



**CALIFORNIA
ENERGY COMMISSION**



California Energy Commission
Clean Transportation Program

FINAL PROJECT REPORT

Compressed Natural Gas Fueling System for a Bus Maintenance Facility

Prepared for: California Energy Commission

Prepared by: Sacramento Regional Transit District

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission 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 Energy Commission allocate up to \$20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

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

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

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the Energy Commission's annual Clean Transportation Program Investment Plan Update. The Energy Commission issued PON-09-006 to store, distribute, and dispense electricity, E-85, Biomass-based diesel, and natural gas. In response to PON-09-006, the recipient submitted an application which was proposed for funding in the Energy Commission's notice of proposed awards May 17, 2010, and the agreement was executed as ARV-09-018 on November 18, 2010.

ABSTRACT

The installation of the compressed natural gas fueling equipment consists of providing and installing compressed natural gas fueling compressors and dispensers at the site. The Equipment will provide Sacramento Regional Transit District with redundant fueling capacity for 250 buses. Work includes furnishing and installing three 1,500 standard-cubic-feet-per-minute compressed natural gas compressor skids, gas dryer, buffer storage, dispensers, and control systems to manage operations and maintenance of system. Also required is coordination and installation of electrical service with Sacramento Municipal Utility and gas service with Pacific Gas & Electric Company equipment and site design, site clearing, pavement removal, earthwork, trenching, modification of onsite utilities, pavement restoration, site design, concrete equipment pads, fencing and lighting. Also included will be a public fueling island for use by other government agencies under cooperative agreements.

Keywords: California Energy Commission, CNG fueling station, Compressed Natural Gas, PG&E, Sacramento Regional Transit District, Twin Rivers Unified School District

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EXECUTIVE SUMMARY

The Sacramento Regional Transit District is a public agency that provides public transit services to the City of Sacramento and the surrounding communities. Since its inception in 1973, the Sacramento Regional Transit District has seen remarkable growth in demand for its services, and as such has caused the current maintenance, operations, and administration facility to become overcrowded with its current 256 bus fleet. The Sacramento Regional Transit District determined additional facilities to be required to accommodate its projected growth to a 500 bus regional fleet size by 2020. To house this new facility, the Sacramento Regional Transit District has bought 14.05 acres located in unincorporated Sacramento County at 3701 Dudley Boulevard in the southwest corner of the former McClellan Air Force Base, with the possibility of acquiring an adjacent 0.705 acre parcel in the northeast corner of the property.

The site selection process was accomplished. The area near the former McClellan Air Force Base was the focus of the search due to its strategic position within the community. Because many routes in the district are located north and east of this site, it is ideal for a second bus maintenance facility. The district considered other sites, such as a 31 acre site on Main Avenue, just outside the former McClellan Air Force Base. However, this site required more construction to accommodate the projected 250 bus portion of the Sacramento Regional Transit District fleet. The chosen site had substantial cost savings as many of the needed facilities already existed. The site has a large building (180,000 square feet) which contained warehousing space for maintenance and shops, and sufficient office space for administration and operative purposes.

The final master plan/concept design phase ended June, 2008, and the project team selected a final site master plan and maintenance building. This site master plan allowed the development of the site to include a compressed natural gas fueling station and equipment, and a transit bus wash facility. Sufficient parking for the fleet of 250 buses was planned.

CHAPTER 1:

Compressed Natural Gas Fueling Station

Project Purpose

In 2009, The Sacramento Regional Transit District (SacRT) was approached by Twin Rivers Unified School District (TRUSD) to form a partnership for use of a compressed natural gas (CNG) fueling station. SacRT had been planning a fueling station at their new facility at 3701 Dudley Boulevard, McClellan, CA. These discussions led to an agreement to provide fueling capability to TRUSD's fleet of natural gas school buses. In January of 2010, SacRT applied for a grant from the California Energy Commission for funding for the purchase and Installation of CNG fueling equipment. The application was subsequently approved and system procurement was initiated for the purchase and installation of a CNG fueling station.

