California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

City of Sacramento Establishment of New Compressed Natural Gas Infrastructure

Prepared for: California Energy Commission

Prepared by: City of Sacramento, Public Works Department

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PREFACE

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

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

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- 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-14-608 to establish and expand infrastructure necessary to store, distribute and dispense compressed natural gas (CNG) for use in natural gas vehicles for school districts and other public entities. In response to PON-14-608, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards August 12, 2015 and the agreement was executed as ARV-15-018 on December 1, 2015.

ABSTRACT

This report details the design, installation, and performance of a $2.8 million compressed natural gas (CNG) fueling facility for the City of Sacramento's Department of Public Works, specifically its commercial refuse vehicle fleet. Funded in part by the California Energy Commission as agreement ARV-15-018, the project aimed to reduce greenhouse gas emissions and lower fuel costs for the city's Solid Waste Fleet. Despite several changes in scope and location during the project, the final installation at the Meadowview site proved to be the optimal solution.

The project objective was to deliver CNG fuel to 100 fleet vehicles responsible for refuse collection across the City of Sacramento. This would allow full retirement of the previously diesel-fueled trucks and terminate the process of filling the existing CNG trucks at a third-party facility, both expensive and time-consuming.

The general arrangement for dispensing fuel to the trucks utilizes 25 quad post fuel standards containing four tethered dispensers each. The fuel is delivered from the main natural gas service under Meadowview Road to the immediate north of the property and travels approximately 1,500 feet south to the equipment yard where it is compressed by three primary compressors and distributed to the time-fill dispenser-equipped parking spaces. There are also two fast-fill dispensers for urgent fueling when required.

The City has enjoyed success with the new facility. In 2014, prior to commencing conversion to CNG, the City consumed 94,201 gallons of diesel fuel for its Solid Waste fleet. This equates to 959 tons of Carbon Dioxide (CO_2) emissions. Today, this consumption has been eliminated, and the objective of reducing operating costs while reducing carbon footprint has been achieved. There have been no significant issues, and the implementation of the system has not resulted in any service disruptions. Although the City does eventually intend to convert the entire refuse fleet to electric in the future, the recommendation to other municipalities would be to install a CNG facility provided funding exists, and conversion to electric is neither feasible nor practical.

Keywords: California Energy Commission, Compressed Natural Gas, CNG, Time-fill, Fast-fill, Solid Waste Fleet, City of Sacramento, Quad Post.

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EXECUTIVE SUMMARY

For years, the City of Sacramento has explored alternatives to diesel fuel to reduce costs and its carbon footprint, aiming to set a positive example for the local community and other jurisdictions. In 2014, the City installed its first Liquified Propane Gas fuel facility as an initial step into alternative fuel technologies. Although the facility achieved modest success, the City continued its focus on alternative fuels, eventually prioritizing compressed natural gas (CNG) during 2014-2015.

During this time, the City pursued and secured the California Energy Commission (CEC) grant of $250,000to construct a new CNG facility at the City's North Area Corporation Yard (NACY). However, budgetary concerns arose due to a potential lawsuit filed against the Division of Solid Waste, prompting the City to set aside funds in case of an adverse ruling. As a result, the project scope was reduced, and the facility's location was shifted to the South Area Corporation Yard (SACY). The revised project included 14 time-fill dual posts and a total of 28 dispensers, but excluded fast-fill dispensers. Although the design was fully permitted and went to bid, the bids received exceeded the budget, leading to further project delays.

During this delay, Solid Waste learned that the impending lawsuit had been either dropped or dismissed, resulting in a windfall of funding to support the full-scope project. In 2017, Solid Waste decided to expand the scope back to 100 time-fill dispensers, two fast-fill dispensers, and to relocate to the project to the Meadowview Solid Waste Facility, home to the bulk of the Solid Waste refuse truck fleet. The current project was subsequently designed, built, and placed into service at this location.

At the start of this project, the City operated 21 CNG vehicles, with 53 more CNG vehicles planned for delivery by 2020. Since the City lacked a nearby CNG fueling facility, its vehicles had to travel an additional 30 minutes to fuel at a third-party station. This extra travel time added unnecessary mileage and increased pollution. By installing its own CNG facility, the City would eliminate these impacts and facilitate the purchase of more CNG vehicles , reducing costs and lowering the carbon footprint of Solid Waste operations.

The objective of this project was to establish a new CNG fueling station at the Meadowview City Service Complex, the operational base for the Division of Solid Waste. This station enabled the City to expand its existing CNG fleet and eliminate the unnecessary trips to third-party CNG fueling facilities. These objectives streamlined operations and significantly reduced pollutants emitted by the previous diesel fueled trucks. The City recognized these benefits as providing cleaner air and better use of taxpayer funds, in terms of fuel costs.

Despite the challenges associated with the project, the overall outcome has been positive. The station has been well-received by refuse fleet drivers, costs have met expectations, and the system is operating reliably. While the City is already demonstrating a new electric refuse truck, the CNG facility will continue to serve the City effectively until that next transition occurs.

