CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Beaumont Unified School District Compressed Natural Gas Refueling Station Expansion

Prepared for: California Energy Commission

Prepared by: Beaumont Unified School District

QUALITY EDUCATION
RELATIONSHIPS HOME SCHOOL RIGOR COMMUNITY RELEVANCE
A Shared Commitment

Gavin Newsom, Governor March

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California Energy Commission

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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 solicitation PON-14-608 to expand fueling infrastructure, fueling stations and equipment. 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-15-015 on December 8, 2015.

ABSTRACT

The Beaumont Unified School District Compressed Natural Gas Refueling Station Project installed new infrastructure at an existing and outdated compressed natural gas refueling station located at the school district's transportation and vehicle maintenance facility at 1001 Cougar Way in Beaumont, California (Riverside County). The grant from the California Energy Commission enabled Beaumont Unified School District to renovate the existing compressed natural gas fueling station. The new facility serves the needs of the District as their fleet of student transportation vehicles continues to be converted from diesel fuel to compressed natural gas. The new facility increased compressed natural gas filling capacity to accommodate these needs and included a new equipment pad and enclosure for security and to reduce noise.

Construction was completed in August 2016 through an energy services contract with AECOM Technical Services and engineered by Allsup Corporation. The project provided an upgraded electrical service, new 125 hp compressor, three (3) dual-nozzle time-fill stations as well as new underground piping for the new hoses and fill nozzles. The new refueling station has a design capacity of 1447 gasoline gallon equivalents per 10 hours of production time.

The refueling station serves the Beaumont Unified School District, the local municipal transportation provider, Pass Transit, and a commercial waste hauler, Waste Management.

Keywords: Beaumont Unified School District, compressed natural gas, fueling station, natural gas infrastructure, natural gas bus fleets

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EXECUTIVE SUMMARY

The goal of this project was to provide the Beaumont Unified School District with an upgraded compressed natural gas refueling station to meet the fueling needs of their expanding fleet of natural gas vehicles. At the time the project was initiated, the Beaumont Unified School District fleet had seven (7) compressed natural gas vehicles. Currently there are nine (9) compressed natural gas buses in service with plans to add at least three (3) more. Beaumont Unified School District currently allows several other local fleets, including the City of Beaumont's "Pass Transit" fleet and the local waste hauler, Waste Management, to use the refueling station during limited hours.

With California Energy Commission funding, Beaumont Unified School District was able to move forward immediately with the construction of the expanded compressed natural gas fueling station project. The District signed a contract with AECOM Technical Services, Inc. to be the lead agent for the design, construction and commissioning of the compressed natural gas fueling station. Allsup Corporation provided the engineering. The design process started on July 28, 2015 and construction was completed within one year.

The project objectives were to add time-fill capability for District vehicles and to enhance the reliability of the fast-fill refueling station. In addition, one of the key components of the project was to solve the noise from the old compressor, which had negatively impacted the relationship between the District and the neighboring community. Public complaints to the agency put the future of the refueling station at risk.

The project demolished the existing compressed natural gas refueling facility as it was undersized, unreliable, and too close to a residential neighborhood. The new compressed natural gas refueling equipment was relocated inside an enclosure with a sound damping roof, further away from the residential neighborhood and closer to the Beaumont Unified School District transportation offices, bus parking area and maintenance facility. The added three (3) dual-nozzle time-fill compressed natural gas dispensers made a total of nine (9) at the site for vehicles. New piping connected them to the new 125 hp compressor and the existing three spherical storage vessels with the capacity to store 36,000 cubic feet of fuel. The District also upgraded the existing single fast fill dispenser.

For the six months after the station was commissioned in August of 2016, the throughput dispensed exceeded that amount estimated in the application, equivalent to 24,000 gallons of gasoline per year (21,000 diesel gallon equivalents/year). Compressed natural gas vehicles emit approximately 20 percent to 25 percent less carbon dioxide than gasoline and diesel vehicles.

CHAPTER 1:
Project Purpose and Equipment Purchase

Introduction

The mission statement of the Beaumont Unified School District (District) is to provide high quality educational opportunities for all students in a safe and secure learning environment through a shared commitment among home, school and community. The District has an obligation to transport some of the students and provides sports teams with bussing to athletic contests. Some diesel buses were replaced by compressed natural gas (CNG) fueled buses more than a decade ago to reduce air pollution right where students congregate.

Beaumont is located in the northwestern part of Riverside County in Southern California. The District proudly serves over 9,700 students through our six (6) elementary schools, two (2) middle schools, one (1) comprehensive high school, one (1) alternative high school, one (1) distance learning institute, and one (1) adult education program. Our District has developed a well-earned reputation for providing highly regarded educational and county-leading extracurricular programs in order to meet the demands of our talented students.

Background

The District's original CNG refueling station was commissioned in 2008 through a partnership with the City of Beaumont and a grant from the South Coast Air Quality Management District. At night the time-fill posts refueled the District bus fleet. Electricity to run the compressor was more expensive in the daytime and cheaper in the evenings. Initially the public access facility was capable of keeping up with the demand for CNG fuel in the area with two (2) public fast-fill dispensers. However, as the use of CNG vehicles became more prevalent, it became clear that the refueling station was not designed to meet the increasing needs of the area's CNG fleet users. The compressor began to fail regularly, leaving the District and other regional users without a public access CNG refueling station. To complicate the situation, a residential community located adjacent to the Transportation Yard began to voice concerns over the constant noise from the compressors. The District took measures to alleviate the noise, such as enclosing the compressors, but they proved ineffective. At the end of 2014, it became apparent that the District needed a solution that would not only address the inadequacies of the facility, but also permanently alleviate the noise concerns; otherwise the future of the facility would be in jeopardy.

