



California Energy Commission Clean Transportation Program

FINAL PROJECT REPORT

Lawndale SmartFuel® Hydrogen Station

Prepared for: California Energy Commission Prepared by: Air Products and Chemicals, Inc.

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California Energy Commission

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- The California Energy Commission
- The Governor's Office of Business and Economic Development (thanks to Tyson Eckerle for his efforts)
- South Coast Air Quality Management District

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PREFACE

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

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

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

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-09-608 to expand California's network of hydrogen refueling stations and to upgrade and to serve the current population of fuel cell electric vehicles as well as accommodate the planned large-scale roll-out of fuel cell vehicles commencing in 2015. In response to PON-09-608, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards November 17, 2010 and the agreement was executed as ARV-10-048 on December 21, 2011.

ABSTRACT

Air Products and Chemicals, Inc. designed, engineered, permitted, constructed, and made operational a hydrogen refueling station at 15606 Inglewood Avenue, Lawndale, California. The Lawndale SmartFuel® hydrogen station was approved for construction on May 19, 2016, and began public fueling in June 2017. The station receives gaseous hydrogen delivered at elevated pressure from an Air Products production facility in southern California. The station is comprised of compression, cooling, and a two-hose dispenser with a customer payment interface are used to refill fuel cell electric vehicles.

Keywords: Air Products and Chemicals, Inc., fuel cell electric vehicles, hydrogen infrastructure, hydrogen refueling station, Lawndale.

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EXECUTIVE SUMMARY

Hydrogen fuel cell electric vehicles, hydrogen refueling stations, and the production and distribution of hydrogen to the stations are expected to play key roles in California as the State transitions to lower-carbon and zero-emission vehicle technologies for light-duty passenger vehicles, transit buses, and truck transport fleets. An equally important role is that of the central fill system for hydrogen production and distribution as covered in this report.

Air Products developed the site configuration and design, and S. Gordin Structural Design and Engineering Services, Inc. performed the detailed engineering design. The site plan was approved by the gas station owner in mid-October of 2014 and was provided to the City of Lawndale as part of the December 22, 2015 application for the City of Lawndale's Site Plan Review. A public meeting to review the application took place on September 9, 2015, at which time the Planning Commission for the City of Lawndale approved the special use permit for the hydrogen station with a number of additional conditions. The site design was completed in February of 2016 with the submittal of plans as part of the Agency Review process. In June of 2016, Southern California Edison confirmed the design.

Construction started on October 31, 2016, with compression, cooling, and dispensing equipment delivered to the site on December 16, 2016. Southern California Edison began installation of the station utilities on February 23, 2017. Final site inspection by the City of Lawndale took place on April 17, 2017.

The process of making the Lawndale SmartFuel® hydrogen station operational began on March 10, 2017, and was completed on June 21, 2017. Automakers performed test fills during this time. Approval of the hydrogen dispenser for retail operations by the California Department of Measurements and Standards was received on June 20 and 22, 2017. Initial use of the Lawndale SmartFuel® hydrogen station by retail customers occurred on June 2017.

The environmental benefits of operating fuel cell electric vehicles is that they offer long term greenhouse gas and petroleum reduction, unlike gasoline vehicles. The Lawndale SmartFuel® hydrogen station contribute to the reduction of greater than 620 metric tons of greenhouse gas emissions and greater than 36,500 gallons of gasoline consumption annually. Furthermore, each fuel cell electric vehicle that is used instead of a gasoline vehicle will reduce greenhouse gas emissions by 4.3 metric tons per year.

CHAPTER 1: Station Design, Permitting, Construction, and Commissioning

1.1 Site Design and Engineering

Air Products held preliminary discussions with S. Gordin Structural Design and Engineering Services, Inc. regarding the Lawndale station. The companies executed a subcontract for design engineering services on March of 2014, and an initial site visit took place on May 27, 2014.

Following this meeting, options for equipment layouts were prepared by the architect for review with the gas station owner. Figure 1 provides an initial equipment arrangement drawing. The drawing was amended to change the equipment orientation and to better accommodate the parking spaces. The site plan was approved by the gas station owner on mid-October of 2014, and Figure 2 provides the approved equipment arrangement drawing.

