CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Long Beach Heavy Duty Freight Vehicle Hydrogen Fueling Station

Prepared for: California Energy Commission

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

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California Energy Commission

Joe Sawa, Jared Leventhal
Primary Authors

Equilon Enterprises LLC (dba Shell Oil Products US)
650 California Street, Suite 2250
San Francisco, California 94108
Shell Hydrogen Website

Agreement Number: ARV-18-002

Chris Jenks
Commission Agreement Manager

Charles Smith
Branch Manager
TRANSPORTATION INTEGRATION AND PRODUCTION BRANCH

Melanie Vail
Deputy Director
FUELS AND TRANSPORTATION

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

At Shell Hydrogen, we are focused on making hydrogen fuel a mainstream and competitive option for zero-emission transportation. Developing the hydrogen fueling station under this Grant Funding Opportunity has accomplished significant progress for Zero Emissions trucking in California. We would like to thank the following individuals and business partners for significant contributions to this success:

- The California Energy Commission Lead Commissioner for Clean Transportation, Patty Monahan, who provides visionary leadership and direction for hydrogen mobility in the Clean Transportation Program, former California Energy Commission Lead Commissioner for Clean Transportation, Janea Scott, who was Lead Commissioner at the time of the Grant award, CEC Hydrogen Unit Supervisor, Jean Baronas, who provided diligent program administration with helpful attention to detail and direct engagement, Chris Jenks, the Commission Agreement Manager, and Officers who provided thoughtful and constructive input to this project.
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- The Nel service, operations, and engineering 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. We are grateful for Nel's continued support for hydrogen refueling stations.
- The team at Fiedler Group, who was instrumental in managing the detailed design and permitting process, drawing from their deep expertise in the retail refueling business.
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- The Local Authorities Having Jurisdiction who worked collaboratively throughout the evaluation and permitting of this station, and in doing so 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.

- TTSI, Tony Williamson, Southern Counties Express, UPS, and fleet managers and drivers who make it possible to distribute, with Zero Emissions, goods to California homes.

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 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.

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 GFO-17-603 for projects that will support infrastructure deployment for Advanced Freight Vehicles. In response to GFO-17-603, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards dated April 6, 2018, and the agreement was executed as ARV-18-002 on December 1, 2018.

ABSTRACT

Equilon Enterprises LLC (dba Shell Oil Products US) designed, engineered, permitted, constructed, and made operational a hydrogen refueling station at 2140 Pier B Street, Long Beach, California 90813. This station is located at the Port of Long Beach and will serve heavy duty freight vehicles and other types of hydrogen fuel cell electric vehicles. The station consists of a fenced equipment compound that encloses hydrogen storage, compression, and cooling equipment. The fueling area has two 700 bar and one 350 bar dispensers and two point of sale terminals.

Keywords: California Energy Commission, ARFVTP, CTP, Long Beach, Equilon Enterprises, Shell Oil Products, Advanced Freight Vehicles, renewable, hydrogen, fueling, infrastructure, FCEV

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TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

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 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 California Energy Commission 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.

Shell built a hydrogen fueling station for heavy duty vehicles, located at the existing Toyota Logistics Services Terminal at the Port of Long Beach. Shell is the Operator of the station.

Under its Grant Funding Opportunity GFO-17-603, the California Energy Commission funded 66.7% of the total budgeted cost of the station while Shell provided the balance for a total budgeted station cost of $12,001,800. The California Energy Commission contributed $8,000,000.

The hydrogen station has a refueling capacity of 1.5 tonnes per day. The station has two, single-hosed 700 bar dispensers on one fueling island and one single-hosed 350 bar dispenser on a second fueling island.

The heavy duty hydrogen station also feeds a light duty hydrogen refueling station for private use by Toyota Logistics Services to complete pre-delivery hydrogen fills of production Toyota Mirai Fuel-Cell Electric Vehicles off-loaded from marine vessels at the port facility, prior to road transport distribution to dealerships for delivery to public customers. The light duty station has one, single-hosed 700 bar dispenser on one fueling island.

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

Shell initiated site acquisition negotiations with Toyota Logistics Services. An entitlement application package was submitted by Toyota to the authorities having jurisdiction in November 2017. The site acquisition agreement between Shell and Toyota was executed in February 2018. Entitlement approval was received in August 2018.

For design and permitting of the heavy duty freight vehicle hydrogen fueling station, pre-application meetings were initiated with the authorities having jurisdiction in May 2019. Plan check was submitted to the authorities having jurisdiction in September 2019. Two rounds of plan check comments were received from the building department. The building department's approval was obtained in March 2020.

Shell initiated equipment procurement with Nel Hydrogen in November 2018. The hydrogen station equipment, supplied by Nel Hydrogen, attained a UL Certificate of Compliance on May

1, 2020 to become the the only comercially available, heavy duty vehicle, hydrogen refueling station equipment set with UL certification. This certification applies to all stations conforming to this design, including the subject station of this report. Time-phased, on-site delivery and installation of equipment was completed in August 2020.

Construction mobilization occurred in March 2020. The station, with all hydrogen equipment installed, was ready for a pre-startup safety review in August 2020. Pre-commissioning activities began in September 2020 and the first fueling of a heavy duty vehicle was performed in June 2021.

The required one-year retail operational period started on July 1, 2021, with the station remaining retail open after this period. From the time of plan check submission with authorities having jurisdiction to the "Operational Station" date of July 1, 2021, the station took 22 months to achieve an "Operational Station" status. A four-truck Station Acceptance Test was completed in September 2022.