Existing Facility

From 2008 until 2016 the fast-fill refueling island provided full access to the public, numerous commercial fleet vehicles and public transportation operators. The existing compressed natural gas storage capacity was 36,000 cubic feet operating at 3,600 psi. Natural gas fueled vehicles are often measured compared to gasoline. One gasoline gallon equivalent (GGE) equals 0.88 diesel gallon equivalent (DGE). The average monthly fuel throughput was 4,589 GGE, which was nearly 55,000 GGE annually (48,000 DGE/year) before this project. The CNG time-fill posts refueled the District fleet at night. One of the existing two public CNG fast-fill dispensers was inoperable when this expansion project was initiated.

The existing compressor, a GESI DX 5075 model, was undersized for the District's growing bus fleet plus commercial CNG customers. Vehicles were unable to fuel immediately one after another. Once a vehicle was refueled, it often took more than 30 minutes for the pressure to be reestablished so that fast-fill fuel dispensing resumed. This delayed response for an unpredictable amount of time was perceived as unreliability. A single air compressor affords no redundancy.

Furthermore, the compressor noise had been the source of numerous complaints to the school district. The existing equipment was sitting in the open, allowing noise from the compressor to disturb residents in the adjacent residential neighborhood. If the existing situation was not addressed, the likelihood of the facility remaining open for public use was slim. At minimum, noise complaints from the neighboring residents may have resulted in limiting the hours of operation for the facility, and in the worst case scenario, resulted in the station being shut down indefinitely.

There are no other public CNG facilities within the Beaumont Unified School District's service area. The nearest facility is in the neighboring City of Banning, approximately eight miles away, which is extremely inconvenient when taking into consideration the lead times required to refuel vehicles while remaining consistent with established student transportation schedules.

Existing Buses

The District's buses (Figure 1) have a 55 or 60 GGE fuel capacity. Of the four different kinds of CNG fuel tanks, the District has the Type 1, all metal, tanks on the buses. The steel or aluminum tanks are proven safe and the most inexpensive, but they are also the heaviest of the options. Each tank weighs 350 lbs. or more, which reduces mileage and puts additional strain on the suspension compared to the lightest tanks.

Figure 1: Beaumont Unified School District bus refueling using time-fill post

Photo Credit: Beaumont Unified School District

Goals of the Agreement

The goal of this Agreement was to design, construct and operate a new CNG facility to reliably fuel the CNG bus fleets of the District and the City of Beaumont, to reduce even more air pollution from student transportation sources.

Project Objectives

The project objectives were to add time-fill capabilities; to enhance the reliability of the fast-fill refueling station; to demolish the existing CNG refueling facility as it was undersized, unreliable, and too close to a residential neighborhood; and to relocate compressor equipment closer to the Beaumont Unified School District transportation office.

Technical Scope of Work

The 125 hp compressor, shown in Figure 2, has a design capacity of 1447 GGE per ten hours of production time and uses the existing three sphere storage vessels with the capacity to store 36,000 cubic feet of fuel.

Figure 2: Beaumont Unified School District CNG Refueling Station

Photo Credit: Beaumont Unified School District

The equipment purchased is listed in Table 1.

Table 1: Equipment List

Quantity	Equipment	Specifications
1	CNG Compressor	125HP ANGI Energy Systems Model # NG150
1	Electronic Valve Panel	ANGI XLE Control
3	Time-Fill Posts	Dual hose 20' hose, Agility Fuels style

Beaumont Unified School District

Three new dual-nozzle time-fill dispensers added made a total of nine time-fill CNG dispensers at the site. The existing single fast fill dispenser was upgraded. The initial scope included the following new equipment and facility upgrades:

- One new natural gas compressor with the following features and performance:
    - 304 scfm at 50 psig gas pressure at the compressor inlet and 4,500 psig discharge pressure
    - 125 hp, 480 VAC, 1800 RPM motor
    - ANGI compressor control system
    - Weatherproof, sound attenuated enclosure
    - On-skid starter panel
    - Time-fill panel for 3,600/3,000 psig fueling
- Space and provisions for a second equal size compressor.
- CNG distribution piping and time-fill fueling dispensers for nine (9) buses.
- Stainless steel high pressure tubing for distribution of CNG to the bus fueling locations.
- Time-fill posts designed for a discharge pressure, temperature compensated, of 3,600 psi and mounted for a maximum hose length of 25 feet.
- A concrete masonry unit wall enclosure for the CNG compressors, storage vessels, dryer, electrical equipment, control panels and related fueling station equipment.
- New 480 VAC, 3-phase electrical service for the fueling station suitable for running the new compressor and all other electrical loads necessary for operating the time-fill CNG fueling system.
- All necessary and required controls for the operation of the time-fill fueling system.
- Removal of existing CNG fueling system including the compressor, controls, electrical system, CNG tubing (including tubing and sleeves below grade), fueling stations, natural gas piping.
- Universal card reader capabilities for partner fleet refueling access.

Electrical Service

Southern California Edison (SCE), the utility provider, reviewed and approved the transformer replacement plan and the new load/distribution panel plan originally submitted in December 2015; resubmitted in March 2016; and finally approved in May of 2016.

Originally, the site had a separate meter serving the CNG equipment that was classified as an electric vehicle charging station. However, the District no longer uses the service for that purpose. Therefore, SCE required that the two meters be consolidated into one service connection point. This change in the electrical plans was not part of the original scope and caused significant delays for the project, which will be discussed in greater detail in Chapter 4 of this report.

CHAPTER 2:
Design and Construction

Project Approach:

The objective of this project was to replace, upgrade, and expand the existing CNG fueling station owned by the District. In 2014, the District started to explore options for the replacement and relocation of the CNG compressor and refueling equipment. In April of 2014, the District issued a Request for Qualifications for an energy services contracts to assist the District with various activities related to Proposition 39-California Clean Energy Jobs Act. AECOM Technical Services, Inc. responded and on September 24, 2014 the District Board of Trustees approved an Energy Audit Agreement with AECOM. The resulting work identified numerous Energy Conservation Measures (ECMs), solar photovoltaic opportunities, and an assessment of the needs at the current CNG refueling station. The energy efficiency and renewable energy portion of the project provided utility cost savings to offset the capital cost of those measures over the life of the project.

