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FINAL PROJECT REPORT

The Las Gallinas Valley Biogas Energy Recovery System Project

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division manages the Gas Research and Development Program, which supports energy-related research, development, and demonstration inadequately provided by both competitive and regulated markets. These natural gas research investments spur innovation in energy efficiency, renewable energy, advanced clean generation, energy-related environmental protection, energy transmission, distribution, and transportation.

The Energy Research and Development Division conducts this public interest natural gas-related energy research by partnering with individuals, businesses, utilities, and public and private research institutions. This program promotes greater gas reliability, lower costs, and increased safety for Californians. It focused on:

- Buildings End-Use Energy Efficiency
- Industrial, Agriculture, and Water Efficiency
- Renewable Energy and Advanced Generation
- Natural Gas Infrastructure Safety and Integrity
- Energy-Related Environmental Research
- Natural Gas-Related Transportation

The Las Gallinas Valley Biogas Energy Recovery System Project is the final report for Contract Number PIR-14-020 and Grant Number PON-14-505, conducted by Cornerstone Environmental Group, LLC, a Tetra Tech company. The information from this project contributes to the Energy Research and Development Division's Gas Research and Development Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the Energy Research and Development Division at ERDD@energy.ca.gov.

ABSTRACT

A biogas energy recovery system was constructed at the Las Gallinas Valley Sanitary District (District) wastewater treatment plant in San Rafael, California. While the potential to generate renewable energy from the treatment of wastewater is well established in the industry, this system utilizes the digester gas generated by the WWTP to operate a pre-commercial biogas utilization system that consumes 100 percent of the WWTP's methane generation. The biogas energy recovery system is comprised of a BioCNG™ 50 System to condition digester gas; two 65-kilowatt microturbines to generate heat and power for the site; a hydronic boiler to provide supplemental heating; and a time-fill compressed natural gas filling station to fuel the District's compressed natural gas flusher truck.

As part of its continued efforts to reduce its reliance on non-renewable energy resources and further its strategic environmental plan, the District envisioned replacing the outdated internal combustion engine previously used for combined heat and power generation. The biogas energy recovery system replaced the internal combustion engine with a more environmentally forward-looking system that provides greater self-sustainability for the site.

Anaerobic digestion, coupled with combined heat and power and the production of renewable compressed natural gas for transportation, provides optimal end-use flexibility for digester gas. The importance of biogas utilization to reduce methane emissions in California is substantial. Since capturing and beneficially using biogas is the best way to mitigate methane emissions, the project demonstrates the application at wastewater treatment facilities throughout the state to help meet the requirements of SB605 (*Short-Lived Climate Pollutants*) and AB32 (*Global Warming Solutions Act*), as well as California's other renewable energy mandates.

Keywords: digester gas, microturbine, gas conditioning, wastewater treatment plant, renewable natural gas, combined heat and power

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California's water system includes more than 900 wastewater treatment plants (WWTPs) that treat and manage roughly 4 billion gallons of wastewater daily. Wastewater treatment is energy intensive, requiring significant electricity and fossil gas to process wastewater into water that is safe to discharge or reuse. This energy demand can be significantly offset by recovering biogas that is produced through the wastewater treatment process. This biogas is often flared, especially at small treatment plants like the Las Gallinas Valley Sanitary District (District).

With assistance from Cornerstone Environmental Group, the District designed and built an innovative, closed-loop biogas energy recovery system (BERS) at its wastewater treatment plant in San Rafael, California. This pre-commercial system recovers 100 percent of the methane gas produced from the anaerobic digestion (the breakdown of organic matter in an oxygen-free environment) of wastewater sludge and conditions it for both onsite combined heat and power (CHP) generation and use as a transportation fuel.

California's wastewater treatment plants can significantly reduce capital and operating costs by installing a highly efficient biogas recovery system that captures and maximizes all available methane (produced and underused by these facilities) and converting it to biogas. Combining this efficient recovery system with CHP provides long-term stability, reduces reliance on the electrical grid, increases annual savings, and lowers ratepayer costs.

Anaerobic digestion coupled with CHP to generate electricity and produce fuel for transportation provides optimal end-use flexibility for biogas resources. In addition, the importance of biogas to reduce methane emissions in California is substantial. Since capturing and using biogas is the best way to mitigate methane emissions, the project demonstrates the application of BERS at WWTPs throughout the state to help meet the requirements of SB605 (*Short-Lived Climate Pollutants*) and AB32 (*Global Warming Solutions Act*), as well as California's ambitious renewable energy mandates.

Project Purpose

In 2013, the District updated its strategic plan, which included furthering its environmental and sustainability goals. The strategic plan called for using the WWTP's digester gas to its full potential to reduce the consumption of non-renewable energy sources. The District first implemented energy generation systems when it installed an onsite internal combustion engine back in the late 1980s. However, revisions to the air quality standards required by the Bay Area Air Quality Management District rated the existing Waukesha engine as out of compliance.

The purpose of the project was to build and operate an innovative pre-commercial biogas energy recovery system that produces conditioned digester gas (CDG) and renewable natural gas (RNG) for CHP generation, and renewable compressed natural gas (RCNG) for use as a transportation fuel. The project also evaluated the operational and performance characteristics of a system which would fully utilize onsite bioenergy resources. This included demonstrating the affordability of the technology and developing strategies to reduce capital costs through a combination of increased system efficiency and maximum utilization of onsite bioenergy resources. Furthermore, the project validated the capability of WWTPs to maximize renewable energy generation and distribution onsite to conserve non-renewable natural gas supplies and reduce greenhouse gas emissions.

One of the drivers for the project was the mandatory removal of the existing internal combustion engine by January 1, 2016. To advance the District's environmental goals, the internal combustion engine was replaced with CHP equipment that would utilize the digester gas and additionally operate seamlessly with the existing wastewater treatment plant's infrastructure. Based on review of available CHP equipment, the internal combustion engine was replaced with two 65-kilowatt Capstone CHP microturbines. To further reduce reliance on non-renewable energy sources, the District planned to phase out diesel trucks and vehicles operated at the site. The project replaced a diesel flusher truck with one that operates off of RCNG produced by the BERS and compressed natural gas (CNG) provided at a District-owned and operated CNG fast-fill fueling station.

On a larger scale, the project purpose was to complete a technically feasible and achievable system that can be replicated at wastewater treatment plants throughout California. The real innovation of this project is the integration of these individual components into a new pre-commercial system that converts 100 percent of the methane produced at the District's wastewater treatment plant into biogas for CHP utilization and transportation fuel. Individual, technically proven, and commercially available components of the integrated system included a biogas energy recovery gas skid, two 65-kilowatt microturbines, a hydronic boiler, and a CNG fueling station. This integrated system combined all of these components in a first-of-its-kind manner that was designed and supported by industry experts working to demonstrate this system at pre-commercial scale.

Project Results

The project completed construction and demonstrated operation over a period of 12 months. The BERS is a critical piece of the wastewater treatment plant's operation and provides both electricity and heating supply to the digester system. At the initial setup of the BERS, digester gas production was as low as 17 standard cubic feet per minute (scfm). Prior to full start-up and the beginning of the 12-month period of data collection, improvements to the digesters were completed and glycerin loads were received at the site. While the construction improvements that were independent of the BERS construction created significant startup delays, they greatly improved the digester system's efficiency and steady generation of digester gas to the BERS, which aided in eliminating potential shutdowns or fluctuations in digester gas production.

During the 12-month period, the average digester gas production was approximately 45,450 standard cubic feet per day (scfd), which averages approximately 32 standard cubic feet per minute (scfm). Of the 45,450 scfd produced by the digesters, an average of 35,080 scfd of

CDG was generated for microturbine operation. This is approximately 17 percent lower than the original proposed amount of CDG (42,480 scfd) that would be produced over the 12-month period.

The original estimated production was 1,512 scfd of RNG for supplemental heat requirements. In actual operation during the 12-month period, there was no need for supplemental heat from the RNG hydronic boiler. The microturbines provide sufficient heating to the digesters' hot-water heat loop.

The average RCNG produced per day over the 12-month period was 196 scfd. Early in the 12-month period, there was insufficient digester gas production and poor digester gas quality to produce RCNG. The focus was to continuously operate the microturbines on digester gas. During this time, the CNG truck at the site used the Smith Ranch fast-fill station, which the investor-owned utility Pacific Gas and Electric Company (PG&E) supplied with natural gas. The original estimated production was 6,048 scfd of RCNG for use as a transportation fuel during the 12-month period. While production of RNG was minimal during the 12-month period, operation of the RNG portion of the BERS showed that it is possible to operate the closed-loop system with no tail-gas flaring required while the microturbines are also in operation. The system can successfully operate with 100 percent methane utilization. As the District continues to operate the system, the value of this RNG production should continue to increase.

A decrease in digester gas output and subsequent low production of CDG and RNG is attributed to several factors (most notably poor digester performance) independent of the BERS capabilities or functionality. With the combination of District-initiated, systemwide improvements, glycerin loading at the beginning of the 12-month period, and a Cornerstone audit of the WWTP digester hot water loop system, biogas generation increased and held at a steady production rate of approximately 32 scfm.

Benefits to California

The production of methane from the anaerobic digestion of wastewater sludge at WWTPs is important in California. Methane is both a source of renewable energy and a short-lived climate pollutant. Capturing and converting methane to biogas is one of the most effective ways to simultaneously create renewable energy and reduce emissions to meet California's ambitious environmental mandates.

Most of the methane produced by wastewater treatment facilities is flared and is either not utilized or underutilized as a renewable energy source. The BERS design enables 100 percent capture of available methane in the digester gas produced for on-site energy and fuel use. This new approach for state wastewater treatment facilities provides an example of a cost-effective, efficient technological strategy for maximizing on-site bioenergy resources for renewable energy production. In addition, the project is the first in California to produce both CDG and RNG for CHP and RCNG for use in vehicles at a wastewater treatment facility. The state-of-the-art BERS incorporates the use of microturbines and a high efficiency package boiler to provide maximum energy efficiency and emissions reductions, while achieving 100 percent utilization of methane to produce biogas for on-site renewable energy use.

On the local scale, the District currently serves over 30,000 people in communities north of San Rafael. This project reduces operating costs for the wastewater treatment facility while also reducing natural gas demand. Conservative operational cost savings are over $100,000 per year, with the majority of those savings from electricity generated by the CHP equipment, and further savings from the avoidance of purchasing diesel fuel (from the availability of onsite RCNG). The BERS and natural gas fueled vehicles significantly reduced emissions when compared with the out-of-compliance internal combustion engine and diesel-fueled vehicles, which were replaced during this project.

The system advances current technology by combining the following three components into an integrated system: 1) ability to cost-effectively clean biogas for use in energy efficient microturbines and a boiler, which both allow for lower air emissions; 2) complete use of biogas onsite in CHP and for transportation fuel use; and 3) re-direction of waste biogas back into the system for 100 percent utilization of bioenergy resources produced at the facility. By showing the ability to capture all of the available methane produced by the District's wastewater treatment-recycled water facility for conversion to biogas, the project demonstrates how all of California's WWTPs can significantly reduce capital and operating costs by installing a highly efficient biogas recovery system that maximizes the use of bioenergy resources. Supplementing the CHP component – which helps create long-term stability, with the fuel component - with its significant yet unpredictable incentives, will increase the ability to increase annual savings and reduce ratepayer costs.

By eliminating the need for external natural gas supplies, the project provides energy stability for the WWTP. The small size of the project demonstrates that despite generating only an average of 32 scfm, there is both flexibility and reliability in the system, which can be improved upon by larger facilities in the future. As part of this project, the District distributed the knowledge gained in this demonstration project with sanitation districts and WWTPs throughout California through webinars, signage, publications, and other outreach avenues.

Key benefits and highlights of the project include:

- **Onsite Biogas Utilization and Biomethane Production.** The project provides electrical generation and CHP, reducing reliance on the grid and eliminating the use of diesel fuel in the District's vehicles. In addition, methane emissions will be greatly reduced, which will help California meet the legal requirements of SB605 and AB32 and other environmental and renewable energy mandates.
- **Promote CHP Adoption.** By installing microturbines to replace the facility's internal combustion engine, the project demonstrates how cleaner technologies can be integrated at existing faculties. The project also demonstrates the ease of transitioning from existing equipment to more environmentally friendly CHP equipment.
- **Improve Economic Attractiveness.** The BERS is designed to offset as many operational costs as possible, including replacing diesel with RCNG and providing electrical generation and heat for the digesters from electricity generation.
- **Increase System Flexibility.** The project lowers grid demand. The BERS provides its own heating for sludge and will not require additional sources of energy outside of

the facility. The project will also produce RNG/RCNG as a transportation fuel, which will help reduce reliance on fossil fuel. The BERS controls allow biogas to be routed in a multitude of ways to maximize the benefits of the system.

