CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Sacramento Hydrogen Station

Prepared for: California Energy Commission

Prepared by: Equilon Enterprises LLC (dba Shell Oil Products US)

Gavin Newsom, Governor

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California Energy Commission

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ACKNOWLEDGEMENTS

At Shell Hydrogen, the company is focused on making hydrogen fuel a mainstream and competitive option for zero-emission transportation. Developing the network of hydrogen fueling stations under this grant funding opportunity has accomplished significant progress for fuel cell electric vehicle customers in California, including the fastest delivery of new stations to date in California for improving coverage and capacity in the fueling network, two fueling positions at each station for improving customer service, station reliability through two entirely redundant systems at each station, and integration under the canopy alongside other fuels for safety of traffic flow, convenience, shelter, and the normalcy of refueling. The authors would like to thank the following individuals and business partners for significant contributions to this success:

- The California Energy Commission (CEC) Lead Transportation Commissioner Patty Monahan, who provided visionary leadership and direction for the hydrogen mobility in the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program, CEC Hydrogen Unit Supervisor, Jean Baronas, who provided diligent program administration with helpful attention to detail and direct engagement, as well as the various Commission agreement managers and officers who provided thoughtful and constructive oversight of the Sacramento station delivery.
- AU Energy, which is a high-quality and forward-thinking owner and operator of the Shell retail stations in California. Varish Goyal, Sunny Goyal, and Kpish Goyal are important business partners for their successful introduction of hydrogen fuel in California and represent the model of family business in California.
- The leading manufacturers of fuel cell electric vehicles, Craig Scott with Toyota Motors North America and Robert Bienenfeld and Stephen Ellis with American Honda. They are important business partners for their direct financial contributions to these stations, as well as their dedication to the introduction of fuel cell electric vehicles. Their ongoing collaboration ensures the highest quality of customer service.
- The Nel Hydrogen service and operations teams who are important business partners for increasing the quality and capacity of hydrogen fueling station equipment in these stations and ongoing partnership in the successful operation and maintenance of the stations.
- The Fiedler Group Team who was instrumental in managing the permitting process, which often entailed the challenging task of introducing jurisdictions to hydrogen refueling stations. Fiedler Group also managed the detailed design and construction on site, drawing from its deep expertise in the retail refueling business.
- The team at Fastech Inc., who did an exceptional job with the construction of the site and was on the front line of managing the daily hazardous aspects of construction. The team's careful work and planning resulted in no injuries to personnel, asset, or the environment.

- The local authorities having jurisdiction for the stations — Sacramento, San Francisco, Berkeley, Walnut Creek, and San Jose — who worked collaboratively throughout the evaluation and permitting of these stations. In doing so, they have continued to expand upon the base of experience that will enable continued expansion of the hydrogen fueling network that is an important component of the infrastructure to transition to zero-emission transportation.

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 to provide grant funds to expand the network of publicly accessible hydrogen refueling stations that serve light-duty fuel cell electric vehicles in California. In response to GFO-15-605, the recipient submitted an application that was proposed for funding in the CEC's notice of proposed awards dated February 17, 2017, and the agreement was executed as ARV-17-002 on September 24, 2017.

ABSTRACT

Equilon Enterprises LLC (dba Shell Oil Products US) designed, engineered, permitted, constructed, and made operational a hydrogen refueling station at 3510 Fair Oaks Boulevard, Sacramento, California. The station consists of a concrete reinforced block compound that encloses hydrogen storage, compression, and cooling equipment; two dispensers with one fueling hose each; and two customer payment point-of-sale terminals. Hydrogen dispensers are colocated with gasoline dispensers under the canopy of an existing Shell gas station.

Keywords: California Energy Commission, Sacramento, Equilon Enterprises, Shell Oil Products, fuel cell electric vehicles, hydrogen refueling station, infrastructure, FCEV

Authors: DiPalma, Julia, Omar Shkeir, and Wayne Leighty. Equilon Enterprises, LLC dba Shell Oil Products US. 2019. *Sacramento Hydrogen Station*. California Energy Commission. Publication Number: CEC-600-2024-033.

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EXECUTIVE SUMMARY

Equilon Enterprises LLC (dba Shell Oil Products US) built a hydrogen refueling station at its existing gasoline station at 3510 Fair Oaks Boulevard, Sacramento. Under its grant funding oportunity GFO-15-605, the California Energy Commission (CEC) provided $2,337,500, funding 58.9 percent of the total station cost, while Shell provided the balance for a total station cost of $3,971,700.

The hydrogen station has a refueling capacity of 400 kilograms per day, dispensed via two single-hose dispensers that are located under the canopy, in the same fueling lanes that gasoline cars use for refueling.

Shell's project team comprised of Fiedler Group (as engineer of record), Nel Hydrogen (as equipment vendor, installer, and operation and maintenance contractor), and Fueling and Service Technologies (Fastech, as general contractor).

The hydrogen station equipment, supplied by Nel Hydrogen, attained a UL certificate of compliance October 25, 2018. This certification applies to all stations conforming to this design.

The station took 27 months to achieve an open retail status, from the time when Fiedler Group initiated preapplication meetings with authorities having jurisdiction to the open retail date of May 22, 2019. First fueling of a fuel cell electric vehicle (FCEV) was done April 2, 2019. The time to open retail after construction crew mobilized was 12 months, which includes a period of about 3 months of no activity due to the station owner executing a gasoline system refurbishment project.

Shell initiated site acquisition negotiations with AU Energy, joint owner and operator for the Sacramento Shell gasoline station. A complete agreement was executed on August 17, 2016.