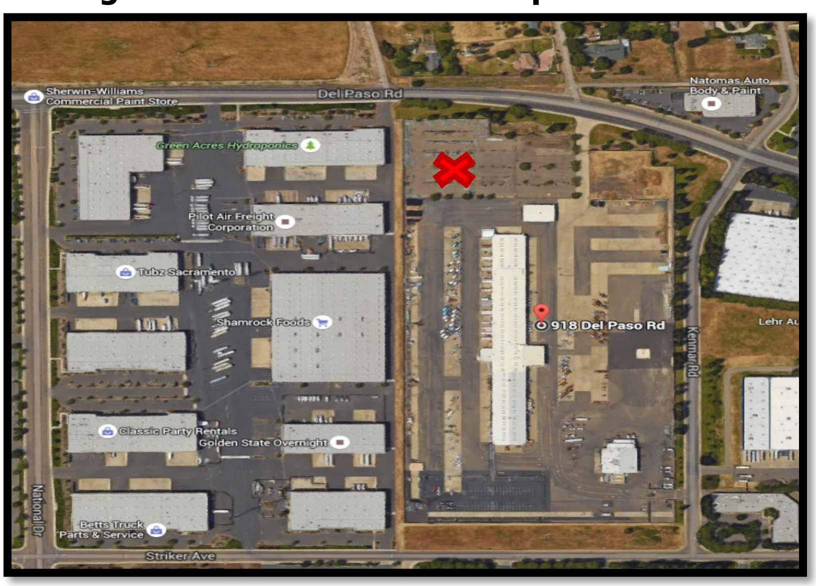
CHAPTER 1: Project Background

Original Project Location and Requirements

North Area Corporation Yard

The original location that was planned as the City's first CNG station was the North Area Corporation Yard (NACY) located at 918 Del Paso Road in North Sacramento, as shown in Figure 1. This site was originally developed in 1986 by Consolidated Freightways, a now defunct national trucking firm. The site was originally selected because of the significant presence of existing of CNG trucks, including vehicles not associated with the Division of Solid Waste such as Autocar rear loader trucks and Freightliner Elgin Broom Bear sweepers. The objective of this project was to install 14 new time-fill stations for a total of 28 dispensers. To support this, one (1) gas compressor rated at 600 standard cubic feet per minute (scfm) and 4,500 pounds per square inch (psig) discharge, a 600 scfm gas dryer, and associated electrical and controls were proposed. The California Energy Commission award a 50% matching grant of $250,000. The project was projected to reduce greenhouse gas emissions by up to 20% with little impact on local traffic. The NACY facility was large enough to easily handle the site modifications necessary to implement this project with virtually no impact on surrounding neighborhoods.

Figure 1: The North Area Corporation Yard



Arial view of the North Area Corporation Yard showing the proposed location of the CNG Station at the north-center of the property.

Source: *City of Sacramento*

Second Proposed Project Location and Requirements
South Area Corporation Yard

The next site chosen to house the revised CNG facility was the South Area Corporation Yard (SACY) (Figure 2). This scope duplicated the NACY project again using 14 dual post time-fill stations for a total of 28 dispensers. The intent was to build CNG filling stations closer to the Division of Solid Waste headquarters at the Meadowview City Service Complex. This way, some drivers could fill up directly in route to the Meadowview facility rather than driving to fill at a third-party facility that was out of route thirty minutes away. This project was fully designed, permitted and put out to bid, but the bid results exceeded the budget. As budget negotiations were in progress, a breakthrough on the Solid Waste funding constraints was reached and the entire project was annulled in favor of expanding the scope again at a more advantageous location.

Figure 2: The South Area Corporation Yard

Arial view of the South Area Corporation Yard showing the proposed location of the CNG Station at the southwest corner of the property

Source: *City of Sacramento*

Final Project Location and Requirements
Meadowview Solid Waste Facility

The final iteration of the project, which was built and is now operational, consists of 100 time-fill, and 2 fast-fill dispenser facility at the Meadowview City Service Complex which also serves as the headquarters for the Division of Solid Waste. As outlined in Figure 3, the facility would occupy the parking area already used for the current fleet of vehicles. This area comprises nearly the entire southern portion of the facility which accounts for 25% of the property.

For this round, the decision was made to deliver the project in a design-build fashion. A Request for Proposals (RFP) was issued, and the project was awarded to Clean Energy Fuels (Clean Energy), of Newport Beach, CA. The guaranteed maximum price for design and installation was $3.024 million. Another $2.145 million was included for an operations and maintenance agreement with Clean Energy for a period of five years. There would be an option for another five-year maintenance contract with CE after the first one expired.

Figure 3: Meadowview City Service Complex

Arial view of the Meadowview City Service Complex showing the proposed location of the CNG Station at the southern end of the property. The equipment yard is located just north of the parking area in a small enclosure.

Source: *City of Sacramento*

Clean Energy completed the design in May of 2021 and construction was scheduled to commence by July 2021. The actual start time for the project was the first week of August 2021. Unfortunately, the project coincided with the COVID-19 pandemic and faced many of the supply-chain challenges that affected other industries. As a result, there were numerous delays and extended lead-times for critical equipment infrastructure. Some of the more notable delays involved the two utility companies associated with the project, Pacific Gas & Electric Co. (PG&E), and the Sacramento Metropolitan Utility District (SMUD). The PG&E gas meter, which relies on a component that was adversely affected by supply chain issues, contributed directly to a 2-month delay. Additionally, the pandemic impacted PG&E's ability to get full work crews to the site in a timely manner.

