and be refueled in under five minutes, in both ways comparable to the average gasoline passenger vehicle. FCEVs have zero tailpipe emissions and produce the same amount of carbon footprint as plug-in electric vehicles. The technology can be readily scaled up to support sport utility vehicles (SUVs); family passenger vans; pick-up trucks; urban package and beverage delivery trucks; heavy-duty trucks and buses. Most auto industry analysts and agencies view fuel cell electric drive technology as a complement to battery electric drive technologies, rather than competition. In order to achieve ZEV deployment goals, both battery and FCEV technologies are needed.

As opposed to battery electric and plug-in hybrid electric vehicles that can be charged in home settings, FCEVs require a new network of refueling stations that dispense pressurized hydrogen. As a result, the auto industry and station development industry have had to co-expand in parallel in building hydrogen FCEVs and hydrogen refueling infrastructure. Without a minimum network of refueling stations available, the auto industry cannot market and sell FCEVs.

Assembly Bill (AB) 118 (Núñez, Chapter 750, Statutes of 2007), created the Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to invest in alternative renewable fuels and advanced transportation technologies to help achieve state's efforts towards climate change solutions, clean air, and alternative energy policies. AB 8 (Perea, Chapter 401, Statutes of 2013) re-authorizes the Clean Transportation Program through January 1, 2024.

The CEC issued solicitation Grant Funding Opportunity (GFO)-15-605, Light Duty Vehicle Hydrogen Refueling Infrastructure, to provide grant funds towards expansion of publicly accessible hydrogen refueling stations. In response, FirstElement Fuel, Inc. submitted an application to start station construction at several locations, including one at 1296 Sunnyvale, Saratoga Road, Sunnyvale CA, 94087. This station was proposed for funding in the CEC's Notice of Proposed Awards on February, 2017.

*Note: If needed, insert a blank page so that Chapter 1 begins on an odd-numbered, right-hand-facing page.*

# CHAPTER 1:
# Purpose

As fuel cell electric vehicles (FCEVs) are deployed in greater quantities, a wider network of refueling stations becomes necessary. This agreement provides a hydrogen refueling station at 1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087. The station equipment stores liquid hydrogen and dispenses gaseous hydrogen.

This project helps address scientific and technical barriers to the build out of hydrogen refueling infrastructure, including addressing the limited availability of hydrogen refueling infrastructure performance data by delivering station performance data for larger capacity stations, namely those which can provide up to 606 kilograms (kg) of hydrogen in 12 hours, or over 1212 kg in 24 hours.

With improvements to the hydrogen refueling stations network along with a corresponding and expected increase in FCEVs, the State of California is on track to reach its carbon reduction and air quality improvement goals. Hydrogen FCEVs are expected to play a critical role in meeting the ZEV mandate targets– which calls for sufficient alternative refueling infrastructure to support up to 1 million ZEVs by 2020 and potentially reaching 1.5 million ZEVs on the road in California by 2025.

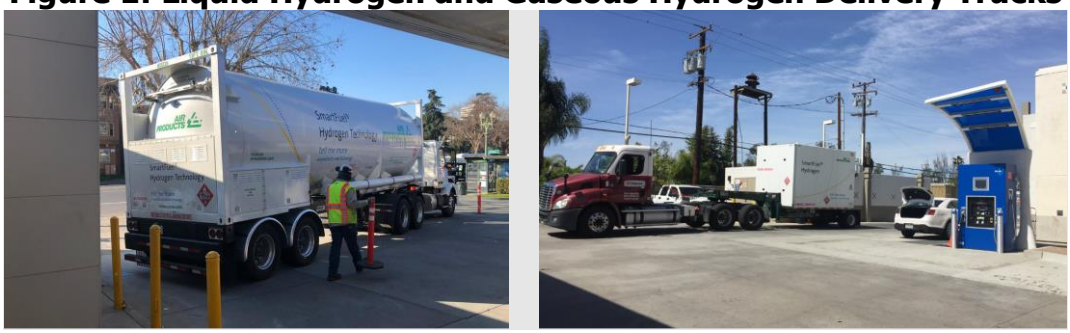
## Inherent Efficiency of Liquid Hydrogen

Liquid hydrogen, as used at the Sunnyvale station, has more storage, transportation, and pumping efficiencies compared to gaseous hydrogen in refueling infrastructure scenarios. Compression of gaseous hydrogen at fueling stations up to the pressures required to fill FCEVs requires 3-5 kWh/kg of electricity. Because pumping liquid hydrogen is much more efficient than compressing a gaseous hydrogen, liquid pump stations use less than 1 kWh/kg to accomplish the same task. This is important because electricity at individual hydrogen stations can be expensive and is generally hard to make renewable.

Because of the extremely cold temperature of liquid hydrogen (-416°F), no additional refrigeration system is required to meet fueling protocol in the SAE J2601 standard cold fill requirements. This saves capital costs, reduces electricity consumption, and in FirstElement Fuel's (FEF) experience, improves reliability.