Fiedler Group initiated preapplication meetings with the authorities having jurisdiction in March 2017. An entitlement application package was submitted to the Sacramento Planning Department in August 2017 and approved in September 2017. A submission to the building department for construction permit was made in early December 2017. Three additional rounds of plan check comments were addressed. Final approval (that is, permit was ready to issue) of the construction permit was obtained March 19, 2018.

Shell initiated equipment procurement with Nel Hydrogen in April 2017. Time-phased, on-site delivery and installation of equipment were completed in March 2019.

After a competitive bidding process, Shell awarded Fastech the contract for civil construction. The contractor began preparing for construction on June 6, 2018. The station, with all hydrogen equipment installed, was ready for a prestartup safety review March 13, 2019. The reason for the long time lapse between mobilization and prestartup safety review was that construction at this site was done in two phases with about four months of no activity between the two phases. This lapse was due to a construction project initiated by the station owner to refurbish the gasoline station.

The first FCEV was filled April 2, 2019, after obtaining a certificate of accuracy for the first dispenser, issued on March 28, 2019, by the California Department of Food and Agriculture,

Division of Measurement Standards. The accuracy of the second dispenser was certified April 10, 2019.

Shell collected one year of operational data and submitted to the CEC. These data include quarterly reporting of all fueling, maintenance, operations data; four hydrogen quality reports; and two reports of dispensed renewable hydrogen. If one average hydrogen FCEV takes one average gasoline midsized sedan off the road, the amount of gasoline displaced due to Sacramento operation using one year of data (May 2019 to June 2020) would equal nearly 9,600 gallons displaced per year.

Shell plans to operate the Sacramento station for at least the next 10 years and plans to operate up to 56 other light-duty stations in California in addition to heavy-duty stations. Shell is a committed participant and supporter of California's vision for the hydrogen refueling station network.

CHAPTER 1: Introduction

Objectives

The Sacramento station is one of seven stations that Equilon Enterprises LLC (dba Shell Oil Products US) designed and constructed under awards from the California Energy Commission (CEC), granted under its grant funding opportunity GFO-15-605. The objective of this project was to design, build, commission, and open a retail hydrogen service station colocated at an existing Shell gasoline station at 3510 Fair Oaks Boulevard, Sacramento. The objective of this station was to demonstrate that a hydrogen refueling station is capable of meeting FCEV consumer convenience needs safely and reliably.

Approach

Shell's overall approach to developing its hydrogen refueling station infrastructure has the following key elements:

- Make the customers refueling experience as similar as possible to that of refueling gasoline-powered vehicles. This is achieved by colocating hydrogen dispensers and associated point-of-sale (POS) terminals with the gasoline dispensers under the canopy of its branded gas stations.
- Employ standardized equipment design, and performance characteristics across all its hydrogen refueling stations.
- Use modular equipment with the smallest possible footprint to permit installation in existing stations that are space-constrained. Such stations are typically located in urban, densely developed sites. Using this modular equipment allows Shell to bring hydrogen refueling stations to city centers.
- Team with engineering firms, equipment manufacturers, and construction contractors with a proven record of designing and building service stations.

Activities Performed

The project team composed of Shell, Nel Hydrogen (Nel), FG and the construction contractor, Fueling and Service Technologies Inc (Fastech), executed the following phases to achieve an open retail station:

- Site acquisition
- Preliminary investigations
- Equipment procurement
- Entitlements
- Design and permitting
- Bid solicitation

- Construction
- Commissioning and startup
- Operational and open retail station
- Data collection and analysis

CHAPTER 2:
Station Design, Construction, and Startup

Major Activities and Timeline

Construction of the Sacramento station required many activities that are listed and described below along with an approximate timeline for their execution. Shell negotiated site acquisition agreement and procured the hydrogen station equipment.

Shell retained Fiedler Group (FG) to prepare documents required for design, entitlements, permitting, bid solicitation, and construction services. FG implemented its phased approach to accomplish the preparation of the documents, exhibits and attain a permit ready to issue status.