However, the CNG refueling station upgrade portion does not have direct utility savings to offset its costs; therefore, it was not eligible for the Proposition 39 funding. Other state funding was needed for the CNG station. In June 2015, the District also applied for a $500,000 Clean Transportation Program grant from the California Energy Commission (CEC) towards the construction of the upgraded CNG refueling station. This funding was awarded in August and the grant started December 8, 2015.

In July 2015, the District approved an energy services contract with AECOM Technical Services to complete the work identified in the audit, including the CNG upgrades, which were estimated to cost approximately $1.4 million out of a total project cost of $7,690,000. The contracting process rewarded teams with recent experience implementing CNG refueling infrastructure projects. Their organized business practices and effective project management led to the successful completion of the planned effort.

Station Design Intent

The long-term design intent of this project was to provide time-fill for the District vehicles and to maintain a fast-fill capacity for emergency use. To resolve the noise concerns of the adjacent residential community, a key component of the project was to relocate the existing infrastructure. Additionally, public fueling was discontinued to cut fast-fill demand and reduce compressor use. The engineers planned smaller capacity, which affected sizing and selection of new CNG equipment. In addition, designers provided equipment layouts, site amenities, components, as well as some ancillary services and elements to provide for future facility expansion, if needed. The site was designed to accommodate two compressors for 100 percent redundancy and future expansion. The upgraded refueling station includes:

1. New 125 HP compressor.
2. Three new dual-nozzle time-fill dispensers located at the center island bus parking.
3. New piping to connect the existing one-hose fast-fill dispenser at the center island.

4. Standby power abilities if the need arises, including a lug panel at the power and control panel for connection.
5. Sound attenuation to best mitigate sound as determined by a sound study conducted at the site.
6. Seismic design criteria for station structural design.
7. Relocate existing dryer and storage vessels (spheres pictured in Figure 3).

Figure 3: Relocated Storage Spheres

Photo Credit: Beaumont Unified School District

The District equipment is sized to move fuel into natural gas vehicles using compression and pressurized storage vessels. Storage is an important component of this station which uses a mid-sized compressor. Without storage, if direct-fill is used with a flow rate of 250 scfm (one compressor operating) and the fast-fill line is connected to a refuse truck having a 50 GGE fill requirement, the time-fill alone would be about 25 minutes not including the time to connect, authorize, disconnect, and drive away. The use of compressed gas storage tanks is a time saver by allowing up to 8 GGE per minute to flow through the hose during the fill using an NGV-1 nozzle and even higher if a transit nozzle is used. Storage also serves as a buffer to the compressor, allowing it to run for longer continuous periods of time rather than a series of short runs with several starts and stops.

Compressor and storage sizing were calculated based on both components working together. Each storage vessel holds 12,000 standard cubic feet at 5,000 psig. With the vessels operating in a three-bank cascaded configuration, the efficiency is 35 percent. Therefore, three vessels provide 25,200 scf (equivalent to roughly 200 GGE). With all the District's buses on time-fill, the low fast-fill demand from other fleets can be met with a single 125 hp compressor and no additional storage beyond the existing three spheres.

The size of the compressor was determined based on a demand over a 1-hour fueling window less the storage. We divided the remaining amount of fuel by 60 minutes/hour to arrive at the compressor throughput in standard cubic feet per minute (scfm).

High pressure stainless steel tubing conveys natural gas from the compressor to storage, fast-fill, and time-fill dispensers. All the tubing was replaced, because the compressor and storage tanks were moved. Almost as important as the compressor capability, the CNG distribution piping enables the fueling speed. The tubing was sized for a possible future operating condition with two fast-fill hoses operating simultaneously, when the pressure drop within the tubing shall not be in excess of 300 psi from storage to the connection point of the farthest dispenser. The project continues a 1-inch priority valve panel from which the fast-fill dispenser and time-fill dispensers connect using ¾" 316 stainless steel tubing using three dedicated lines for fast-fill and one dedicated for time-fill. This makes sure valves do not become a bottleneck. A vehicle fill to 30 GGE should take five to seven minutes.

Changes to Facility Access

The upgraded fast-fill facility is no longer a public access refueling station. Instead, the new CNG refueling station is now a limited access facility, with only specific fleets having access to the fast-fill refueling. This decision was made for numerous reasons; mostly to alleviate the noise issues associated with a public fueling facility. Due to the close proximity of the station to residential neighborhoods, it was in the community's best interest to restrict the access hours and number of vehicles using the facility.

CNG Infrastructure Built

The electrical upgrades and the concrete pad installation were completed in July 2016. The photograph in Figure 4 shows the newly installed transformer at the Transportation and Vehicle Maintenance Yard. The electrical system was upgraded to back feed the existing 400-amp, 240/120 volt, 3-phase service from the new 600-amp 480/277-volt service.

Figure 4: Electrical Upgrades for CNG Station

Photo Credit: Beaumont Unified School District

The station will not operate without electricity. Provisions to accommodate standby power are now in place; however, a standby power generator was not included in the scope of work.

The construction at the school district's transportation and vehicle maintenance facility at 1001 Cougar Way, Beaumont, California was completed in August of 2016. Three new dual-nozzle time-fill dispensers added made a total of nine time-fill CNG dispensers at the site. The existing one-hose fast-fill dispenser continued at the center island with universal card reader capabilities for partner fleet refueling access. Underground high pressure piping was replaced or moved. Sound mitigation was achieved by locating the new compressor behind block walls and installing a weather-resistant sound attenuation enclosure over the compressor. The existing three spherical storage vessels and natural gas dryer were placed in the spacious new enclosure with the new 125 hp compressor. The equipment enclosure was relocated away from the adjacent residential housing tract and closer to the maintenance shed and bus parking area. The ailing old compressor was removed, as shown in Figure 5.