Delivery of liquid hydrogen is common in the industrial gas industry. This means that the safety, costs, and operational experience of using liquid hydrogen are well understood. Liquid hydrogen delivery trucks can easily carry 10 or more times the deliverable hydrogen of equivalently sized gaseous hydrogen trucks (Figure 1). This higher capacity enables multiple stops to different stations before have to constantly return to the plant for a new load, which in turn, substantially reduces emissions and carbon associated with trucking hydrogen.

**Figure 1: Liquid Hydrogen and Gaseous Hydrogen Delivery Trucks**



Liquid hydrogen truck can deliver 2,400 kgs (left) compared to 120 kgs for gaseous H2 truck (right).
Source: FirstElement Fuel, Inc.

## Higher Capacity Results in Lower Price at the Pump

Because of our dedicated hydrogen supply, volume equipment purchasing, CEC grant funding, and California Air Resources Board's hydrogen refueling infrastructure (HRI) credit value, FEF has been able to lower the hydrogen price at the pump to $13.00 per kg (approximating $5.20 of comparative gasoline) significantly decreasing the current price at the pump.

With the Sunnyvale station capacity of 1,212 kg/day:

- Installed two dual sided dispenser, one with 2 H70 hoses and 1 H35 hose and the other with 2 H70 hoses. This configuration allows for four fueling positions (any three can be used simultaneously) to improve customer experience and reduce wait times
- Have over 900 kg of storage to mitigate potential supply disruptions better
- Reduce retail hydrogen price in comparison with gasoline and brining price parity

These leaps in performance and price are made possible by moving to liquid hydrogen production, distribution, storage, and pumping. Producing liquid hydrogen generally takes more energy compared with gaseous hydrogen, but the storage costs and energy densities exceed those of gaseous hydrogen. Like most industrial processes, scale is an important factor in both cost and efficiency for hydrogen production. Because liquid hydrogen is relatively inexpensive to store and transport, a single large, efficient, and optimized facility can be used to serve the entire network. This efficiency results in lower cost hydrogen supply. In addition, pumping liquid hydrogen is inherently more efficient than compressing gaseous hydrogen. Therefore, the pumps used in at the Sunnyvale stations are considerably smaller, more efficient, have higher throughput, and lower cost than comparable compressor systems.

The advantages of liquid hydrogen production, delivery, and storage are common knowledge in the hydrogen industry. But most stations rely on gaseous hydrogen because, historically, there has been enough excess gaseous hydrogen from existing industrial applications for the insignificant amount needed for FCEVs, and because new liquid hydrogen production requires substantial capital investment. FEF is fortunate to have developed a secure source to acquire liquid hydrogen for the current batch of stations that will enable a substantial reduction in the price of hydrogen at the pump.

## Sustainability and Environmental Impacts

FEF notes that hydrogen and FCEVs are among the most effective means to achieve sustainable transportation in California. This is part of FEF's mission statement and the motivation for starting this company in the first place. FEF aims to grow the proportion of FCEVs on the road as quickly as possible so that California, and the world, can fully capitalize fully on the environmental benefits of electric propulsion. FEF understands that, based on years of analysis and research, FCEVs can change the world in a positive way by:

- Reducing criteria pollutant emissions
- Improving urban air quality
- Reducing greenhouse gas emissions
- Reducing dependency on petroleum

Part of the FEF core business strategy is to accelerate the adoption of FCEVs and to maximize the potential environmental benefits simultaneously through a conscientious approach to the fuel supply chain, the operation of hydrogen station projects, and throughout the hydrogen station development and construction process for the hydrogen station in Sunnyvale, CA.

# CHAPTER 2:
# Approach

FEF has worked hard and considers itself to have built the largest, most experienced and dedicated team for retail opening and operation of hydrogen refueling stations. FEF has successfully created the largest and most reliable hydrogen refueling network in the world and has provided original equipment manufacturers (OEMs) the confidence to release FCEVs on a large scale into the California market. FEF stations has shown the best up-time performance in California. Primary in the FEF culture is a focus on the customer experience and a focus on the safety and security of the FEF team and stations. To that end, FEF has developed and continues to refine rigorous technical and safety training procedures for the service and maintenance personnel.

## Field Service Operations Technical Training

FEF Technical Training policies are intended to ensure that personnel have the right tools and experience required for the job. No employee is put in a situation where their safety is compromised. For that reason, FEF has implemented a competence tracking system where employees are graded based on their level of knowledge in a specific field of work. The four major competence categories include:

- Observer: personnel can only assist in a task
- Supervised: personnel can perform the task only if supervised
- Independent: personnel can perform the work unsupervised
- Trainer: where the personnel can train others on the task

For an employee to be qualified to work independently in the field, they must meet the competence criteria after working with a trainer for enough time. A typical supervised training period is one to two months or more.

## Field Service Safety Training

In addition to hands-on station operational technical training, FEF personnel are constantly discussing, learning, and reviewing general safety procedures and operations.