Description of Work Accomplished

Contractor designed, built, and tested CNG fueling station for SacRT at McClellan Park, California pursuant to contract plans and specifications. All equipment, components, material, labor, transportation, documentation and warranties required to make CNG system fully functional and to comply with plans and specifications were provided. Work included, but was not limited to:

- Verifying operating requirements, natural gas quality and moisture content, and other environmental characteristics to ensure proper equipment sizing and providing recommendations for alternately sized or configured equipment.
- Developing equipment and site layout plans.
- Accomplishing utility coordination and interconnections.
- Applying for and receiving all permits. The project team met all inspection requirements, and approvals necessary for code compliance and safety.
- Acquiring or creating equipment for complete CNG facility, including:
 - Three 1,500 standard cubic feet per minute (SCFM) fully-enclosed CNG compressor skids.
 - One twin-tower natural gas dryer.
 - Nine high-pressure American Society of Mechanical Engineers storage vessels.
 - Four transit-type dispensers and 1 light-duty dispenser.
 - One defueling system.
 - Fuel-management controllers.
 - CNG Control System.
 - Control-air system and other components required for CNG fueling station.
- Training for maintenance and safety.
- Creating maintenance manuals, equipment and system as-built.

- CNG facility testing and commissioning.
- Providing a one year warranty.

CHAPTER 2:

System Criteria

The CNG fueling station must produce CNG from natural gas transported and delivered by Pacific Gas & Electric Company (PG&E), the local natural gas utility, to a meter set assembly. The delivery pressure at meter-set-assembly outlet will be regulated to 350 pounds per square inch gauge (PSIG), for purposes of calculating pressure drops and compressor output.

The CNG fueling station will initially be required to fuel 250 transit buses in an 8-hour window, fueling four transit buses simultaneously. Average fueling load per transit bus is expected to be approximately 6,040 standard cubic feet based on data from SacRT's existing CNG fueling station. Average dwell time between fueling events is estimated to be 2.5 minutes while average fuel time is expected to be approximately six minutes.

CNG will be available 24 hours per day, with continuous transit bus fueling hours primarily between 5:30 pm and 1:30 am. The CNG fueling station must also be designed for occasional heavy and light-duty fueling outside of primary operating hours.

Assuming a configuration of three 1,500 SCFM compressors, 50 percent redundancy must be provided for a nominal aggregate skid discharge of 3,000 SCFM.

The CNG fueling station, including all components, materials, and systems, must be capable of operation and maintenance at specified performance levels without impairment in an outdoor temperature range of 20°F to 115° (-6.7°C to 46.1°C).

The CNG fueling station including all components, materials, and systems, must be designed and constructed on the principle of maintainability by SacRT.

Design Improvements

The contractor must verify all equipment needs and requirements contained herein based on SacRT CNG fueling criteria. The contractor may propose alternate or additional equipment configuration and improvements, with explanations of how the proposed design is more suitable for SacRT's long-term fueling station operation and maintenance practices. Equipment manufacturers or compressor configurations other than those specified herein must be proposed during the bid period.

Data Collection and Analysis

This analysis is based upon six months data collection of the system throughput and the impact of CNG vehicles upon the environment. The data collected includes:

- Number of vehicles (fleet and non-fleet) fueled per day per station.
- Number of days per year vehicles are fueled per station.
 - 365 days per year for the four transit fueling dispensers. The public fueling dispenser is projected to being used 365 days per year as well.

- Maximum capacity of the new fueling system:
 - CNG systems demonstrate the capability of fueling 250 transit buses in an 8-hour fueling window, fueling four transit buses simultaneously. Average fueling load per transit bus is approximately 6,040 SCFM based upon collected data. Average fuel time is 4.5 minutes.
- Gallons of gasoline and/or diesel fuel displaced by using natural gas (with associated mileage information):
 - In 2012, the SacRT fleet of 200 40-foot CNG fueled transit buses has collectively traveled 6,924,000 miles. The average fuel efficiency of a diesel powered transit bus is 2.33 miles per gallon, which amounts to 2,972,000 displaced gallons of diesel.
- Expected air emission reductions (in grams per brake horsepower-hour) for fleet vehicles:
 - By providing an additional CNG fueling source, this project potentially reduces greenhouse gas (GHG) and petroleum in two ways. One way is using cleaner burning CNG gas instead of clean burning gasoline and diesel. Reduced per capita consumption of fuel because public/bus transit is used instead of single occupant automobiles.
 - In addition, the existing fueling infrastructure on the site prevents a negative environmental impact, and the vehicle technology currently exists and is environmentally compatible.
 - The principal benefit of this project is the reduction in air pollutants because CNGs burn cleaner than gasoline or diesel. This is particularly relevant to the Sacramento metropolitan area, where there is not constant air circulation.
 - Based upon the California Air Resources Board Annual Report for Sacramento Regional Transit Agency, the 202 CNG transit buses each save 0.1 grams per brake horsepower- hour of diesel particulate matter, the standard for diesel buses. The Nitrous Oxide (NO_x) standard is based upon the age of each transit bus. There are 104 2002-to-2003-model-year buses with a NO_x emission of 344 grams per brake horsepower-hour, five 2006-model-year-buses with a total NO_x emission of 11 grams per brake horsepower-hour, and 91 2008-model-year buses with a total NO_x emission of 109.2 grams per brake horsepower-hour.
- The duty cycle of the current fleet and the expected duty cycle of future vehicle acquisitions that will use the natural gas fueling station:
 - The fueling system and planned fueling facility will have a 200 bus capacity and could refill as many buses in an 8-hour period.
- Specific employment and economic development resulting from the project:
 - The microeconomic impacts include reduced costs, temporary increase in construction and manufacture jobs, and increased availability of public transit in the Sacramento region. The CNG industry derives a benefit including expansion of business opportunities, and creation of CNG fueling manufacture and