Shell will continue to operate and maintain the hydrogen refueling station to support Toyota and the committed fleet operators who intend to operate the Fuel Cell Electric Trucks beyond the term of the funding agreement and through the end of the economic lifetimes of the trucks and station equipment.

CHAPTER 1:
Introduction

Objectives

The Long Beach heavy duty vehicle (HDV) Fuel Cell Electric Vehicle (FCEV) hydrogen refueling station (HRS) was designed, built, and commissioned by Shell under an award from the California Energy Commission (CEC), under its grant funding opportunity GFO-17-603. The objective of this project was to open one of the first three public access HDV fueling stations for hydrogen FCEVs.

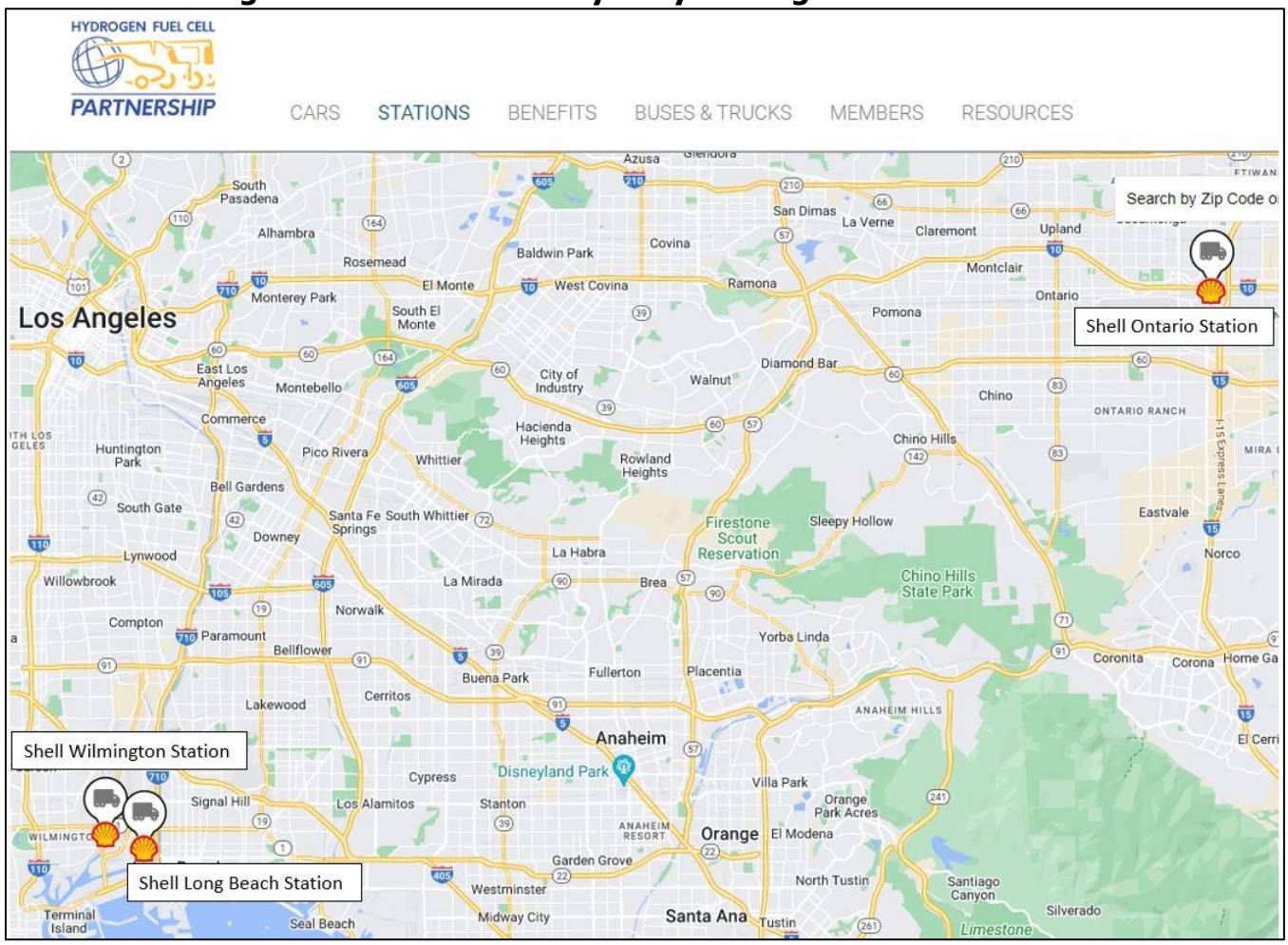
Under the terms of the CEC GFO-17-603, the project developed a high-capacity hydrogen fueling station servicing and promoting the expansion of zero-emission fuel cell electric Class 8 drayage trucks throughout one of the world's largest freight hubs at the Port of Long Beach. With a station designed to source hydrogen from 100% renewable biogas, the infrastructure was installed strategically to make the greatest impact on the available heavy duty fleet. The station uses either delivered gaseous hydrogen or produced gaseous hydrogen piped from the neighboring third-party tri-generation fuel cell power generation plant operated by Fuel Cell Energy (FCE).

Shell brought to this project a world-wide track record of experience in constructing renewable fuel infrastructure. Toyota brought its substantial knowledge from the deployment of the highly successful Toyota Mirai FCEV. Together, Shell and Toyota were well positioned and equipped to deliver this project successfully and, in doing so, make significant progress in transforming the freight transportation sector in an area facing overcrowding and hazardous air quality. This partnership provided the resources and expertise necessary to successfully execute an efficient and cost-effective station.