Some limited site design activities were undertaken following submittal of the Zoning Subdivision application in May of 2015 and following receipt of the special use permit in September of 2015. Following acceptance by Air Products of the terms of the special use permit, Air Products and S. Gordin Structural Design & Engineering Services, Inc., were able to start finalizing the various drawing packages. The site design was completed in February of 2016 with the submittal of plans as part of the Agency Review process. In June of 2016, Southern California Edison confirmed the design.

Figure 3 provides the equipment layout drawing that was submitted to the City.



Source: Air Products and Chemicals, Inc.



Source: Air Products and Chemicals, Inc.



Source: Air Products and Chemicals, Inc.

1.2 Permitting Process 1.2.1 Equipment Procurement

In parallel with the site activities, Air Products began the equipment design and procurement immediately after execution of the Grant Agreement, Air Products began the equipment design and procurement activities for the eight sets of SmartFuel® hydrogen station equipment that would be deployed as part of the overall project. A draft scope of work for the equipment design efforts was prepared in April of 2012. Purchase orders for long-lead items began to be issued in the summer of 2012, and the design team to fabricate a prototype of several of the key containerized components; any lessons learned from this effort could then be used in the design and fabrication of the remaining units.

The component with the longest lead time was the high-pressure storage vessels which are critical components to the hydrogen fueling process. At the time of project execution, only one vendor could provide these tubes. The first set of vessels was delivered to Air Products in June of 2013, and the remaining tubes were shipped beginning in April of 2014.

1.2.2 Entitlement Process

Air Products met with the Planning Department for the City of Lawndale on July 23, 2014 to review information on the permitting process. The City required a Site Plan Review and approval of a Zoning Subdivision application prior to the start of the Agency Review of permitting documents.

Following completion of the equipment arrangement drawing, Air Products and S. Gordin Structural Design & Engineering Services, Inc., submitted drawings for the Site Plan Review application on December 22, 2014. Air Products received conditional approval on February 25, 2015. Approval was contingent upon on approval of the upcoming detailed structural and electrical design from the fire department and building departments and any changes to the special use permit for the property.

Air Products and S. Gordin Structural Design & Engineering Services, Inc. then prepared and submitted the Zoning Subdivision application on April 29, 2015. This process required a public hearing which took place on September 9, 2015. At the hearing the Planning Commission for the City of Lawndale approved the special use permit for the hydrogen station with a number of additional conditions. The City issued the modification to the permit on October 28, 2015. Air Products reviewed the document and signed an affidavit of acceptance that was submitted to the City on November 30, 2015.

Air Products submitted the structural and electrical plans to the LA County Department of Building and Safety in February of 2016. The building plans were approved on February 23, 2016. A separate package was submitted to the Petrochemical Division of the LA County Fire Department on March 8, 2016 and were approved on March 22, 2016. The electrical review required changes to the drawings which were resubmitted on April 27, 2016. Electrical plans were then approved on May 19, 2016.

1.3 Construction

Following a bid process, Air Products executed the construction subcontract to Fueling and Service Technology, Inc. on October 14, 2016. Construction started on October 31, 2016, with compression, cooling, and dispensing equipment delivered to the site on December 16, 2016. Southern California Edison began installation of the station utilities on February 23, 2017. Final site inspection by the City of Lawndale took place on April 17, 2017.

1.4 Commissioning of the Station

Following the completion of utility construction by Southern California Edison, commissioning activities were undertaken by Air Products' engineering and operations staff. Initial equipment operation, hydrogen sampling, and test fills into an Air Products test tank and into automaker test vehicles were performed during this time.

Following completion of a series of test fills by automakers, notification that the Lawndale SmartFuel® station was ready for H70 retail operation was provided by Air Products to the

Governor's Office of Business and Economic Development on June 20, 2017. The station was ready for H35 retail operation on June 23, 2017.

1.4.1 Division of Measurement Standards Certification

The California Department of Food and Agriculture's Division of Measurement Standards (DMS) is responsible for enforcing California weights and measures laws and regulations and must certify any device used for metering the sale of commercial items within California. The permanent DMS approval was received for the Lawndale SmartFuel® hydrogen station on June 20, 2017 for H35 fueling and on June 22, 2017 for H35 fueling. FirstElement Fuel, Inc. performed the testing as a registered service agent. Figure 4 provides a photograph of the dispenser with the DMS stickers in place.