technology jobs. Since SacRT was near capacity with their fueling capability, the addition of this second CNG facility will allow the bus fleet to expand to meet increased public transit demand. As the fleet expands, jobs will be created at SacRT at the new fueling site and other SacRT locations.

- Source of natural gas and any current or expected use of renewable natural gas:
 - PG&E transports natural gas, purchased through the California State Natural Gas Consortium, to the station. There are no plans to use renewable natural gas, however, it will be used if available.
- Energy efficiency measures used in the facility that may exceed Title 24 standards in Part 6 of the California Code of Regulations.
 - The building consists of 150,000 square feet of maintenance floor space, with a series of 15 banks of skylights providing natural light for the floor of the facility. This allows the building to use natural light in addition to the building lighting system during daylight operations.
- Potential job creation, economic development, and increased state revenue as a result of expected future expansion:
 - This project reduces vehicular traffic by moving gasoline and diesel automobile commuters to cleaner-burning CNG buses. The move away from operating gasoline and diesel vehicles will achieve sustainable reductions of GHG emissions as these vehicles produce more air pollutants than CNG buses. Also, many low-income drivers are more likely to use public transportation and often drive older, higher-emission vehicles.
- Quantified estimate of the project's carbon intensity values for life-cycle GHG emissions
 - The CNG fueling source this project provides encourages GHG and petroleum reduction in two ways. First, this project doubles the capacity of the SacRT for CNG fueling, increasing CNG use over gasoline and diesel use. Second, the CNG fueling source reduces fuel consumption by encouraging public/bus transit use over the use of single occupant automobiles.
- Comparison of any project performance and expectations provided in the proposal to Energy Commission with actual project performance and accomplishments:
 - The project team used the latest technology to construct this new CNG fueling source. The new fueling system meets all expectations and contract performance parameters.

CHAPTER 3:

System Testing

Tests to gauge the readiness of the CNG system include:

- Functionality Tests:
 - The contractor must perform leak tests of high-pressure CNG piping sections, systems, and appurtenances by maintaining a dry nitrogen charge at 110 percent of its respective working pressure for 30 minutes while the charge source is disconnected. No water or other liquids may be used. Use gauge must be scaled to between 110 percent and 300 percent of test pressure. Piping and tubing must be subject to leak checks using a solution approved by tube fitting manufacturer.
 - At a minimum, successful completion of the following functionality tests is required:
 - Emergency shutdown at button/station locations, including required valve closures.
 - Low suction pressure on each skid (close skid-supply ball valves).
 - Temperature-compensated fill from each dispenser, including verification of dispenser panel operation, and auto-stop on fill completion. Testing must include verification of “settled” fill pressure vs. ambient temperature 2 hours following fills. Fills must be within 4 percent of 3,600 pounds per square inch (PSI) design-fill pressure, temperature compensated to 70°F (21.1°C).
 - Correct operation of fuel-management system at each dispenser, including authorization of transaction, energizing of dispenser, and recording of transaction data (fill volume, time/date stamp, event ID, and pump number).
 - Contractor must calibrate and test public fueling dispenser for compliance with county weights and measures.
 - Alarm or automatic initiation of dryer regeneration must be based on dew point (generate false positive at hygrometer).
 - Contractor must verify correct annunciation on programmable logical controller for test events.
 - Contractor must observe compressor operation, including stage pressures and temperatures, and verifying function of controller, including triggering selected faults, such as high inter-stage temperature.
 - Contractor must verify proper operation of master control system to include buffer operation during sequential bus fueling of a specified number of buses.