- **Achieve High Efficiency.** The project installed new high efficiency equipment that will help maximize benefits of the BERS.
- **Utilize Waste Heat.** All waste heat produced will be used to heat wastewater sludge.

CHAPTER 1: Introduction

Introduction

The Las Gallinas Valley Sanitary District (District), with assistance from the Cornerstone Environmental Group, designed and constructed an innovative, closed-loop biogas energy recovery system (BERS) at the District's recycled wastewater facility in San Rafael, California. When fully operational, this pre-commercial system recovered 100 percent of the methane produced from the mesophilic anaerobic digestion of wastewater sludge at the facility and conditioned it for onsite combined heat and power (CHP) generation and transportation fuel use.

Project Goals and Overview

The goals of the proposed project were to: 1) build and operate an innovative pre-commercial biogas energy recovery system that produces both conditioned digester gas (CDG) and renewable natural gas (RNG) for CHP generation and renewable compressed natural gas (RCNG) for use as a transportation fuel; 2) evaluate the operational and performance characteristics of the proposed system; 3) demonstrate the affordability of the technology and strategy to reduce capital costs through the increased system efficiency and maximum utilization of onsite bio-energy resources; and 4) validate the capability for wastewater treatment facilities to maximize renewable energy generation and distribution onsite to conserve non-renewable natural gas supplies and reduce greenhouse gas (GHG) emissions. To achieve these goals, the project team pursued several objectives:

- Build a pre-commercial BERS located at the District's wastewater treatment plant (WWTP).
- Operate the proposed system for 12 months per year.
- Produce 42,480 standard cubic feet per day (scfd) of CDG or 15.63 million scf of CDG per year of operation for CHP generation.
- Produce 1,512 scfd of RNG or 0.55 million scf of RNG per year supplemental heat requirements.
- Produce 6,048 scfd of RCNG or 2.21 million scf of RCNG per year of operation for use as a transportation fuel.
- Share knowledge gained in this demonstration with sanitation districts and WWTPs throughout California through webinars, signage, publications, and other outreach avenues.

The development of the project was key to meeting the District's environmentally friendly strategic plan. One of the drivers for the project was the mandatory removal of the existing internal combustion (IC) engine by January 1, 2016. To continue furthering the District's environmental goals, the IC engine was replaced with CHP equipment that would utilize the digester gas and operate seamlessly with the majority of the existing WWTP infrastructure. In addition, to further reduce reliance on non-renewable energy sources, the District planned to phase out diesel-fueled trucks and vehicles utilized at the site. The project replaced a diesel flusher truck with one that operates off RCNG produced by the BERS and CNG provided at a District owned and operated CNG fast-fill fueling station.

CHAPTER 2: System Design

Project Planning and System Design

The project design phase included several key design components – identifying what renewable energy/fuel the District set out to generate with the BERS; addressing facility layout concurrent with selection and sizing of end-use equipment; and determining priority of system outputs.

The District set out to design and install a system that would replace the existing IC engine with a regulatory compliant piece of equipment. The IC engine provided CHP for the facility, providing electricity to operate equipment within the area of the digesters as well as providing heat for the hot water loop of the digester pumping system. In addition to CHP, the District's goal of phasing out diesel-fueled trucks from the facility with CNG trucks would be initiated through the BERS project.

Flow Rate Output

Prior to selection and sizing of end-use equipment, the method and equipment of the gas conditioning needed to be determined. The parameters necessary for proper gas conditioning would be further refined after equipment selection so that the end-use equipment received biogas at the specified pressure, flow rate, and conditioning. At the time of design, the totalized flow rate meter was indicating that the digester was generating approximately 32 standard cubic feet per minute (scfm). To verify the digester gas output, volatile solid reduction calculations were prepared to estimate a range of digester gas flow rates based on information provided by the District of total effluent flow and percentage of volatile solids. The range confirmed that a design flow rate of 35 scfm was appropriate. Based on that knowledge, the proposed gas conditioning system was sized to accommodate 50 scfm so that a potential increase in output could still be handled if needed in the future. Sizing the gas conditioning system to handle even higher flow rates would make the equipment inefficient at the lower flow rates of its normal mode of operation.

Biogas Conditioning Equipment

During preparation of the biogas conditioning equipment specification, it was expected that the conditioning system would be required to remove hydrogen sulfide, moisture, particulates, volatile organic compounds (VOC), siloxanes, and, in order to produce RNG, carbon dioxide. In addition to the typical conditioning requirements, one key goal of the project was to eliminate the need for tail gas destruction resulting from carbon dioxide removal during the production of RNG. This was included in the equipment specification so that the proposed manufacturer would design the system to handle tail gas recirculation. The potential for tail gas recirculation went hand in hand with the selected end use equipment for the condition digester gas. Because the rerouting of the tail gas would decrease the heating value of the incoming conditioned digester gas to the selected CHP equipment, it was essential that the selected equipment could handle the potential fluctuations in heating value of the fuel supply. This was a key criterion of the CHP equipment selection.

Using several pieces of equipment all interconnected to produce the necessary output, the biogas conditioning system conditions the digester gas through the removal of particulates, moisture, hydrogen sulfide, siloxane, VOCs, and carbon dioxide. Specifically, to operate in conjunction with the selected end-use equipment (microturbines), the CDG is compressed and cooled prior to delivery to the equipment. A portion of the CDG continues on to the carbon dioxide removal membranes for further refining of RNG quality.

After the biogas conditioning system specification was prepared, it was distributed to several biogas conditioning system manufacturers. The system selected was the BioCNG 50 System. The BioCNG 50 System utilizes a closed loop system that captures 100 percent of the methane produced by the digesters. During conditioning of the digester gas to RNG, BioCNG uses membranes for the removal of carbon dioxide, whereby tail gas, composed primarily of carbon dioxide, is generated. However, during the removal of carbon dioxide, a percentage of methane is removed and enters the carbon dioxide tail gas stream as well, generating a tail gas that has a potential concentration as high as 30 percent methane. In the BERS, the tail gas produced is returned to the front end of the system for biogas conversion and the methane that was removed by the carbon dioxide membranes is circulated back to the front of the process train. Through on/off cycles of RNG production, where during the off-cycle all digester gas entering the system is conditioned and directed to the microturbines and destroyed, the system maintains a relatively consistent incoming digester gas composition despite the recirculation of the tail gas during on-cycles for RNG production. The existing onsite flare is only needed for emergency situations.

This closed loop system benefits the District by reducing energy costs and improving energy efficiency through the elimination of an ancillary flare and 100 percent utilization of methane generation. Not only does the closed loop system reduce capital and operating costs that in return lower costs to ratepayers; it also reduces methane emissions to help meet California's environmental mandates.

The system is mounted on two skids, with a single free-standing vessel:

Skid 1 Includes:

- **A Glycol Chiller** – This equipment is used to lower the dew point of the conditioned digester gas.
- **A Control Panel** – Motor starter and process logic controller for the control and operation of the system, including the microturbines.
- **A Siemens Gas Analyzer** – This equipment obtains small samples off the RNG gas stream to confirm that the gas parameters are sufficient for use in CNG vehicles.

Skid 2 Includes:

- **Compressors** – Capable of creating at least a 100 pounds per square inch gauge (psig) at 50 scfm to provide sufficient inlet pressure to the microturbines.

- **VOC/Siloxane Removal Media** – Carbon-based commercially available media is used for the removal of VOCs and siloxanes.
- **Carbon Dioxide Removal Membranes** – The membranes are provided by Air Liquide and used to remove carbon dioxide from the gas stream.
- **Mercaptan Odorization System** – To re-odorize the RNG after it has been cleaned.

Free Standing Vessel Includes:

- **Hydrogen sulfide removal vessel** – The vessel is filled with commercially available media that is selected based on the level of hydrogen sulfide in the raw digester gas.

CHP Equipment Selection

The CHP equipment was required to provide CHP while also being able to seamlessly adjust to small changes in heating value of the incoming fuel during production of CNG. In addition, because of the small amount of available room at the site, and the required Bay Area Air Quality Management District (BAAQMD) air regulations, the equipment needed to have a small footprint and low emission rates that would not require additional emission controls.

Based on the anticipated flow rate (approximately 35 scfm) and methane concentration of the conditioned digester gas (approximately 60 percent methane), two 65-kilowatt (kW) microturbines were selected for installation. Cornerstone specified that Capstone microturbines were to be procured. Capstone has demonstrated reliability in the WWTP biogas utilization industry and has continued to improve its product over time. In addition, a distributor/service representative is located relatively close to the site.

The microturbines selected were CR65-ICHP renewable fuel model, which is commercially available and have been involved in multiple case studies, which are available for review on the Capstone website. The benefits of selecting commercially available and industry proven technologies include a reduction in purchasing costs and minimization of operational and maintenance issues that have been remedied during the years of the equipment being in service.

The internal combined heat and power (ICHP) model is equipped with a heat recovery unit that is placed on the top of the microturbine and does not require any additional footprint. The heat recovery unit operates as a heat exchanger to heat up incoming water through the use of the exhaust heat generated from CDG combustion. The hot water loop in the digester room is connected to the heat recovery loop off of the microturbines. The majority of heating demand for the digester hot water loop is met through the microturbines' heat recovery capabilities.

The microturbines meet the California Air Resource Board emissions requirements without any additional emissions control equipment, which helped to decrease air permitting timelines (CARB, 2024).

Some additional characteristics that supported the decision for the selection of Capstone microturbines instead of an IC engine included:

- Low maintenance and downtime.
- No lubricant or coolant needed – meaning no storage of lubricants or additional materials onsite.

- Small design for easy, low cost installation with minimal footprint.
- Electrical efficiency of 29 percent.
- 251,000 British thermal units per hours (Btu/hr) of heat recovery.
- UL2200 and UL 1741 classified for raw natural gas and biogas operation.

Facility Layout

Following selection of equipment, selecting the precise location of each piece of equipment that would create the most efficient layout and meet electrical and building codes, was a challenge. The site is relatively small and working with space constraints while also making sure to accommodate the buffer zones required by the National Electric Code and the offset distances to ensure that equipment could be accessed in the future, was a challenge.

The final facility layout that was selected was an area of green space that was previously covered in trees and located immediately next to the digesters. This layout did require the removal of trees but allowed for the least amount of piping and removal of existing pavement. The equipment placed in this area is out of the way of traffic and the majority of piping was able to be placed below ground or supported along the outside of the digesters themselves. In addition, placement of the microturbines adjacent to the digester pumping room allowed for hot water loop pumps to be minimized to avoid having to install large pumps to get water to and from the room.

The greatest challenge for the facility layout, was locating equipment that was not rated for placement in gaseous environments, which included the glycol chiller and the control panel for the system. These two pieces of equipment are located furthest from the digesters, and in the case of the control panel, it was able to be mounted on the outside of the nearby maintenance building wall.

Modes of Operation

The following outlines the two modes within which the BERS operates. The flow rates presented in the following table are based on an average 30 scfm available for raw digester gas; this quantity alters during the course of the system operation depending on digester influent causing flow rates to vary, such as an increase due to fats, oils, and grease incorporated into the digester influent. For the purposes of this section, 30 scfm was used as the average flow rate. There are two modes of operation – CDG and RNG.

In CDG Mode, all of the digester gas that has been conditioned to CDG is directed to the microturbines. The total gas flow of 30 scfm at 63 percent methane content operates two microturbines at 50 kW each; approximately 70 percent capacity. In CDG Mode all available digester gas is used beneficially to generate electricity and approximately 353,000 Btu/hr, sufficient to meet the average digester heating load.

The CDG Mode is employed if the storage tank is completely filled with RNG and the heating demand is being met by the microturbines so that the hydronic boiler does not need to run.

