CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Scaling Up the True Zero Network

Hydrogen Station

350 Grand Avenue, Oakland, California

Prepared for: California Energy Commission

Prepared by: FirstElement Fuel, Inc.

January 2022 | CEC- 600-2022-042

California Energy Commission

Tim Brown
George Wu
Primary Authors

FirstElement Fuel, Inc.
5281 California Ave, Suite 260
Irvine, CA 92617
www.truezero.com
Agreement Number: ARV-16-030

Sebastian Serrato
Commission Agreement Manager

Kevyn Piper
Commission Agreement Officer
ZERO-EMISSION VEHICLE AND INFRASTRUCTURE OFFICE

Hannon Rasool
Deputy Director
FUELS AND TRANSPORTATION

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

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

FirstElement Fuel graciously thanks Toyota for their vision and fortitude, Honda for their innovation and environmental commitment, Linde for their partnership in advancing sustainable hydrogen infrastructure, Tatsuno for their dedication to innovation and reliability, and of course, Jean Baronas, Sebastian Serrato, Kevyn Piper, and many others at the California Energy Commission for tremendous, sustained confidence in clean, alternative transportation.

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 solicitation 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 applied for funding in response to the CEC's notice of proposed awards February 17, 2017, and the agreement was executed as ARV-16-030 on July 25, 2017.

ABSTRACT

Per funding agreement ARV-16-030 between the California Energy Commission (CEC) and FirstElement Fuel, Inc. (FEF), FEF designed, engineered, permitted, constructed, and commissioned a hydrogen refueling station at 350 Grand Avenue, Oakland, California 94610. 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, a dispenser with two fueling positions, a customer payment interface, and a canopy.

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

Please use the following citation for this report:

Brown, Tim (FirstElement Fuel, Inc.). 2021. *Scaling Up the True Zero Network. Hydrogen Station – 350 Grand Avenue, Oakland, California*. California Energy Commission. Publication Number: CEC-600-20XX-XXX.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

EXECUTIVE SUMMARY

Hydrogen fuel cell electric vehicles (FCEVs) and hydrogen refueling stations are expected to play key roles in California as the state transitions to lower-carbon and zero-emission vehicle (ZEV) technologies for light-duty passenger vehicles, transit buses, and truck transport fleets. 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. More specific actions to bring FCEVs to California markets are in the Governor's *Zero Emission Vehicle Action Plan*.

Hydrogen fuel cell electric drive technology offers tremendous potential for the light-duty passenger vehicle market and medium- and heavy-duty truck and bus markets. FCEV passenger vehicles can drive more than 300 miles on a tank of hydrogen and can be refueled in 3 to 4 minutes the way gasoline passenger vehicles are fueled. They have zero tailpipe emissions, while the carbon footprint is nearly the same as plug-in electric vehicles. The technology can be readily scaled up for SUVs, family passenger vans, pick-up trucks, urban package and beverage delivery trucks, and 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 as a competing technology. Both battery and FCEV technologies will be needed in California to achieve the ZEV deployment goals.

In contrast 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 for consumer use. This has meant that the auto industry and station development industry have had to co-develop two new technologies in parallel: hydrogen refueling infrastructure and hydrogen fuel cell electric vehicles. FCEVs cannot be widely marketed and sold to consumers without a minimum network of refueling stations available.

Assembly Bill (AB) 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, 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 Clean Transportation Program has an annual budget of approximately $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 non-road 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.

The CEC issued solicitation 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 (FCEVs. To be eligible for funding under GFO-15-605, the projects must also be consistent with the CEC's Clean Transportation Program Investment Plan updated annually.

In response to GFO-15-605, FirstElement Fuel, Inc. submitted application number 9 for several stations, including one at 350 Grand Avenue, Oakland, California 94610, which was proposed for funding in the CEC's Notice of Proposed Awards on February 17, 2017.

The CEC contributed $1,870,000 of the total $2,968,588.21 cost to design, engineer, permit, construct, and commission the station.