By servicing Los Angeles' largest freight corridor, the project reduced greenhouse gases and harmful criteria pollutants, particularly to surrounding disadvantaged communities. The development of this station, potentially the largest in North America, made progress in unlocking barriers to full hydrogen adoption in the heavy duty freight sector, which serves as a crucial pathway towards decarbonizing transportation in California.

In conjunction with this project, Toyota led development and production of ten Fuel Cell Electric Trucks (FCETs). Shell replicated this heavy duty hydrogen refueling station at two more locations in Wilmington and Ontario, California, and the City of Los Angeles Harbor Department (Port of Los Angeles) supported a working program as part of the Zero- and Near Zero-Emission Freight Facilities Project (ZANZEFF), grant number G17-ZNZE-10. This 'Shore-to-Store' program proved the use case of FCETs and a hydrogen fueling network for Class 8 drayage trucking between the Ports of Los Angeles and Long Beach and the railheads located within the Inland Empire. Figure 1 illustrates the network of refueling stations, courtesy of the Hydrogen Fuel Cell Partnership.

Figure 1: California Heavy Duty Fueling Station Network



Source: Hydrogen Fuel Cell Partnership

CHAPTER 2:
Station Design, Construction and Startup

Major Activities and Timeline

Construction of the heavy duty freight vehicle hydrogen fueling station at the Port of Long Beach required activities that are listed and described below along with an approximate timeline for their execution. Shell negotiated a site acquisition agreement and procured the hydrogen station equipment. The site acquisition agreement between Shell and Toyota was executed on February 23, 2018. Toyota obtained entitlement approval through the Port of Long Beach for site developments which included the heavy duty hydrogen fueling station.

Shell retained Fiedler Group (FG) to prepare documents required for design, 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 (RTI) status. The project team, which comprised Shell, Nel, FG and the construction contractor Fastech, executed the following phases to achieve a retail open station:

- Preliminary Investigations
- Entitlements
- Equipment Procurement
- Design and Permitting
- Bid Solicitation
- Construction
- Commissioning and Startup
- Operational and Retail Open Station

A notable effect on the project schedule from March 2020 was the prevalence of the worldwide COVID-19 pandemic. This impacted all means of project execution, ranging from construction worker activity to logistics, and from key personnel availability to supply chain resilience. While extended durations in the timeline are attributed to such complexities, the project team is proud to have delivered amid the challenging circumstances.

Preliminary Investigations (May 17, 2018 to July 30, 2018)

The project team investigated the requirements of various government agencies and utilities. This entailed discovery of requirements, codes, ordnances, and regulations that impact permitting and design criteria. A site investigation report was developed based on agencies contacted. The following agencies were contacted: City of Long Beach Planning Department, Building Department, Fire Department, California Department of Industrial Relations – Pressure Vessels, and local utility Southern California Edison. A preliminary site plan was prepared based on Shell's design requirements, agency findings, and site visit.

Entitlement Process (November 14, 2017 to August 21, 2018)

Toyota submitted the entitlements drawing package to the authorities having jurisdiction (AHJ) on November 14, 2017. The Port of Long Beach Harbor Department verified that the project meets the zoning requirements and approved aesthetic, safety and other details that are important to the port. Two rounds of plan-check comments were received and addressed. Approval was received on August 21, 2018.

Equipment Procurement (November 26, 2018 to August 10, 2020)

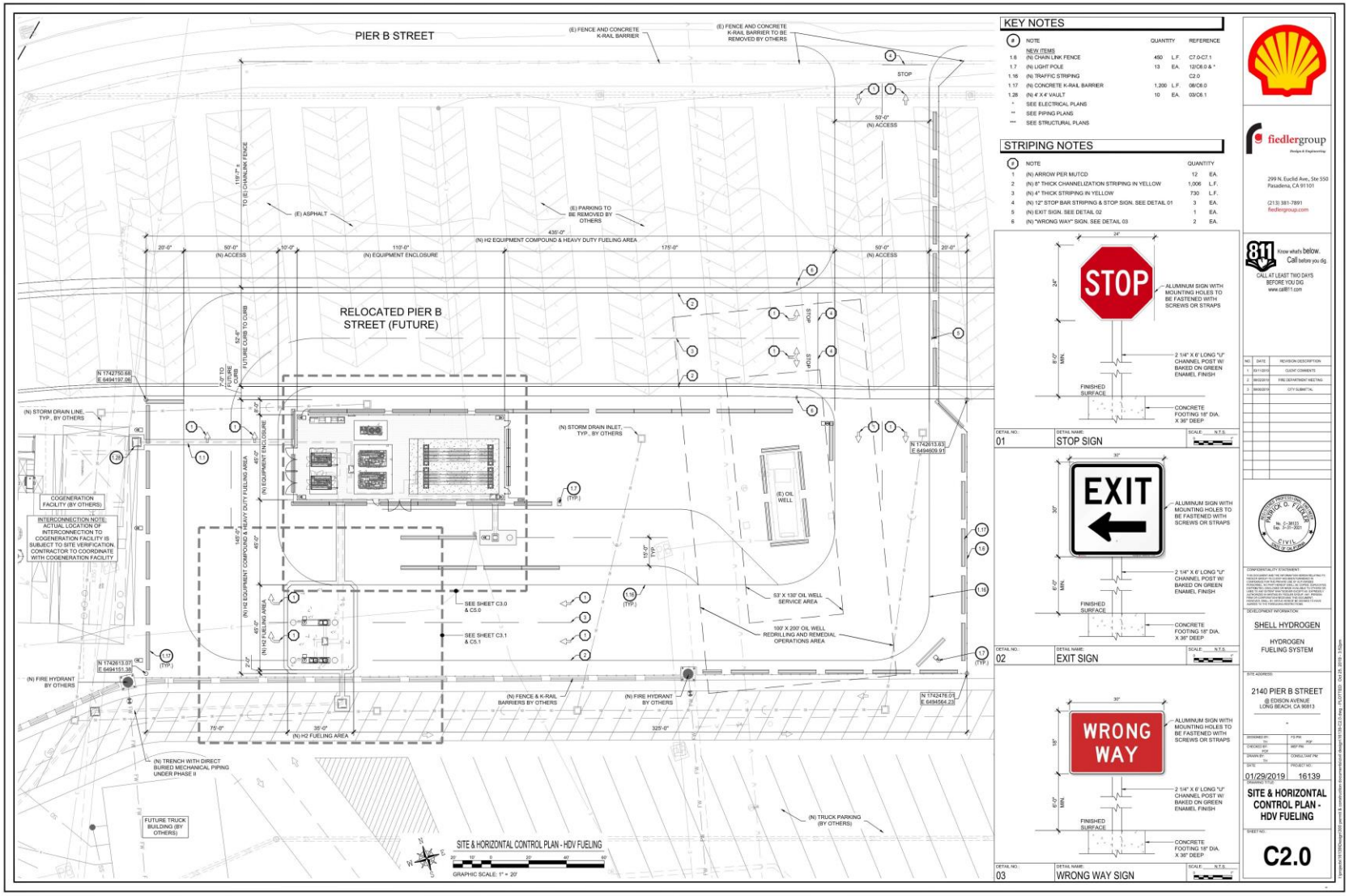
Shell selected Nel Hydrogen in Herning, Denmark to supply the hydrogen station equipment. Nel was contracted to supply, install, and commission all equipment necessary to achieve an operational hydrogen station. Nel supplied the following major hydrogen station equipment: station module (containing the compressor and hydrogen cooling system), storage module and associated valve panels, supply cabinet and associated human machine interface (HMI), hydrogen dispensers, and all interconnecting mechanical pipe and tubing between the equipment. Equipment delivery was timed to synchronize with the construction schedule. All equipment was delivered to the site and installed by August 10, 2020.