During conditioning of the digester gas to RNG, the gas conditioning skid uses membranes for the removal of carbon dioxide, whereby tail gas composed primarily of carbon dioxide is generated. However, during the removal of carbon dioxide, a percentage of methane is removed with and enters the carbon dioxide tail gas stream as well, generating a tail gas that has a potential concentration as high as 30 percent methane. In the BERS, the waste gas produced is returned to the front-end of the system for biogas conversion and, therefore, the methane that was held back by the carbon dioxide membranes is circulated back to the front of the process train. Through on- and off-cycles of RNG production, wherein during the off-cycle all digester gas entering the system is conditioned and directed to the microturbines and destroyed, the system maintains a relatively consistent incoming digester gas composition despite the recirculation of the tail gas during on-cycles for RNG production. Therefore, the existing waste gas burner is only needed for emergency situations; there is no utility flare installed as part of this system for destruction of tail gas. Based on 30 scfm at 63 percent methane, the gas flow balance is shown below (Table 1):

Table 1: Gas Conditioning Compositions

	Flow (scfm)	Methane Content (%)
Incoming Digester Gas	30	63
Tail Gas from CO2 Removal Module	7	34
Blended Gas (Digester Plus Tail Gas)	37	57
Input to the CO2 Removal Module	12	57
CDG - Microturbine Input	25	57
RNG – Storage Tank Input	5	95

Digester Gas and Tail Gas are blended at the inlet to the gas compressor, downstream of the hydrogen sulfide removal vessel. Following the moisture and siloxane/VOC removal described above, the pressurized gas flow, now CDG, is split between the Carbon Dioxide Removal Module and one microturbine as displayed in the gas balance table above. In RNG mode the production rate of RNG, five scfm is equivalent to two to three gallons of gasoline equivalent per hour. On a continuous basis the system would produce, on average, approximately 61 gallons of gasoline equivalent per day of RNG for use as vehicle fuel.

The amount of CDG split to the microturbine is sufficient to operate one microturbine at full capacity, generating 65kW of electricity and approximately 251,000 Btu/hr of recoverable heat. Because the single microturbine may not produce enough heat to meet the digester heating load, the hydronic boiler, operating on RNG makes up the difference in heat demand. Any RNG used for heat production is not available for vehicle fuel.

The closed-loop system is operational and works to eliminate the need for flaring of tail gas from the production of RNG. This closed loop system benefits the District by reducing energy costs and improving energy efficiency through the elimination of an ancillary flare and 100 percent utilization of methane generation. Not only does the closed loop system reduce capital and operating costs that in return lower the cost to the ratepayer.

CHAPTER 3: System Installation and Commissioning

System Construction

The major construction of the BERS occurred from November 2015 through May 2016. Some items remained to be installed/completed after that time, but the key construction was completed in that time frame (Figure 1). Project construction included:

- Clearing of the area proposed for equipment placement. This required the removal of existing trees and the excavation of the existing ground surface to allow sufficient burial depth for below ground piping and conduit.
- Installation of framing for foundation pouring for equipment and pipe supports.
- Welding of gas conveyance and hot water loop piping, then placement and installation requiring either pipe burial, pipe stand installation, or pipe strut for the piping along the outside of the digester wall or inside the digester pump building.
- Placement of equipment, including the use of a crane for the microturbines.
- Installation of the hot water loop components including the new heat exchanger and hot water loop pumps.
- Electrical connections of the microturbine to the existing onsite electrical grid and electrical and communication wiring from the system equipment to the BioCNG control panel.
- Installation of the time-fill RNG station and canopy.

Figure 1: View from the Top of the Digesters of the Completed Construction

Source: Las Gallinas Valley Sanitary District

Start-up Challenges

During system construction and start-up, some hurdles were encountered that were resolved over time. There were several challenges that created significant delays in start-up of the system. Firstly, during system start-up, the digester was producing approximately 17 scfm, as opposed to the design quantity of 35 scfm. Cornerstone, BioCNG, and the District were in discussions on a regular basis to troubleshoot and recalibrate the system as necessary to operate at this lower flow. Options proposed included the installation of a third smaller (35 kW) microturbine or operating in full RNG mode with flaring of tail gas or intermittent operation of the microturbine for removal of carbon dioxide from the system. It was decided by the District board that the team should not make any changes in equipment size to accommodate this lower flow, but rather wait until the proposed digester improvements had been completed.

In mid-2016, it was planned that the primary digester would be cleaned and receive an improved mix system. The primary digester was expected to not be in service until at least December. The issue with attempting to operate the BERS during these improvements was that the gas flow would not always be consistent until the primary digester was back in service, and therefore, it was best to leave the BERS idle during these improvements.

In October of 2016, the District decided to commence a project that involved the primary digester rehabilitation. The construction included replacement of the vertical chopper pump. Because there had been a steady increase in digester gas output resulting from the other digester improvements that had been done at the site it was anticipated that additional improvements would continue to help biogas output. Therefore, full start-up was delayed until the digester improvements were completed to avoid any issues with disruptions in digester gas supply; the digester rehabilitation work was not planned to be completed until late April 2017.

In early 2017, there had been some instrumentation relocation as well as digester improvements completed. After completion of this work, the primary digester would be filled. Once the primary digester internal work was done and all of the sludge and gas piping was completed, the District filled the digester with primary effluent and began the process of heating and introducing thickened sludge to the primary digester to bring the anaerobic digester process up to full treatment. At the time, the District anticipated a three- to four-week period before experiencing full gas production.

During this time period, the team was in communication with the gas conditioning manufacturer, BioCNG, due to a concern in the incoming biogas quality. Based on the available gas samples, the RNG portion of the system could not start-up with the current percentage of nitrogen in the incoming biogas stream. At that time, without the elimination of air intrusion that was evident in the lab samples, it was decided it would be best to continue to hold off on start-up until site maintenance was completed and the air intrusion could be located. Ongoing site maintenance that was being performed to improve digester gas output would interfere with operating the BERS in a continuous uninterrupted manner. Therefore, start-up was delayed until no additional improvements were being done.

During August 2017, BioCNG and Regatta (microturbine distributor) were onsite for the "soft start-up" of the BERS. The primary goal of the soft start-up was to confirm that the digester improvements helped to generate an increase in gas quality and quantity, as well as to operate the microturbines only. During this start-up the microturbines were the only equipment (in conjunction with the BioCNG skid) to go through start-up because the recent digester gas samples were showing an air intrusion in the gas quality that was degrading the gas enough to create an issue with operating any equipment that requires CNG quality gas to operate off of the RNG that would be produced from the system.

During the soft start-up, the microturbines were fully operational, appearing to have good digester gas quality and quantity available to them. The issue that arose was that the hot water heat loop pumps were not functioning, causing an emergency shutdown on the microturbines because the heat in the system had no way of getting into the heat exchanger with the hot water loop pumps not operational. After some investigation, it was determined that the buckets in the motor control center where the hot water loop pumps terminate is not properly wired. After contacting the electrical engineer that worked on the project, it was determined that an electrician would need to visit the site to confirm if the wiring was incorrect or the buckets themselves were the issue.

During the soft start-up, digester gas sampling was performed with a handheld GEM (biogas meter). It was believed that the air intrusion that had been evident in the biogas sampling that the site was performing had been addressed after the monitoring shown below was collected. The source of the air intrusion was believed to be the anti-siphon valves on the mixing pumps which were introducing air into the digester gas. The site closed these air valves. The following digester gas qualities were obtained.

Gas quality readings from the GEM at the flare: Methane - 58.0 percent; Carbon dioxide - 39.9 percent; Oxygen - 0.0; Nitrogen - 2.4 percent.

In October 2017, the District collected an additional digester gas sample. The results indicated reduced air infiltration after some modification to WWTP piping. However, there still appeared to be air intrusion indicated by the ratio of nitrogen to oxygen in the sample. Cornerstone with Tetra Tech performed an audit of the WWTP to identify if the poor digester gas quality was a result of equipment/system failures or the digester process. It was discovered that an air compressor hose was loose and introducing air into the digester system. Once this item was addressed, the biogas quality greatly improved. In December 2017, start-up was completed with BioCNG coming to the site to provide start-up assistance and on-site training. At this time, the 12-month data collection period began.

CHAPTER 4:
System Operation and Results

System Operations

Since the beginning of system operations and during continued operations, the BERS has been operating in compliance with the regulatory requirements established under its Permit to Operate (PTO) issued by the BAAQMD. The BERS did not receive any Notice of Violation or initiate any request for variances during the 12-month operational period.

Cornerstone previously provided monthly progress reports to the California Energy Commission (CEC) in accordance with the scope of work within the Agreement between the District and the CEC dated May 29, 2015. Each progress report included mention of any system operational issues and the estimated monthly production of digester gas, CDG, RNG, and RCNG, as well as electrical and heating generation from the microturbines.

The District's supervisory control and data acquisition (SCADA) system consultant revised the data retrieval reports so that the actual output information from the BERS was available for the data collection analysis. Parameters collected included the total digester flow, total kW generated by each of the microturbines, total scfm to the waste gas burner, and the combined total scfm of CDG that went to the microturbines.

Some of the system parameters are not collected because of lack of instrumentation or the set-up of the data retrieval report, therefore the output values were estimated based on the following back-calculations:

- **Runtime per microturbine** – If kW were generated by the microturbine for the day, it was assumed that it operated 1,440 minutes for that day. Total run time was a summation of each day of 1,440 minutes.
- **kWh (kilowatt-hour) per microturbine** – The kWh generated by the microturbine was back-calculated based on the kW generated by the microturbine for the day assuming the microturbine operated for 24 hours in a day.
- **Heat output per microturbine** – The heat output from the microturbines is not collected through the SCADA, but to completely disregard the heat output would not take into consideration all the components of system efficiency. Therefore, to calculate the heat output, the runtime of the microturbine in hours (minutes/60) was multiplied by 0.42 million British thermal units per hour (MMBtu/hr) to calculate the MMBtu heat output for the month for each microturbine. The 0.42 MMBtu/hr is from the Capstone datasheet. The 0.42 MMBtu/hr is the full heating potential of the microturbine and the site is not operating at full heating potential. However, there is no basis for selecting a factor to reduce the heat output by to account for not utilizing the full heat output. The highlighted cells in the summary tables indicate where values were above the 12-month average (Tables A-1 and B-1). The months with the highest efficiency, also had the highest heat output.

Results

During this 12-month period, use of the RNG and RCNG was minimal. First, the District did not need the use of RNG in the on-site boiler because the microturbines were providing sufficient heating supply to the hot water heat loop for digester temperature control. Second, the CNG fueled truck was in and out of commission, therefore RCNG was not needed onsite.

For the first half of the year, there were issues with the CNG fueling station that needed to be addressed before on-site usage could proceed. During that time, the Districts utilized the CNG fueling station that was installed at Smith Ranch Road and is supplied by Pacific Gas & Electric Company (PG&E) natural gas. The time-fill RCNG fueling station located at the wastewater treatment plant is now operation.

During the 12-month period, the microturbines continued to operate with no issues directly related to their performance. Microturbine shutdowns were the result of electrical malfunctions or digester upsets.

Operational Costs and Savings

The BERS generates electricity for the on-site electrical grid. The savings from the electrical generation is not tracked by the District through its PG&E billing because the individual electrical generation components across the site are aggregated on the bill, making it impossible to distinguish what cost savings is generated by which electrical generation equipment (e.g., the District also operates a solar farm). However, based on the data collected of the kW of electricity generated by the microturbines during the 12 months of operation, it can be estimated that the site saved approximately $53,000 over the 12-month period. This is based on the assumption that the site pays $0.12 per kWh and an average per month electrical generation by the microturbines is 36,522 kWh per month (438,264 kWh per year). In addition, because the hot water heating loop receives sufficient heating supply from the microturbines, there is no need for supplemental heat from a non-renewable resource (natural gas, propane, etc.). The site has not been utilizing a non-renewable resource for its heating supply prior to the BERS since an IC engine was onsite and generating heat for the hot water loop; therefore, no operational savings are assumed for the heat generated by the microturbines.

There are operational costs for the BioCNG gas conditioning skid. The BioCNG staff made an initial site visit and then will provide two semi-annual site visits per year to perform operations and maintenance for the system. In addition, the BioCNG contract includes remote on-call assistance to help the District personnel and to remotely access the system to adjust controls. This contract with BioCNG is $20,000 per year, which includes the initial site visit that will not be needed in the following years of operation.