CHAPTER 1: Purpose

Hydrogen distribution and dispensing infrastructure is not readily available to meet projected commercial targets for the deployment of FCEVs. As FCEVs are deployed in greater quantities, a network of refueling stations is needed to provide coverage which takes advantage of the range of the vehicle, and provides a means to transport, store, and dispense hydrogen. This agreement provides a hydrogen refueling station at 350 Grand Avenue, Oakland, California 94610. The station equipment stores liquid hydrogen and dispenses gaseous hydrogen.

This project will help 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 that can provide up to 310 kg of hydrogen in 12 hours, or over 800 kg in 24 hours.

Improvements to the network of hydrogen refueling stations and an expected corresponding increase in FCEVs will support the carbon reduction and air quality improvement goals of the State of California, such as the Zero Emission Vehicle (ZEV) Mandate, which calls for sufficient alternative refueling infrastructure to support up to 1 million ZEVs by 2020, reaching 1.5 million ZEVs on the road in California by 2025. Hydrogen FCEVs are expected to play a critical role in meeting the ZEV Mandate targets.

Inherent Efficiency of Liquid Hydrogen

Liquid hydrogen, as used at the Oakland station, has storage, transportation, and pumping efficiencies compared to gaseous hydrogen in hydrogen infrastructure scenarios. Compression of gaseous hydrogen at fueling stations up to the pressures required to fully fill FCEVs requires 3-5 kWh/kg of electricity. Because pumping liquid is more efficient than compressing gas, liquid pump stations use less than 1 kWh/kg to accomplish the same task. This is important because electricity at hydrogen stations is expensive and 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'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 are generally well understood. Liquid hydrogen delivery trucks can easily carry 10 or more times the deliverable hydrogen as equivalently-sized gaseous hydrogen trucks (Figure 1). This enables multiple stops and "short, milk runs" without constantly returning to the plant to get a new load and 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

With the Oakland station capacity of 808 kg/day:

- Two simultaneous fueling positions to improve customer experience and reduce wait times
- Over 808 kgs of storage is available to better mitigate potential supply disruptions.
- Retail hydrogen price is competitive with gasoline on a per mile basis.

These quantum leaps in performance and price are made possible by moving to liquid hydrogen production, distribution, storage, and pumping. It generally takes more energy to produce liquid hydrogen, but the storage costs and densities far 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, optimized facility can be used to serve the entire network. This results in lower cost hydrogen supply. In addition, pumping a liquid is inherently more efficient than compressing a gas. Therefore, the pumps used in the generation of station located in Oakland 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 there has historically been enough excess gaseous hydrogen from existing industry 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 for liquid hydrogen for the current batch of stations that will enable substantially reducing the price of this fuel.

Sustainability and Environmental Impacts

FEF notes that hydrogen and fuel cell vehicles are the most effective means to achieve sustainable transportation in the State of California. That 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 FCVs on the road as quickly as possible so that California, and the world, can fully capitalize on the environmental benefits of electric propulsion. FEF understands that, based on years of analysis and research, fuel cell vehicles 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 simultaneously accelerate the adoption of FCEVs and to maximize the potential environmental benefits through a conscientious approach to the fuel supply chain, the operation of hydrogen station projects, and even the hydrogen development process for the hydrogen station in Oakland.

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 OEMs the confidence to release FCEVs on a large scale into the California market. FEF stations have the best up-time performance in California. Primary in the FEF culture is a focus on the customer experience and on the safety and security of the FEF team and stations. To that end, FEF has developed and continued to refine rigorous technical and safety training procedures for 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 competence 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: 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. 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.

<u>Communication</u>

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 during at least three meetings. Additionally, prior to beginning every operational meeting a moment is taken to discuss a "Safety Moment."