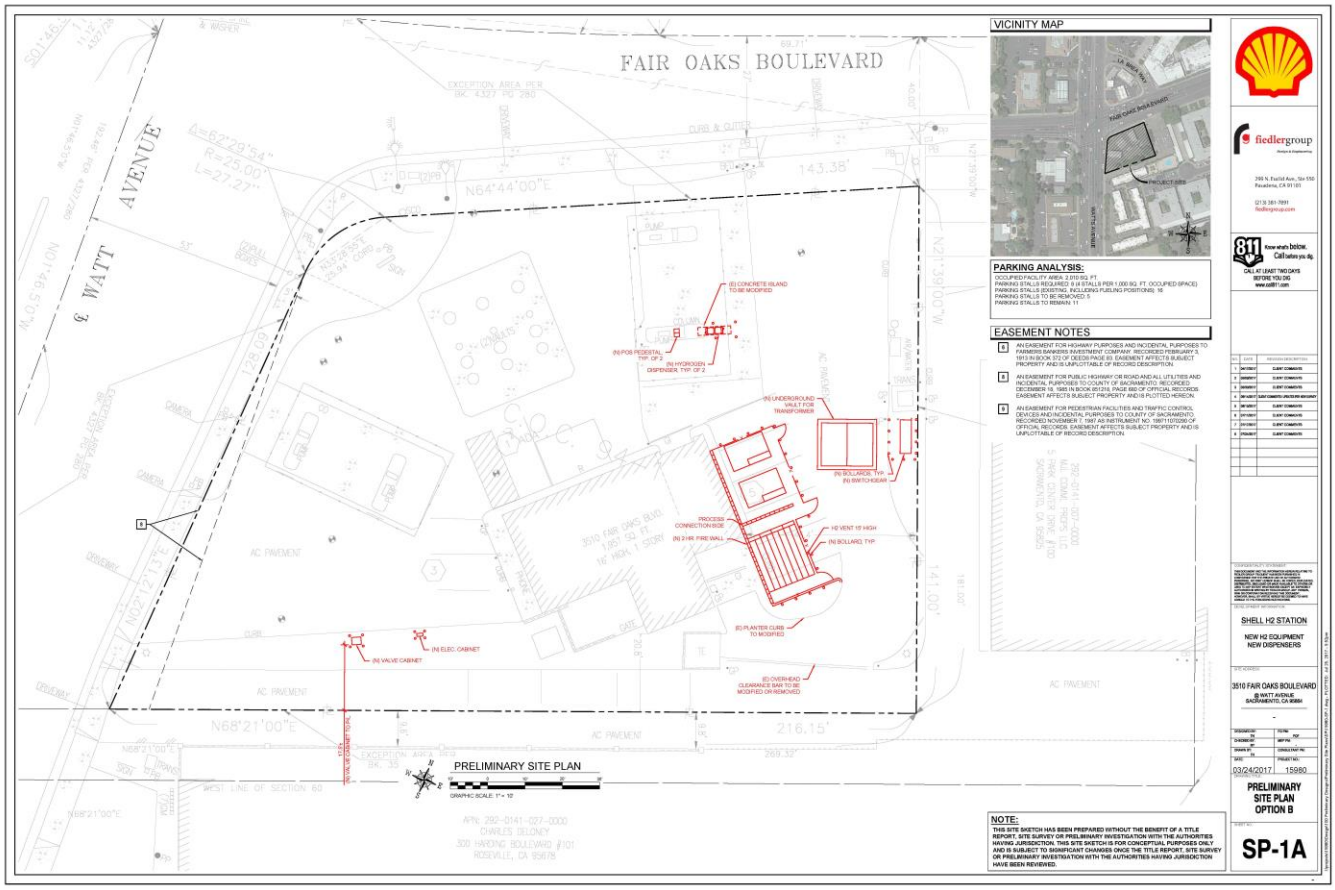
Site Acquisition (August 2016)

The Sacramento station is at an existing Shell-branded station operated by AU Energy (AUE). The site is jointly owned by Shell and AUE. Shell and AUE entered negotiations to build a hydrogen station and executed a completed agreement on August 17, 2016.

Preliminary Investigations (March 2017 to July 24, 2017)

FG investigated the requirements of various government agencies and utilities. This investigation entailed discovery of requirements, codes, ordnances, and regulations that affect entitlements, permitting, and design criteria. A site investigation report was developed based on agency contact. The following agencies were contacted: Department of Community Development — Planning and Environmental Review, Sacramento County; Sacramento Metro Fire; and the local utility, Sacramento Municipal Utility District (SMUD). The project team prepared a preliminary site plan based on Shell's design requirements, agency findings, and site visit. Figure 1 illustrates the preliminary site plan.

Figure 1: Preliminary Site Plan



Credit: Fiedler Group/Shell

NOTE: Original drawing is higher resolution.

Equipment Procurement (April 10, 2017, to March 13, 2019)

Shell selected Nel to supply the hydrogen station equipment. Shell contracted with Nel to supply, install, and commission all equipment necessary to achieve an operational hydrogen station. Nel supplied the following major hydrogen station equipment: station module (containing compressor and hydrogen cooling system), storage module and associated valve panels, supply cabinet and associated human machine interface, hydrogen dispensers, and all interconnecting mechanical pipe and tubing between the equipment. The equipment delivery was timed to synchronize with the construction schedule. All the equipment was delivered to the site and installed by March 13, 2019.

Shell purchased the POS terminals from COMDATA.

Entitlement Process (August 16, 2017, to September 11, 2017)

FG submitted the entitlements drawing package to the authority having jurisdiction (AHJ), the City of Sacramento, on August 16, 2017. The planning department verified that the project meets the zoning requirements and approved aesthetic, landscaping, and other details that are important to the community. One set of plan check comments was received and addressed. Shell received approval September 11, 2017. Figure 2 illustrates the site plan approved by the planning department.

Site Design and Permitting (Completed March 19, 2018)

FG submitted the first design drawing package to the AHJ, the City of Sacramento, on December 6, 2017. Four sets of plan check comments were received and addressed. Shell received final approval of the construction permit March 19, 2018. Figure 3 illustrates the site plan permitted for construction.

Bid Solicitation (February 1, 2018, to March 23, 2018)

FG prepared a bid solicitation package consisting of the drawing set, technical documents, and project manual. Shell invited four prequalified general contractors to bid. Two contractors declined to bid, citing workload constraints and unavailability for the planned mobilization date of April 2, 2018. Shell invited each contractor to attend a one-on-one prebid meeting. Shell received two bids and evaluated them against an engineer's independent cost estimate. In addition to cost, other factors that Shell used to evaluate bids are prior similar experience and current capability, safety performance, financial strength, and ability to mobilize and complete construction per required schedule. Shell awarded a construction contract to Fastech on March 23, 2018.