Replacement of media in the BioCNG skid is the greatest operational cost. The site has not yet had any media change outs but is planning for the siloxane removal media in Spring 2019. The costs for the media itself are approximately $2,000; the site operations will perform the media replacement. There will be costs associated with disposal of the media as well. In addition, monthly gas testing is performed to determine siloxane bleed through. This testing is performed every month at a cost of $180 per report. Within two years, it is anticipated that staff will need to replace the hydrogen sulfide removal media. Costs are not known at this time but are estimated to be approximately $10,000 for one media change out.

The District did not hire additional personnel to operate the system; existing on-site operators were trained to provide daily oversight, system adjustments, and data download. There are no additional costs associated with labor for operating the system.

Maintenance of the microturbines systems is addressed under a system maintenance agreement for the site. This agreement is a yearly cost of $11,000. The District is currently in a five-year contract with CAL Microturbine to perform this service agreement.

Biogas Production

The following bullet points were proposed as project expectations in the original proposal to the CEC. Following the bullet point is a summary of the actual performance of the BERS regarding that project expectation.

- **42,480 scf per day of CDG**

Based on the 12-month data collection, the average daily production of CDG was 35,080 scfd. The average production of raw digester gas was 45,450 scfd. At the initial set-up of the BERS, digester gas production was as low as 17 scfm. Prior to full start-up and the beginning of the 12-month period of data collection, the improvements to the digesters were completed and glycerin loads were received at the site.

The amount of digester gas that was not conditioned to CDG went to the waste gas burner. The utilization of digester gas in the waste burner ranged from two to 35 percent of the hourly flow over the course of the year. Several factors lead to the continued use of the waste gas burner:

- There were several weeks when the digesters were having difficulty and inconsistent digester gas production disabled the microturbines from being operational. Therefore, the remaining digester gas that was not utilized in the existing boiler for production of heating supply to the digester hot water loop was destroyed in the waste gas burner.
- The waste gas burner is currently operating on a continuous pilot set-up, which requires a small portion of digester gas to be supplied to the waste gas burner so it is ready to operate should the microturbine(s) shutdown. To eliminate the constant pilot, the site must have the waste gas burner manufacturer visit the site to change over the operation from a continuous pilot to one that is initiated on pressure. This would mean resetting the operation of the waste gas burner so that a pressure switch upstream of the waste gas burner would signal to the control panel that an increase in pressure resulting from incoming gas flow is present and the waste gas burner must ignite. Changing over the waste gas burner mode of ignition would increase system efficiency and increase the production of CDG. In its efforts to continue to increase the output and efficiency of the system, the District is in the process of changing the flare pilot system operation.

- **1,512 scf per day for RNG supplemental heat requirements**

There was no need for supplemental heat to be supplied by the RNG boiler; therefore, this performance goal was not met as it was not necessary. The microturbines provide sufficient heating to the digesters' hot water heat loop, supplying approximately 240 MMBtu/month. This would equate to a digester gas flow rate of approximately 393,445 scf per month at a heating value of 610 Btu/cf diverted to the RNG system.

Improvements in the digesters and the digester pumping system increased the heating efficiency and ability to retain heat in the digester system, thereby lowering the need for heating demand that would need to be supplied by supplemental heat from the RNG boiler. The ability to supply the full heating demand through the operation of the microturbines provides more CDG to be available for electrical generation and RNG for vehicle fuel.

- **6,048 scf per day of RCNG**

The average RCNG produced per day over the 12-month period was 196 scfd. Early in the 12-month period, there was insufficient digester gas production to produce RCNG. The focus was to continuously operate the microturbines on digester gas. During this time, the CNG truck at the site utilized the fast-fill station located at the Smith Ranch Fueling Station that is supplied natural gas by PG&E.

A leak in the RNG storage tank led to more delays in producing RCNG since there was no ability to store it for use in the time-fill RCNG fueling station. During testing of the slow-fill RCNG station, the storage tank was utilized, and the leak discovered. During the time period of emptying the tank and repairing the leak, no RCNG was produced.

In the later months of the year, a transformer malfunctioned and a short time after there was an upset with the digester. The decrease and inconsistency in digester flow required that the digester gas prioritize use in the microturbines since a back-up CNG supply existed at the Smith Ranch fueling station.

- **100 percent methane utilized**

The closed-loop system is operational and works to eliminate the need for flaring of tail gas from the production of RNG. During conditioning of the digester gas to RNG, the gas conditioning skid uses membranes for the removal of carbon dioxide, whereby tail gas (containing some methane) is generated. As previously discussed, this tail gas is rerouted to the front-end of the system for combustion in the microturbines.

However, reducing the full potential of 100 percent utilization is the use of the waste gas burner. As previously mentioned, the waste gas burner is currently operating on a continuous pilot set-up, which requires a small portion of digester gas to be supplied to the waste gas burner, so it is ready to operate should the microturbine(s) shutdown. The site is planning to eliminate this mode of operation so that the waste gas burner operation is initiated by pressure and does not require a continuous pilot gas of CDG.

While production of RNG was minimal during the 12-month period, operation of the RNG portion of the BERS showed that it is possible to operate the closed-loop system with no tail gas flaring necessary while the microturbines are also in operation. The system can successfully operate with 100 percent methane utilization.

Emission Reductions

The emissions analysis was prepared based on a comparison between the previous equipment operations and the new BERS equipment. For both the previous and existing operational scenarios, an assumed average flow rate of 35 scfm is used which is based on the design intent for the project.

For the previously existing system, the emissions are based on the operation of the Waukesha IC engine, the existing boiler, and the existing waste gas burner. The emissions factors for the equipment are based on the previous PTO for the IC engine, which also included the existing boiler and the waste gas burner.

Assumptions for the previous system operations included:

- The waste gas burner, IC engine, and boiler operate 8,760 hours per year at their respective flow rates.

The estimated emissions from the BERS is based on the operation of two microturbines and the existing waste gas burner. Because the site SCADA system does not automatically track any use of the existing boiler, and because it was not readily used after adjustment of the microturbines, any potential emissions from the existing boiler were not included in the emissions analysis. Additionally, because the emissions calculations are based on 12 months of operational data and the CNG truck and RNG boiler were not consistently used (or not used at all in the case of the RNG boiler) during that 12-month period, the reduction in emissions based on the CNG truck operating on CNG instead of diesel, were not included in these estimates. For information on the emissions reductions resulting from the transition of the District's flusher truck from diesel to CNG, refer to the final report prepared by Cornerstone for Agreement ARV-15-038 with the CEC under the "Natural Gas Fueling Infrastructure Installation Project."

Assumptions for the current system operations include:

- The waste gas burner operates 8,760 hours per year at 3 scfm.
- Microturbine 1 and 2 each operate for a total of 8,760 hours per year, with each piece of equipment operating off of half of the remaining available flow rate (approximately 16 scfm each).
- The use of the RNG boiler or CNG truck was not included in emissions reductions.
- The operation of the existing boiler was assumed to be zero as it was operated a negligible amount of time during the 12 months.

In comparing the previous operations to the current operations, it is key to note that the same fuel – digester gas – was utilized in the previous and current scenarios. Therefore, reduction in emissions GHGs such as carbon dioxide and methane are minimal because the emissions factors are heavily based on the fuel utilized and heat input (flow rate and heating rate of the fuel) and not the control devices used in combustion. The emissions factors are based on the

United States Environmental Protection Agency references provided by 40 Code of Federal Regulations (CFR). Furthermore, the significant reduction in methane for the IC engine is most likely overestimating the methane emissions from the IC engine. This is because detailed emissions information is not available for the IC engine, the potential to emit under the "organics" category of the PTO is used for the methane emissions. The PTO has an "organics" category for emissions that is the summation of Precursor Organic Compounds/Volatile Organic Compounds/Reactive Organic Compounds. Because the individual breakdown of the contributing compounds is not available, the "organics" category for the IC engine is conservatively assumed to be methane only.

The reduction in pollutants is most greatly seen in the criteria pollutants of NO_x, sulfur dioxide (SO_2), particulate matter (PM), and carbon monoxide (CO). The IC engine was operating with 1980's technology and would no longer meet BAAQMD regulatory requirements. The reduction in emissions between the IC engine and the microturbine highlights how combustion technology has improved over the years. The following tables show the reduction in emissions between the previous and current operational scenarios (Tables 2 through 4).

Table 2: Previous Operational Devices and Associated Daily Emissions

Device	Flow (scfm)	CH_4 (lbs/day)	SO_2 (lbs/day)	NO_x (lbs/day)	PM_{10} lbs/day	CO lbs/day
Waukesha Engine Model F1197G	24	40.9	10.9	99	0.35	25.1
Existing Boiler	8	0.04	0.100	0.001	0.021	0.002
Digester Gas Flare	3	0.34	0.80	2.85	0.24	9.50
Totals:	**35**	**41.27**	**11.80**	**101.85**	**0.62**	**34.61**

Notes:

- Emissions for Waukesha Engine Model F1197G provided by the BAAQMD as lbs/day (pounds per day) in the facility Permit-to-Operate dated August 30, 2014.
- Emission factors for Existing Boiler derived from BAAQMD issues PTO. Factors include - 900,000 Btu/hr in the air permit; and 0.0 NOx lbs/day; 0.1 SO_2 lbs/day; and 0.1 CO lbs/day from the PTO. Organics are calculated based on GHG emissions calculations.
- Digester Gas Flare emission factor for CH_4 derived from 40 CFR 98, Subpart C, General Stationary Fuel Combustion Sources Table C-1. Emission factor for NOx derived from 2013 Source Test of the Digester Gas Flare. Emission factor for SO_2 derived from a concentration of 300 ppm (parts per million) H2S as outlined in Table 6-2, Air Quality Assessment Report Dry Fermentation Anaerobic Digestion Facility, Sierra Research, Inc. 2011. Operations assumed 8760 hours per year.

Source: Las Gallinas Valley Sanitary District

Table 3: Current Operational Devices and Associated Daily Emissions

Device	Flow (scfm)	CH_4 (lbs/day)	SO_2 (lbs/day)	NO_x (lbs/day)	PM_{10} lbs/day	CO lbs/day
Microturbine 1	16	0.05	0.75	0.72	0.09	6.20
Microturbine 2	16	0.05	0.75	0.72	0.09	6.20

Device	Flow (scfm)	CH_4 (lbs/day)	SO_2 (lbs/day)	NO_x (lbs/day)	PM_{10} lbs/day	CO lbs/day
Digester Flare	3	0.34	0.80	2.85	0.24	9.50
Totals:	**35**	**0.43**	**2.30**	**4.29**	**0.42**	**21.90**

Notes:

- Microturbine emissions factor for NOx per manufacturer's specifications for digester gas. Emission factor for SO_2 derived from peak H2S concentration of 197 ppm. Emission factor for CH_4 per Capstone Microturbine System Emissions Technical Reference Sheet. Emissions calculated under assumption that microturbines are operational for 8,760 hours per year.
- Digester Gas Flare emission factor for CH_4 derived from 40 CFR 98, Subpart C, General Stationary Fuel Combustion Sources Table C-1. Emission factor for NOx derived from 2013 Source Test of the Digester Gas Flare. Emission factor for SO_2 derived from a concentration of 300 ppm H2S as outlined in Table 6-2, Air Quality Assessment Report Dry Fermentation Anaerobic Digestion Facility, Sierra Research, Inc. 2011. Operations assumed 8760 hours per year.

Source: Las Gallinas Valley Sanitary District

Table 4: Calculated Reduction in Emissions from Previous to Current Operations

	CH_4 (lbs/day)	SO_2 (lbs/day)	NO_x (lbs/day)	PM_{10} lbs/day	CO lbs/day
Previous Operations	41.27	11.80	101.85	0.62	34.61
Current Operations	0.43	2.30	4.29	0.42	21.90
Calculated Change	**-40.85**	**-9.50**	**-97.57**	**-0.19**	**-12.70**

Source: Las Gallinas Valley Sanitary District

Economic and Community Benefits

While projects of this type have the potential for job creation, no permanent jobs were developed at the site for the BERS. The existing on-site personnel were trained to operate the system and provide equipment modifications through the system control panel. In addition, there was not any expected increase in state revenue because of the project. Furthermore, the District does not plan on expanding the facility which would most likely require the hiring of at least one new employee whose full-time responsibilities would be to maintain and operate the BERS.