### Communication

The Field Service Team meets three times per week to discuss operational status and safety procedures. A new safety topic is introduced at every meeting and is discussed in at least three meetings. Additionally, prior to beginning every operational meeting a short briefing is set aside to discuss a "Safety Moment".

### Training Methods

The safety training program uses some or all of the following communication methods: video instruction, group discussion, homework, quick phone quizzes and when possible, practical hands-on practice. Attendance is tracked to ensure that, at a minimum, each employee

attends two of these safety sessions. At these meetings, all new policies and procedures are introduced, and the employee is told where this information resides within the company.

### Special Work

Before a new task is conducted or whenever a newly introduced task does not have established procedures, pertinent employees are trained to perform a Job Hazard Analysis prior to beginning the work.

### Contractors

In some cases, where FEF requires the help of a contractor, for example in construction, refrigeration or crane operation, FEF only employs contractors who are qualified to do the work, have a similar vision for safety and have a proven track record. FEF has reviewed these records through contractor's U.S Occupational Safety and Health Administration Form 300A for the past three years. If there are any major injuries in the records, FEF investigates further to ensure that the contractor has the right culture and policies in place.

## Station Operation and Maintenance

FEF has established a preventive maintenance plan for the Sunnyvale station that mandates monthly, quarterly, semi-annual, and annual scheduled maintenance activities. Each week the team manager reviews the preventive maintenance schedule for FEF's stations, opens work orders for each station with the tasks to be completed by the technicians on duty, and verifies completion of the prior week's work orders. As a part of scheduling routine, the team managers plan and stagger maintenance activities to avoid cluster shutdowns of adjacent stations in the network to avoid area-wide unavailability.

Far too often a robust service machine falters due to lack of communication. Therefore, simply relying on a chart of maintenance activities on a map is not sufficient. FEF goes a few steps further. The FEF hydrogen engineers are in constant contact with each other, literally 24 hours a day, seven days a week. The team also meets three times a week for operational meetings with management, schedulers and service technicians. FEF uses internal social media apps and cloud-based documentation for companywide communication at all times. The entire team knows the status of all activities at each station from any connected computer, tablet or smart phone. This communication serves greatly in the coordination of planned maintenance, emergency maintenance, stress testing, press events, employee vacations, etc.

Additionally, FEF coordinates its planned maintenance activities at the Sunnyvale station by instructing all technicians to plan work such that the outage time is minimized and the station can return to working conditions with limited down time. Each technician has a personalized sign to let customers know that maintenance is being done while the station remains open.

# CHAPTER 3:
# Activities Performed

FEF took many steps to bring the Sunnyvale hydrogen refueling station project to completion. The following synopsis highlights the most critical items, provides detail on each one, and states the timing required for each step for this project.

## Site Acquisition

Three independent objectives must be achieved to develop a successful hydrogen station project:

1) The location must meet the needs of customers
2) The parcel must have sufficient space to install hydrogen fueling equipment safely
3) The landowner and/or business operator must be willing to participate

FEF searches for sites by first selecting specific geographic areas, then narrowing down to only those with room for hydrogen fueling equipment, and finally, negotiating with landowners.

In early 2016, FEF took steps to identify and acquire appropriate sites for the station. FEF worked with historic vehicle sales data, academic publications, OEM, and CEC's Station Location Areas specified in the solicitation to select desired market locations. FEF then analyzed specific properties within the target locations to find sites that could meet the space requirements for hydrogen fueling equipment.

After selecting general locations and specific sites, FEF contacted station owners and operators to negotiate lease opportunities. FEF executed a 10-year lease with the property owner of 1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087 on July 22, 2016.

**Figure 2: Property View During Acquisition Phase**


View of the property where the station is located, looking from Sunnyvale Saratoga Road.

Source: FirstElement Fuel, Inc.

## Equipment Procurement

The equipment packages installed at the Sunnyvale Hydrogen Refueling Station is comprised of three main components: compressing and dispensing equipment manufactured by Linde, LLC; ground storage unit manufactured by FIBA; and point of sale (dispenser) manufactured by Tatsuno. The FEF team started the equipment procurement process early on in the station's development, evaluating and visiting various component and part suppliers. As a hydrogen station integrator, FEF assessed and helped design an equipment package utilizing leaders in the industry to assemble an equipment package that exceeded the minimum technical requirements in the solicitation.

As a result of efficiencies of liquid hydrogen listed in Chapter 1, FEF decided to upgrade the throughput and capacity of the Sunnyvale station bringing the station dispensing capacity per day to 1,212 kgs of hydrogen. This decision to upgrade the station capacity resulted in a delay in the approval and engineering design process, more expenditures by FEF, but the added benefits (improved customer experience, storage to weather supply disruptions and lower price at pump) of the increased capacity far outweighed the delay and the additional cost to FEF.

**Figure 3: Installed Dual Sided Tatsuno Dispenser**


Source: FirstElement Fuel, Inc.