<u>Training Methods</u>

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

When a new task is being conducted or the task does not have established procedures, pertinent employees are all trained on performing 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. These records are viewed through their U.S. Occupational Safety and Health Administration Form 300A for the past three years. If there are any major injuries in the records, these are investigated 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 station in Oakland that mandates monthly, quarterly, semi-annual and annual scheduled maintenance activities. Each week the team manager reviews the preventive maintenance schedule, opens work orders for each site with the tasks to be completed by the technicians on duty, and verifies completion of the prior week's work orders. As a routine part of the scheduling, the team managers arrange the planned maintenance activities to avoid cluster shutdowns of adjacent stations in the network that would otherwise create 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 always uses 21st century internal social media apps and cloud-based documentation for companywide communication. The entire team knows the status of all activities at each station from any connected computer, tablet, or smart phone. This heightened communication serves greatly in the coordination of planned maintenance, emergency maintenance, stress testing, press events, vacations, etc.

Additionally, FEF coordinates its planned maintenance activities at the Oakland station so that all technicians are instructed to plan work so that outage time is minimized and the station can return to working conditions with limited down time. Each technician has a personalized sign to let station customers know that maintenance is being done, but the station is still open.

CHAPTER 3: Activities Performed

There were many steps required to bring the Oakland 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 safely install hydrogen fueling equipment.
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 sites that have room for hydrogen, and finally, negotiating with landowners.

In August 2016, FEF took steps to identify and acquire appropriate sites for the station. FEF worked with historic vehicle sales data, academic publications, automakers, and the CEC's Station Location Areas 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. A Letter of Intent was executed with the property owner at 350 Grand Avenue, Oakland, California 94610 on August 18, 2016. A 10-year lease was executed on May 8, 2017.

Figure 2: Property View during Acquisition Phase

View of the property from SWC Grand Avenue and Perkins Street, looking northeast.

Equipment Procurement

The equipment packages installed at the Oakland Hydrogen Refueling Station are 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, evaluating and visiting various component and part suppliers. As hydrogen station integrators, FEF assessed and helped design an equipment package utilizing leaders in the industry to assemble an equipment package that vastly exceeded the minimum technical requirements required by the solicitation.

As noted in the previous chapter, FEF decided to upgrade the throughput and capacity of the Oakland station bringing the station dispensing capacity per day to 808 kgs of hydrogen. This decision resulted in a slight delay in the approval and engineering design process, but the added benefits far outweighed the cost.

Figure 3: Installed Tatsuno Dispenser with two Fueling Positions

Source: FirstElement Fuel, Inc.

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

Source: FirstElement Fuel, Inc.

Site Design and Engineering

FEF started the site design on April 7, 2017, where FEF engaged internal permitting and engineering teams to proceed with design scope. Due to equipment package upgrade process, where time was spent finalizing the equipment footprint with the equipment supplier, the preliminary site plan was not completed until October 30, 2017, allowing the project to proceed with entitlement approval process.

Entitlement

The local planning department must verify 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.

An entitlement package was submitted on December 20, 2017, where FEF staff were subsequently notified that FEF was eligible for an administrative approval and project could proceed to building plan check.

Building Plan Check

As noted above with redesigned equipment, the equipment footprint was not finalized until June of 2018 at which point FEF engaged internal engineers to complete construction drawings, needed for building department approval. A building permit application was submitted on July 18, 2018 and approved on November 13, 2018. With the City of Oakland, the building code review was approved August 15, 2018, but a separate approval was required by Hazmat and other permits required for the approval to build resulting in the later approval date.

Figure 5: Approved Building Permit – 350 Grand Ave.

Permits for which no major inspection has been approved within 180 days shall expire by limitation. No refund more than 180 days after expiration or final.

350 GRAND AVE

CITY OF OAKLAND

CITY OF OAKLAND

250 FRANK H. OGAWA PLAZA ▪ 2ND FLOOR ▪ OAKLAND, CA 94612

350 GRAND AVE

Planning and Building Department
www.oaklandnet.com

PH: 510-238-3891
FAX: 510-238-2263
TDD: 510-238-3254

Permit No: B1803491 Non-Residential Building - Alteration **Permit Issued:** 11/13/2018

Job Site: 350 GRAND AVE **Schedule Inspection by calling:** 510-238-3444

Parcel No: 010 077601300

District:

Project Description: Installation of a hydrogen fueling dispenser and associated hydrogen equipment, including bollard installation at existing fueling station.