Figure 4: Lawndale SmartFuel® Dispenser following DMS Certification

Source: Air Products and Chemicals, Inc.

1.4.2 Customer Usage

The first public customer fueled at the Lawndale SmartFuel® station in late June of 2017, and the station has been used regularly since then. Dispensed volumes totaled 371 kilograms in July of 2017, 1,355 kilograms in August of 2017, and 1,260 kilograms in September of 2017. A photograph of the Lawndale SmartFuel® hydrogen station is provided in Figure 5.



Figure 5: Lawndale SmartFuel® Hydrogen Station

Source: Air Products and Chemicals, Inc.

1.4.3 Station Online Status System Activated

The California Fuel Cell Partnership station online status system provides regularly updated station status information to fuel cell vehicle drivers. Air Products has provided California Fuel Cell Partnership station status information regarding its stations since the inception of station online status system. The H70 dispenser at the Lawndale station was added to station online status system on June 23, 2017 and the H35 dispenser was added on June 26, 2017. A screenshot of the station online status system network that includes the Lawndale SmartFuel® hydrogen station is shown in Figure 6.

Figure 6: Screenshot of California Fuel Cell Partnership SOSS Showing Lawndale SmartFuel® Hydrogen Station Status



Source: Air Products and Chemicals, Inc.

The station is open and active.

1.4.4 Environmental Impacts

Hydrogen is stored as a compressed gas in an above-ground tank concealed behind a wall at this station. Hydrogen is nontoxic, colorless, and odorless, so hydrogen station equipment is outfitted with appropriate sensors to provide immediate notification in case a leak occurs. No solid or liquid waste will be produced at this site.

There was no additional landscaping added for the construction of the hydrogen refueling station, and, therefore, no additional irrigation water will be consumed.

CHAPTER 2: Location and Schematics of the Station

The hydrogen station at 15606 Inglewood Avenue receives gaseous hydrogen delivered at elevated pressure from an Air Products production facility in southern California. The station is comprised of compression, cooling, and a two-hose dispenser with a customer payment interface are used to refill fuel cell electric vehicles.

2.1 Lawndale SmartFuel® Hydrogen Station in the Network

Figure 7 shows the location of the Lawndale SmartFuel® hydrogen station at 15606 Inglewood Avenue in relation to other stations in the Southern California network.



Figure 7: The Lawndale SmartFuel® Hydrogen Station

Source: Air Products and Chemicals, Inc.

2.2 Schematic Layout of the Lawndale SmartFuel® Hydrogen Station

As shown below, Figure 8 depicts an overview of the Lawndale SmartFuel® hydrogen station components. Hydrogen is produced by Air Products at a central fill system located in southern California, and the gas is delivered by a high-pressure tube trailer and pressure-transferred to a ground storage module at the station. Hydrogen is compressed as needed to fill the high-pressure storage tubes that are integral in providing a full fill to fuel cell vehicles that use the H70 nozzle. Gas is taken from storage and cooled based on the dispenser programming that meets the Society of Automotive Engineers J2601 fueling protocol; Air Products has patents which cover elements of the station operation and the dispensing process.



Figure 8: Schematic Depicting SmartFuel® Hydrogen Station Equipment

Source: Air Products and Chemicals, Inc.

Figure 9 shows a detailed view of the actual final, as-built configuration of the Lawndale SmartFuel® hydrogen station.

Table 1 shows the list of subcontractors and grant agreement budget under this project.



Source: Air Products and Chemicals, Inc.

Table 1: List of Subcontractors and Grant Agreement Budget
Air Products and Chemicals, Inc., Allentown, PA

Air Products and Chemicals, Inc., Allentown, PA		
H2 station equipment	\$666,222	
Fueling and Service Techno	ology, Inc., Buena Park, CA	
Construction	\$207,186	
S. Gordin Structural Design & Engine	eering Services, Inc., Carson City, NV	
Design and permitting services	\$41,395	
California Energy Commission Grant	\$581,578	
Air Products Cost Share	\$333,225	
Total Energy Commission cost share	64%	
Total Budget	\$914,803	

Source: Air Products and Chemicals, Inc.