However, as part of the construction activities, there were temporary jobs created. The general contractor was Western Water. The total construction cost based on the final invoice received from Western Water was $2,564,585. Because the labor and material charges are not listed separately on the invoice, the assumption is made that half of the total cost is resulting from labor charges, approximately $1,282,290. Based on a prevailing wage rate of $50 per hour (the average between the high- and low-end ranges of prevailing wage straight-time hourly rates issued for Northern California in February 2018), there were approximately 25,646 hours of labor time for the project (DIR, 2018). Western Water had personnel onsite a total of 317 days as indicated by their invoice. The number of laborers per day is not available and would have varied depending on the type of activity being completed. In addition, materials that were used in the construction of the system could have been manufactured in California, thereby creating a demand for manufacturing labor at these facilities.

In general, renewable energy projects generate increased revenue for the state through local and state taxes on the purchase of equipment and materials for the construction of the system, engineering design, permitting, and construction activities. In California, tax exemptions are available on the purchase of manufacturing equipment that are used to manufacture "Alternative Source products" such as biofuels. The District received a tax exemption on the microturbines, gas conditioning skid, and the purchase of construction materials under the California Alternative Energy and Advanced Transportation Financing Authority Manufacturing Sales and Use Tax Exclusion Program. While taxes were not generated through the purchase of those materials, state revenue was generated through the taxes received on the construction labor, engineering efforts and permitting fees.

Operational Challenges

During the design, construction, and operation of the BERS, challenges were encountered and after some brainstorming, were resolved. After analyzing the 12 months of data, there are some areas for improvement that were identified that would increase overall system efficiency:

- The District should retain the services of the flare manufacturer to eliminate the need for a constant pilot to the waste gas burner. This would allow all of the digester gas to be prioritized to the microturbines/RCNG without compromising the functionality of the waste gas burner as an on-call destruction device under emergency conditions.
- Early in the data collection process, the SCADA consultant had not yet completed their programming work, making the retrieval of data cumbersome and inefficient. The data collected from January through May was in a format that required back calculating some parameters because of a lack of clarity in the data. The data retrieval process is much more streamlined now and clearer to review and analyze. As a lesson learned, it would benefit future projects to have the SCADA consultant work closely with the engineers to prepare a program that is easy to retrieve and analyze the data.
    - Other data collection issues include:
        - The flow meter of the existing boiler has no connection to SCADA, so the flow rate to the equipment is not recorded automatically, but rather by hand. This information is not easily retrievable for data analysis and an assumption was made in the calculations to back-calculate the flow rate that was going to existing boiler.
        - The total gas flow meter reading is typically slightly higher/lower than the sum of the other three flow meters (CDG, waste gas burner, RNG). Therefore, the data collection sheets include a box titled "Gas Unaccounted For." Per the District, the gas that is unaccounted for likely does not exist and is just an over measurement from the total gas flow meter. The site should have the total digester gas flow meter calibrated to provide a more accurate evaluation of the system's efficiency. (This bullet is discussed

further in the following bullet points.) Per the manufacturer recommendations, at a minimum, the flow meter should be calibrated annually.

- The gas quality during the first few months of operation was lower than anticipated (58 percent methane) which decreased the efficiency output of the system. After a few months of the digester recovering from maintenance downtime, receipt of glycerin loads, and locating and eliminating an air line that was leaking ambient air into the digester, it was confirmed through laboratory testing that the methane content increased to 61 percent methane.
- Because of low digester flows early in the project, only one microturbine was able to run continuously. To avoid intermittent shutdowns of the second microturbine, it was decided that one microturbine would operate at a time until flows could be increased. Increases to flow occurred after the digester was completely up and running after downtime from repairs and following receipt of glycerin for boosting digester gas production. However, the District has decided to operate one microturbine at a time, transitioning between microturbines every two weeks.
- The District was not able to obtain an accurate reading with the total digester gas flow meter. Based on information received from the District, prior to the existing Kurz model, the site used a Fluid Components International (FCI) flow meter. This FCI flow meter was the same brand, but different model as the one measuring microturbine flow which provides an accurate reading. When the FCI was in service, it would typically read around 17 scfm, which at the time was accurate for the low flow condition. In August 2017, the District replaced the FCI flow meter with the current Kurz flow meter. The Kurz flow meter at times reads more than double the flow than the previous FCI flow meter readings.

  Reviewing the current 24-hour trend and during steady gas production, the Kurz total digester gas flow meter is reading approximately 32 scfm and the waste gas burner reads 0.2 scfm. During periods of the day when digester gas production is strong, the Kurz total digester gas flow meter reads approximately 35 scfm and the waste gas burner reads approximately three scfm. During steady and strong gas production periods, the microturbine is drawing 22-25 scfm. According to the District, at any given time there is a spread of approximately 10 scfm that cannot be accounted for. This leads to inaccurate calculated efficiency since the total flow rate is reading higher/lower than that which is utilized by the system, which creates uncertainty in the available flow. This uncertainty also restricts the District to only operate one microturbine at a time to avoid potential low-flow shutdown of a microturbine.

  The District is unsure the reason for the discrepancy in the flow meter readings. A technician needs to be called to the site for flow meter calibration, ensuring that all the flow meters are properly calibrated to eliminate any question on which meter is causing issues. The unaccounted digester gas flow is not going to the boiler (the existing boiler flow meter is not connected to the SCADA system; therefore, the flow is not reviewable from the data collection, but it is manually monitored). Furthermore, the District has not used the existing boiler as a heat source for several months, ever since Cal Microturbine adjusted the temperature settings on the microturbines to heat the hot water loop to an appropriate level to heat the digester. The unaccounted digester gas is a result of inaccurate flow measurement causing the gas numbers to not add up correctly.

CHAPTER 5: Conclusion and Recommendations

Conclusions

Notwithstanding some hurdles overcome during the course of the project, the BERS is now a continuously functioning system, fully integrated into the day-to-day operations at the District's site. The BERS is an example to other wastewater treatment facilities in California that despite the relatively small nature of the project (only operating with approximately 32 scfm) the output of the system is significant. Considering the economy of scale for larger facilities, the project represents the potential options for biogas utilization from WWTPs.

Recommendations

Some key recommendations developed from lessons learned during the design and construction of the facility, include:

Biogas Utilization Study

Prior to the start of design and construction, a feasibility report was provided to the team that was prepared by others. The report was based on conditions that had changed at both the site and in the WWTP and biogas utilization industry. Despite the thoroughness of the report, it is recommended for future designers that test data and proposed cost estimates are verified before taking a feasibility report for face value. One particular issue that was encountered because of the information provided was: 1) not accounting for potential funding opportunities in the cost estimates thereby overestimating the proposed total project costs; and 2) quantity of biogas available for project usage was overestimated based on faulty instrumentation readings.

In the end, grant funding that was awarded covered approximately 20 percent of the total project costs, which could make or break the decision to proceed with a project.

In addition, after site improvements, the biogas quantity did increase to the flow rate presented in the report, but significant oversizing of project equipment, or a completely failed project could have resulted from the misinformation. Verifying the quantity and quality of biogas before and during the project to ensure that consistency is occurring at the site is vital for project success. A laboratory testing or monitoring program should be implemented at the onset of the project and continue through the operation of the system to ensure that the digesters are operating in accordance with project specifications. Furthermore, equipment such as flow meters and pressure gauges, which are providing system operational data must be calibrated at the beginning of the project to ensure that accurate information is being used as the basis for equipment sizing.

Avoid Accelerated Design and Construction Schedules

Due to the requirement of replacing the IC engine at the site, the construction timeline was significant shortened. There was a rush at the beginning of the project and then a long lull before start-up because of the digester improvements. Firstly – avoid accelerated design and construction schedules because they can increase projects costs and or reduce project quality. Design decisions can be hastily made that are not ideal for the long-term operation of the system since the team is looking at a very short-time frame to work within. In addition, project quality can decrease because of the need to install multiple portions of the project in a short timeframe. Furthermore, cost increase tactics and change orders can quickly become part of an accelerated timeframe that would not necessarily come into play with a longer timeline for construction.

In addition, if any improvements are planned that would interrupt the continuous operation of the new system, or impact the construction of the project, they should ideally be planned for beforehand. This will avoid system start-up delays while also making sure that new equipment and system piping are integrated in the most efficient manner with the new site improvements.

Research Other Projects

Researching the types of challenges other projects faced during design, construction, or operation is key to avoiding the same mistakes. Information reports, such as this one, are excellent sources of potential hurdles that a project may face. This is especially true in the relatively new field of biogas utilization where off the shelf, everyday projects, are not common.

During the initial design phase of the project, the team was hesitant to utilize microturbines because of some project information that made them appear unfavorable. Several projects were reviewed, and conversations were had with the manufacturer to ensure that any issues that had been common in the past were addressed.

Facility Location Considerations

When considering the project layout, key aspects of equipment placement that need to be considered:

- Does the equipment have the required buffer areas around it per manufacturer recommendations and to meet the applicable codes (i.e., electrical, plumbing)?
- Will there be modifications to the plant in the future that may adversely affect the system location?
- The placement of equipment needs to be coordinated so that pieces that require more significant machinery for placement, like cranes, can access the area.
- Placement needs to take into consideration the need for potential placement, maintenance, and media change-outs.

Need for Knowledgeable Facility Operators

It is key that at least one (if not two) site personnel become the point of contact who are familiar with the operations and equipment of the site. These individuals will become the ones knowledgeable on the new system equipment and will help to quickly identify problems should they arise in the future. In the case of the BERS, when air intrusion was identified, there were difficulties identifying where the potential source could be coming from. The go-to on-site person was quickly able to run down a list of potential air sources, thereby, identifying an eliminating the air intrusion. This should be the same person/people that become familiar with the new system, so they can understand the integration of the two and identify potential problems.

Integration of State-of-the-Art Equipment in an Older Facility

Integration of older facility equipment and systems with the newer equipment can create challenges for seamless integration between the two systems. For example, the main electrical panel that was being reconfigured to work with the new electrical for the hot water loop pumps required the contractor to obtain wire buckets that could be utilized in the older system. Furthermore, integrating the new and old hot water loop components together decreased the efficiency of the system. It would have been advantageous for a full reconfiguration of the hot water loop system to be completed during the construction process.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
BAAQMD	Bay Area Air Quality Management District
BERS	biogas energy recovery system
Btu	British thermal unit
Btu/hr	British thermal units per hour
CDG	conditioned digester gas
CEC	California Energy Commission
CEQA	California Environmental Quality Assessment
CFR	Code of Federal Regulations
CHP	combined heat and power
CNG	compressed natural gas
CO	carbon monoxide
District	Las Gallinas Valley Sanitary District
FCI	Fluid Components International
GEM	biogas meter
GHG	greenhouse gas
IC	internal combustion
ICHP	internal combined heat and power
kW	kilowatt
kWh	kilowatt-hour
lbs/day	pounds per day
MMBtu/hr	million British thermal units per hour
NO_x	oxides of nitrogen
PG&E	Pacific Gas and Electric
PM	particulate matter
POC	precursor organic compounds
ppm	parts per million
psig	pounds per square inch gauge
PTO	Permit to Operate
RCNG	renewable compressed natural gas
RNG	renewable natural gas
SCADA	supervisory control and data acquisition

Term	Definition
scfd	standard cubic feet per day
scfm	standard cubic feet per minute
SO_2	sulfur dioxide
Mesophilic	Functioning within a temperature range to optimize anaerobic digestion with bacteria that grow and thrive in a medium temperature range. For anaerobic digestion, this range is from 85°F (30°C) to 100°F (38°C) (Sacramento State University, 2019).
VOC	volatile organic compound
WWTP	wastewater treatment plant

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ENERGY RESEARCH AND DEVELOPMENT DIVISION

Appendix A: Monthly Operations Summary

May 2024 | CEC-500-2024-050

APPENDIX A: Monthly Operations Summary

Appendix A, Monthly Operations Summary, provides an overview of the 12 months of operational data from the operation of the Las Gallinas Valley Sanitary District (District) Biogas Energy Recovery System (BERS). The BERS was operational in December 2017, with data collection beginning in January 2018. The 12-month collection of data is from January through December of 2018. This Appendix provides a summary of data collection during that period with a brief narrative on any equipment or system stoppages/challenges encountered for the month that would have resulted in decreased system output. A more detailed data analysis and conclusions of the 12 months of operational data is presented in Appendix B, Data Analysis Summary.

Since the beginning of system operations and during continued operations, the BERS has been operating in compliance with the regulatory requirements established under its Permit to Operate (PTO) issued by the Bay Area Air Quality Management District (BAAQMD). The BERS did not receive any Notice of Violation or initiate any request for variances during the 12-month operational period.