**Figure 4: Linde Unit (Compressing and Dispensing Equipment)**

Source: FirstElement Fuel, Inc.

## Site Design and Engineering

The site design for the Sunnyvale station on April 7, 2017, where FEF engaged internal permitting and engineering teams to proceed with design scope. As a result of upgrading equipment package, additional time was spent some time modifying the equipment footprint with the equipment supplier and engineering team, with site design drawings released on December 27, 2017, allowing the project to proceed with entitlement approval process.

## Entitlement

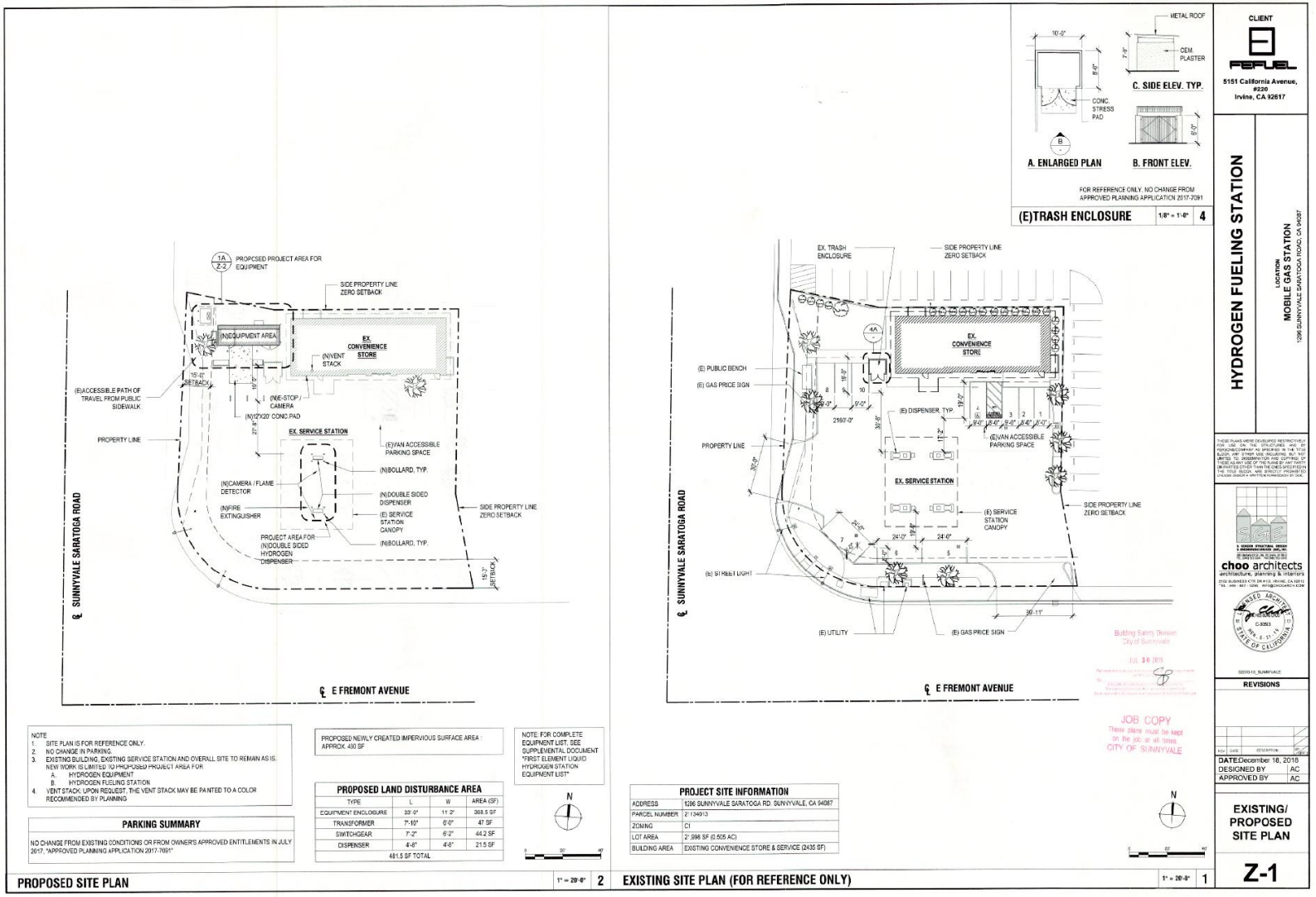
The local planning department typically verifies that the project meets the zoning requirements of the proposed location, and approve any aesthetic, landscaping or other details that are important to the community.

FEF submitted an entitlement package on February 21, 2018, which the city approved following review and corrections with the city approved on June 27, 2018.

## Building Plan Check

Upon completion of the construction/engineering drawings, FEF submitted the initial building permit application on October 25, 2018. Following review and corrections with the various building departments at the City of Sunnyvale, FEF received the final clearances and the building permit on August 17, 2020.