The SMUD transformer was also delayed due to similar circumstances. It did not arrive on site until the first week of June 2022. More problems between Clean Energy and their electrical subcontractor caused further delay in getting the system energized once the transformer was fully operational. Much of the year 2022 was lost dealing with delays based on many differing factors.

Construction ultimately concluded by May of 2023, and after the necessary start up and commissioning activities were completed by Clean Energy, the final inspection of the project was conducted. The facility was turned over to the Division of Solid Waste and opened for general operation in June 2023. It has operated successfully since that time.

CHAPTER 2: Facility Design Parameters

Overall Design Requirements

See Tables below for notable design requirements for the project. These were developed by the Engineer of Record as a result of City of Sacramento objectives.

Table 1: Compressor Design Requirements

MANUFACTURER	QUANTITY	Horsepower (HP)	SCFM	Pressure (in/out) (psig)	Notes
Clean Energy Fuels	3	150	302	35/4,500	One compressor dedicated to fast-fill

Source: City of Sacramento/Clean Energy

Table 2: Gas Dryer Design Requirements

MANUFACTURER	QUANTITY	Max Pressure (psig)	Service Pressure (psig)	Notes
PSB Industries	1	200	15-140	4” inlet & outlet; 927 SCFM @ 35psig

Source: City of Sacramento/Clean Energy

Table 3: CNG Fast-fill High Pressure Vessel Design Requirements

MANUFACTURER	QUANTITY	Max Pressure (psig)	Service Pressure (psig)	Notes
Allied Equipment	1	5,000	4,500	48” inside diameter; 33.5 cu.ft. storage volume

Source: City of Sacramento/Clean Energy

Table 1 defines the design parameters to fuel 100 CNG refuse trucks determined by the engineers to meet the City of Sacramento’s needs. Once gas flow rates are determined, the required inlet pressure from PG&E is determined to successfully move the volume of gas over the necessary distances for each truck to be fueled properly and within the specified time frame. These are the variables used to size the main compressors. Those calculations yielded a necessity for 302 cubic feet per minute at 35 pounds per square inch, which requires three compressors rated at 150 horsepower each. This setup is sufficient to serve the time-fill and fast-fill dispensers under any conditions.

The gas dryer is a critical piece of equipment. Through the dehumidification process using refrigerant coils, heat, and filtration, the gas is guaranteed to enter the compressors free of any moisture or other contaminants harmful to the compressor’s reciprocating parts. Table 2 shows the engineering parameters associated with this equipment. The gas dryer can withstand a max pressure of 200 psig and runs at a service pressure of 15-140 psig.

Table 3 shows the engineering data with regards to the high-pressure spherical storage tank for use with the fast-fill station. This tank is rated for a max pressure of 5,000 psig to provide the ability to fill a CNG truck to 80% capacity in less than 30 minutes. The storage tank is also located within the equipment yard.

Other notable equipment includes 22 quad fuel posts and four modified quad fuel posts manufactured by Clean Energy, with one outlet capped to create three dispensers per post. The project also features a two-dispenser fast-fill station manufactured by Wayne Fueling Systems and a remote card reader.

Gas Pressure Requirements

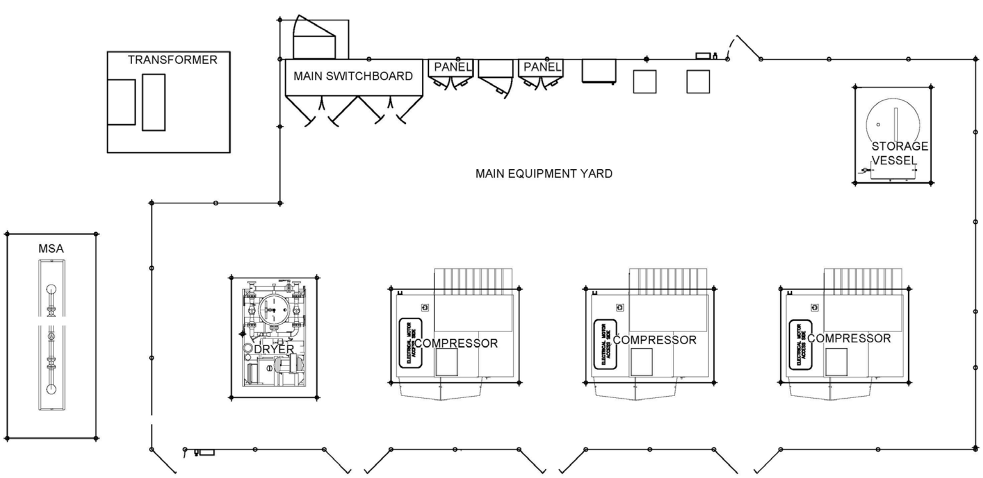
Gas pressure is a critical factor for CNG facilities, as fueling cannot occur without sufficient pressure. For this project, the City required an incoming gas pressure from the utility between 28 and 35 pounds per square inch (psi) floating pressure. However, PG&E typically supplies natural gas at no more than 5 pounds per square inch gauge (psig). After negotiations, the City secured a commitment letter from PG&E guaranteeing a minimum incoming gas pressure of 28 psig. This pressure ensure the three compressors have the necessary conditions to boost the gas pressure to the required 4,500 psig as shown in Table 1 above.