Data Collection

Cornerstone previously provided monthly progress reports to the CEC in accordance with the scope of work within the Agreement between the District and the CEC dated May 29, 2015. Each progress report included mention of any system operational issues and the estimated monthly production of digester gas, conditioned digester gas (CDG), renewable natural gas (RNG), and renewable compressed natural gas (RCNG), as well as electrical and heating generation from the microturbines. The monthly data analysis tables are provided as an attachment to this Appendix.

After the SCADA consultant revised the data retrieval reports, the actual output information was available for most of the data collection information, including the total digester flow, total kW generated by each of the microturbines, total scfm to the waste gas burner, and the combined total scfm of CDG that went to the microturbines.

Some of the system parameters are not collected because of lack of instrumentation or the set-up of the data retrieval report, therefore the values were estimated based on the following back-calculations:

- **Runtime per microturbine** – If kW were generated by the microturbine for the day, it was assumed that it operated 1440 minutes for that day. Total run time was a summation of each day of 1440 minutes.
- **kWh per microturbine** – The kWh generated by the microturbine was back-calculated based on the total kW generated by the microturbine for the day assuming the microturbine operated for 24 hours in a day.

- **Heat output per microturbine** – The heat output from the microturbines is not collected through the SCADA, but to completely disregard the heat output would be to not take into consideration all the components of system efficiency. Therefore, to calculate the heat output, the runtime of the microturbine in hours (minutes/60) was multiplied by 0.42 million British thermal units per hour (MMBtu/hr) to calculate the MMBtu heat output for the month for each microturbine. The 0.42 MMBtu/hr is from the Capstone datasheet. The 0.42 MMBtu/hr is the full heating potential of the micro-turbine and the site is not operating at full heating potential. However, there is no basis for selecting a factor to reduce the heat output by to account for not utilizing the full heat output. The highlighted cells in Table A-1 indicate where values were above the 12-month average. The months with the highest efficiency, also had the highest heat output.

System Operations

During this 12-month period, use of the RNG and RCNG was minimal. First, the District did not need the use of RNG in the on-site boiler because the microturbines were providing sufficient heating supply to the hot water heat loop for digester temperature control. Second, the CNG fueled truck was in and out of commission, therefore RCNG was not needed onsite.

For the first half of the year there were issues with the CNG fueling station that needed to be addressed before on-site usage could proceed. During that time, the District utilized the CNG fueling station that was installed at Smith Ranch road and is supplied by PG&E natural gas. The time-fill RCNG fueling station located at the wastewater treatment plant is snow operation.

System Upsets

In the monthly progress reports, system status was provided to highlight any issues that affected the overall efficiency and system output of the BERS. The system upsets are summarized below:

- January - The RNG storage tank was unable to store RNG because of a leak which was to be addressed by Western Water (general contractor) and the District. BioCNG did confirm that RNG could be produced, and with laboratory sampling confirmed a minimum 93 percent methane content.
    - The format of the data output report during this month made it difficult to analyze the data; the site SCADA consultant was working to address the retrieval format.
    - During this period only one microturbine had been fully operational. This was being done to ensure a smooth continuous operation of the system while the digesters got back up to full gas production after being down for maintenance.
    - The site was accepting loads of glycerin to boost gas production.

- February - The RNG storage tank was unable to store RNG because of a leak which was to be addressed by Western Water and the District.
  - The format of the data output report during this month made it difficult to analyze the data; the site SCADA consultant was working to address the retrieval format.
  - During this period only one microturbine had been fully operational. This was being done to ensure a smooth continuous operation of the system while the digesters got back up to full gas production after being down for maintenance.
  - The site was accepting loads of glycerin to boost gas production.
- March - The RNG storage tank was unable to store RNG because of a leak which was to be addressed by Western Water and the District.
  - The format of the data output report during this month made it difficult to analyze the data; the site SCADA consultant was working to address the retrieval format.
  - The site was accepting loads of glycerin to boost gas production.
- April - The RNG storage tank was unable to store RNG because of a leak which was to be addressed by Western Water and the District.
  - The format of the data output report during this month made it difficult to analyze the data; the site SCADA consultant was working to address the retrieval format.
  - The site was accepting loads of glycerin to boost gas production.
- May – While the RNG storage tank leak has been addressed, the time-fill RNG station and RNG boiler were not operational at this time. The time-fill fueling station manufacturer needed to come to the site to initiate start-up and on-site training. The SCADA consultant addressed the data retrieval format issues which created an easier format for the data output report to be reviewed. No other system issues.
  - Even though May had relatively low scfm, because the site ran one microturbine 24/7 and another for 13 days, the heat output contributes significantly to the system efficiency based on how the heat output is calculated.
- June - The RNG boiler was not operational at this time due to a faulty pressure regulating valve; however, the use of the RNG boiler was not needed because sufficient heating was supplied by the microturbines. No other system issues.
- July - The time-fill RNG station was not used at this time because the CNG truck was out of commission; however, start-up has been completed for the time-fill station so it is ready once the CNG truck is in commission. The RNG boiler was not being used because of the faulty pressure regulator that is waiting to be replaced; however supplemental heating is not needed from the RNG boiler at this time. No other system issues.

- August - The time-fill RNG station was not used at this time because the CNG truck was out of commission. The RNG boiler was not being used because of the faulty pressure regulator that is waiting to be replaced; however supplemental heating is not needed from the RNG boiler at this time. No other system issues.
  - Only one microturbine was operated during this month at almost full capacity. Microturbine #1 has a loss of communications shutdown alarm and could not communicate with the Unison panel. CalMicroturbine came to the site to replace a wiring harness which fixed a communications problem.
  - The site typically will only operate one microturbine at a time and rotate the In-Service unit every week or two.
- September - The RNG boiler was not being used because of the faulty pressure regulator that is waiting to be replaced; however supplemental heating is not needed from the RNG boiler at this time. Data assumes 17 days of operation in the month of September because the system was not operational for 13 days due to a transformer failure. The system was up and running after 13 days.
- October - The RNG boiler was not being used because of the faulty pressure regulator that is waiting to be replaced; however supplemental heating is not needed from the RNG boiler at this time.
- November – The RNG boiler was not being used because of the faulty pressure regulator that is waiting to be replaced; however supplemental heating is not needed from the RNG boiler at this time. Data assumes 24 days of operation due to sludge feeder downtime and system shutdown related to those digester issues.
- December – The RNG boiler was not being used because of the faulty pressure regulator that is waiting to be replaced; however supplemental heating is not needed from the RNG boiler at this time. There was a digester upset which lowered gas production. Due to the low gas flow, the site had to shut down the microturbines. After the digester was back to normal health, the microturbines were unable to start until Capstone visited the site in mid-December.

Table A-1: Monthly Data Summary Table

	Total Digester Gas Production (scf/month)	Average SCFM Digester Production (scfm)	CDG Produced and Utilized in Microturbines (scf/month)	Waste Gas Burner (scf/month)	Electricity Produced from Microturbines (kw-h)	Average kw based on both Microturbines (kw)	Total Microturbine Runtime (min)	Heat Produced from Microturbines* (MMBTU)	RNG Produced (scf/month)	RNG DGE per Month (DGE)	System Efficiency (%)
January	1,633,997	37	1,633,997	NA	48,360	33	44,640	312	-	-	50%
February	1,400,082	35	1,400,082	NA	43,680	33	40,320	282	-	-	53%
March	1,458,452	33	868,131	NA	35,880	29	66,240	464	-	-	69%
April	1,415,096	34	879,455	535,641	36,696	31	54,720	383	-	-	62%
May	1,111,319	25	1,017,368	93,951	42,048	30	63,360	444	-	-	91%
June	1,291,317	30	1,126,212	162,172	42,624	44	51,840	363	2,933	22	68%
July	1,582,370	35	1,420,370	162,000	42,312	44	56,160	393	-	-	56%
August	1,453,034	33	1,420,370	32,664	42,408	29	44,640	312	-	-	52%
September	976,792	40	620,163	345,306	19,296	31	30,240	212	11,323	83	48%
October	1,540,641	35	1,138,577	26,270	45,312	53	50,400	353	15,815	116	56%
November	1,304,381	38	861,570	26,270	31,200	47	40,320	282	40,574	298	54%
December	1,193,005	27	241,557	280,893	8,448	16	15,840	111	-	-	47%
Monthly Average over 12-months	1,363,374	33	1,052,321	185,019	36,522	35	46,560	326	5,887	43	59%

* Assumed BTU/cf of 950.
SCFM - Standard Cubic Feet per Minute
CDG- Conditioned Digester Gas
kw-h - kilowatt-hour
MMBTU- Million British thermal units
DGE- Diesel Gallon Equivalents
NA - Information not available
Highlighted cells have values that were greater than the 12-month average.

Operational Costs

The BERS generates electricity for the on-site electrical grid. The savings from the electrical generation is not tracked by the District through its PG&E billing because the individual electrical generation components across the site are aggregated on the bill, making it impossible to distinguish what cost savings is generated by which electrical generation equipment (e.g., the District operates a solar farm). However, based on the data collected of the kw of electricity generated by the microturbines during the 12 months of operation, it can be estimated that the site saved approximately $53,000 over the 12-month period. This is based on the assumption that the site pays $0.12 per kwh and an average per month electrical generation by the microturbines is 36,522 kwh per month (438,264 kwh per year). In addition, because the hot water heating loop receives sufficient heating supply from the microturbines, there is no need for supplemental heat from a non-renewable resource (natural gas, propane, etc.). The site has not been utilizing a non-renewable resource for its heating supply prior to the BERS since an internal combustion engine was onsite and generating heat for the hot water loop; therefore, no operational savings are assumed for the heat generated by the microturbines.

There are operational costs for the gas conditioning skid, the BioCNG unit. The BioCNG staff made an initial site visit and then will provide two semi-annual site visits per year to perform operations and maintenance for the system. In addition, the BioCNG contract includes remote on-call assistance to help District site personnel and to remotely access the system to adjust controls. This contract with BioCNG is $20,000 per year, which includes the initial site visit that will not be needed in the following years of operation.

Replacement of media in the BioCNG skid is the greatest operational cost. The site has not yet had any media change outs but is planning for the siloxane removal media in Spring 2019. The costs for the media itself are approximately $2,000; the site operations will perform the media replacement. There will be costs associated with disposal of the media as well. In addition, monthly gas testing is performed to determine siloxane bleed through. This testing is performed every month at a cost of $180 per report. Within two years, it is anticipated that staff will need to replace the hydrogen sulfide removal media. Costs are not known at this time but are estimated to be approximately $10,000 for one media change out.

The District did not hire additional personnel to operate the system; existing on-site operators were trained to provide daily oversight, system adjustments, and data download. There are no additional costs associated with labor for operating the system.

Maintenance of the microturbines systems is addressed under a system maintenance agreement for the site. This agreement is a yearly cost of $11,000. The District is currently in a 5-year contract with CAL Microturbine to perform this service agreement.

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Appendix B: Data Collection and Analysis Summary

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APPENDIX B: Data Collection and Analysis Summary

Appendix B, Data Collection and Analysis Summary, analyzes the throughput, usage, and operations data from the Las Gallinas Valley Sanitary District (District) Biogas Energy Recovery System (BERS) operations. This Appendix summarizes the project's biogas production; reduction in air emissions (specifically from methane (CH_4), hydrogen sulfide (H_2S), and oxides of nitrogen (NO_x); specific jobs or economic development resulting from this project; and the project's performance as compared to the project expectations presented in the original proposal to the California Energy Commission (CEC). The data analysis is based on the collection of twelve consecutive months of operational data.

The BERS was operational as of December 2017, with data collection beginning in January 2018. The twelve months of data are from January through December of 2018. Cornerstone Environmental Group, LLC (Cornerstone) previously provided monthly progress reports to the CEC in accordance with the scope of work within the Agreement between the District and the CEC.

Economic Impacts - Job Creation, Economic Development, and Increased State Revenue

While projects of this type have the potential for job creation, no permanent jobs were developed at the site for the BERS. The existing on-site personnel were trained to operate the system and provide equipment modifications through the system control panel. In addition, there was not any expected increase in state revenue because of the project. Furthermore, the District does not plan on expanding the facility which would most likely require the hiring of at least one new employee whose full-time responsibilities would be to maintain and operate the BERS.