Related Permits: DS170515

	Name	Applicant	Address	Phone	License #
Owner:	MAJOR BRAND GAS INC		2712 COWELL RD CONCORD, CA		
Contractor-Employee:	LAFLECHE BREAULT	X	1643 WEST ORANGEGROVE AVE ORANGE, CA	(714) 532-8800	
Contractor:	THE W CORPORATION		1643 WEST ORANGEGROVE AVE ORANGE, CA	(714) 532-8800	799597

PERMIT DETAILS: Non-Residential/Building/Alteration

General Information

Green Code Checklist:		Sets Of Plans:	3	Report - Soil/Geotech:	2
		Structural Calculations:	2	Energy Calculations (T24):	0

Proposed Building Information

Building Use:		Number Of Stories:		Fire Sprinklers:	
Occupancy Group:		Number Of Units:		Total Floor Area (sq ft):	0
Construction Type:		No. of Additional Bedrooms:		Additional Floor Area (sq ft):	

Work Information

Job Value: $250,000.00

TOTAL FEES TO BE PAID: $0.00

Plans Checked By ______________ Date __________ Permit Issued By [signature] Date 11/13/18

Finalized By ______________ Date __________

Source: FirstElement Fuel, Inc.

Site Preparation and Construction

After receiving the approval to build, FEF selected DBA Vantage Company as the general contractor to perform construction work for the Oakland Hydrogen Station.

On November 14, 2018, the construction team broke ground and started work equipment pads that serve as a base for the Linde Compressing and Dispensing unit and the FIBA storage tubes. This initial scope encompassed demolition, form work, laying initial conduit connections, and pouring concrete. Vantage completed the concrete pour and restored operation to drive aisles on December 19, 2018, which marked the completion of Phase 1 of construction.

FEF divided their construction progress into two phases as a result of the equipment shipment from Germany being delayed by a couple of months to March 28, 2018.

Figure 6: Mobilization and Breaking Ground at 350 Grand Avenue

Source: FirstElement Fuel, Inc.

Figure 7: Completed Equipment Pad at the Completion of Phase 1

Source: FirstElement Fuel, Inc.

Figure 8: Progress Photo of Trenching and Demolition Work Around Dispenser Pad

Source: FirstElement Fuel, Inc.

On May 2, 2019, the Linde equipment package arrived in the United States where the team began scheduling and coordinating the equipment installations. The equipment install occurred on May 20, 2019, with careful coordination with crane operators as well as logistic coordinators to ensure that equipment was delivered on site and ready for install.

Figure 9: Equipment Delivery – Crane Lift

Crane lifting hydrogen compressing and dispensing unit off delivery truck in Oakland

Energize and Mechanical Connections

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

At this point a slight delay was noted for city inspections. The City of Oakland was having unprecedented development and the city was not accepting third-party inspections. Specifically, electrical inspections resulted in a critical path delay as FEF was unable to bring power to the site until these inspections had occurred. To further complicate matters, the utility provider PG&E needed to perform their respective inspection before scheduling work to energize site.

To proceed with the commissioning scope and continue progress, the next phase was completed utilizing generator power. The permanent utility connection was approved on October 10, 2019.

On June 28, 2019, FEF completed final punch list items, inspections, and site walk with the owner and the station was ready to be handed off to begin the commissioning phase.

Commissioning

On July 1, 2019, FEF started the commissioning phase where the equipment is tested to verify that the station is ready dispense hydrogen. See Table 1 for a summary of tasks performed to commission the station, and Figure 10 highlighting a key milestone in receiving the first liquid hydrogen delivery on site.