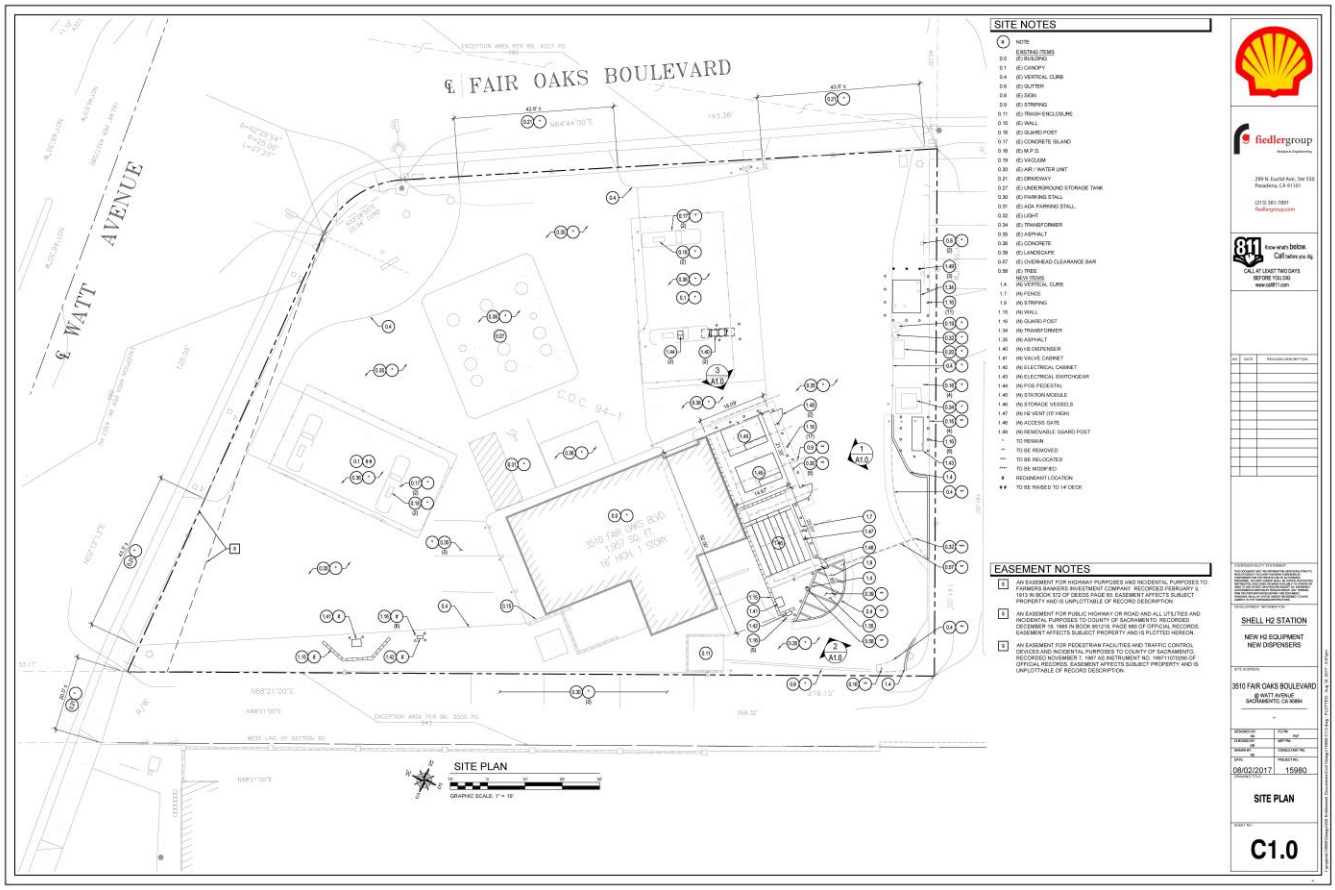
Construction (May 29, 2018, to March 13, 2019)

Fastech initiated preconstruction activities at the site on May 29, 2018, and mobilized to the site on June 6, 2018. All hydrogen station equipment was installed by March 13, 2019.

The construction at this site was done in two phases with about four months of no activity between the two phases due to a construction project initiated by the station owner to refurbish the gasoline station.

Utility service was energized November 30, 2018. Shell project managers, in conjunction with Fastech, FG, and the operations and maintenance contractor, conducted the prestartup safety review (PSSR) March 13, 2019, and created a check list of actions. Figure 4 illustrates assembly of the storage module and two compressor modules set on the foundation. Figure 5 illustrates the completed hydrogen station.