Site Design and Permitting (September 6, 2019 to March 10, 2020)

The first design drawing package was submitted to the city on September 6, 2019. Two sets of plan check comments were received and addressed. Final approval of the construction permit was obtained on March 10, 2020.

Figure 2 illustrates the site plan permitted for construction.

Figure 2. Site Plan for Construction



Source: Shell

Bid Solicitation (October 25, 2019 to February 10, 2020)

The bid solicitation package consisted of the drawing set, technical documents, and project manual. Three pre-qualified general contractors were invited to bid, and three bids were received and evaluated against an engineer's independent cost estimate. In addition to cost, evaluated factors included: prior similar experience and current capability, safety performance, financial strength, and the ability to mobilize and complete construction according to the required schedule. Shell awarded a construction contract to Fiedler Group on February 10, 2020.

Construction (March 16, 2020 to August 14, 2020)

The construction crew mobilized to the site on March 16, 2020. All hydrogen station equipment was installed by August 14, 2020.

Figure 3 illustrates assembly of the storage module on its foundation.

Figure 4 illustrates the lift and set of one of two station modules on its foundation. Figure 5 illustrates the completed installation of the dispensers and point of sale (POS). Figure 6 is an aerial view of the entire station.

For pre-commissioning, the pre-startup safety review (PSSR) was conducted on September 23, 2020 and a checklist of actions was developed. Due to the lack of utility power, a motor-generator set was used to conduct the PSSR.

Utility service was energized on October 26, 2020.