Electrical Capacity Requirements

The facility required a new 480-volt, three-phase electrical service with a 750 kilovolt-amperes (kVa) transformer supplied by SMUD to provide sufficient power. A main switchboard and motor control center for each compressor is located within the yard. Each of the three motor control centers that serve the compressors are rated for 250 amps. Much of this equipment, along with the associated mechanical equipment, is shown in Figure 4. SMUD provided an 800-amp service with a maximum fault current of 17,100 amps.

Since its opening, the CNG facility has averaged approximately 40,000 kilowatt-hour (kWh) of electrical consumption per month, with a peak monthly demand of 230 kilowatts (kW).

Figure 4: Equipment Yard Layout



Plan view of the Equipment Yard located just north of the truck parking area. North is up on the page. The SMUD transformer is located at the northwest corner of the pad outside the fenced enclosure. The PG&E gas meter assembly is

located directly west and also outside the fence. Within the enclosure shows the main switchboard and electrical panels along the north edge of the fence, and the high pressure fast-fill spherical tank at the northeast corner. At the southwest corner is located the Gas Dryer unit, and along the southern portion of the enclosure sits the three main compressors lined up west to east.

Source: *City of Sacramento/Clean Energy*

CHAPTER 3: Construction Phase

Equipment Installation

Following a design-build process, the team procured equipment as soon as design allowed. The COVID-19 pandemic caused significant delays in lead times, and the customized nature of the equipment being built made it essential to expedite production to stay on schedule. The project's most critical items were the three massive compressors, which were the most sophisticated items and required the longest fabrication time. The compressors arrived on site in September 2021 and were placed in the equipment yard. Figure 5 provides a clear view of one of the compressors.

Figure 5: One of Three CNG Compressors Delivered

One of the Clean Energy-supplied compressors. Each compressor is encased by a stainless-steel enclosure. They are rectangular in nature with some irregular shapes to accommodate the large reciprocating compressor inside, at left. An access door is located to the right for ease of maintenance work. Electrical conduits routed below grade enter the housing at lower left. The gas train assembly is located at lower right.

Source: *City of Sacramento*

The filter dryer was another complex component with a longer production lead time. Its primary function is to ensure moisture-free natural gas, protecting the compressors from potential damage caused by excessive water intrusion into the compressor chamber. Moisture can severely harm rapidly reciprocating equipment. The filter dryer achieves this through a process of multiple filtering, cooling, and reheating of the gas. Figure 6 shows the filter dryer immediately following installation.

Figure 6: Filter Dryer Assembly

Filter Dryer assembly. Entire apparatus is mounted on a skid painted lime green. At the upper left is the condenser that is part of the refrigerant drying system. The large tank to the right is the evaporator barrel that brings the gas flow below the dew point. Directly in front of the evaporator is the refrigerant dry which protects the compressor which is located at the lower left.

Source: *City of Sacramento*

The high-pressure spherical storage tank was another major item and was necessary to provide a high-pressure buffer between the compressors and the fast-fill dispensers. A photo of it during the construction is shown in Figure 7.

Figure 7: High-Pressure Spherical Tank

The spherical High-Pressure Tank is approximately 48-in diameter and sits on a raised, integral cylindrical stand of 24-in diameter. It is painted in a shade of antique white.

Source: *City of Sacramento*

The fast-fill station operates like a standard gas pump, offering a quick refueling option for vehicles low on fuel. It fills the tank to 80 percent capacity, allowing the vehicle to complete its daily route without significant delay. Figures 8 and 9 show the fast-fill station alongside an example of a time-fill station are shown in. The primary difference between time-fill and fast-fill lies in their methodology. Time-fill dispensers are designed to very slowly admit natural gas into the vehicle tank, minimizing back pressure that could prevent a complete fill. The process occurs overnight when the trucks are not in use, ensuring they are fully fueled and ready for operation each morning. In contrast, fast-fill systems deliver high volumes of gas at very high pressure, filling a tank to 80 percent capacity in less than 30 minutes. While fast-fill systems allow for quick turnarounds, the reduced fill capacity accommodates the gas dynamics and back pressures inherent to rapid fueling. This makes fast-fill ideal for situations where a vehicle needs to quickly refuel and return to service with minimal downtime.

Figure 8: Fast-Fill Station

Figure 9: Time-Fill Station

Figure 8, left, shows the single fast-fill station and dispenser. This apparatus resembles a typical gas pump that the public uses, with a rectangular upright position with digital readouts for the operator to watch while filling, and the hose/dispenser socket at right. At right in Figure 9, a typical time-fill quad post is shown. The posts rise vertically out of the associated K-rail with four dispensers per post. Each hose is allowed to extend to the truck fuel intakes. Electrical conduits and gas pipe are routed along the tops of the K-rails.