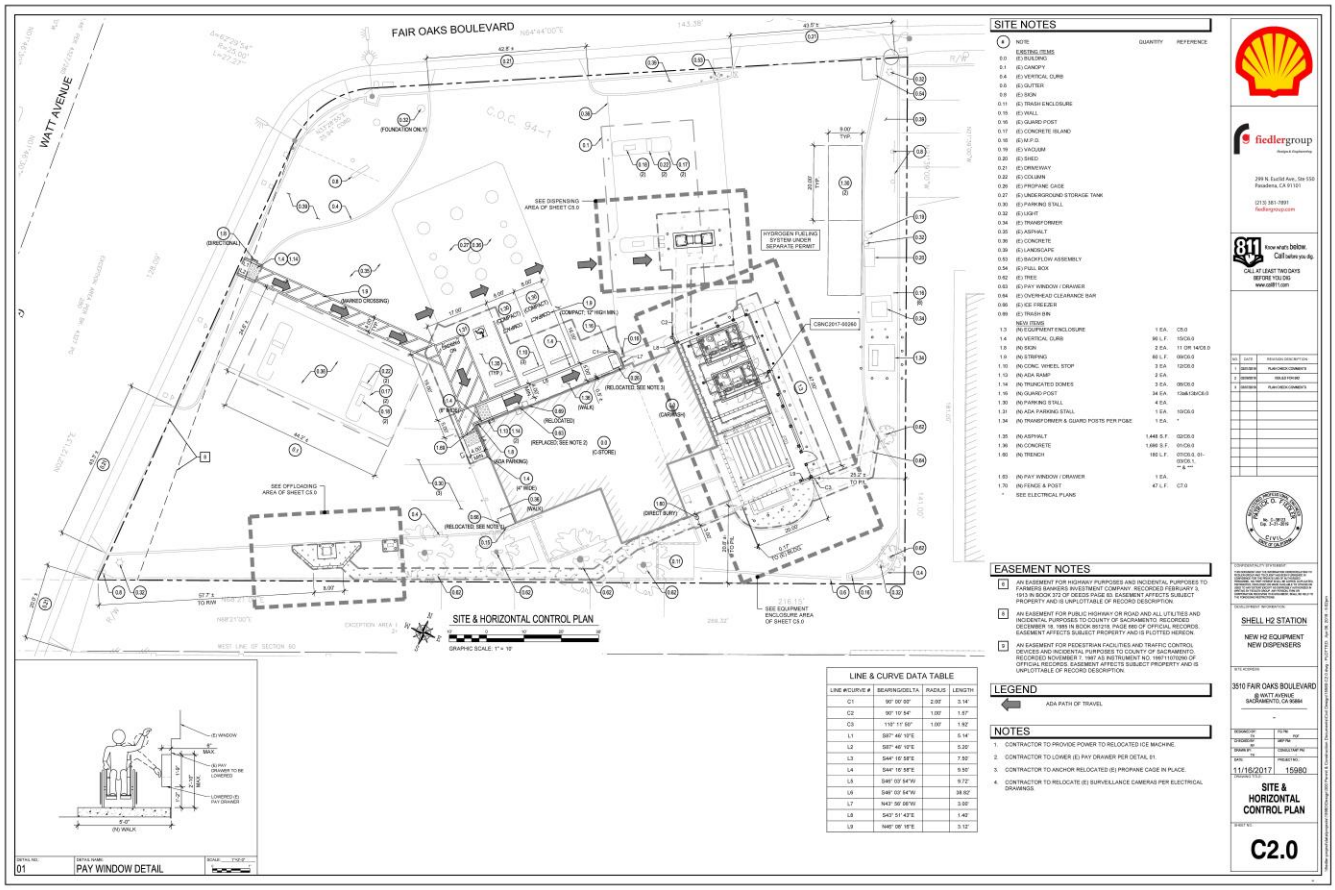
Figure 2: Site Plan Approved by the Planning Department



Credit: Fiedler Group/Shell

NOTE: Original drawing is higher resolution.

Figure 3: Site Plan for Construction



Credit: Fiedler Group/Shell

NOTE: Original drawing is higher resolution.

Figure 4: Field Assembly

Field assembly of storage module (above) and two compressor modules (below).
Photo Credit: Fiedler Group/Shell

Figure 5: Completed Assembly Images

View of the dispensers and POS (above) and fenced equipment compound (below).
Photo Credit: Fiedler Group/Shell

Commissioning and Startup (March 13, 2019, to April 2, 2019)

PSSR actions that were deemed prerequisite for introduction of hydrogen into the system were completed March 13, 2019. The project team introduced hydrogen into the system March 19, 2019. California Department of Food and Agriculture, Division of Measurement Standards (DMS), certified dispenser accuracy March 28, 2019, and April 10, 2019. Commissioning and startup activities continued until April 2, 2019, when the first FCEV was filled. Figure 6 illustrates fueling of the first FCEV. Figure 7 illustrates results of hydrogen purity test.

Operational Station (April 4, 2019)

The project team deemed the station "operational" April 4, 2019. Shell achieved connection to the Station Operational Status System (SOSS) on March 11, 2019. Figure 8 illustrates the SOSS status of the new Sacramento station.

Open Retail Station (May 22, 2019)

The station served the first retail customer May 22, 2019. The project team deemed the station to be open retail as of the same date.

Figure 6: First Fueling of an FCEV

Honda Clarity fueled on April 2, 2019.
Credit: Fiedler Group/Shell

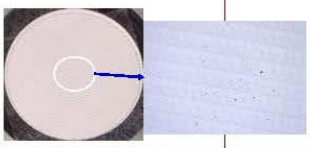
Figure 7: Hydrogen Fuel Quality Report (March 29, 2019)