Figure 3. Field Assembly of Storage Module

Source: Shell

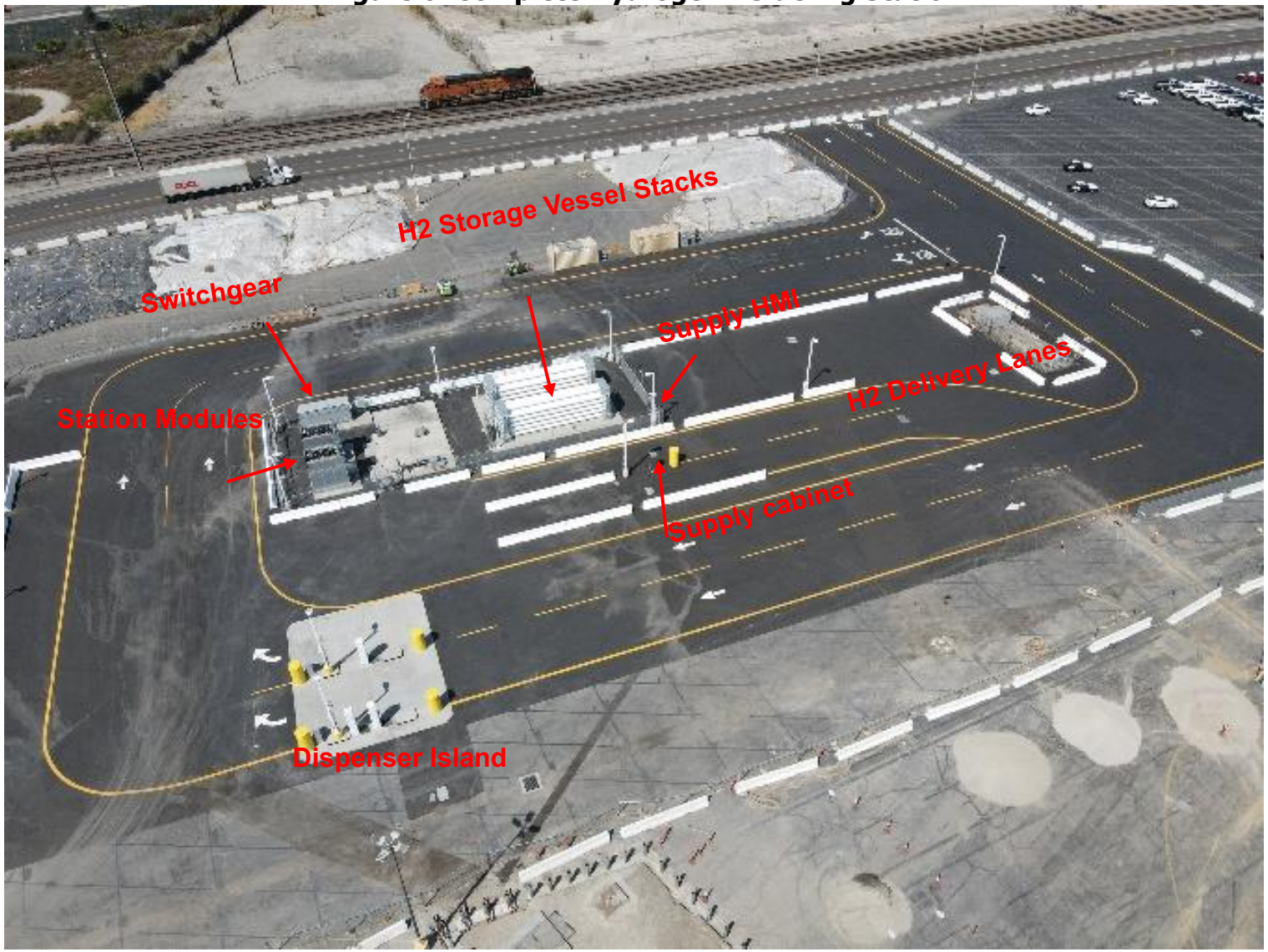
Figure 4. Lift and Set of Station Module

Source: Shell

Figure 5. Dispensers and Point of Sale Pedestals

Source: Shell

Figure 6. Complete Hydrogen Refueling Station



Source: Shell

Commissioning and Startup (August 14, 2020 to October 03, 2022)

PSSR actions that were deemed prerequisite for introduction of hydrogen into the system were completed on November 12, 2020. Hydrogen was introduced on November 20, 2020. The California Department of Food and Agriculture, Division of Measurement Standards (DMS), certified the dispenser accuracy on April 14, 2021. Initial commissioning and startup activities continued until June 11, 2021 when the first heavy duty FCEV was filled. Figure 7 illustrates fueling of the first heavy duty FCEV. Figure 8 illustrates results of the hydrogen purity test.

Figure 7. First Fueling on June 11, 2021

Source: Shell

Figure 8. Hydrogen Fuel Quality Report

SmartChemistry.com

NEL POLB H70 @12/22/2020

SAE J2719-202003	SAE J2719 Limits - µmol/mol	Smart Chemistry Limits -µmol/mol	Concentration (µmol/mol)
H_2O (ASTM D7843)	5	0.5	0.84
Total hydrocarbons except methane (C_1 equivalent) (ASTM D7892)	2	0.01	0.135
Acetone			0.0660
Isopropyl Alcohol			0.0150
Propane			0.0480
Propene			0.0057
O_2 (ASTM D5466 & Delta F Trace Oxygen Analyzer)	5	0.2	< 0.2
CH_4 (ASTM D5466)	100	0.001	2.9
He (ASTM D1946)	300	10	42
N_2 (ASTM D7649)	300	1	5.8
Ar (ASTM D7649)	300	0.2	1.4
CO_2 (ASTM D7649)	2	0.03	0.032
CO (ASTM D5466)	0.2	0.00001	0.00014
Total S (ASTM D7652)	0.004		0.000018
Hydrogen Sulfide		0.000002	0.0000053
Carbonyl Sulfide		0.000001	0.0000033
Methyl Mercaptan (MTM)		0.000002	< 0.000002
Ethyl Mercaptan (ETM)		0.000004	< 0.000004
Dimethyl Sulfide (DMS)		0.000004	0.0000047
Carbon Disulfide		0.000001	0.0000046
Isopropyl Mercaptan (IPM)		0.000004	< 0.000004
Tert-Butyl Mercaptan (TBM)		0.000004	< 0.000004
n-Propyl Mercaptan		0.000004	< 0.000004
Thiophene		0.000004	< 0.000004
Diethyl Sulfide		0.000004	< 0.000004
n-Butyl Mercaptan		0.000004	< 0.000004
Dimethyl Disulfide (DMDS)		0.000004	< 0.000004
Tetrahydrothiophene (THT)		0.000004	< 0.000004
Formaldehyde (ASTM D7892)	0.01	0.001	< 0.001
Formic Acid (ASTM D5466)	0.2	0.0009	0.0026
Ammonia (ASTM D5466)	0.1	0.02	< 0.02
Halogenated Compounds (halogen ion equivalent)	0.05		< 0.001
Cl_2 (ASTM D5466)		0.0001	< 0.0001
HCl (ASTM D5466)		0.0004	< 0.0004
HBr (ASTM D5466)		0.0007	< 0.0007
Organic Halides (R-XCl) (ASTM D7892, Smart Chemistry limit is for each individual organic halide)		0.001	< 0.001
Hydrogen Fuel Index	99.97%		**99.994737%**
Total Non-Hydrogen Gases	300		**53**
CO + HCHO + HCOOH	0.2	0.00005	**0.0027**