Table 1: Commissioning Checklist

Commissioning Tasks		FE1020-Oakland 350 Grand Avenue, Oakland, CA 94610
Date:		
Operator:		
No.	Complete If yes check box	Tasks
1	☑ Check	Cleaning Skid
2	☑ Check	Pressure Test
3	☑ Check	Electrical Startup
4	☑ Check	Mechanical Landing
5	☑ Check	PSV Check
6	☑ Check	Calibrate Gas Detectors
7	☑ Check	Safety Function Test
8	☑ Check	Vacuum H2 Storage
9	☑ Check	Purge GH2 Storage
10	☑ Check	Vacuum LH2 Tank
11	☑ Check	Purge LH2 Tank
12	☑ Check	FillFluids
13	☑ Check	Cooldown LH2 Tank and Fill
14	☑ Check	Remove and Pump Drive
15	☑ Check	Cleaning Pump Vessel
16	☑ Check	Install Pump Insert
17	☑ Check	Install Pump Coupling
18	☑ Check	Purge pump vessel and head room
19	☑ Check	Cooldown the pump
20	☑ Check	Recalibrate Pump Level Sensor
21	☑ Check	Power on Dispenser'
22	☑ Check	Pressure Test Dispenser

Source: FirstElement Fuel, Inc.

Figure 10: First Liquid Hydrogen Fuel Delivery

Source: FirstElement Fuel, Inc.

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.

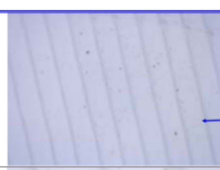
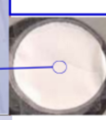
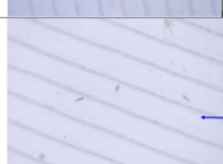
Acting as a Registered Service Agent and working with the local County Weights and Measures Officer as a witness, FEF successfully completed the DMS Testing on August 5, 2019.

As part of this process Fuel Quality Testing was performed, where results are summarized in Figure 11.

Figure 11: Hydrogen Fuel Quality Testing Report

SmartChemistry

SAE J2719 — Sample Received on 08/07/2019 & 08/06/2019 — **First Element Oakland H70**

SUMMARY	SAE J2719 Limits -µmol/mol	Smart Chemistry Detection Limits -µmol/mol	Concentration (µmol/mol)
H_2O (ASTM D7649)	5	2	**< 2**
Total Hydrocarbons -C_1 Basis (ASTM D7892)	2		**0.067**
Methane			0.067
O_2 (ASTM D7649)	5	2	< 2
He (ASTM D1946)	300	10	< 10
N_2 & Ar (ASTM D7649)	100		
N_2		5	< 5
Ar		0.4	< 0.4
CO_2 (ASTM D7649)	2	0.03	< 0.03
CO (ASTM D5466)	0.2	0.0004	**0.00045**
Total S (ASTM D7652)	0.004		**0.000014**
Hydrogen Sulfide		0.000002	**0.0000045**
Carbonyl Sulfide		0.000002	**0.0000070**
Methyl Mercaptan (MTM)		0.000002	< 0.000002
Ethyl Mercaptan (ETM)		0.00001	< 0.00001
Dimethyl Sulfide (DMS)		0.000002	< 0.000002
Carbon Disulfide		0.000001	**0.0000021**
Isopropyl Mercaptan (IPM)		0.00001	< 0.00001
Tert-Butyl Mercaptan (TBM)		0.00001	< 0.00001
n-Propyl Mercaptan		0.00001	< 0.00001
Thiophene		0.00001	< 0.00001
Diethyl Sulfide		0.00001	< 0.00001
n-Butyl Mercaptan		0.00001	< 0.00001
Dimethyl Disulfide (DMDS)		0.00001	< 0.00001
Tetrahydrothiophene (THT)		0.00001	< 0.00001
Formaldehyde (ASTM D7892)	0.01	0.01	< 0.01
Formic Acid (ASTM D5466)	0.2	0.0005	< 0.0005
Ammonia (ASTM D5466)	0.1	0.01	< 0.01
Total Halogenates	0.05		< 0.01
Cl_2 (ASTM D5466)		0.0001	< 0.0001
HCl (ASTM D5466)		0.0004	< 0.0004
HBr (ASTM D5466)		0.0007	< 0.0007
Total Organic Halides (32 compounds in red and bold listed in "Non-Methane Hydrocarbons") (ASTM D7892, Smart Chemistry limit is for each individual organic halide)		0.001	< 0.001
Particulate Concentration (ASTM D7651)	1 mg/kg	**Side 1, Sampled on 8/7/2019**	**0.18 mg/kg**
Particulates Found & Size (ASTM D7634)		**Side 2, Sampled on 8/6/2019**	**0.11 mg/kg**
Side 1 		**This is the 0.2µm Teflon particulate filters after Particulate sampling @Side 1. Neither pinhole nor oil stain is found.**	**There are total 153 particulates found (sizes in micrometer) - 165, 130, 86, 82, 81, 75, 74, 72, 69, 63 (2), 54, 49, 45 (2), 44, 43, 39 (2), 38, 37 (2), 36 (2), 35 (2), 33 (4), 32, 31 (3), 30, 29 (4), 28 (6), 27 (2), 26 (5), 25 (3), 24 (2), 23 (8), 22 (2), 21 (4), 20, 19 (8), 17 (13), 16 (28), 14 (20), 12, 11 (11).**
Side 2 		**This is the 0.2µm Teflon particulate filters after Particulate sampling @Side 2. Neither pinhole nor oil stain is found.**	**There are total 43 particulates found (sizes in micrometer) - 375, 308, 228, 156, 128, 91, 82, 77, 65, 49, 44 (2), 39, 38, 32, 29 (2), 27, 25 (2), 24 (3), 23, 20 (5), 18 (2), 17 (2), 16 (4), 14 (5), 11.**
Hydrogen Fuel Index	99.97%		**99.999993%**