Source: *City of Sacramento*

Installation of Piping

The system uses various types of piping and tubing to transport natural gas from Meadowview Road to the farthest CNG dispenser at the south end of the yard. Flow rate and pressure determine the type of materials used for this conveyance. The main six-inch diameter pipeline runs approximately 1,500 feet from the point of connection at Meadowview Road to the meter at the equipment yard and is mainly comprised of polyethylene pipe. This transitions to black steel piping just before routing above grade to the gas meter assembly, which is comprised of all black steel. While polyethylene and black steel pipe are generally rated for similar pressures, black steel is preferred for above-ground installations due to its durability against environmental elements, accidents, and vandalism. The gas piping remains steel up to the compressor connections. Beyond the compressors, plastic tubing carries the gas to their respective dispensers in the field.

Utility Work

The installation of the major equipment provided by PG&E and SMUD required extensive coordination and advanced planning. Lead times for transformers and gas meters are lengthy, but delay became even more challenging during the peak of the COVID-19 pandemic. Figures 10 and 11 show the trenching for the piping and the gas meter assembly shortly after installation, while Figures 12 and 13 depict the SMUD electrical conduit and transformer. These components were installed in April and June of 2022, respectively, making them some of the last major pieces of equipment set in place for the project. Connections to this equipment would follow after.

Figure 10: Main Gas Trench

Figure 10 shows gas line from Meadowview Rd. after trench was backfilled extending into the distance northward toward Meadowview Rd. To the right is a backhoe used for the work. Laying on the ground to the left is more polyethylene gas pipe to be installed later.

Figure 11: Gas meter Assembly

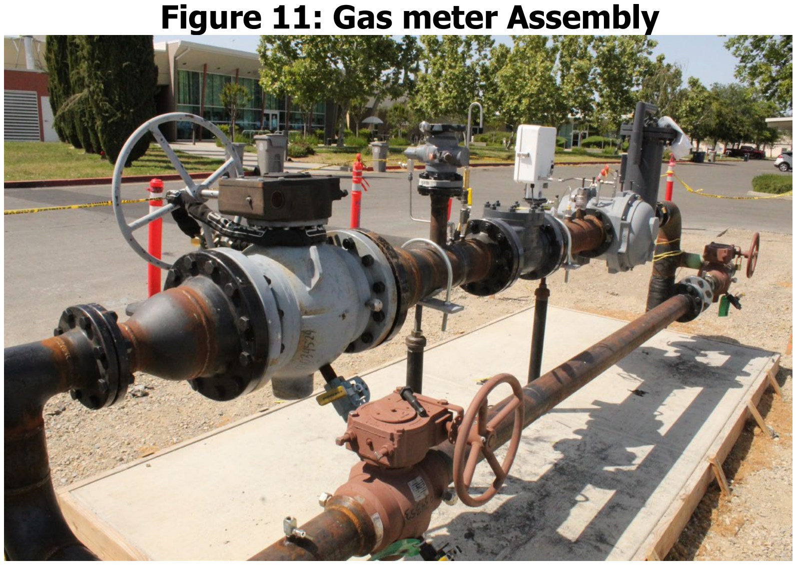


Figure 11 shows gas meter assembly with meter at center and two large isolation valves at each end. Bypass line to the right for maintenance.

Figure 12: Electrical Trench

Figure 12 shows electrical trench cut through grass field behind one of the Administration Buildings. Two light gray electrical conduits are in place at the bottom of the trench.

Figure 13: Electrical Transformer

Figure 13 shows rear view of large green SMUD transformer in place on its concrete pad. At front are the large fins to facilitate heat rejection.

Source for Figs 10-13: *City of Sacramento*

Connection Work

After completing the utility work, the team focused on connecting the gas and electrical systems to the main equipment. Beyond the Equipment Yard, the gas line was connected from the center median at Meadowview Road to the inlet side of the gas meter/regulator assembly. Additionally, the connection was made from the compressor manifold piping to the outlet side of the meter, completing the entire piping system from the street to the compressors.

Flexible plastic piping extends from the compressor outlets, first to the fast-fill fueling station and then to the time-fill fueling stations located at the existing parking spots for the solid waste trucks. The quad-post dispensers are installed within the K-rails, which serve as barriers, with the gas piping secured along the top of the K-rails and protected by a shroud.

Electrical service was routed from a nearby administration building through a trench that crossed a grass field and asphalt driveway to the transformer. Additional low-voltage wiring was necessary to ensure the integrated control system, complete with all of its failsafe features, was fully operable. Once the system was electrically energized and gas service activated, Clean Energy technicians conducted a two-week commissioning period. By June 2023, the work was concluded, and the station was turned over to the Department of Solid Waste for normal operations. The station continues to function as expected to this day.

CHAPTER 4: Data Collection and Analysis

Method of Obtaining Data

The control system that operates the CNG system provides more than enough diagnostics to satisfy the requirements of this report. The City also utilizes EnergyCAP, a utility account management system, to monitor all electrical and natural gas accounts in the City. With this software, City staff can simply log into the system and access energy usage data uploaded through the monthly billing records.

For this project, the City needed six months of gas and electrical consumption to be expended before a reliable sample-size of data could be realized. Most calculations relied on the natural gas consumption as the primary parameter. Figure A-1 provides a typical output report for natural gas use, customizable to any user-defined time period.

Unfortunately, during the initial data collection period, the PG&E gas meter failed and was offline for approximately three months. This issue caused delays in data collection, necessitating a term-extension amendment to the project timeline. Once the meter was replaced, data collection resumed, and the required information was gathered successfully.