Source: SmartChemistry

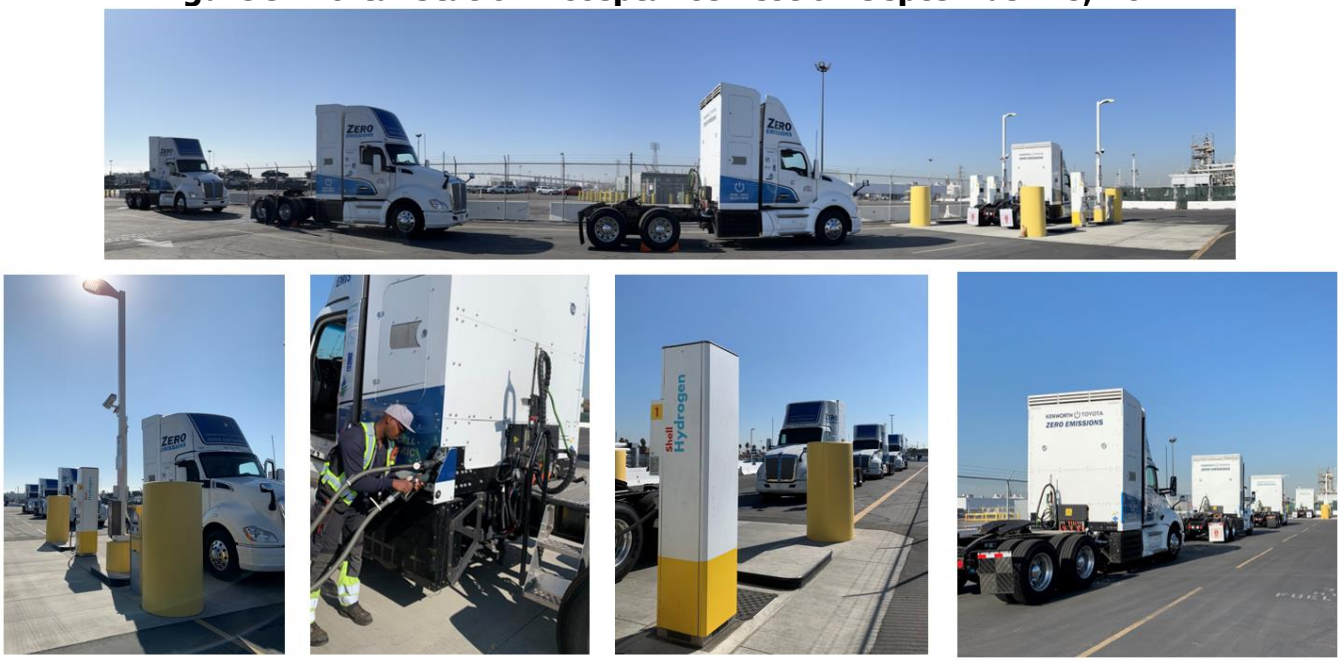
Operational Station (July 1, 2021)

The station was deemed operational as of July 1, 2021. On July 7, 2021, Shell formally notified the Energy Commission that the station was operational as of July 1, 2021. The mandatory one-year operational period for data collection was from August 1, 2021 to July 31, 2022, with the station continuing to remain open beyond this period. Incremental engineering improvements were made while the station was open, and subsequently the station successfully passed a four-truck back-to-back fueling Station Acceptance Test on September 28, 2022. Figure 9 illustrates several angles of the Station Acceptance Test. The period prior to September 28, 2022 was deemed 'soft open', defined as customer fueling by appointment and with the presence of Nel technicians, to both ensure a satisfactory user experience and to balance simultaneous operations with implementation of the incremental engineering improvements.

The hydrogen supply will continue to be delivered until the neighboring third-party tri-generation fuel cell power generation plant comes online and begins to produce hydrogen. At the time of this report, start-up of the third-party tri-generation facility is expected in 2023.

Figure 10 illustrates an aerial view of the site as of November 2022.

Figure 9: Portal Station Acceptance Test on September 28, 2022



Source: Shell

Figure 10: Aerial View of Site

Source: Shell

CHAPTER 3:
Data Collection and Analysis

Data Reporting

During the one-year period of operational data collection, the major drayage trucking routes accounting for FCET mileage were along the interstate corridors illustrated in Figure 1. The data was reported to the National Renewable Energy Laboratory (NREL) along several dimensions: fueling logs, compression, dispensing, safety, and quality. Over the data collection period, at the Port of Long Beach station alone, over 4,155 kilograms (4.155 tonnes) of gaseous hydrogen was dispensed.

Economic Impact

The project required construction and high-tech firms to build and maintain the Port of Long Beach station. The funding was predominantly awarded to California construction and technology firms who had the expertise and qualifications. The workers and firms developed hydrogen dispensing expertise during the construction and support of the refueling station which 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 Port of Long Beach 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 one full-time permanent role to manage the construction and project phase of the development of the station, 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.

For operations, 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 advanced station repair. Until the neighboring third-party tri-generation fuel cell power generation plant comes online and begins to produce hydrogen, Air Products and Chemicals Inc. supplies and transports the hydrogen fuel to the Port of Long Beach 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 utilized to provide government services to disadvantaged communities, which can provide a direct benefit to the community. Tax generation began at project launch and is ongoing with the operation of the station.

Environmental Impact

If one average Class 8 hydrogen FCET takes one average Class 8 diesel heavy duty truck off the road, the amount of diesel displaced due to this station operation was approximately 7,895 gallons of diesel based on the 4,155 kilograms of hydrogen dispensed to Class 8 hydrogen FCETs during the data collection period.