Source: FirstElement Fuel, Inc.

Hydrogen fueling station performance validation is accomplished through the Hydrogen Station Equipment Performance (HyStEP) testing device and was performed on August 26-27, 2019, to validate that the station can meet the fueling protocol standards. The results were reviewed by the OEM manufacturers and approved for station opening on September 20, 2019.

Operational and Open Retail

The California Fuel Cell Partnership (CaFCP) Station Operational Status System (SOSS) provides regularly updated station status information to fuel cell vehicle drivers. FEF developed software in-house that provides the required updates to the SOSS system. The Oakland hydrogen station began sending regular status updates to SOSS September 20, 2019.

The Oakland station met requirements for open retail status September 20, 2019.

As a result of running on generator power, the station operated under a temporary certificate of occupancy, until October 10, 2019, where it transitioned to full operational status once the utility connection was energized allowing for permanent certificate of occupancy to be issued.

Figure 12: Station Operation Status System – Oakland

Oakland - Grand Ave

H35* Status: ONLINE
H35* Inventory: 435.71 KG
H70* Status: ONLINE
H70* Inventory: 435.71 KG

Last Updated: Monday, 6/28/2021, 7:06 PM
*H35 = 35 MPa or 5,000 PSI
*H70 = 70 MPa or 10,000 PSI

350 Grand Avenue, Oakland, CA 94610

View in Map

Opening Hours: 24/7

Station Customer Service: (844) 878-9376

The Oakland station is one of the highest capacity hydrogen stations open in the San Francisco Bay Area.