However, as part of the construction activities, there were temporary jobs created. The general contractor was Western Water. The total construction cost based on the final invoice received from Western Water was $2,564,585. Because the labor and material charges are not listed separately on the invoice, the assumption is made that half of the total cost is resulting from labor charges, approximately $1,282,290. Based on a prevailing wage rate of $50 per hour (the average between the high- and low-end ranges of prevailing wage straight-time hourly rates issued for Northern California in February 2018), there were approximately 25,646 hours of labor time for the project (DIR, 2018). Western Water had personnel onsite a total of 317 days as indicated by their invoice. The number of laborers per day is not available and would have varied depending on the type of activity being completed. In addition, materials that were used in the construction of the system could have been manufactured in California, thereby creating a demand for manufacturing labor at these facilities.

In general, renewable energy projects generate increased revenue for the state through local and state taxes on the purchase of equipment and materials for the construction of the system, engineering design, permitting, and construction activities. In California, tax exemptions are available on the purchase of manufacturing equipment that are used to manufacture "Alternative Source products" such as biofuels. The District received a tax exemption on the microturbines, gas conditioning skid, and the purchase of construction materials under the California Alternative Energy and Advanced Transportation Financing Authority Manufacturing Sales and Use Tax Exclusion Program. While taxes were not generated through the purchase of those materials, state revenue was generated through the taxes received on the construction labor, engineering efforts and permitting fees.

Project Performance and Expectations

The following bullet points were proposed as project expectations in the original proposal to the CEC. Following the bullet point is a summary of the actual performance of the BERS regarding that project expectation.

42,480 standard cubic feet (scf) per day of Conditioned Digester Gas (CDG)

Based on the 12-month data collection, the average daily production of CDG was 35,080 scf. The average production of raw digester gas per day was 45,450 scf. At the initial set-up of the BERS, digester gas production was as low as 17 standard cubic feet per minute (scfm). Prior to full start-up and the beginning of the 12-month period of data collection, the improvements to the digesters were completed and glycerin loads were received at the site.

The amount of digester gas that was not conditioned to CDG went to the waste gas burner. The utilization of digester gas in the waste burner ranged from 2 to 35 percent over the course of the year. Several factors lead to the continued use of the waste gas burner:

- There were several weeks when the digesters were having difficulty and inconsistent digester gas production disabled the microturbines from being operational. Therefore, the remaining digester gas that was not utilized in the existing boiler for production of heating supply to the digester hot water loop was destroyed in the waste gas burner.
- The waste gas burner is currently operating on a continuous pilot set-up, which requires a small portion of digester gas to be supplied to the waste gas burner so it is ready to operate should the microturbine(s) shutdown. To eliminate the constant pilot, the site must have the waste gas burner manufacturer visit the site to change over the operation from a continuous pilot to one that is initiated on pressure. This would mean resetting the operation of the waste gas burner so that a pressure switch upstream of the waste gas burner would signal to the control panel that an increase in pressure resulting from incoming gas flow is present and the waste gas burner must ignite. Changing over the waste gas burner mode of ignition would increase system efficiency and increase the production of CDG. In its efforts to continue to increase the output and efficiency of the system, the District is in the process of changing the flare pilot system operation.

1,512 scf per day for supplemental heat requirements

There was no need for supplemental heat to be supplied by the renewable natural gas (RNG) boiler; therefore, this performance goal was not met as it was not necessary. The microturbines provide sufficient heating to the digesters' hot water heat loop, supplying approximately 240 MMTBU/month. This would equate to a digester gas flow rate of approximately 393,445 scf/month at a heating value of 610 Btu/cf diverted to the RNG system.

Improvements in the digesters and the digester pumping system increased the heating efficiency and ability to retain heat in the digester system, thereby lowering the need for heating demand that would need to be supplied by supplemental heat from the RNG boiler. The ability to supply the full heating demand through the operation of the microturbines provides more CDG to be available for electrical generation and RNG for vehicle fuel.

6,048 scf per day of renewable compressed natural gas (RCNG)

The average RCNG produced per day over the 12-month period was 196 scf. Early in the 12-month period, there was insufficient digester gas production to produce RCNG. The focus was to continuously operate the microturbines on digester gas. During this time, the CNG truck at the site utilized the fast-fill station located at the Smith Ranch Fueling Station that is supplied natural gas by PG&E.

A leak in the RNG storage tank led to more delays in producing RCNG since there was no ability to store it for use in the time-fill RCNG fueling station. During testing of the slow-fill RCNG station, the storage tank was utilized, and the leak discovered. During the time period of emptying the tank and repairing the leak, no RCNG was produced.

In the later months of the year, a transformer malfunctioned and a short time after there was an upset with the digester. The decrease and inconsistency in digester flow required that the digester gas prioritize use in the microturbines since a back-up CNG supply existed at the Smith Ranch fueling station.

100 percent CH_4 utilized

The closed-loop system is operational and works to eliminate the need for flaring of tail gas from the production of RNG. During conditioning of the digester gas to RNG, the gas conditioning skid uses membranes for the removal of carbon dioxide, whereby tail gas is generated. During the removal of carbon dioxide, a percentage of CH_4 is removed with and enters the carbon dioxide tail gas stream as well, generating a tail gas that has a potential concentration as high as 30 percent CH_4. In the BERS, the waste gas produced is returned to the front-end of the system for biogas conversion and, therefore, the CH_4 that was held back by the carbon dioxide membranes is circulated back to the front of the process train. Through on- and off-cycles of RNG production, wherein during the off-cycle all digester gas entering the system is conditioned and directed to the microturbines and destroyed, the system maintains a relatively consistent incoming digester gas composition despite the recirculation of the tail gas during on-cycles for RNG production. Therefore, the existing waste gas burner is only needed for emergency situations; there is no utility flare installed as part of this system for destruction of tail gas. As previously discussed, the waste gas burner is currently operating on a continuous pilot set-up, which requires a small portion of digester gas to be supplied to the waste gas burner so it is ready to operate should the microturbine(s) shutdown. The site is planning to eliminate this mode of operation so that the waste gas burner operation is initiated by pressure and does not require a continuous pilot gas of CDG.

While production of RNG was minimal during the 12-month period, operation of the RNG portion of the BERS showed that it is possible to operate the closed-loop system with no tail gas flaring necessary while the microturbines are also in operation. The system can successfully operate with 100 percent CH_4 utilization.

Throughput, Usage, and Operations Data

Table B-1 summarizes key parameters of the system operation. When no system upsets were present, the electrical and heating generation for the system operated continuously without interruptions and provided the site with electricity and sufficient heating to meet the demand of the digester hot water heat loop.

RNG production during the 12-month data collection period was minimal. This was due in part to the factors previously mentioned – leakage at the RNG storage tank and significant delay in repairing the leak; delay in start-up at the time-fill fueling station; and the CNG truck being out of commission.

Table B-1: Monthly Data Summary Table

	Total Digester Gas Production	Average SCFM Digester Production*	CDG Produced and Utilized in Microturbines	Waste Gas Burner	Electricity Produced from Microturbines	Average kw of Microturbine 1*	Average kw of Microturbine 2*	Total Microturbine Runtime (Combined Total)	Total Heat Produced from Microturbines **	RNG Produced ***	RNG DGE per Month	System Efficiency
	(scf/month)	(scfm)	(scf/month)	(scf/month)	(kw-h)	(kw)	(kw)	(min)	(MMBTU/month)	(scf/month)	(DGE)	(%)
January	1,633,997	37	1,633,997	NA	48,360	65	-	44,640	312	-	-	50%
February	1,400,082	35	1,400,082	NA	43,680	65	-	40,320	282	-	-	53%
March	1,458,452	33	868,131	NA	35,880	40	17	66,240	232	-	-	42%
April	1,415,096	34	879,455	535,641	36,696	49	12	54,720	237	-	-	44%
May	1,111,319	25	1,017,368	93,951	42,048	54	6	63,360	272	-	-	64%
June	1,491,733	35	1,126,212	162,172	42,624	56	32	51,840	327	2,933	22	55%
July	1,582,370	35	1,112,130	162,000	42,312	47	40	56,160	273	-	-	43%
August	1,453,034	33	1,133,302	36,918	42,408	57	-	44,640	274	12,982	95	49%
September	802,230	33	620,163	345,306	19,296	48	14	30,240	125	11,323	83	41%
October	1,540,641	35	1,138,577	26,270	45,312	56	50	50,400	293	15,815	116	49%
November	1,304,381	38	861,570	60,408	31,200	55	39	40,320	202	40,574	298	44%
December	1,193,005	27	241,557	280,893	8,448	32	-	15,840	55	-	-	40%
Monthly Average over 12-months	1,365,528		1,002,712	189,284	36,522	--	--	--	240	6,969	51	48%
Average Value Over Operational Days		33				43	15					

*The average value presented is calculated by dividing the total unit produced and dividing by the actual days that the system was operational over the course of the 12 months (345 days).
This is so account for the system operating in some months less than the actual number of days in a month.

** The total heat produced is based on the run time of the microturbines multiplied by the total potential heat output as a ratio of the average kW produced by the microturbine over the full potential (65 kW).

*** Assumed BTU/cf of 950.

SCFM - Standard Cubic Feet per Minute

CDG- Conditioned Digester Gas

kw-h - kilowatt-hour

MMBTU- Million British thermal units

DGE- Diesel Gallon Equivalents

NA - Information not available

Highlighted cells have values that were greater than the 12-month average.

Areas for Improvement

After analyzing the 12 months of data, there are some areas for improvement that were identified that would help with overall system efficiency:

- The District should retain the services of the flare manufacturer to eliminate the need for a constant pilot to the waste gas burner. This would allow all of the digester gas to be prioritized to the microturbines/RCNG without compromising the functionality of the waste gas burner as an on-call destruction device under emergency conditions.
- Early in the data collection process, the SCADA consultant had not yet completed their programming work, making the retrieval of data cumbersome and inefficient. The data collected from January through May was in a format that required back calculating some parameters because of a lack of clarity in the data. The data retrieval process is much more streamlined now and clearer to review and analyze. As a lesson learned, it would benefit future projects to have the SCADA consultant work closely with the engineers to prepare a program that is easy to retrieve and analyze the data.
    - Other data collection issues include:
        - The flow meter of the existing boiler has no connection to SCADA, so the flow rate to the equipment is not recorded automatically, but rather by hand. This information is not easily retrievable for data analysis and an assumption was made in the calculations to back-calculate the flow rate that was going to existing boiler.
        - The total gas flow meter reading is typically slightly higher/lower than the sum of the other three flow meters (CDG, waste gas burner, RNG). Therefore, the data collection sheets include a box titled "Gas Unaccounted For." Per the District, the gas that is unaccounted for likely does not exist and is just an over measurement from the total gas flow meter. The site should have the total digester gas flow meter calibrated to provide a more accurate evaluation of the system's efficiency. (This bullet is discussed further in the following bullet points.) Per the manufacturer recommendations, at a minimum, the flow meter should be calibrated annually.
- The gas quality during the first few months of operation was lower than anticipated (58 percent CH_4) which decreased the efficiency output of the system. After a few months of the digester recovering from maintenance downtime, receipt of glycerin loads, and locating and eliminating an air line that was leaking ambient air into the digester, it was confirmed through laboratory testing that the CH_4 content increased to 61 percent CH_4.
- Because of low digester flows early in the project, only one microturbine was able to run continuously. To avoid intermittent shutdowns of the second microturbine, it was decided that one microturbine would operate at a time until flows could be increased. Increases to flow occurred after the digester was completely up and running after downtime from repairs and following receipt of glycerin for boosting digester gas

production. However, LGSVD has decided to operate one microturbine at a time, transitioning between microturbines every two weeks.