## Figure 5: Approved Building Plans




Source: FirstElement Fuel, Inc.

## Site Preparation and Construction

After receiving the approval to build, FEF selected and hired a general contractor to perform construction work for the Sunnyvale Hydrogen Station.

On October 18, 2019, the construction team broke ground and started work addressing existing site conditions, and relocated equipment necessary for gas station operations. Shortly thereafter the construction team proceeded with demolition, formwork laying initial conduit connections and pouring concrete for our equipment pads that serve as the base of our Linde compressing and FIBA storage units.

**Figure 6: Sunnyvale Concrete pad pour**


Source: FirstElement Fuel, Inc.

## Equipment Installation

The equipment install occurred on December 11, 2019, with careful coordination with crane operators as well as the logistic coordinators to ensure that equipment was delivered on site and ready for install.

**Figure 7: Linde Equipment Installation at the Sunnyvale Station**


Source: FirstElement Fuel, Inc.

On March 16, 2020, COVID-19 lockdown orders were issued as a result of the COVID-19 pandemic. The FEF team responded immediately with implementing and following the proper health and safety protocols to ensure that construction could proceed.

As a result of the COVID-19 lockdown orders, subcontractors on the job suffered from financial troubles and notified the project that they would be unable to resume work any time soon. FEF remobilized an alternate team to restart and complete construction work.

**Figure 8: Tatsuno Dispenser installation at the Sunnyvale Station**


Source: FirstElement Fuel, Inc.

## Energization and Mechanical Connections

Following equipment installation, contractors completed scope to make sure that both mechanical and electrical connections were property terminated and ready for energization.

Given issues with COVID-19 and the delay in scheduling of public utility work and inspections, our commissioning scope was started on temporary power.

To proceed with the commissioning scope and to continue progress, FEF used generator power to complete the next phase. The permanent utility connection was subsequently approved on October 23, 2020.

## Commissioning

On July 14, 2020 FEF started the commissioning phase where the equipment is tested to verify that the station is ready dispense hydrogen. Table 1 summarizes tasks performed to commission the station.

**Table 1: Commissioning Checklist**

| Commissioning Tasks | FE1022- Sunnyvale 1296 Sunnyvale Saratoga Rd 94086 |
|---|---|
| Date: 03/12/21 | |
| Operator: Edgard Curiel | |

| No. | Complete<br>If yes check box | Tasks |
|---|---|---|
| 1 | | Cleaning Skid |
| 2 | | Pressure Test |
| 3 | | Electrical Startup |
| 4 | | Mechanical Landing |
| 5 | | PSV Check |
| 6 | | Calibrate Gas Detectors |
| 7 | | Safety Function Test |
| 8 | | Vacuum H2 Storage |
| 9 | | Purge GH2 Storage |
| 10 | | Vacuum LH2 Tank |
| 11 | | Purge LH2 Tank |
| 12 | | FillFluids |
| 13 | | Cooldown LH2 Tank and Fill |
| 14 | | Remove and Pump Drive |
| 15 | | Cleaning Pump Vessel |
| 16 | | Install Pump Insert |
| 17 | | Install Pump Coupling |
| 18 | | Purge pump vessel and head room |
| 19 | | Cooldown the pump |
| 20 | | Recalibrate Pump Level Sensor |
| 21 | | Power on Dispenser' |
| 22 | | Pressure Test Dispenser |

Source: FirstElement Fuel, Inc.

## Station Testing

The California Department of Food and Agriculture Division of Measurement Standards (DMS) is responsible for enforcement of California weights and measures laws and regulations and must certify any device used for metering the sale of commercial items within California.

Acting as a Registered Service Agent and working with the local County Weights and Measures Officer as a witness, FEF successfully completed the DMS testing on September 11, 2020.

Hydrogen fueling station performance validation is accomplished through the Hydrogen Station Equipment Performance (HyStEP) testing device and was performed on September 23,2 2020 to validate that the station is able to meet the fueling protocol standards. The results were reviewed by the OEM manufacturers and approved for station opening on February 12, 2021.