Figure 5: Demolition of Original CNG Refueling Station

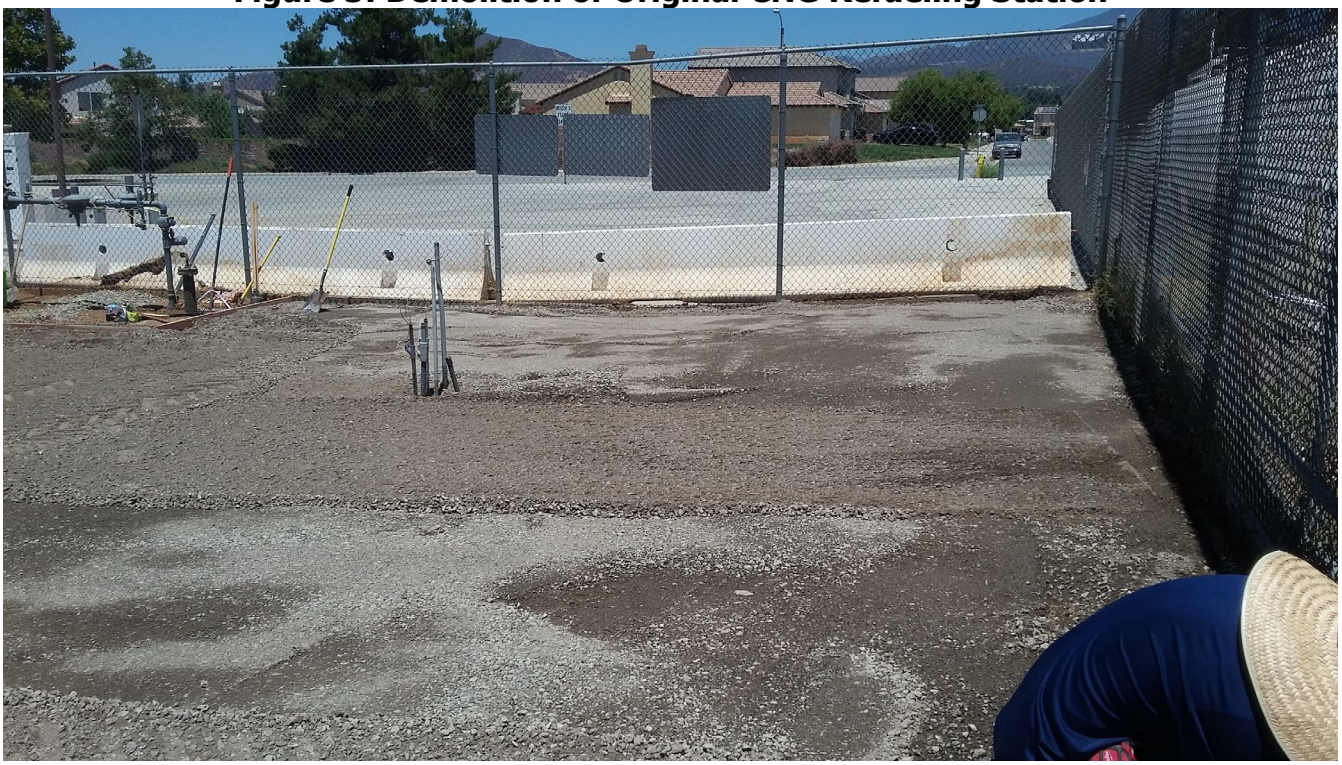

Photo Credit: Beaumont Unified School District

CHAPTER 3:
Project Operations

Project Run Conditions

Since the District does not currently have a computerized fuel management system, utility bills received from Southern California Gas Company dedicated to the CNG refueling station provided the natural gas volume consumed. Station service hours and compressor run time were reduced from 24 hours a day before this upgrade to 18 and then down to 16 hours a day both to prevent the industrial sound and to reduce the electric bill (Table 2).

Table 2: Monthly Fueling Time and Volume

Variable	Aug 2016	Sep 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Total
Natural Gas (Therms)	2,292	2,835	2,789	2,565	2,288	2,633	15,402
Compressor (Hours/Day)	18	18	19	16	14	16	-
Station Open (Days/Month)	18	21	20	18	15	16	-

Source: Beaumont Unified School District

The District recorded the District's CNG fleet miles traveled per the terms of the grant agreement. Tables 3 through 8 show the odometer readings from each month.

Table 3: Vehicle Miles Traveled August 2016, Schools in Session 18 Days

Bus #	Mileage Beginning	Mileage End	Mileage August
241	204,031	205,589	1,558
245	118,466	118,529	63
246	198,350	199,687	1,337
247	45,722	46,665	949
248	45,351	46,191	840
249	50,070	51,958	1,888
250	94,696	94,798	102
251	0	0	0
252	0	0	0
253	0	0	0
Total	**-**	**-**	**6,731**

Source: Beaumont Unified School District

Table 4: Vehicle Miles Traveled September 2016, Schools in Session 21 Days

Bus #	Mileage Beginning	Mileage End	Mileage
241	205,589	206,959	1,370
245	118,529	119,364	835
246	199,687	201,646	1,959
247	46,665	47,705	1,040
248	46,191	47,262	1,071
249	51,958	54,148	2,190
250	94,798	95,411	613
251	0	714	714
252	0	0	0
253	0	0	0
Total	**-**	**-**	**9,792**

Source: Beaumont Unified School District

Table 5: Vehicle Miles Traveled October 2016, Schools in Session 19 Days

Bus #	Mileage Beginning	Mileage End	Mileage
241	206,959	208,541	1,582
245	119,364	120,710	1,346
246	201,646	202,860	1,214
247	47,705	48,665	960
248	47,262	48,362	1,100
249	54,148	55,975	1,827
250	95,411	96,546	1,135
251	714	904	190
252	0	73	73
253	0	0	0
Total	**-**	**-**	**9,427**