From the one year of operational data, 92 tonnes of carbon dioxide equivalent (CO2e) were avoided. Further emission savings (negative) include:

- -28.8 kilograms of nitrogen oxides (NOx)
- -0.6 kilograms of particulate matter of size less than 2.5 microns (PM2.5)
- -1.4 kilograms of hydrocarbons (HC)
- -10.1 kilograms of carbon monoxide (CO)

Carbon Intensity Value

Shell established a Tier 2 joint pathway[1], which is a dairy and swine manure (DSM) renewable natural gas to hydrogen pathway via "book and claim" accounting. The pathway was certified for use in April 2022 and the environmental attributes of DSM derived biomethane are procured from the RDF Stevens Upgrader located in Morris, Minnesota. The upgrading facility is registered to ampRenew Offtake I, LLC (9041) which is a joint applicant to the pathway. The pathway is consistent with the Lookup Table Compressed Hydrogen pathway produced in California from central steam methane reforming of biomethane with two notable exceptions: the gaseous hydrogen transportation distance is lower than the default 100 miles distribution distance modeled in the Lookup Table pathway carbon intensity (CI), and the feedstock for hydrogen production was matched to biomethane attributes derived from dairy and swine manure digester gas with a lifecycle CI of -147.2 gCO2e/MJ. Across the first year of operation, the Long Beach heavy duty freight vehicle hydrogen fueling station dispensed 51% renewable content, and 49% non-renewable content. This calculation is based on the 100% renewable hydrogen pathway being established in April 2022, in the middle of the data collection period. During this first year of operation, the weighted average carbon intensity of the hydrogen fuel dispensed is -15.44 grams of CO2e per megajoule of hydrogen dispensed. The negative value connotes a greenhouse gas emission savings.

Energy Efficiency Measures

While a Title 24 report was not required for this station, Shell monitors and manages energy use and efficiency for continuous improvement and the global greenhouse gas emission inventory is subject to independent assurance.

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[1] Approved Tier 2 joint pathway: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/comments/tier2/b0348_cover.pdf

Project Assessment and Evaluation

The original objectives of the project were to provide a hydrogen refueling station at the Port of Long Beach, California, in collaboration with the public and private sectors, with the following results:

- Demonstrate that a sustainable economic business model is achievable for hydrogen refueling station sites for freight, featuring the considerable experience of the project team in retail station design, operations, and maintenance.
- Provide evidence that hydrogen refueling station technology can fuel heavy duty trucks safely and reliably.
- Prove the technology readiness, scalability and economic viability of the project team's hydrogen refueling station design to dispense enough fuel at 700 bar pressure for 10-15 FCETs per day.
- Demonstrate that the project team's hydrogen refueling station can be fueled with 100% renewable hydrogen.

At the time of this report, the station has met all heavy duty demand on the road, as illustrated in Figure 11. Although double-digit numbers of FCETs have yet to require refueling in a single day, the project team has demonstrated station performance based on station testing and proven capabilities. All evidence shows that the station is proven to be both safe and reliable. From the creation of the Tier 2 joint pathway, the station has established and been proven to dispense 100% renewable hydrogen, and the sustainable economic business model is exemplified. The project has met the objectives of this Grant Funding Opportunity.