**Figure 11: Hydrogen purity certification issue for the Sunnyvale site.**

SmartChemistry

| SUNNYVALE | Sample Sampled on 08/30/2020 09/01/2020 | | H70 Dispenser 1 | H70 Dispenser 2 |
|---|---|---|---|---|
| SAE J2719 | SAE J2719 Limits, µmol/mol | SmartChemistry Limits, µmol/mol | Concentration (µmol/mol) | Concentration (µmol/mol) |
| $H_2O$ (ASTM D7649) | 5 | 2 | < 2 | < 2 |
| Total hydrocarbons except methane ($C_1$ equivalent) (ASTM D7892) | 2 | 0.01 | < 0.01 | < 0.01 |
| $O_2$ (ASTM D7649) | 5 | 0.5 | 0.92 | 0.93 |
| $CH_4$ (ASTM D5466) | 100 | 0.001 | 0.0048 | 0.0069 |
| He (ASTM D1946) | 300 | 10 | < 10 | < 10 |
| $N_2$ (ASTM D7649) | 300 | 2 | 2.2 | 2.1 |
| Ar (ASTM D7649) | 300 | 0.2 | < 0.2 | < 0.2 |
| $CO_2$ (ASTM D7649) | 2 | 0.03 | < 0.03 | < 0.03 |
| CO (ASTM D5466) | 0.2 | 0.00001 | 0.000060 | 0.000084 |
| Total S (ASTM D7652) | 0.004 | 0.00004 | 0.000025 | 0.000027 |
| Hydrogen Sulfide | | 0.000002 | 0.0000051 | 0.0000056 |
| Carbonyl Sulfide | | 0.000001 | 0.000014 | 0.0000061 |
| Methyl Mercaptan (ATM) | | 0.000002 | < 0.000002 | < 0.000002 |
| Ethyl Mercaptan (ATM) | | 0.000004 | < 0.000004 | < 0.000004 |
| Dimethyl Sulfide (ATM) | | 0.000002 | < 0.000002 | < 0.000002 |
| Carbon Disulfide | | 0.000001 | 0.0000056 | 0.0000079 |
| Isopropyl Mercaptan (ATM) | | 0.000004 | < 0.000004 | < 0.000004 |
| Tert-Butyl Mercaptan (ATM) | | 0.000004 | < 0.000004 | < 0.000004 |
| n-Propyl Mercaptan | | 0.000004 | < 0.000004 | < 0.000004 |
| Thiophene | | 0.000004 | < 0.000004 | < 0.000004 |
| Diethyl Sulfide | | 0.000004 | < 0.000004 | < 0.000004 |
| n-Butyl Mercaptan | | 0.000004 | < 0.000004 | < 0.000004 |
| Dimethyl Disulfide (ATM) | | 0.000004 | < 0.000004 | < 0.000004 |
| Tetrahydrothiophene (THT) | | 0.000004 | < 0.000004 | 0.0000074 |
| Formaldehyde (ASTM D7892) | 0.2 | 0.001 | < 0.001 | < 0.001 |
| Formic Acid (ASTM D5466) | 0.2 | 0.0005 | < 0.0005 | < 0.0005 |
| Ammonia (ASTM D5466) | 0.1 | 0.02 | < 0.02 | < 0.02 |
| Total Halogenates | 0.05 | | < 0.001 | < 0.001 |
| $Cl_2$ (ASTM D5466) | | 0.0001 | < 0.0001 | < 0.0001 |
| HCl (ASTM D5466) | | 0.0004 | < 0.0004 | < 0.0004 |
| HBr (ASTM D5466) | | 0.0007 | < 0.0007 | < 0.0007 |
| Total Organic Halides (ASTM D7892, Smart Chemistry limit is for each individual organic halide) | 32 compounds in bold red in Non-Methane Hydrocarbons report | 0.001 | < 0.001 | < 0.001 |
| Particulate Concentration (SAE J2719 Limit: 1 mg/kg) (ASTM D7651) | | | Dispenser 1 Side 1: 0.022 mg/kg<br>Dispenser 1 Side 2: 0.43 mg/kg | Dispenser 2 Side 1: 0.052 mg/kg<br>Dispenser 2 Side 2: 0.048 mg/kg |
| Particulates Found & Size (ASTM D7834) | | | Dispenser 1 Side 1: No Particulate<br>Dispenser 1 Side 2: 99 Particulates & soil stain | Dispenser 2 Side 1: 512 Particulates<br>Dispenser 2 Side 2: 1 Particulate |
| Hydrogen Fuel Index | 99.97% | | 99.999688% | 99.999693% |
| Total Non-Hydrogen Gases | 300 | | 3.1 | 3.1 |
| CO + HCHO + HCOOH | 0.2 | 0.00005 | 0.000060 | 0.000084 |