CHAPTER 3: Data Collection and Energy Analysis

The Lawndale SmartFuel® hydrogen refueling station is supplied by hydrogen generated via steam methane reformation that converts methane (CH4) and water (H2O) to hydrogen (H2) and carbon dioxide (CO2) and along with an equilibrium amount of carbon monoxide (CO):

Steam/Methane Reforming Reaction	$CH_4 + H2O + Heat \Leftrightarrow CO + 3H2$
Water-Gas Shift Reaction	$CO + H2O \Leftrightarrow CO2 + H2 + Heat$

Per California Senate Bill 1505 (Lowenthal, Chapter 877, Statutes of 2006) and PON-09-608, which funded this project, at least one-third of the hydrogen dispensed will be produced from renewable energy sources.

Hydrogen is supplied to the hydrogen fueling station from Air Products' hydrogen production facilities in Wilmington/Carson, California. Renewable biogas is being procured as feedstock for the facilities, resulting in delivered hydrogen product that meets the 33 percent renewable requirements.

Air Products has a contract for sourcing the renewable biogas that meets Public Resources Code Section 2574(b)(1); documentation is provided in Figure 10. Although California has a substantial amount of biogas, local supply cannot be injected into California pipelines under California Health and Safety Cost Section 25420. Air Products' biogas supply for this project is sourced outside California and transported to California with connection to a natural gas pipeline within the Western Electricity Coordinating Council region that delivers gas into California.

Figure 10: Documentation of Biogas Sources

Exhibit A RB Supply Sources Shell Energy North America (US), L.P.

Supply Source	Address	Pipeline/LDC	Receipt	Dolivery
Grientres Landfill	635 Toby Road Keney, PA 25846	National Fuels Gas TETCO NGPL EPNG Socal Gas FAR	Landfill meter Net Pusi-Bristorie Tetor-Sweet Loke 3825 EPNG Jel 3083 Topock	Bristorie NGPL-Swort Lake EPING Jal 3083 Topick Socal Citygate
Imparlai Landfill	11 Boggs Road Imperial, PA 15126	Netional Fuels Ges TETCO NGPL EPNG Socal Gas FAR	Landfill meter Nat Fuel-Bristoria Tatco-Sweet, Laku 3825 EPNS Jal 3083 Topock	Bristoria NGPL-Sweet Laka EPING JM 3083 Topock Socil Citygate

SELF-GENERATION INCENTIVE PROGRAM DIRECTED BIOGAS FUEL SUPPLIER ATTESTATION

J, Shell Energy North America (US), L.P., hereby attest that Directed Biogas will be supplied to Air Products and Chemicals, Inc. by nomination and will comply with all applicable rules of the Self-Generation Incentive Program (SGIP) including but not limited to;

- a) Contract will include term (minimum of 5 years), cost, amount of renewable fuel injected on a monthly basis for the length of the contract, address of renewable fuel facility, and facility address of Host Customer.
- b) Documentation will be provided that shows that the third party gas provider can inject the renewable fuel into the natural gas pipeline.
- c) The Renewable Fuel Supplier facility must produce fuel that meets the SGIP definition of renewable fuels.
- d) The gas must be injected into a natural gas pipeline system that is either within the Western Electricity Coordinating Council (WECC) region or interconnected to a natural gas pipeline in the WECC region that delivers gas into Celifornia.

The undersigned understands that non-compliance to any SGIP requirements will be grounds for partial or complete incentive refund.

Shell Energ	y North America (US), L.P.
Signature:	Edecante Dan
Name Printed:	Edward BROWN
Title:	Vice President
Company	Shell ENERGY North American (US), d.P.
Date:	3/21/2011

Source: Air Products and Chemicals, Inc.

Hydrogen is delivered to the Lawndale SmartFuel® hydrogen refueling station by a Department of Transportation-certified high-pressure delivery trailer.