Method of Analyzing Data

The data was analyzed through use of an Excel spreadsheet using all of the consumption data produced by EnergyCAP. Due to the inability of obtaining certain data, parameters such as non-methane hydrocarbons and formaldehydes were excluded from analysis per CEC advisement. Formulas and equations were researched for best suitability in calculating oxides of nitrogen (NOx) reductions and particulate matter (PM) 2.5 particulate reductions. Carbon intensity is a constant for both diesel fuel and CNG, thus no calculation was performed; the values are merely reported. All formulas used to calculate the data in the spreadsheet will be listed in their entirety in Appendix B.

Results

The six-month CNG data collection and analysis spreadsheet provides a clear summary of the results and the desired pollutant reduction outcome. It is important to note that the immediate post-construction period yielded a situation that slightly altered the final objective of operating 100 time-fill dispensers. During the design period, it had been overlooked that the vehicle operators could sit on the left or right side of the cab. As a result, hazardous footing conditions at seven dispenser locations led the Division of Solid Waste to eliminate those spots for safety reasons. As such, the facility now operates with 93 active time-fill dispensers.

The six-month spreadsheet presents all the required data collection and analysis based on natural gas consumption at the entire facility. It also includes calculations for throughput capacity, last known annual diesel consumption prior to the first replacement CNG vehicles being purchased, and emission reductions such as NOx and $PM_{2.5}$ particulate matter.

Table 4: Six-Month Data Collection Spreadsheet

SIX-MONTH CNG DATA COLLECTION AND ANALYSIS																
Month	No. of Days Each Truck is Fueled	Gas Usage (Therms)	Throughput (BTU)*	Max Capacity (CuFt)	Gallons Diesel Displaced (GAL)**	Electric Use (kWh)	Expected Air Emissions Reduction (mo)									
												Particulate				
							Q_{diesel} (MMBtu)	Q_{CNG} (MMBtu)	NOx_{DIESEL} (lbs)	NOx_{CNG} (lbs)	Reduction (lbs)	$PM10_{Diesel}$	$PM2.5_{Diesel}$	$PM10_{CNG}$	$PM2.5_{CNG}$	PM 2.5 Reduction
December 2023	20	55,819	5,581,900,000	276,880	7,850	41,911	14.20	3.49	26.99	0.35	26.64	72,220	61,387	4,984	4,236	57,151
January 2024	23	49,656	4,965,600,000	246,310	7,850	43,738	14.20	3.10	26.99	0.31	26.68	72,220	61,387	4,434	3,769	57,618
February 2024	21	51,195	5,119,500,000	253,943	7,850	36,558	14.20	3.20	26.99	0.32	26.67	72,220	61,387	4,571	3,885	57,502
March 2024	21	48,330	4,833,000,000	239,732	7,850	36,233	14.20	3.02	26.99	0.30	26.68	72,220	61,387	4,315	3,668	57,719
April 2024	22	51,172	5,117,200,000	253,829	7,850	35,818	14.20	3.20	26.99	0.32	26.67	72,220	61,387	4,569	3,884	57,503
May 2024	23	48,876	4,887,600,000	242,440	7,850	40,784	14.20	3.05	26.99	0.31	26.68	72,220	61,387	4,364	3,709	57,678

Notes:
* Throughput based on an average of 28 psi service pressure.
** Based on City Fleet Division-based data on diesel fuel consumed in 2014 when the entire fleet was operating on diesel.

Economic Impacts

The construction of the $3 million CNG Fueling Station has positively impacted the local economy in several indirect ways. According to the City of Sacramento's metrics, developed by the Center for Strategic Economic Research, the new infrastructure is expected to create 22 total jobs -14 direct jobs and 8 through indirect and induced activities.

Beyond the immediate construction impacts, future economic impacts include increased tax revenue from the direct sale of natural gas to the City. The City of Sacramento imposes a 7.5 percent Utility Users Tax, which also applies to the City itself. This generates approximately $1,400 per month in revenue, which is used to support the City's interests and benefit its residents.

Additionally, the Gas Public Purpose Program (PPP) Surcharge of $0.04866 per therm of gas use is applied in accordance with Public Utilities Code Sections 890-900 and Gas PPP Surcharge Decision 04-08-010. Under the jurisdiction of the California Public Utilities Commission (CPUC), gas utilities are required to implement updated gas PPP surcharge rates. Gas PPP surcharge rates recover authorized funding for Energy Efficiency (EE), Energy Savings Assistance (ESA), CARE, California State Board of Equalization (BOE) administrative expense, and gas public-interest Research, Development, and Demonstration (RD&D) programs. This surcharge amounts to nearly $1,200 per month, much of which lands in the State of California's revenue coffers.

Renewable Energy

There have been informal discussions between the City of Sacramento and Clean Energy concerning the use of renewable natural gas , also known as biomethane. This is a 100% renewable energy source which is produced from organic matter like agricultural crops, forestry waste, and manure. Major sources of biomethane are landfills, dairies, and wastewater treatment plants. Although discussions with the Fleet Division have taken place, no executive decisions have been made regarding this prospect.