Source: Beaumont Unified School District

Table 6: Vehicle Miles Traveled November 2016, Schools in Session 16 Days

Bus #	Mileage Beginning	Mileage End	Mileage
241	208,541	210,227	1,686
245	120,710	121,656	946
246	202,860	203,318	458
247	48,665	49,449	784
248	48,362	49,238	876
249	55,975	57,421	1,446
250	96,546	97,151	605
251	904	2,284	1,380
252	73	93	20
253	0	128	128
Total	**-**	**-**	**8,329**

Source: Beaumont Unified School District

Table 7: Vehicle Miles Traveled December 2016, Schools in Session 15 Days

Bus #	Mileage Beginning	Mileage End	Mileage
241	210,227	211,731	1,504
245	121,656	122,296	640
246	203,318	203,469	151
247	49,449	50,043	594
248	49,238	50,055	817
249	57,421	58,793	1,372
250	97,151	97,947	796
251	2,284	3,603	1,319
252	93	228	135
253	128	128	0
Total	**-**	**-**	**7,328**

Source: Beaumont Unified School District

Table 8: Vehicle Miles Traveled January 2017, Schools in Session 16 Days

Bus Number	Mileage Beginning	Mileage End	Miles
241	211,731	213,133	1,402
245	122,296	122,493	197
246	203,469	204,211	742
247	50,043	50,784	741
248	50,055	50,820	765
249	58,793	60,363	1,570
250	97,947	98,265	318
251	3,603	5,000	1,397
252	228	621	393
253	128	128	0
Total	**-**	**-**	**7,525**

Source: Beaumont Unified School District

Together, all ten CNG buses traveled 49,132 miles in the six months August 2016 through January 2017.

The District acquired three buses and put them into service over the data-collection period. The expansion of the CNG fleet during ARV-15-015 resulted in the reduction of the District's diesel fuel consumption by about 1,150 gallons. When public fueling was discontinued to reduce noise at a certain date, several non-district fleets slowly, irregularly, reduced station fueling visits (Table 9). The mileage of those vehicles was not captured. Not every CNG therm was used for school bus fuel, thus, insufficient data was collected to determine fuel efficiency of the District's CNG buses.

Table 9: Fuel Use Averages

Variable	16-Aug	16-Sep	16-Oct	16-Nov	16-Dec	17-Jan
Average Number of Non-District Vehicles Fueled	1	2	0	2	0	0
Average Number of District Buses Fueled	7	7	8	9	9	9
Avg. Miles Traveled per Bus by Odometer Reading	963	1,295	919	919	814	835

Source: Beaumont Unified School District

CHAPTER 4:
Results

Conversion Factors Natural Gas Dispensed

The natural gas volume on Beaumont Unified School District CNG station monthly utility bills from August 2016 through January 2017 was converted from therms to millions of British thermal units (MMBtu), and standard cubic feet (SCF) in Table 10. The relationships are:

- 1 MMBtu = 1,000,000 Btu = ten therms
- one therm = 100,000 Btu
- One standard cubic foot (SCF) = 1,037 Btu[1]

Table 10: Fuel Volume in Various Units

Variable	16-Aug	16-Sep	16-Oct	16-Nov	16-Dec	17-Jan	Total
NG Utility Bills (Therms)	2,292	2,835	2,789	2,565	2,288	2,633	15,402
NG (MMBtu)	229.2	283.5	278.9	256.5	228.8	263.3	1,540.2
CNG Dispensed (SCF)	221,022	273,385	268,949	247,348	220,636	253,905	1,485,246

Source: Beaumont Unified School District

CNG sold at filling stations is priced in dollars per gasoline gallon equivalent, not therms, scf or Btu. Unsurprisingly, one GGE corresponds to the amount of natural gas with the same energy content as one gallon of gasoline. The grant contract specifically asks for "gallons of gasoline and/or diesel fuel displaced". There are several methods to estimate the volume.

Fuel Displaced

Fuel Volume Estimate Method 1

Assume the old diesel buses that have been replaced by CNG buses got five miles per gallon. Divide the 49,132 miles traveled by five to estimate the 9,826 gallons diesel old buses would have burned, the Fuel Volume Estimate Method 1 in Table 11. The miles have five digit accuracy, but the fuel efficiency is just a rule of thumb for old diesel engines. Rounding 9,826 to 1-digit accuracy, the CNG displaced approximately 10,000 gallons of diesel in half a year.

Natural gas fuel is legally dispensed in gasoline gallon equivalents. When comparing the energy, the very rough estimate for the half year is 1.142 x 9,826 DGE = 11,222 GGE used by school buses. Rounding, the CNG displaced approximately 11,000 gallons of gasoline in half a year.

[1] eia.gov Units and calculators explained (https://www.eia.gov/energyexplained/units-and-calculators/)

Table 11: Fuel Volume Estimate Method 1

Bus Number	Total Vehicle Miles Traveled	Estimated Diesel Fuel Displaced (Gallons) by CNG in half a year	Rough CNG volume (Gasoline Gallon Equivalent)
241	9,102	1820.4	2079
245	4,027	805.4	920
246	5,861	1172.2	1339
247	5,062	1012.4	1156
248	5,469	1093.8	1249
249	10,293	2058.6	2351
250	3,569	713.8	815
251	5,000	1000.0	1142
252	621	124.2	142
253	128	25.6	29
TOTAL	**49,132**	**9,826**	**11,222**

Source: Beaumont Unified School District

Fuel Volume Estimate Method 2 Convert Therms to GGE

Fuel Volume Estimate Method 2 uses the typical conversion rate of 1.25 therms per GGE[2] offered by the Love's truck stop fueling chain owner Trillium. Note that this could be called 125,000 Btu/gallon of gasoline. The 15,402 therms divided by 1.25 converts to 12,300 GGE per half year with 3 significant figures.

Fuel Volume Estimate Method 3 Convert Btu to GGE

We could also convert the energy of CNG[3] dispensed with these conversion factors:

- 1 MMBtu = 6.81 DGEs
- 1 MMBtu of Gasoline = 7.74 GGEs

The 1,540.2 MMBtu is about 10,500 DGE and about 11,900 GGE.