Figure 11: Station Meeting Customer Demand

Source: Shell

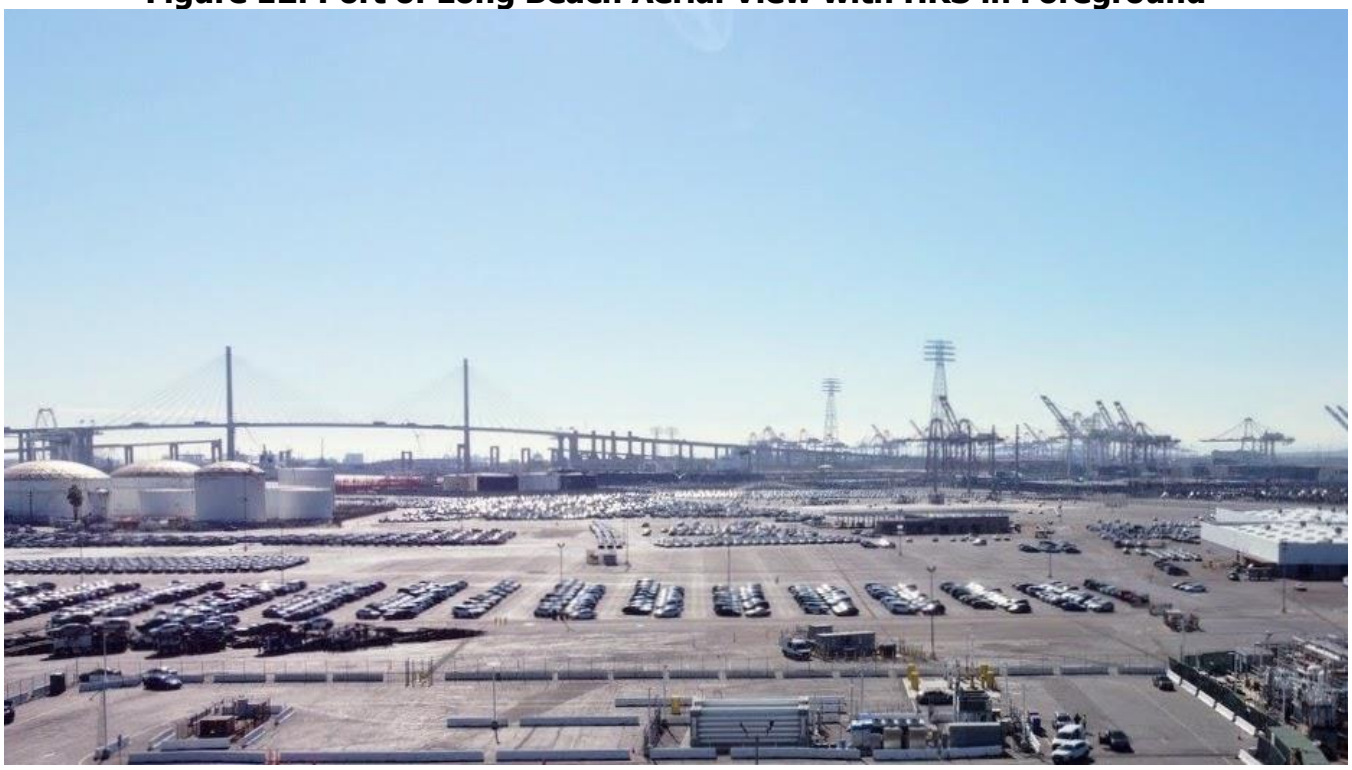
CHAPTER 4:
Statement of Future Intent

Shell will continue to operate and maintain the HRS to support Toyota and the committed fleet operators who intend to operate the FCETs beyond the term of the funding agreement and through the end of the economic lifetimes of the trucks and station equipment. Shell and Toyota entered an exclusive sub-lease for the area hosting the HRS for a primary term through 2028 which follows concurrently with Toyota's lease with Port of Long Beach, as illustrated in Figure 12.

The station has and will continue to support further demand growth with successful deployment of FCETs with capability to fuel trucks at 350 bar and 700 bar, expanded access to multiple truck operators, de-bottlenecking to increase fueling capacity, and expansion of fueling capacity.

Shell aims to build on the successes of the HD HRS at Port of Long Beach to start the full launch of a California-wide Heavy duty Hydrogen Refueling Network. Like Port of Long Beach, the primary use-case for the network will be for Class 8 trucks, including drayage, medium-, and long-haul with intense duty cycles and return-to-base operations.

Figure 12: Port of Long Beach Aerial View with HRS in Foreground



Source: Shell

CHAPTER 5:
Findings, Conclusions, and Recommendations

Shell is grateful for the opportunity to have delivered this project. Given that this is a first-generation heavy duty freight vehicle hydrogen fueling station, future heavy duty hydrogen station development needs to consider several recommendations. First, the nascent nature of the sector necessitates a focus on a growth and learner mindset for all parties involved. Second, project schedules are better served when accounting for risks associated with extended review periods and varying degrees of technology readiness levels. Third, flourishing of this new market will continue to require a commitment to collaboration over competition, amongst every participant in the value chain.

With the economic operation demonstrated through this project and as demand grows for zero emission technologies in Port of Los Angeles and Port of Long Beach, refueling for FCETs will need to expand to a network of refueling stations positioned along drayage and warehouse routes. Having completed the HD HRS at Port of Long Beach, Shell is positioned to continue servicing the increasing demand with multiple HD HRS in the area that could become part of such a future network.

California is an important hydrogen market and therefore Shell will further leverage its market presence and network development for operation and business development. Shell is continuing to invest in hydrogen technologies here in California and around the world, bolstering Shell's commitment to operate and maintain the station beyond the term of the funding agreement. This new guiding statement called the *Shell Purpose* states, "We power progress together by providing more and cleaner energy solutions." This aligns Shell to provide more energy while planning for a long-term role in tackling climate change for current and future generations. The Shell Hydrogen business is part of the Emerging Energy Solutions organization and therefore is an important part of Shell's future. Shell Hydrogen is expected to grow even more quickly in the 2020s as Shell works toward its target to become a net-zero emissions energy business by 2050 or sooner.

Shell is a committed participant and supporter of California's vision for the Hydrogen Highway. To this end, Shell's commitment to California is further demonstrated by continuing to match funds with CEC for the construction of heavy duty vehicle fueling stations at the Port of Long Beach, Wilmington, and Ontario along with a network of light-duty stations.

Acronyms

AHJ	Authorities Having Jurisdiction
ARFVTP	Alternative and Renewable Fuels and Vehicle Technology Program
CA	California
CEC	California Energy Commission
CI	Carbon Intensity
CO	Carbon Monoxide
CO2e	Carbon Dioxide Equivalent
CTE	Center for Transportation and the Environment
CTP	Clean Transportation Program
DMS	Division of Measurement Standards (of California Department of Food and Agriculture)
DSM	Dairy and Swine Manure
FASTECH	Fueling and Service Technologies, Inc.
FCE	Fuel Cell Energy
FCET	Fuel Cell Electric Truck
FCEV	Fuel Cell Electric Vehicle
FG	Fiedler Group
GFO	Grant Funding Opportunity
HC	Hydrocarbons
HD	Heavy Duty
HDV	Heavy Duty Vehicle
HMI	Human Machine Interface
HRS	Hydrogen Refueling Station
NOx	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
PM2.5	Particulate Matter of size less than 2.5 microns
POLA	Port of Los Angeles

POLB	Port of Long Beach
POS	Point of Sale (terminal)
PSSR	Pre-Startup Safety Review
RTI	Ready to Issue
TTSI	Total Transportation Services
UL	Underwriters Laboratories
UPS	United Parcel Service
ZANZEFF	Zero- and Near Zero-Emission Freight Facilities Project