www.SmartChemistry.com

SAE J2719

Sampling Date & Starting Time: 03/29/2019

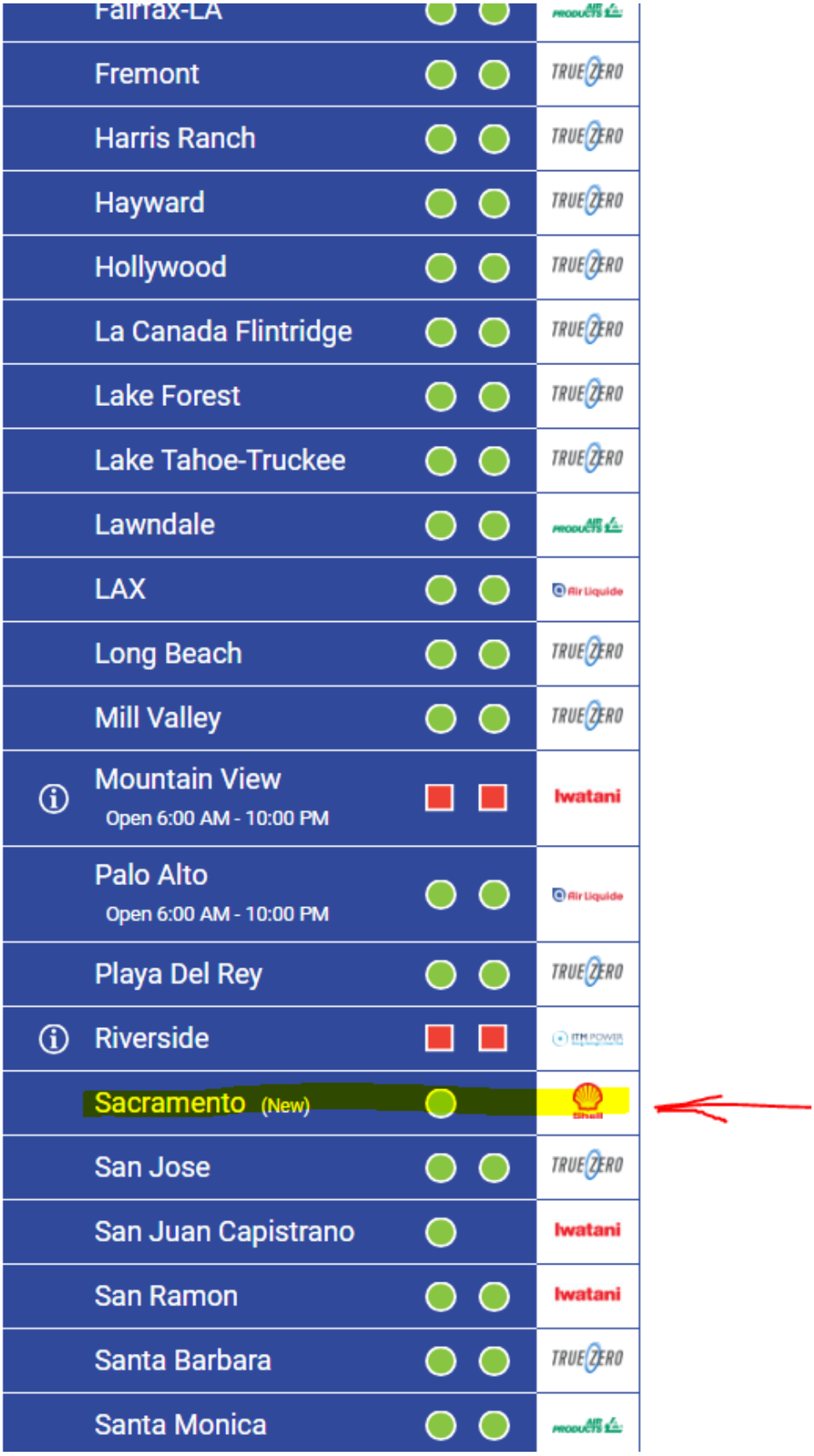
NEL Fair Oaks H70

SUMMARY	SAE J2719 Limits - µmol/mol	SMART CHEMISTRY Detection Limits - µmol/mol	Concentration (µmol/mol)
H_2O (ASTM D7843)	5	1	< 1
Total Hydrocarbons $-C_1$ **Basis** (ASTM D7892)	2		**0.051**
Methane			0.051
O_2 (ASTM D7941)	5	2	< 2
He (ASTM D7949)	300	10	< 10
N_2 & Ar (ASTM D7941)	100		
N_2		5	< 5
Ar		0.4	< 0.4
CO_2 (ASTM D7940)	2	0.05	< 0.05
CO (ASTM D5466)	0.2	0.0005	**0.00057**
Total S (ASTM D7652)	0.004		**0.000017**
Hydrogen Sulfide		0.000002	**0.0000064**
Carbonyl Sulfide		0.000002	**0.0000083**
Methyl Mercaptan (MTM)		0.00001	< 0.00001
Ethyl Mercaptan (ETM)		0.00001	< 0.00001
Dimethyl Sulfide (DMS)		0.00001	< 0.00001
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	0.005	< 0.005
Formic Acid (ASTM D5466)	0.2	0.0005	< 0.0005
Ammonia (ASTM D5466)	0.1	0.005	< 0.005
Total Halogenates	0.05		< 0.01
Cl_2 (ASTM D5466)		0.0002	< 0.0002
HCl (ASTM D5466)		0.001	< 0.001
HBr (ASTM D5466)		0.0005	< 0.0005
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		**0.010 mg/kg**
Particulates Found & Size (ASTM D7844) 		This is the 0.2 µm Teflon particulate filters after 1.6 kg hydrogen from hydrogen nozzle without any flow regulation or restriction (ASTM D7650). No pinhole is found.	**There are total 54 particulates found (sizes in micrometer) - 162, 155, 146, 138, 130, 112, 102, 99, 98, 95, 77, 76, 74, 73, 71 (2), 70, 69, 67, 64, 62, 59, 54, 49, 48, 46, 40, 39, 36, 32, 29 (3), 26 (2), 24 (4), 23 (3), 19 (3), 18 (4), 16 (4), 15.**
Hydrogen Fuel Index	99.97%		**99.999995%**

Credit: Shell

Figure 8: SOSS Webpage Screenshot

Sacramento listed as a new station.



Credit: Shell

List of Subcontractors and Value

Table 1 below lists the subcontractors and the value of their contracts.