The environmental benefits of using fuel cell electric vehicles were calculated based on the annual reduction in greenhouse gas (GHG) emissions and petroleum consumption. This calculations were compared to California Air Resource Board's (CARB) Low Carbon Fuel Standard (LCFS) lifecycle emissions of light-duty gasoline vehicles. For the analysis on GHG emissions and the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model; gaseous hydrogen has been appended with calculations to deliver compressed hydrogen gas with 33.3 percent renewable energy content from a large central hydrogen production facility to a cluster of fuel cell stations in Southern California. For the hydrogen supply pathway and hydrogen fueling station, the lifecycle emission of hydrogen energy supply is estimated at 75.2 grams of carbon dioxide equivalent (CO2e) per megajoule on a full wellto-wheels basis. CARB's LCFS lifecycle emissions estimate for a similar pathway for compressed hydrogen from central reforming of natural gas (LCFS Pathway HYGN005) is 88.3 grams CO2e/ megajoule. In factoring in an Energy Efficiency Ratio of 2.5 for fuel cell electric vehicle's established under California LCFS the resulting emissions performance for fuel cell electric vehicles is 148 grams CO2e/mile. In comparison to a LCFS light-duty gasoline vehicle baseline, the hydrogen supply pathway results in a 62 percent reduction in well-to-wheel greenhouse emissions relative to California gasoline.

Relating to the Lawndale SmartFuel® hydrogen refueling station, this level of relative GHG reduction to the LCFS 2016 baseline for gasoline vehicles each fuel cell electric vehicle deployed in the market will reduce GHG emissions by 4.3 metric tons per year. The station has the potential to contribute to the reduction of 620 metric tons of GHG emissions and greater than 36,500 gallons of gasoline consumption annually. The long-term greenhouse gas and petroleum reduction that could be realized by widespread adoption of fuel cell electric vehicles in the marketplace is enormous.

CHAPTER 4: Statement of Future Intent

Air Products has executed an initial lease with the landowner with options for annual extensions.

As part of its ongoing support to hydrogen fueling stations in California, Air Products has a fully staffed operations department which can address station maintenance and emergency situations. Air Products utilizes a 24-hour Equipment Support Team to monitor for alarms from the hydrogen station (in addition to any local alarms at the point of use). Air Products employs technicians in the Los Angeles Basin area that are trained in the specialized requirements for hydrogen fueling stations.

CHAPTER 5: Conclusion

The following is a list of important findings from the Lawndale SmartFuel® hydrogen station project:

- In order to shorten the time needed to permit a hydrogen fueling station, both the applicant and the various agencies responsible for review and approval must provide timely and complete responses to correspondence between the parties.
- The hydrogen station equipment at Lawndale has common components to other stations supplied by Air Products. This helps to increase the efficiency of the project management process.

GLOSSARY

CALIFORNIA AIR RESOURCES BOARD (CARB or ARB)—The "clean air agency" in the government of California, whose main goals include attaining and maintaining healthy air quality; protecting the public from exposure to toxic air contaminants; and providing innovative approaches for complying with air pollution rules and regulations.

CARBON DIOXIDE (CO2)—A colorless, odorless, nonpoisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent).

CARBON DIOXIDE EQUIVALENT (CO2e)—A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.

CARBON MONOXIDE (CO)—A colorless, odorless, highly poisonous gas made up of carbon and oxygen molecules formed by the incomplete combustion of carbon or carbonaceous material, including gasoline. It is a major air pollutant on the basis of weight.

DIVISION OF MEASUREMENT STANDARDS (DMS)–Enforcement of California weights and measures laws and regulations is the responsibility of the Division of Measurement Standards (DMS). The Division's activities are designed to:

Ensure the accuracy of commercial weighing and measuring devices.

Verify the quantity of both bulk and packaged commodities.

Enforce the quality, advertising and labeling standards for most petroleum products.

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 the vast majority of weights and measures enforcement activities at the local level.¹

GREENHOUSE GASES (GHG)—Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

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

LOW CARBON FUEL STANDARD (LCFS)—A set of standards designed to encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and therefore, reduce greenhouse gas (GHG) emissions. The LCFS standards are expressed in terms of the

¹ <u>California Department of Food and Agriculture Division of Measurement Standards</u>

⁽https://www.cdfa.ca.gov/dms/)

"carbon intensity" (CI) of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California to cut greenhouse gas emission and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options.