CHAPTER 4: Results

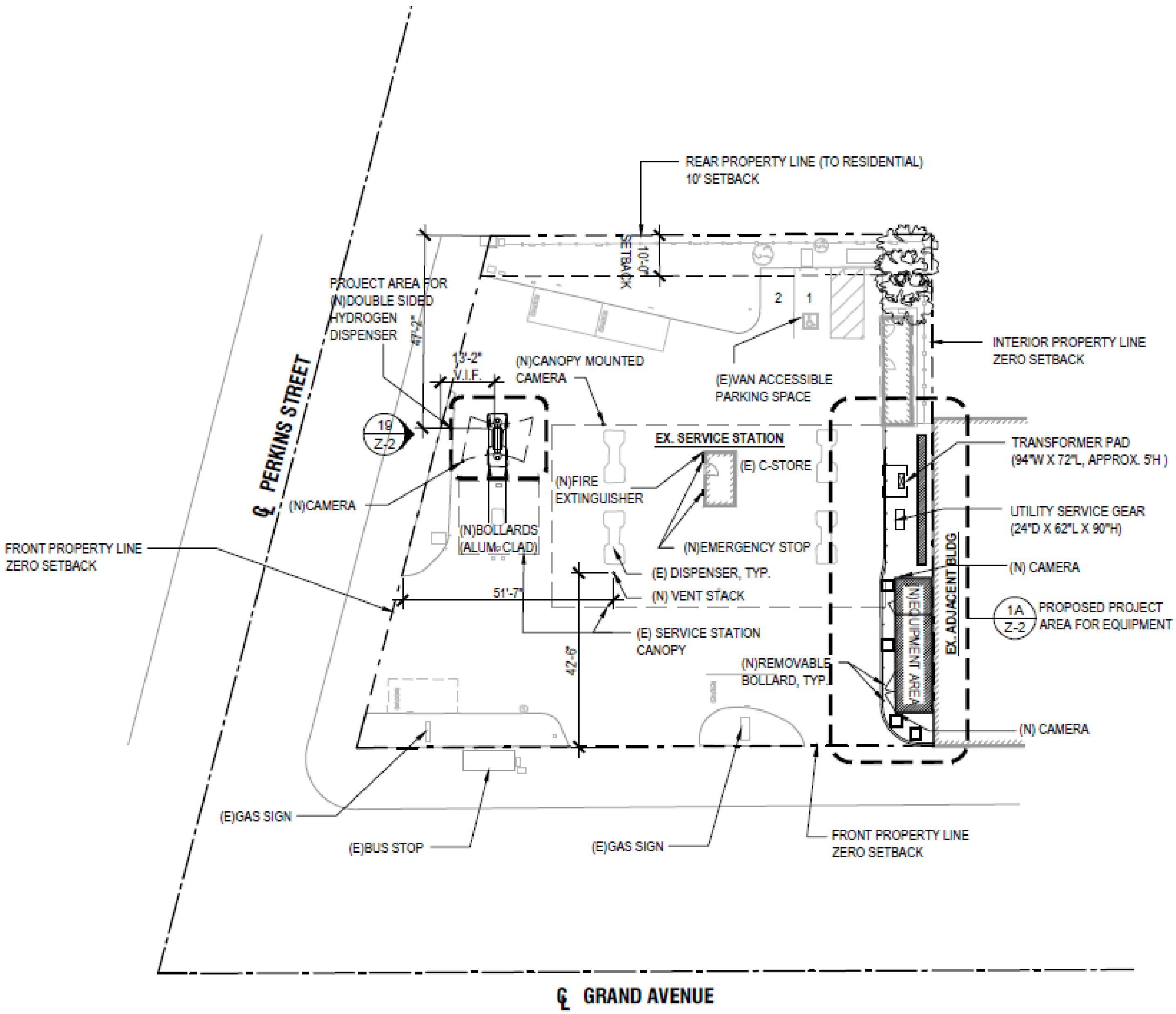
Oakland Hydrogen Station Open

The Oakland hydrogen station is the first liquid hydrogen station FEF opened that has a capacity of more than 800 kilograms. This larger capacity plays a pivotal role in the infrastructure needs of today serving the greater number of FCEVs on the road today. Additionally, with two fueling positions that allow two cars to fill simultaneously, FEF is able improve the customer experience and reduce that amount of time waiting for an open pump.

Figure 13: Completed Oakland Hydrogen Station

Source: FirstElement Fuel, Inc.

Figure 14: Completed Site Layout – Oakland



Source: FirstElement Fuel, Inc.

Since the first fill occurred September 20, 2019, that station has dispensed over 19,000 kgs in its first year of usage and recorded just under 7,500 fills. As a result of COVID-19 FEF noticed a drop in usage around the second quarter of 2020, with usage starting to build back up in the latter part of the year as drivers return to the road. The table below summarizes the data collection during this first year.