Table 1: List of Subcontractors

Vendor/ Supplier	Description	CEC Grant	Shell Match	Total Cost
EQUIPMENT SUPPLIERS				
Nel Hydrogen, San Leandro, CA	Hydrogen station equipment — supply, install and commission the station	$2,261,019.00	$573,729.00	$2,834,748.00
COMDATA, Brentwood, TN	Supply POS terminals for recording sale transactions	$34,333.94	$0.00	$34,333.94
Benfield, White Plains, NY	Supply switchgear for power distribution	$25,950.00	$0.00	$25,950.00
SMUD, Sacramento CA	Utility service, transformer, and meter	$16,197.06	$11,942.94	$28,140.00
	Total, Equipment	**$2,337,500.00**	**$585,671.94**	**$2,923,171.94**
SUBCONTRACTS				
Fastech, Buena Park, CA	General contractor for civil construction	$0.00	$637,785.00	$637,785.00
Fiedler Group, Pasadena, CA	Engineering, procurement, construction, and management	$0.00	$305,019.00	$305,019.00
Fiedler Group, Pasadena, CA	Design, engineering, and permitting	$0.00	$105,737.06	$105,737.06
	Total, Subcontracts	**$ 0.00**	**$1,048,541.06**	**$1,048,541.06**
	Grand Total	**$2,337,500.00**	**$1,634,213.00**	**$3,971,713.00**

Source: Fiedler Group/Shell

CHAPTER 3:
Data Collection and Analysis

Data Reporting

Shell collected one year of operational data and submitted to the CEC. These data include quarterly reporting of all fueling, maintenance, operations data; four hydrogen quality reports; and two reports of dispensed renewable hydrogen. Due to delays from COVID-19 and delayed components, the sampling system procured by Shell was unavailable. Shell completed tests for the first and second quarters of 2020 in August 2020.

Economic Impact

The project required construction and high-tech firms to build and maintain the Sacramento station. The funding was predominantly awarded to California construction and technology firms that had the expertise and qualifications. The workers and firms developed hydrogen dispensing expertise during the construction and support of the refueling station. This expertise was valuable and will be directly transferable to other hydrogen refueling station developers in California and abroad for the foreseeable future.

The on-site jobs to handle the initial construction for the Sacramento station included roughly 25 full-time temporary positions, including local engineering resources, masonry and electrical workers, pipefitters, welders, truck drivers, environmental engineers, and others. Internally, Shell created two full-time permanent roles to manage the construction and project phase of station development and one full-time permanent role to maintain the station, collect and report the technical data, and support the operations. Shell also created one full-time role to develop future hydrogen refueling station growth within California.

Shell estimates the funding awarded to California-based companies and employees to be about $750,000 for the Sacramento station. The California-based companies that Shell contracted with included Nel and Air Products and Chemicals, Inc. Nel supplied critical fueling dispenser and equipment for the station and established full-time positions solely to prepare market expansion and provision of equipment for California. The team consists of California-based technicians who are qualified and trained to conduct maintenance, as well as any advanced station repair. Air Products and Chemicals, Inc. supplies and transports the hydrogen fuel to the Sacramento station and manufactures the hydrogen fuel predominantly from California-based operations.

The generation of California taxes is a direct and immediate economic benefit. These taxes can be used to provide government services to the disadvantaged communities, which can provide a direct benefit to the community. These taxes were generated upon project launch and continues with station operation.

Environmental Impact

If one average hydrogen FCEV takes one average gasoline midsized sedan off the road, the amount of gasoline displaced due to Sacramento operation using one year of data (May 2019

to June 2020) would equal nearly 9,600 gallons displaced per year. This value includes four months of no fueling due to hydrogen delivery issues with a hydrogen supplier.

The resulting air emissions reduction is estimated to be at least 85 metric tons of carbon dioxide equivalent (CO_2e) per year. The assumptions used to calculate this emissions reduction are listed below.

- Average mileage of a midsized hydrogen FCEV is 312 miles per tank, and one tank is on average 5 kilograms of hydrogen.
- Average mileage of a midsized gasoline sedan is 434 miles per tank, and one tank is on average 12 gallons of gasoline.
- The amount of CO_2e for a hydrogen FCEV is 145 grams of CO_2e per mile.
- The amount of CO_2e for a gasoline vehicle is 390 grams of CO_2e per mile.
- Both CO_2e values are simulated per the GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) model.[1]
- The calculation does not account for any offsets using greenhouse gas credits.

Carbon Intensity Value

The carbon intensity value for the supply chain for the Sacramento station is 139 grams of CO_2 per megajoule. The energy efficiency ratio of fuel cells relative to gasoline or diesel is 2.5 which means that FCEVs can go 2.5 times as far as gasoline powered car on the same amount of energy.

Energy Efficiency Measures

Shell monitors and manages energy use and efficiency for continuous improvement, and the global greenhouse gas emission inventory is subject to independent assurance.

1 Argonne National Laboratory. The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model, https://greet.es.anl.gov/.

CHAPTER 4:
Statement of Future Intent

Shell plans to operate the Sacramento station for at least the next 10 years. Shell has further subcontracted with the equipment vendor, Nel, for the operation, maintenance, and repairs of the system. Nel has local maintenance and engineering capability and staff in Northern California. The system is outfitted with remote monitoring and automatic alarm communication systems that will send alerts to designated Shell and Nel personnel.

Shell is a committed participant and supporter of California's efforts to establish a hydrogen refueling network. To this end, Shell has matched funds with CEC for the construction of six other hydrogen refueling stations in Northern California. Shell's commitment is further demonstrated with its match share for the construction of a heavy-duty vehicle fueling station at the Port of Long Beach, Wilmington, and Ontario, as well as the GFO-19-602 proposed award to build 50 additional light-duty stations in California.

CHAPTER 5:
Findings, Conclusions, and Recommendations

The Sacramento station was built in a record-breaking pace. The time elapsed from the day of submission of the entitlement exhibits to the station becoming open retail was 17 months (adjusted for temporary demobilization due to station owners project). Adjusted time elapsed from when the contractor began preparing for construction to open retail was 7.5 months.