Fuel Volume Estimate Method 4 Convert SCF to GGE

The Alternative Fuels Data Center of the U.S. Dept of Energy recommends using a nationwide average energy measure between low and high heating value of CNG, 123.57 SCF/GGE.[4]

1,485,246 SCF/(123.57 SCF/GGE) = 12,019.5 GGE

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[2] Learn About CNG (https://www.trilliumcng.com/en/learn-about-cng/commonly-used-terms)

[3] CNG Units. (http://www.nat-g.com/why-cng/cng-units-explained)

[4] Gasoline and Diesel Gallon Equivalency Methodology. U.S. Dept of Energy Alternative Fuels Data Center. (https://afdc.energy.gov/fuels/equivalency_methodology.html)

This is 12,000 GGE per half year with 3 significant figures.

Analysis of Fuel Volume

The energy content of liquid fuels like gasoline and diesel actually varies considerably between summer and winter and also depending on what sort of oxygenate is blended in.[5] The energy content of natural gas varies depending on source, too. Since the converted values vary as shown in Table 12, but have similar answers, none is disqualified. Method 1 has the least significant figures. Because Methods 2 and 3 are conversion factors from commercial entities, while Method 4 is from the authoritative U.S. DOE, the authors chose Method 4. The total throughput for the first six months was 12,000 GGE (10,500 DGE).

Table 12: Comparison Calculation Methods Fuel Displaced in Half a Year

Variable	Method 1	Method 2	Method 3	Method 4
Diesel Displaced (DGE)	10,000	-	10,500	-
Gasoline Equivalent Dispensed (GGE)	11,000	12,300	11,900	12,000

Source: Beaumont Unified School District

We cannot conclude that 49,000 miles per 12,000 GGE is a 4 miles per gallon fuel efficiency, because 54 vehicles used the fuel while only 49 were buses that drove those miles. Yet all those vehicles improved the air quality.

Proposed Compared with Actual Project Performance

The new system supported the CNG buses and other vehicles with an estimated 24,000 GGE/year through time-fill and fast-fill dispensers together. In the grant application the district estimated 20,571 GGE annual throughput for the newly upgraded CNG facility. Proposed project performance was comparable but less than the actual project performance.

Carbon Intensity Conversion Factors

Since CO_2 is the dominant greenhouse gas, other greenhouse gases have been assigned a CO_2 equivalent (CO_{2e}) unit. CNG engines emits 7.2 pounds CO_{2e} less than ultra-low sulfur diesel for every gallon burned.[6] Old diesel buses have been replaced by CNG buses. The emissions of the two engine types are calculated in Table 13. The difference in the right column is the benefit of the CNG fuel reduced emissions.

[5] CNG Units. (http://www.nat-g.com/why-cng/cng-units-explained)

[6] Your Fleets Fuel Use. (https://www.gtsummitexpo.socialenterprises.net/assets/docs/past-events/GTSE-tacoma-2016/april-5/gtse-tacoma-2016-GTSE-Session-1B-Rick-Wallace-ODOE-Calculating-Your-GHG-Emissions-April-5th.pdf)

Table 13: GHG Reduction Benefit of the CNG Fuel

Variable	Ultra-Low Sulfur Diesel	Natural Gas	Difference in GHG Emissions for half a year
Given Fuel Consumed by Fleet (MMBtu)	1,540.2	1,540.2	-
Convert Units Fuel Consumed [947.8 Btu = 1MJ] (MJ[7])	1,625,008	1,625,008	-
Look Up Carbon Intensity (g CO_{2e}/MJ[8])	100.45	79.21	-
Produced GHG (g CO_{2e})	163,232,054	128,716,884	-
GHG (MT CO_{2e})	163.2	128.7	34.5
Convert Units [2,204.6 lbs /MT] x [1 ton/2,000 lbs] (T CO_{2e})	179.9	141.9	38.1

Source: CEC Editing Staff

GHG Emissions Avoided (76 Tons CO_{2e}/y)

About 76 tons CO_{2e} were reduced per year.

Environmental Benefits of Natural Gas

Both natural gas and diesel are fossil fuels. According to the Natural Gas Vehicles of America,[9] quoting the well-respected CA GREET 2.0 model, the environmental benefits of natural gas are:

- Combusting natural gas produces 27 percent fewer CO_2 emissions than diesel fuel on energy equivalent basis.

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[7] Energy Conversion Calculators (https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php)

[8] CARB Fuel Pathway Table (https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities) accessed 12/18/2020. class = Lookup Table

[9] Environmental Benefits of Natural Gas (https://www.ngvamerica.org/wp-content/uploads/2018/03/NGVAmerica-White-Paper-Fleets-Run-Cleaner-on-Natural-Gas_V2.pdf) page 4

- CNG in heavy duty vehicles has 13 to 17 percent fewer greenhouse gas emissions compared to diesel on a well-to-wheel basis.

Air Pollutants

Fine particulate matter less than or equal to 2.5 microns in diameter (PM2.5) is mostly derived from combustion, vehicle exhaust as well as stationary combustion sources. The particles are either directly emitted or are formed in the atmosphere from the combustion gases, such as NOx and SOx combining with ammonia.[10]

If the diesel fuel was eliminated and not replaced with CNG, the pollutants in Table 14 would be reduced.

Table 14: Emission Pollutant Reduction

Diesel Decrease (Gallons)	Carbon Dioxide (lbs.)	PM 2.5 (oz.)	NOx (oz.)	SOx (oz.)
	multiplier 22.38	multiplier 0.0007	multiplier 0.1468	multiplier 0.0004
10,500	234,990	7.35	1541.4	4.2

Source: Diesel Emissions Quantifier (https://cfpub.epa.gov/quantifier/index.cfm?action=main.home)

Testing of commercial buses showed a 97 percent PM reduction and a 58 percent reduction in oxides of nitrogen (NOx) with buses running on CNG rather than diesel.[11] CNG is a clean-burning fuel that performs well against current vehicle emissions standards.