CHAPTER 5: Lessons Learned and Next Steps

This project faced numerous challenges, both during its development and construction. The three iterations of the project, each considering different location options, consumed three years of time. Budget issues within the Division of Solid Waste experienced added further delays, leading to a Stop Work Order being issued by the CEC in September 2018. This Stop Work Order was not lifted until December 2020, when the City confirmed its design-build contract and commitment to completing the project. Despite the Stop Work Order, the City decided to proceed, and the design phase continued during this period.

Several other factors contributed to time delays. Changing the project location required issuing a new RFP, another review process, more contract negotiations, and another request for City Council approval. After selecting Clean Energy as the design-build contractor, these processes took over a year. The contract negotiations with Clean Energy alone extended for six months. Although the RFP closed in April 2019, the final contract was not executed until June 10, 2020 due to the complexity of negotiations.

Once construction began, the COVID-19 pandemic was well underway. While the City could not have anticipated this, the pandemic led to significant delays caused by supply chain disruptions and labor shortages, further affecting the already delayed schedule.

Reflecting on those challenges, the primary lessons learned revolve around the decision-making process and the back-and-forth on determining location and funding. Premature decisions were made early in the project regarding the site location and funding. Therefore, it is strongly recommended that dedicated funding be secured upfront and that the best possible site is selected from the start.

Looking ahead, the Division of Solid Waste will continue to collaborate with Clean Energy for operations and preventative maintenance as part of the contract. The City plans to convert its entire fleet of solid waste vehicles to fully electric vehicles. While an electric demonstrator truck has already been delivered to the Meadowview facility, no schedule has been set full conversion.

GLOSSARY

AMPERE (Amp)- The practical meter-kilogram-second unit of electric current that is equivalent to a flow of one coulomb per second or to the steady current produced by one volt applied across a resistance of one ohm. (Merriam-Webster)

BLACK STEEL PIPE- a type of pipe made from carbon steel that is used for a variety of applications, including gas and water distribution, fire sprinkler systems, and transporting oil, grease, and lubricants.

CALIFORNIA ENERGY COMMISSION (CEC)-The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibility are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including aiding to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.

CARBON DIOXIDE (CO_2) - A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO_2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO_2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent). The major source of CO_2 emissions is fossil fuel combustion. CO_2 emissions are also a product of forest clearing, biomass burning, and non-energy production processes such as cement production. Atmospheric concentrations of CO_2 have been increasing at a rate of about 0.5% per year and are now about 30% above preindustrial levels. (EPA)

CARBON INTENSITY (CI)- The carbon intensity is the emission rate of a given pollutant relative to the intensity of a specific activity, or an industrial production process. (Wikipedia)

CLEAN ENERGY – Clean Energy Fuels

COMPRESSED NATURAL GAS (CNG)- Natural gas compressed to less than 1% of its volume at standard atmospheric pressure. To provide adequate driving range, CNG is stored onboard a vehicle in a compressed gaseous state at a pressure of up to 3,600 pounds per square inch. (US DOE)

CPUC – California Public Utilities Commission

FAST-FILL STATION- Fast-fill stations receive fuel from a local utility line at a low pressure and then use a compressor on site to compress the gas to a high pressure. Once compressed, the CNG moves to a series of storage vessels, so the fuel is available for a quick fill-up. (US DOE)

FAULT CURRENT- instantaneously unanticipated electrical surges that may occur on utility distribution and transmission networks (Source: Superconductivity News Update, U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability).

GAS DRYER- a device that removes water vapor from natural gas before it's used or stored for fueling vehicles.

HORSEPOWER (HP)- A unit for measuring the rate of doing work. One horsepower equals about three-fourths of a kilowatt (745.7 watts).

K-RAIL- A concrete barrier used to separate lanes of traffic, protect pedestrians, and reroute traffic.

KILOVOLT (kv)- One-thousand volts (1,000). Distribution lines in residential areas usually are 12 kv (12,000 volts).

KILOWATT-HOUR (kWh)- The most commonly used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumed 534 kWh in an average month.

kVa – kilovolt-amperes

LOW-VOLTAGE- Low voltage is typically defined as a voltage of 120 volts or less.

NACY – North Area Corporation Yard, City of Sacramento.

NITROGEN OXIDES (OXIDES OF NITROGEN, NOX)- The term 'nitrogen oxides' (NOx) is usually used to include two gases-nitric oxide (NO), which is a colorless, odorless gas and nitrogen dioxide (NO2), which is a reddish-brown gas with a pungent odor. Nitric oxide reacts with oxygen or ozone in the air to form nitrogen dioxide. Inhalation of the pure gases is rapidly fatal. Other oxides of nitrogen include NO3 (nitrogen trioxide), N2O (nitrous oxide), N2O4 and N2O5. Nitrous oxide is a potent greenhouse gas and also causes damage to the ozone layer. (European Environment Agency)

PEAK LOAD (DEMAND kW)- The highest electrical demand within a particular period of time. Daily electric peaks on weekdays occur in late afternoon and early evening. Annual peaks occur on hot summer days.

PG&E – Pacific Gas & Electric Co.

PM2.5- (PARTICULATE MATTER) fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller. This fraction of particulate matter penetrates most deeply into the lungs. (US EPA)

PM10 (PARTICULATE MATTER) - inhalable particles, with diameters that are generally 10 micrometers and smaller. (US EPA)

POLYETHYLENE- a synthetic resin and the most commonly used plastic in the world.