Source: FirstElement Fuel, Inc

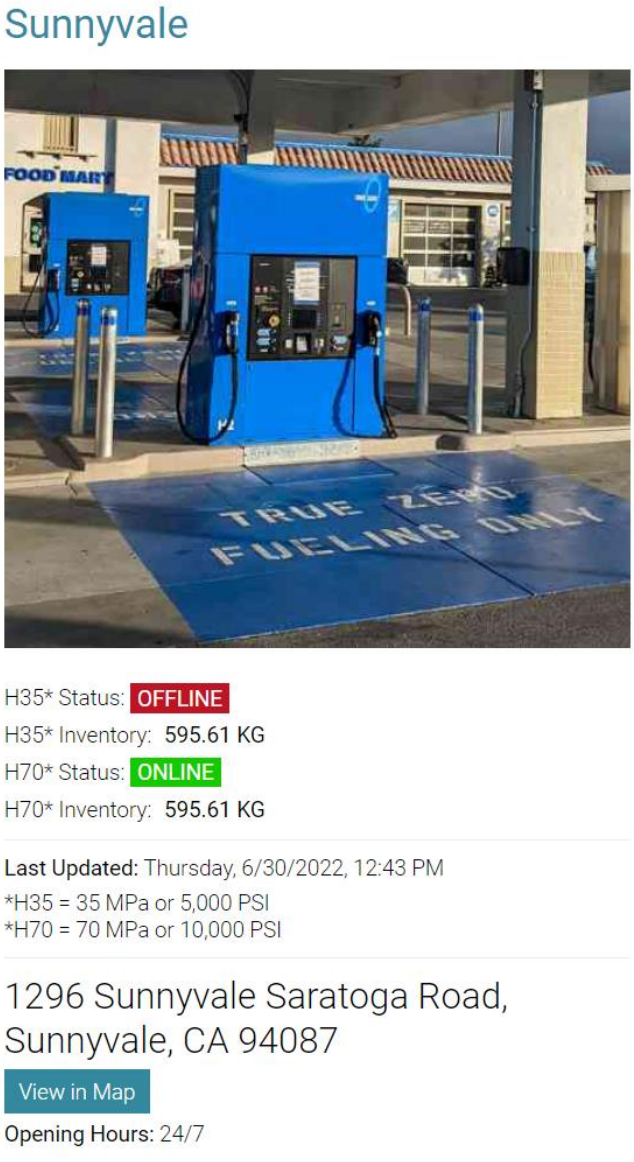
## Operational and Open Retail

Despite completing the majority of the construction and commissioning scope, FEF experienced a delay in achieving the open retail status pending energization of our site.

The California Fuel Cell Partnership Station Operational Status System (SOSS) provides regularly updated station status information to FCEV drivers. FEF developed software to serve updates to SOSS about the amount of hydrogen available at the station. The Sunnyvale station began sending regular status updates to SOSS on February 11, 2021.

The Sunnyvale station met requirements for open retail status on March 2, 2021.

**Figure 12: Station Operation Status System – Sunnyvale**




Source: California Fuel Cell Partnership

# CHAPTER 4:
# Results

## Sunnyvale Hydrogen Station Open

The Sunnyvale hydrogen station is the third liquid hydrogen station that FEF has opened which has a fueling capacity of more than 1,200 kilograms per day. This larger fueling capacity plays a pivotal role in the infrastructure needs of today serving the greater number of FCEV on the road today. Additionally, with four fueling positions that allows three cars to fill simultaneously, FEF is able to improve the customer experience and reduce the amount of time customers have to wait for an open pump.

**Figure 14: Completed Sunnyvale Hydrogen Station**


Source: FirstElement Fuel, Inc.

## Data Collection and Energy Analysis

Since the first fill that occurred at the Sunnyvale station on February 11, 2021, the station has dispensed over 37,000 kgs in its first year of usage and recorded just over 25,000 fills. The table below summaries our data collection during this first year.

**Table 2: Data Collection During First Year**

| Month | KGs Dispensed | Count of Fills | Avg KG Dispensed |
|---|---|---|---|
| Mar-21 | 396.83 | 578 | 0.69 |
| Apr-21 | 1,808.75 | 2,188 | 0.83 |
| May-21 | 3,381.60 | 3,839 | 0.88 |
| Jun-21 | 495.00 | 1,113 | 0.44 |
| Jul-21 | 0.13 | 4 | 0.03 |
| Aug-21 | 172.77 | 397 | 0.44 |
| Sep-21 | 3,014.73 | 2,229 | 1.35 |
| Oct-21 | 6,503.95 | 3,322 | 1.96 |
| Nov-21 | 7,350.92 | 3,284 | 2.24 |
| Dec-21 | 7,656.63 | 4,018 | 1.91 |
| Jan-22 | 5,287.89 | 2,844 | 1.86 |
| Feb-22 | 1,791.98 | 1,236 | 1.45 |
| **Total** | **37,861.18** | **25,052** | **1.13** |

Source: FirstElement Fuel, Inc.

The Sunnyvale hydrogen refueling station is supplied by hydrogen generated via the Steam Methane Reformation that converts methane (CH4) and water (H2O) to hydrogen (H2) and carbon dioxide (CO2):

$$CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$$

Per California Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006), Environmental Standards for Hydrogen Production, at least one-third of the hydrogen sold by FirstElement Fuel, Inc.'s state funded hydrogen refueling stations will be produced from renewable sources.

During the first year of operation, FEF has been able to procure environmental attributes necessary to achieve 100% renewable hydrogen for the hydrogen dispensed at the Sunnyvale hydrogen refueling station. These attributes have been procured directly by FEF through a third party in order to increase the renewable supply.

Hydrogen is supplied to the hydrogen fueling stations from Linde's hydrogen production facilities in Ontario, CA, as well as Air Liquide's North Las Vegas facility.

## Subcontractors and Budgets

Table 3 summarizes a detailed view of the budget to construct the Sunnyvale hydrogen station.