- Reliability Tests: These tests consist of fueling under normal-use conditions for eight consecutive weekdays. The system must have no failures in compressor operation, dryer operation, normal dispenser operation, or fuel-management system, during the test period. If any failure occurs, test must be repeated in entirety. Final acceptance of the system may only be declared upon successful completion of test. Contractor must provide all onsite troubleshooting coordination including coordination of suppliers and trades during test.
 - Any of the following constitute a failure:
 - An inability of the CNG system to dispense CNG at specified pressures and rates, accounting for temperature compensation at settled conditions.
 - Failure of the dryer to provide dried gas in accordance with Society of Automotive Engineers J 1616 and/or inability to regenerate or auto terminate.
 - Failure of compressor to start and run within factory-listed operating pressures and temperatures.
 - Failure of the programmable logical controller, valve panel, fuel-management system and/or dispensers to operate as specified.
 - Presence of audible or visible gas leak.
 - Auto-fault shutdown of any CNG compressors, except those caused by Emergency shutdown button activation, gas-detection system, variations in gas supply pressure, or damage to system beyond contractor's control.
 - The contractor may take equipment offline for scheduled maintenance during test period, provided maintenance is consistent with manufacturer's recommendations, and does not impinge on primary fueling window. The contractor must provide maintenance until successful completion of the test, including provision of consumables.
 - The contractor's corrective work preceding and during performance test must be documented at the time of repair by any technicians performing the repair. If the contractor suspects a cause of fault beyond the scope of the respective firm or responsibility, the contractor must notify SacRT immediately. The contractor must not implement repairs until the condition(s) of failure have been documented and other firm(s) have been notified and provided documentation of condition. SacRT will not pay the contractor for any work or repair that is implemented during testing above that of the original contract amount. The contractor must notify SacRT and then receive SacRT approval of intent to perform any work that the contractor deems to be outside scope of the contract, prior to performance of any such work.

CHAPTER 4:

Report Summary and Conclusions

Testing has proven that this system is capable of fueling 250 buses in an eight-hour period, meeting the project requirement. In order to accomplish this, the team needed to fuel four buses simultaneously in around six minutes. The average fueling time was about 3 ½ minutes. The remainder of the testing showed that the system operated as planned with little down time. The system provides a much needed redundancy to SacRT, at a location outside the downtown Sacramento area. The downtown area is potentially subject to levee breaks and flooding. Additionally, TRUSD can now fuel their fleet of CNG buses using the new system. Previously, TRUSD was using a nearby station that had reached the end of its useful life and was to be demolished as soon as TRUSD transitioned to the new station.

The new station is located on a site with an 180,000 square foot building renovated for use as a bus maintenance facility. SacRT will split the fleet, operating half of their buses at this new facility. This allows fleet expansion, which is not possible at the downtown location.

GLOSSARY

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.

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

NITROGEN OXIDES (NO_x) - Oxides of nitrogen that are a chief component of air pollution that can be produced by the burning of fossil fuels.

PACIFIC GAS & ELECTRIC COMPANY (PG&E) - An electric and natural gas utility serving the central and northern California region.

POUNDS PER SQUARE INCH (PSI) - a unit of pressure or of stress based on avoirdupois units. It is the pressure resulting from a force of one pound-force applied to an area of one square inch.

POUNDS PER SQUARE INCH GAUGE (PSIG) - The pressure relative to atmosphere.¹

SACRAMENTO REGIONAL TRANSIT DISTRICT (SacRT) – The regional transit provider in the capital of California (the 5th largest economy in the world), operating over 70 bus routes (fixed-route, microtransit and dial-a-ride), 43 miles of light rail, ADA paratransit services, 3,100 bus stops and 52 light rail stations all within a 400 square-mile service area throughout Sacramento County.²

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.

TWIN RIVERS UNIFIED SCHOOL DISTRICT (TRUSD) – A school district that Twin serves an 82 square mile area covering the communities of Arden Fair, Del Paso Heights, Dos Rios, Elverta, Foothill Farms, Gardenland, McClellan Park, Natomas, Northgate, North Highlands, North Sacramento, Robla, Rio Linda and Woodlake. The district includes 52 school sites—29 elementary, five middle, four comprehensive high schools, three charters at seven sites and seven alternative schools.³

¹ [National Wildfire Coordinating Group Glossary Webpage](https://www.nwccg.gov/glossary/a-z) (https://www.nwccg.gov/glossary/a-z)

² [Sacramento Regional transit District Webpage](http://www.sacrt.com/) (http://www.sacrt.com/)

³ [Twin Rivers Unified School District Webpage](http://www.twinriversusd.org/) (http://www.twinriversusd.org/)