Table 2: Data Collection During First Year of Operation

Month	Kgs Dispensed	Count of Fills	Avg Kgs Dispense
October-19	2,949.02	1055	2.80
November-19	2,412.66	897	2.69
December-19	2,264.19	992	2.28
January-20	1,939.31	804	2.41
February-20	2,287.74	909	2.52
March-20	1,405.54	603	2.33
April-20	594.12	315	1.89
May-20	737.01	341	2.16
June-20	1,006.56	347	2.90
July-20	1,102.41	375	2.94
August-20	1,335.49	452	2.95
September-20	1,236.80	408	3.03
Grand Total	**19,270.84**	**7498**	**2.58**

Source: FirstElement Fuel, Inc.

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 Oakland 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 Air Products' hydrogen production facilities in Sacramento, California.

Subcontractors and Budgets

A detailed view of the budget to construct the Oakland hydrogen station is summarized in Table 3.

Table 3: Agreement Budget - Oakland

Category	Agreement Reimbursable Budget	Agreement Match Share Budget	Total Project Budget
Compressing and Pump	$ 1,367,015.00	$ 42,595.29	**$ 1,409,610.29**
Ground Storage	$ 152,514.00	$ -	**$ 152,514.00**
Dispenser	$ 262,700.00	$ -	**$ 262,700.00**
Equipment	*$ 1,782,229.00*	*$ 42,595.29*	***$ 1,824,824.29***
Materials/Misc.	*$ -*	*$ 162,055.51*	***$ 162,055.51***
I&D Consulting	$ -	$ 100,274.49	**$ 100,274.49**
SGE Consulting Engineers	$ -	$ 74,572.71	**$ 74,572.71**
Vantage Company	$ 87,771.00	$ 719,090.21	**$ 806,861.21**
Subcontractors	*$ 87,771.00*	*$ 893,937.41*	***$ 981,708.41***
Indirect Costs	*$ -*	*$ -*	***$ -***
Total	**$ 1,870,000.00**	**$ 1,098,588.21**	**$ 2,968,588.21**

Source: FirstElement Fuel, Inc.

Statement of Future Intent and Findings

In addition, FEF has built an in-house maintenance team that has the personnel, equipment, and resources to maintain and repair the FEF stations as quickly as possible throughout California.

To augment onsite personnel across the entire FEF network, a comprehensive data collection and monitoring system has been implemented. The Oakland station is included in the 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 has implemented rigorous Computerized Maintenance Management Systems (CMMS) and Enterprise Asset Management systems (EAM) to schedule and track maintenance, repairs, and inventory at the Oakland station. Work orders will be generated, completed, and logged for all maintenance and repair activities. This will help maximize station up-time and enable tracking of key performance indicators.

The following are two findings from the Oakland hydrogen station project:

- Because the Oakland station represents the first station constructed that incorporates FEF's next generation of stations that features FEF's larger capacity liquid hydrogen storage, substantial learnings were made in the design, permitting, and construction phases that were carried forward in station builds.

- A major delay in energization of the Oakland hydrogen station resulted from utility design, inspection, and install process with PG&E. FEF was required to commission and operate the site under generator power to move the project forward. On future sites, where applicable, FEF has adjusted phasing plans to prioritize challenging utility installs.

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 responsibility 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 helping 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 (CO_2) - 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. CO_2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO_2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent). The major source of CO_2 emissions is fossil fuel combustion. CO_2 emissions are also a product of forest clearing, biomass burning, and nonenergy production processes such as cement production. Atmospheric concentrations of CO_2 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 with responsibilities that include Enforcement of California weights and measures laws and regulations. The Division's activities are designed to:

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.

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 (H_2) - A colorless, odorless, highly flammable gas, the chemical element of atomic number 1.

METHANE (CH_4) - 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 CH_4.

WATER (H_2O) - 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°C.