This project occurred in a disadvantaged community with a CalEnviroScreen 3.0 rating between 80-85 percent. The poverty rate and incidence of cardiovascular disease are high. Eighteen percent of the population is children under 10. The ground level ozone that produces smog is particularly high.

Cost Benefit Analysis

The grant was crucial to renovating this alternative fueling facility in Riverside County. All the grant funds were spent on equipment. No match funds were required by the contract. The legislation behind the grant funds considers the cost-benefit analysis, grant dollar per GHG reduced, an important component to measuring the success of the project. The old station only served for 8 years. Let's say the benefits of this station are steady for 8 years.

69 Metric tons CO_{2e}/year x 8 years = 552 MT CO_{2e} over life of project

$500,000/552 MT CO_{2e} over life of project = $906/ MT CO_{2e}

The cost-benefit is $906/ MT CO_{2e}.

[10] AQMD.gov. 2006. (final-methodology-to-calculate-pm2-5-and-pm2-5-significance-thresholds.pdf)

[11] Natural Gas Buses: Separating Myth from Fact (https://www.nrel.gov/docs/fy00osti/28377.pdf)

CHAPTER 5:
Lessons Learned

The three key lessons learned drawn from the project are: 1) coordinate with all public utilities early; 2) select the location of the CNG facilities carefully; and 3) identify a clear plan for facility use before finalizing contract.

The first lesson learned throughout the course of this project was the importance of coordinating with all public and private utilities. Two incidents negatively affected the timeline. The first incident was a result of inaccuracies in mapping of underground utilities, which led to the accidental severance of a fiber optic line running beneath the project site. The repair was scheduled relatively quickly and the overall impact on the project was negligible, but the inconvenience could have been avoided. Research the underground utility lines in the dig site in advance. Coordination with all public utilities is key to completing CNG projects on time and on budget.

The second incident was much more significant and caused a far more detrimental impact on the project schedule and budget. Before construction began, in October 2015, the project construction and engineering team met at the site with a representative from SCE to identify the requirements for the electrical service upgrade for the new compressor. Then, in February 2016, SCE provided a draft "work order drawing" showing the interconnection between the upgraded electrical equipment that was part of the CNG upgrade and the utility's service equipment. Roughly a month after the drawing was received, SCE notified the project contractors that the site would be required to consolidate the two existing meters on the property into one service connection. This was not shown on the work order drawing, nor was it discussed during the site walk. SCE did not allow for any exceptions to the service meter consolidation unless the District proposed an alternative that did not require an electrical service upgrade. This information was not available at the beginning of the project and did not arrive for 4 months. The utility decision resulted in a redesign of the electrical upgrade, significant time delays, and additional project costs. The key lesson from this experience was to work closely with the utility providers from the very beginning of the design phase of the project, wait for their perspective before detailed design, and to verify whether any obscure utility rules would apply to the proposed scope of work.

The second lesson learned pertains directly to the location of the CNG refueling facility. For this project, the location of the compression equipment was of particular concern. The original location of the CNG refueling station was immediately adjacent to a residential community. While initially this did not cause a significant concern, as the use of the facility increased and the equipment began to fail, there were numerous complaints about the compressor run times and the emergency warning signals going off when the equipment failures occurred. The situation became so contentious that the neighboring residents were at the point of litigating against the existence of the facility.

The District took many interim steps to address the concerns of the nearby residents while the ultimate solution of relocating the compression equipment was being vetted. This included the rental of a temporary compressor to alleviate the stress on the overused compressor and reduce the number of times that the compression equipment had to reset. The District also

covered the compressor with a metal roof to try and mitigate some of the noise. Unfortunately, neither of these solutions provided any real relief for the concerned residents. Ultimately, the District recognized that the only way to continue to operate the CNG refueling station at the Transportation and Vehicle Maintenance Yard, which is an ideal location for the District, was to relocate the equipment as far away from the residential neighborhood as possible and to invest in noise attenuating features.

Without the funding provided by the California Energy Commission, the District would likely have had to shut down the facility permanently in order to avoid litigation. This would have reduced the availability of alternative fueling facilities in a region of Riverside County that is already lacking in this crucial infrastructure.

The lesson learned from this experience was to identify all stakeholders who may be affected by a new refueling facility in order to mitigate any potential concerns as soon as possible. This includes commercial, residential, agricultural, and industrial neighbors, which will likely all have different concerns about the placement of CNG refueling equipment in their vicinity.

During this project, the strategy for the use of the facility changed throughout the process. Initially, the facility was going to be upgraded to allow for public use, which was no different than the access offered at the original refueling facility. However, midway through the project, it was decided that the District would restrict use to only District vehicles. This change was reported to the Energy Commission, approved by our Commission Agreement Manager, and documented in the April 2016 Monthly Progress Report. The access change is being phased in gradually. During the first six months of operations, the newly upgraded facility was shared in a limited way with non-District vehicles, mainly the local public transportation provider's fleet and limited other fleets. This is likely a temporary situation as the City of Beaumont, the public agency which operates Pass Transit, is in the process of constructing their own CNG refueling facility. The third lesson learned from this project is the difficulty in planning and committing to a strategy for the future use of a CNG refueling facility. Existing fuel customers depend on the station. The revenues from outside fleets are helpful. Reducing noise can be time dependent. Perhaps the relative weight of each benefit could be voiced by stakeholders in a survey.

Understanding the ultimate facility use is key to sizing the equipment appropriately. When the District initially began the project, the goal was to use the new compressor as the primary piece of equipment, with the old compressor as backup for peak need. However, once the District made the decision to restrict access, the additional equipment (storage vessels) and the relocation of the old compressor became unnecessary. Ultimately, this decision did not cause any issues with the budget or timeline for completing the project, but the lesson learned was to identify a clear strategy and plan for facility use in order to avoid these types of mid-project adjustments which could potentially impact a project's success.