POUNDS PER SQUARE INCH GUAGE (PSIG)- The pressure relative to atmosphere.

PPP – Public Purpose Program

RENEWABLE ENERGY- Renewable energy comes from unlimited, naturally replenished resources, such as the sun, tides, and wind. Renewable energy can be used for electricity generation, space and water heating and cooling, and transportation. (US DOE)

RFP – Request for Proposal

SACY – South Area Corporation Yard, City of Sacramento

SMUD – Sacramento Metropolitan Utility District

STANDARD CUBIC FEET PER MINUTE (SCFM)- the molar flow rate of a gas corrected to standardized conditions of temperature and pressure thus representing a fixed number of moles of gas regardless of composition and actual flow conditions.

TIME-FILL STATION- Time-fill stations use a fuel line from a utility that delivers natural gas at a low pressure to a compressor on site. Unlike fast-fill stations, vehicles at time-fill stations are generally filled directly from the compressor, not from fuel stored in high pressure vessels. (US DOE)

TRANSFORMER- A device, which through electromagnetic induction but without the use of moving parts, transforms alternating or intermittent electric energy in one circuit into energy of similar type in another circuit, commonly with altered values of voltage and current.

APPENDIX A:
Utility Billing Data

Figure A-1: Monthly Gas Consumption Data Charts

Source: *City of Sacramento*

ENERGYCAP HOSTED Utility Account Management

	Natural Gas	
	Use THERM	**Cost**
12-2023	39,275.4	$64,260
01-2024	54,598.1	$91,596
02-2024	47,225.8	$75,134
03-2024	50,462.4	$69,282
04-2024	50,545.1	$57,998
05-2024	50,941.4	$56,520
Total	**293,048.2**	**$414,791**

Source: *City of Sacramento*

Figure A-2: Monthly Electric Consumption Data Charts

ENERGYCAP HOSTED Utility Account Management

	Electric		
	Use kWh	**Demand kW**	**Cost**
12-2023	39,583.9	230	$6,453
01-2024	39,200.6	229	$6,686
02-2024	35,616.7	228	$6,459
03-2024	38,573.3	227	$7,011
04-2024	38,017.4	227	$6,958
05-2024	43,325.4	227	$8,497
Total	**234,317.3**	**230**	**$42,063**

Source: *City of Sacramento*

APPENDIX B:
Formulas Used in Obtaining Results

Gas Throughput Capacity (BTU) = Therms x 100,000 BTU/Therms

Maximum Flow Capacity$_{CNG}$ (CuFt) = Throughput Capacity (BTU)/HHV$_{CNG}$ (BTU/lb)

Heat Input, $Q = U_{max} \times H_v/(\text{control efficiency} \times 10^6)$
where,

U_{max} = Maximum potential fuel usage of the engine (*gal* fuel*/mo*) or (CuFt/mo)
H_v = Heating value of the fuel (*BTU/lb diesel*) or (*BTU/scf CNG*)[1]

$NOx = Q \times EF_{NOx}$

where,

EF = NOx Emissions Factor (shown in *constants* below) for each fuel involved

$PM_{10} = Q \times EF_{PM10}$

where,

EF = PM_{10} Emissions Factor (shown in *constants* below) for each fuel involved

$PM_{2.5} = PM_{10} \times .85$

Assuming 85% of PM_{10} emissions are $PM_{2.5}$

CARBON INTENSITY VALUES[2]
Diesel: 94.76 gCO_2e/MJ
CNG: 63.64 gCO_2e/MJ

Constants Used in Calculations Above[3]			
Emissions Factors	**Value**	**Units**	**Source**
Diesel Fuel EF(CO_2):	10.21	kg(CO2)/GAL	EPA
CNG Fuel EF(CO_2):	0.05444	kg(CO2)/SCF	EPA
Diesel Fuel EF(Nox):	1.9	lb/MMBtu	EPA
CNG Fuel EF(Nox):	0.10	g/MMBtu	EPA
Diesel Fuel EF_{PM10}	9.2	g/GAL	EPA

[1] U.S. Environmental Protection Agency. "General Conformity Training Modules: Appendix A Sample Emissions Calculations". Last modified December 17, 2024. https://www.epa.gov/general-conformity/general-conformity-training-modules-appendix-sample-emissions-calculations

[2] California Air Resources Board. "Methods to Find the Cost-Effectiveness of Funding Air Quality Projects". Published December 2022. https://ww2.arb.ca.gov/sites/default/files/2023-01/Cost%20Effectiveness%20Tables%202022_final.pdf

[3] U.S. Environmental Protection Agency. "Emission Factors for Greenhouse Gas Inventories". Last modified September 15, 2021. https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf

CNG Fuel EF_{PM10}	0.018	lb/SCF	EPA
Fuel Heating Values (HHV)	Value	Units	
Diesel Fuel Heating Value:	19300	BTU/lb	EPA
CNG Fuel Heating Value:	20160	BTU/lb	EPA

Diesel Emission Control Eff.	80	%
CNG Fuel Energy Density Value:	0.05	lb/scf
CNG Emission Control Eff.	80	%
Diesel Fuel Energy Density Value:	7.5	lb/GAL

Formulas of general nature and widely accepted in the scientific community are not sourced.