**Table 3: Agreement Budget – Sunnyvale**

| Category | Agreement Reimbursable Budget | Agreement Match Budget | Total Project Budget |
|---|---|---|---|
| Compressing and Bulk Storage Equipment | $ 1,367,715 | $ 21,878 | **$ 1,389,593** |
| Ground Storage | $ 154,314 | $ 144,470 | **$ 298,784** |
| Dispenser | $ 262,700 | $ 236,000 | **$ 498,700** |
| *Equipment* | *$ 1,784,729* | *$ 402,348* | ***$ 2,187,077*** |
| *Materials/Misc.* | *$ -* | *$ 77,303* | ***$ 77,303*** |
| I&D Consulting PM | $ - | $ 39,350 | **$ 39,350** |
| SGE Consulting Engineers | $ - | $ 60,883 | **$ 60,883** |
| I&D Consulting Permitting | $ - | $ 29,996 | **$ 29,996** |
| Site Construction | $ 85,271 | $ 1,830,134 | **$ 1,915,405** |
| *Subcontractors* | *$ 85,271* | *$ 1,960,363* | ***$ 2,045,634*** |
| *Indirect Costs* | *$ -* | *$ -* | ***$ -*** |
| **Total** | **$ 1,870,000** | **$ 2,440,014** | **$ 4,310,014** |

Source: FirstElement Fuel, Inc.

## Statement of Future Intent

FEF intends to own and operate the refueling station at 1296 Sunnyvale Saratoga Road, Sunnyvale, CA 94087 for at least 10 years. FEF has invested capital to build the station and will require many years of operation to recoup the costs. FEF has executed an initial 10-year lease with the landowner with the possibility for extension.

In addition, FEF built a maintenance team with the personnel, equipment, and resources to maintain and repair the station as quickly as possible.

To augment onsite personnel across the FEF network, FEF has implemented a comprehensive data collection and monitoring system. FEF maintenance personal can access a breadth of real-time performance and sensor data, live video feeds, and historic usage data, and can control some features of the station remotely 24 hours a day.

In addition to remote monitoring, FEF implemented a computerized maintenance management systems and an enterprise asset management system to schedule and track maintenance, repairs, and inventory. These systems will generate, complete, and log work orders for all maintenance and repair activities. They will also help maximize station up-time and enable tracking of key performance indicators.

## Findings, Conclusions and Recommendations

The following three findings from the Sunnyvale hydrogen station project:

- Because the Sunnyvale station represents one of early stations constructed that incorporates our next generation liquid hydrogen storage, substantial learnings were made in the design, permitting, and construction phases that were carried forward in our future station builds.
- Major delays in commissioning the Sunnyvale hydrogen station resulted from the delays due to the COVID-19 pandemic and the lock down orders, utility design, inspection and install process with PG&E.

# GLOSSARY

BATTERY ELECTRIC VEHICLE (BEV)—Also known as an "All-electric" vehicle (AEV), BEVs utilize energy that is stored in rechargeable battery packs. BEVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

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 Energy Commission'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.

CALIFORNIA FUEL CELL PARTNERSHIP (CaFCP) -- The California Fuel Cell Partnership is an industry/government collaboration aimed at expanding the market for fuel cell electric vehicles powered by hydrogen to help create a cleaner, more energy-diverse future with no-compromises to zero emission vehicles.

CARBON DIOXIDE (CO2) - A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent). The major source of CO2 emissions is fossil fuel combustion. CO2 emissions are also a product of forest clearing, biomass burning, and nonenergy production processes such as cement production. Atmospheric concentrations of CO2 have been increasing at a rate of about 0.5 percent per year and are now about 30 percent above preindustrial levels. (EPA)

DIVISION OF MEASUREMENT STANDARDS (DMS) – a Division of the California Department of Food and Agriculture who's responsibilities include Enforcement of California weights and measures laws and regulations. The Division's activities are designed to:[1]

1. Ensure the accuracy of commercial weighing and measuring devices.
2. Verify the quantity of both bulk and packaged commodities.
3. Enforce the quality, advertising and labeling standards for most petroleum products.

[1] https://www.cdfa.ca.gov/dms/

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.

HYDROGEN (H2) - A colorless, odorless, highly flammable gas, the chemical element of atomic number 1.

METHANE (CH4) - A light hydrocarbon that is the main component of natural gas and marsh gas. It is the product of the anaerobic decomposition of organic matter, enteric fermentation in animals and is one of the greenhouse gases. Chemical formula is CH4.

WATER (H2O) - A colorless, transparent, odorless, tasteless liquid compound of hydrogen and oxygen. The liquid form of steam and ice. Fresh water at atmospheric pressure is used as a standard for describing the relative density of liquids, the standard for liquid capacity, and the standard for fluid flow. The melting and boiling points of water are the basis for the Celsius temperature system. Water is the only byproduct of the combination of hydrogen and oxygen and is produced during the burning of any hydrocarbon. Water is the only substance that expands on freezing as well as by heating and has a maximum density at 4.