Establishing new power service is time-consuming, and it can very easily become the critical path for project completion. Early engagement with the utility to obtain a detailed understanding of their process, procedures, inspection milestones, and its timeline is recommended.

One unique design element is the employment of a "remote" offload point. Hydrogen delivery trailers maneuvering on site would not permit offloading directly adjacent to the equipment compound. The project team employed a solution to remotely mount the "delivery cabinet" on the south east corner of the property. This solution will allow hydrogen delivery trailers to pull through the property with limited impact to existing operations while successfully offloading its payload.

The National Fire Protection Association — Hydrogen Technologies Code (NFPA 2) is a critical tool for working with permit agencies. The code clearly defines fire safety guidelines that enable local jurisdictions and builders to reach common ground while ensuring safety via the rigorous NFPA code-writing process. For this project, the station siting and set back decisions were based on the Performance Based Analysis provisions of the NFPA 2 code. These provisions are an important tool in NFPA 2 that makes the construction of hydrogen stations in an urban environment practical and feasible.

The Sacramento station has contributed toward fulfilling the goals of CEC's Clean Transportation Program and specifically toward the goals of GFO-15-605. The goals of the project were achieved with extensive teamwork by Shell and contracting partners, as well as a robust operations and maintenance plan that built on Shell's maintenance philosophies to track reliability threats and respond to maintenance required in a timely manner. Customer feedback was positive and indicated pleasant fueling experiences that were equivalent in ease and speed to refueling conventional gasoline vehicles. Some customers noted communication issues of the point-of-service screen, and improvements to the customer-facing interface are underway to address these issues. Insights gained from the project are invaluable and will be applied toward future projects to continue to further the success of hydrogen refueling stations.

Some recommendations for changes in future projects include extensively testing the POS system and integrating it with the dispenser for a flawless customer experience, as well as adding signage aids to guide customers to the hydrogen dispensers, especially if they are in the forecourt between other gasoline dispensers. Improvements to project management include starting the permitting process with the utility companies as soon as possible, given that it is often the critical path on projects, as well as finding ways to optimize the

commissioning process and lessen the time it takes to perform DMS certification, Hydrogen Station Equipment Performance (HyStEP) testing, and automaker approval. Technical improvements are continuously reviewed throughout the lifecycle of the project and operational phases, however one notable technical improvement that was observed throughout the Sacramento project was to introduce a pressure differential alarm that detects if there are any leaks in the system throughout remote monitoring.

GLOSSARY

Alternative and Renewable Fuels and Vehicle Technology Program (ARFVTP) — Created by Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), the program with an annual budget of about $100 million supports projects that develop and improve alternative and renewable low-carbon fuels, improve alternative and renewable fuels for existing and developing engine technologies, expand transit and transportation infrastructures, establish workforce training programs, conduct public education and promotion, and create technology centers, among other tasks.

AU Energy (AUE) — a fuel wholesaler and retailer that owns and operates Shell retail stations in California.

Authority having jurisdiction (AHJ) — An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

California Division of Measurement Standards (DMS) — Enforcement of California weights and measures laws and regulations is the responsibility of the Division of Measurement Standards. The division works closely with county sealers of weights and measures who, under the supervision and direction of the Secretary of Food and Agriculture, carry out most weights and measures enforcement activities at the local level. Ensuring fair competition for industry and accurate value comparison for consumers is the primary function of the county/state programs.

Carbon dioxide equivalent (CO_2e) — A measure used to compare the emissions from various greenhouse gases based upon the associated global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents (MMTCDE)" or "million short tons of carbon dioxide equivalents (MSTCDE)." The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated GWP. MMTCDE= (million metric tons of a gas) * (GWP of the gas) For example, the GWP for methane is 24.5. This means that emissions of 1 million metric tons of methane is equivalent to emissions of 24.5 million metric tons of carbon dioxide. Carbon may also be used as the reference and other greenhouse gases may be converted to carbon equivalents. To convert carbon to carbon dioxide, multiply the carbon by 44/12 (the ratio of the molecular weight of carbon dioxide to carbon). (EPA)

Fiedler Group (FG) — the engineer of record for the Citrus Heights hydrogen refueling station.

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.

Global Warming Potential (GWP) — The relative warming of a greenhouse gas over a specified period of time as compared to carbon dioxide (GWP of 1). GWP allows for the conversion of different greenhouse gas emissions into the same emissions unit, carbon dioxide equivalents (CO2E).

Hydrogen Station Equipment Performance (HyStEP) device — a device that has been designed to carry out the test methods of CSA HGV 4.3 to measure that stations follow the fueling protocols standard SAE International J2601.

Kilogram (kg) — The base unit of mass in the International System of Units that is equal to the mass of a prototype agreed upon by international convention and that is nearly equal to the mass of 1,000 cubic centimeters of water at the temperature of the associated maximum density.

Metric Ton — a unit of mass equal to 1000 kilograms.

National Fire Protection Association (NFPA) — a global self-funded nonprofit organization, established in 1896, devoted to eliminating death, injury, and property and economic loss due to fire, electrical, and related hazards.

Pre-startup safety review (PSSR) — a safety review conducted before startup of a new or modified facility to ensure that installations meet the original design or operating intent to catch and reassess any potential hazard due to changes during the detailed engineering construction phase of a project.

Sacramento Municipal Utility District (SMUD) — an electric utility serving the greater Sacramento region.

SAE International J2601 — a fueling standard that establishes the protocol and process limits for hydrogen fueling of light duty vehicles.

Station Online Status System (SOSS) — a mobile-friendly website that shows station availability and provides other station information such as hours of operation, address, and the hydrogen station operator and developer.