CHAPTER 6: Conclusions

The Beaumont Unified School district is taking steps to reduce the bus fleet impact. Transportation-related pollution is the state's number one source of harmful diesel particulates, smog-forming nitrogen oxides, and GHG emissions. Medium- and heavy-duty vehicles such as school buses and garbage trucks are the largest source of diesel particulate matter, the leading contributing factor to cancer caused by air pollution. Furthermore, residents living in low-income and disadvantaged communities are exposed to higher levels of transportation-related toxic diesel particulate matter.

Natural gas has great advantages as an alternative fuel, including its domestic availability, an established distribution network, relatively low cost, and emissions benefits.[12] The school system gains energy security by using a familiar utility product, natural gas, in a privately-controlled CNG fueling station.

Time-fill stations are well suited to school buses because they are parked overnight in a fleet parking lot owned by the District. While it is technically possible to accurately measure CNG fuel dispensed to each vehicle, it is generally cost prohibitive and complicated. The utility bills tell 15,402 therms of fuel was dispensed in six months. The ten buses drove 49,132 miles per odometer readings in that half year. The fuel volume was about 24,000 GGE/year (21,000 DGE/y).

Designing a CNG station for a fleet requires calculating the right combination of pressure and storage needed for the types of vehicles being fueled. The initial design for two compressors was based on continued public fueling of the usual flow of customers along with the school buses. Yet public pressure to reduce the noise was so powerful that the District made hard decisions to reduce the hours of operation and flow of traffic. The design was revised, with redundancy of equipment sacrificed. A concrete block enclosure with sound attenuation over the compressor dampened the sound. The new CNG refueling station equipment was relocated further away from the residential neighborhood. A smaller station with one new compressor now serves the limited access facility for a few small fleets.

Labor costs previously spent for refueling the buses elsewhere decreased. The CNG fueling facility expansion supported temporary construction jobs and provided business for local material suppliers.

Project Success

The major success was that the adjacent residential community voiced no additional complaints since the refueling station was relocated and the sound attenuation measures were added. In addition, the newly upgraded equipment provides much needed reliability and emergency fueling access while also allowing the District to continue to expand their fleet of CNG vehicles. The District purchased an additional three CNG vehicles during the project. The

[12] Natural Gas Benefits (https://afdc.energy.gov/fuels/natural_gas_benefits.html)

fast-fill option has been useful when there are off-hours student transportation needs, such as sporting events or field trips.

Labor costs previously needed for refueling the buses at another station decreased. Using the new system, all ten of the District's buses are refueled slowly as in Figure 5, unattended, with just 20-30 minutes hook-up labor. This has resulted in a significant savings in labor costs for the District compared to driving to another site and waiting for a fill.

The completed CNG refueling station achieved these goals:

1. Reduced the CNG equipment noise.
2. Improved equipment reliability.
3. Expanded time-fill capacity for additional District fleet CNG buses.

Future Plans

A second compressor is advisable for redundancy when funds are available.

A standby power generator would add to emergency readiness.

The tubing and valves actually installed were sized for two fast-fill hoses operating simultaneously, a possible future expansion. If the demand for fast-fill increases significantly, additional storage and a second fast-fill hose with a high flow transit nozzle is advisable. If added, two vehicles requiring 30 GGE should be able to complete fueling in five to seven minutes.

GLOSSARY

BEAUMONT UNIFIED SCHOOL DISTRICT (DISTRICT) - There are fourteen active K – 12 schools in the Beaumont Unified School District serving the city of Beaumont and the unincorporated area of Cherry Valley, located in the Northwest part of Riverside County in California.[13]

BRITISH THERMAL UNIT (Btu)—The standard measure of heat energy. It takes one Btu to raise the temperature of one pound of water by one degree Fahrenheit at sea level. MMBtu stands for one million Btu.

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 responsibilities 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 providing assistance to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.

COMPRESSED NATURAL GAS (CNG)—Natural gas that has been compressed under high pressure, typically between 2,000 and 3,600 pounds per square inch, held in a container. The gas expands when released for use as a fuel.

DIESEL GALLON EQUIVALENT (DGE)—The amount of alternative fuel it takes to equal the energy content of one liquid gallon of diesel fuel.

GASOLINE GALLON EQUIVALENT (GGE)—The amount of alternative fuel it takes to equal the energy content of one liquid gallon of gasoline. GGE allows consumers to compare the energy content of competing fuels against a commonly known fuel—gasoline. GGE also compares gasoline to fuels sold as a gas (natural gas, propane, and hydrogen) and electricity.

GREENHOUSE GAS (GHG)—Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_x), halogenated fluorocarbons (HCFCs), ozone (O_3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

MEGAJOULE (MJ)—A joule is a unit of work or energy equal to the amount of work done when the point of application of force of one newton is displaced one meter in the direction of the force. It takes 1,055 joules to equal a British thermal unit. It takes about one million joules to make a pot of coffee. A megajoule itself totals one million joules.

POUNDS PER SQUARE INCH GAUGE (PSIG)—The pressure relative to atmosphere.

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[13] Beaumont Unified School District (https://en.wikipedia.org/wiki/Beaumont_Unified_School_District)

SOUTHERN CALIFORNIA EDISON (SCE)—One of the nation's largest electric utilities, which delivers power to 15 million people in 50,000 square miles across central, coastal, and Southern California, excluding the City of Los Angeles and some other cities.

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.

STANDARD CUBIC FOOT (SCF)—One cubic foot of gas at standard temperature and pressure (60˚F [15.6˚C] at sea level). Since both temperature and air pressure affect the energy content of a cubic foot of natural gas, the SCF is a way of standardizing. One SCF = 1,020 Btu.

THERM—A non-SI unit of heat energy equal to 99976 Btu (almost 100,000 Btu or 0.10 MMBtu).