- The District has not been able to obtain an accurate reading with the total digester gas flow meter. Based on information received from the District, prior to the existing Kurz model, the site used a Fluid Components International (FCI) flow meter. This FCI flow meter was the same brand, but different model as the one measuring microturbine flow which provides an accurate reading. When the FCI was in service, it would typically read around 17 scfm, which at the time was accurate for the low flow condition. In August 2017, the District replaced the FCI flow meter with the current Kurz flow meter. The Kurz flow meter at times reads more than double the flow than the previous FCI flow meter readings.
- Reviewing the current 24-hour trend and during steady gas production, the Kurz total digester gas flow meter is reading approximately 32 scfm and the waste gas burner reads 0.2 scfm. During periods of the day when digester gas production is strong, the Kurz total digester gas flow meter reads approximately 35 scfm and the waste gas burner reads approximately 3 scfm. During steady and strong gas production periods, the microturbine is drawing 22-25 scfm. According to the District, at any given time there is a spread of approximately 10 scfm that cannot be accounted for. This leads to inaccurate calculated efficiency since the total flow rate is reading higher/lower than that which is utilized by the system, which creates uncertainty in the available flow. This uncertainty also restricts the District to only operate one microturbine at a time to avoid potential low-flow shutdown of a microturbine.
- The District is unsure the reason for the discrepancy in the flow meter readings. A technician needs to be called to the site for flow meter calibration, ensuring that all the flow meters are properly calibrated to eliminate any question on which meter is causing issues. The unaccounted digester gas flow is not going to the boiler (the existing boiler flow meter is not connected to the SCADA system; therefore, the flow is not reviewable from the data collection, but it is manually monitored). Furthermore, the District has not used the existing boiler as a heat source for several months, ever since Cal Microturbine adjusted the temperature settings on the microturbines to heat the hot water loop to an appropriate level to heat the digester. The unaccounted digester gas is a result of inaccurate flow measurement causing the gas numbers to not add up correctly.

Emissions Analysis

The emissions analysis was prepared based on a comparison between the previous equipment operations and the new BERS equipment. For both the previous and existing operational scenarios, an assumed average flow rate of 35 scfm is used which is based on the design intent for the project.

For the previously existing system, the emissions are based on the operation of the Waukesha internal combustion (IC) engine, the existing boiler, and the existing waste gas burner. The emissions factors for the equipment are based on the previous Permit to Operate (PTO) for the IC engine, which also included the existing boiler and the waste gas burner.

Assumptions for the previous system operations:

- The waste gas burner, IC engine, and boiler operate 8,760 hours per year at their respective flow rates.

The estimated emissions from the BERS are based on the operation of two microturbines and the existing waste gas burner. Because the site SCADA system does not automatically track any use of the existing boiler, and because it was not readily used after adjustment of the microturbines, any potential emissions from the existing boiler were not included in the emissions analysis. Additionally, because the emissions calculations are based on 12 months of operational data and the CNG truck and RNG boiler were not consistently used (or not used at all in the case of the RNG boiler) during that 12-month period, the reduction in emissions based on the CNG truck operating on CNG instead of diesel, were not included in these estimates. For information on the emissions reductions resulting from the transition of the District's flusher truck from diesel to CNG, refer to the final report prepared by Cornerstone for Agreement ARV-15-038 with the CEC under the "Natural Gas Fueling Infrastructure Installation Project".

Assumptions for the current system operations:

- The waste gas burner operates 8,760 hours per year at 3 scfm.
- Microturbine 1 and 2 each operate for a total of 8,760 hours per year, with each piece of equipment operating off of half of the remaining available flow rate (16 scfm each).
- The use of the RNG boiler or CNG truck was not included in emissions reductions.
- The operation of the existing boiler was assumed to be zero as it was operated a negligible amount of time during the 12 months.

In comparing the previous operations to the current operations, it is key to note that the same fuel – digester gas – was utilized in the previous and current scenarios. Therefore, reduction in emissions of greenhouse gases (GHGs) such as carbon dioxide (CO2) and CH_4 are minimal because the emissions factors are heavily based on the fuel utilized and heat input (flow rate and heating rate of the fuel) and not the control devices used in combustion. The emissions factors are based on the United States Environmental Protection Agency references provided by 40 Code of Federal Regulations. Furthermore, the significant reduction in CH_4 for the IC engine is most likely overestimating the CH_4 emissions from the IC engine. This is because detailed emissions information is not available for the IC engine, the potential to emit under the "organics" category of the PTO is used for the CH_4 emissions. The PTO has an "organics" category for emissions that is the summation of Precursor Organic Compounds/Volatile Organic Compounds/Reactive Organic Compounds. Because the individual breakdown of the contributing compounds is not available, the "organics" category for the IC engine is conservatively assumed to be CH_4 only.

The reduction in pollutants is most greatly seen in the criteria pollutants of NO_x, sulfur oxide (SO_2), particulate matter (PM), and carbon monoxide (CO). The IC engine was operating with 1980's technology and would no longer meet Bay Area Air Quality Management District (BAAQMD) regulatory requirements. The reduction in emissions between the IC engine and the microturbine highlights how combustion technology has improved over the years. The following tables show the reduction in emissions between the previous and current operational scenarios (Tables B-2 through B-4).

Table B-2: Previous Operational Devices and Associated Daily Emissions

Device	Flow (scfm)	CH_4 (lbs/day)	SO_2 (lbs/day)	NO_x (lbs/day)	PM_{10} lbs/day	CO lbs/day
Waukesha Engine Model F1197G	24	40.9	10.9	99	0.35	25.1
Existing Boiler	8	0.04	0.100	0.001	0.021	0.002
Digester Gas Flare	3	0.34	0.80	2.85	0.24	9.50
Totals:	**35**	**41.27**	**11.80**	**101.85**	**0.62**	**34.61**

Notes:

- Emissions for Waukesha Engine Model F1197G provided by the Bay Area Air Quality Management District (BAAQMD) as lbs/day in the facility Permit-to-Operate dated August 30, 2014.
- Emission factors for Existing Boiler derived from BAAQMD issues PTO. Factors include - 900,000 Btu/hr in the air permit; and 0.0 Nox lbs/day; 0.1 SO_2 lbs/day; and 0.1 CO lbs/day from the PTO. Organics are calculated based on GHG emissions calculations.
- Digester Gas Flare emission factor for CH_4 derived from 40 CFR 98, Subpart C, General Stationary Fuel Combustion Sources Table C-1. Emission factor for Nox derived from 2013 Source Test of the Digester Gas Flare. Emission factor for SO_2 derived from a concentration of 300 ppmH2S as outlined in Table 6-2, Air Quality Assessment Report Dry Fermentation Anaerobic Digestion Facility, Sierra Research, Inc. 2011. Operations assumed 8760 hours per year.

Table B-3: Current Operational Devices and Associated Daily Emissions

Device	Flow (scfm)	CH_4 (lbs/day)	SO_2 (lbs/day)	NO_x (lbs/day)	PM_{10} lbs/day	CO lbs/day
Microturbine 1	16	0.05	0.75	0.72	0.09	6.20
Microturbine 2	16	0.05	0.75	0.72	0.09	6.20
Digester Flare	3	0.34	0.80	2.85	0.24	9.50
Totals:	**35**	**0.43**	**2.30**	**4.29**	**0.42**	**21.90**

Notes:

- Microturbine emissions factor for Nox per manufacturer's specifications for digester gas. Emission factor for SO_2 derived from peak H2S concentration of 197 ppm. Emission factor for CH_4 per Capstone Microturbine System Emissions Technical Reference Sheet. Emissions calculated under assumption that microturbines are operational for 8,760 hours per year.
- Digester Gas Flare emission factor for CH4 derived from 40 CFR 98, Subpart C, General Stationary Fuel Combustion Sources Table C-1. Emission factor for Nox derived from 2013 Source Test of the Digester Gas Flare. Emission factor for SO_2 derived from a concentration of 300 ppm H2S as outlined in Table 6-2, Air Quality Assessment Report Dry Fermentation Anaerobic Digestion Facility, Sierra Research, Inc. 2011. Operations assumed 8760 hours per year.

Table B-4: Calculated Reduction in Emissions from Previous to Current Operations

	CH_4 (lbs/day)	SO_2 (lbs/day)	NO_x (lbs/day)	PM_{10} lbs/day	CO lbs/day
Previous Operations	41.27	11.80	101.85	0.62	34.61
Current Operations	0.43	2.30	4.29	0.42	21.90
Calculated Change	-40.85	-9.50	-97.57	-0.19	-12.70

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Appendix C: Technology/Knowledge Transfer Summary

May 2024 | CEC-500-2024-050

APPENDIX C: Technology/Knowledge Transfer Summary

Appendix C, Technology/Knowledge Transfer Summary, provides an overview of the efforts to transfer the technical information gained during the design, construction, and operation of the Biogas Energy Recovery System (BERS) at the Las Gallinas Valley Sanitary District (District) wastewater treatment plant in San Rafael, California.

The District previously operated an internal combustion (IC) engine for destruction of its digester gas which generated electricity and supplemental heat for the hot water loop. Due to air permitting requirements established by the Bay Area Air Quality Control Board (BAAQMD), the IC engine was required to be phased out because of the inability to meet air quality standards. To replace the electrical and heat supplied by the IC engine, the District installed two 65 kW microturbines for electrical generation and heating supply to the digester hot water loop. This installation allows the District to continue to provide a renewable energy option for digester gas destruction. In addition, the BERS was designed to provide for the utilization of a portion of the digester gas to fuel compressed natural gas (CNG) vehicles.

Key factors of this project that are interesting discussion points include:

- The relatively small area for the project construction;
- The lower quantity of digester gas (less than 50 standard cubic feet per minute) that provides a fuel supply to both microturbines and RNG vehicles; and
- The integration of the generation of electricity, heating, and RNG in one project.

The technical transfer activities are targeted to several different groups. Attendance and presenting at conferences and the Technical Advisory Committees were focused on gathering other WWTPs and others in industry to discuss the project and their experiences with similar projects.

Cornerstone blog posts are written in "layman's" terms so that others that are not intimately involved in the technical aspects of projects can understand the interesting relatively new ways renewable energy is being generated.

Technical transfer of the information gained during the design, construction, and operation of the system will be disseminated through the following ways:

- Online articles/blog posts
    - Cornerstone prepares blog posts for the company website to showcase projects that we feel would be of interest to the engineering/renewable energy community. A blog post discussing the BERS project was prepared and currently available for viewing on our website.
    - To spread awareness to the community that the District serves, a section of its website will provide a presentation/informational PDF on the project.

- Conference papers/presentations
    - Conferences are an excellent way for Cornerstone and the District to discuss the project specifics and the funding opportunities available for projects of this size and field questions from others that work in renewable energy:
        - Pacific Northwest Clean Water Association (PNCWA), Boise ID, October 2015
        - Colorado SWANA Rocky Mountain Chapter Annual Conference, Keystone CO, October 2016
        - Water Environment Foundation (WEF) Residuals and Biosolids Conference, Phoenix AZ, May 2018
        - PNCWA Pre-Conference Workshop – October 21, 2018
- Site tours
    - On October 17, 2018, the District hosted a dedication event. The individuals in attendance included consultants, contractors, and city and state officials (e.g., assembly member representatives and district board members).
- Technical Advisory Committee (TAC) Meetings
    - Two TAC meetings have been held, both of which were conducted at the site after the construction of the BERS.
    - The TAC meetings were well attended by a variety of agencies – East Bay Mud, the California Association of Sanitation Agencies, Central Marin Sanitation Agency (WWTP), Waste Management, LA County Sanitation District, Monterey Regional Waste Management District, and the California Air Resources Board, have all attended one or both of the meetings.
- Industry organizations
    - The BERS project was a finalist for the American Biogas Council's Annual Biogas Industry Award, which has a category for projects from the municipal sector given to projects that promote the use of renewable natural gas.
- Addition outlets include:
    - White papers/case studies
    - Targeted outreach to potential customers/collaborators/policy makers

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Appendix D: Production Readiness Plan

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APPENDIX D: Production Readiness Plan

This Product Readiness Plan describes the equipment used for the operation of the Biogas Energy Recovery System (BERS) at the Las Gallinas Valley Sanitary District (District) wastewater treatment plant in San Rafael, California.

The District previously operated an internal combustion (IC) engine for destruction of its digester gas which generated electricity and supplemental heat for the hot water loop. Due to air permitting requirements established by the Bay Area Air Quality Control Board (BAAQMD), the IC engine was required to be phased out because of the inability to meet stricter air quality standards. To replace the electric and heat supplied by the IC engine, the District installed two 65 kW combined heat and power microturbines for electrical generation to the on-site grid and heating supply to the digester hot water loop. To operate the microturbines off of digester gas, a digester gas conditioning skid was installed to condition the gas for use in the microturbines. In addition, this digester gas conditioning skid can also further upgrade the conditioned digester gas to renewable natural gas (RNG) that can supply the RNG to onsite vehicle fueling or for a boiler, if additional digester heating is needed. A hydronic boiler that runs off the RNG was installed to provide the additional digester heating as needed. A compressed natural gas (CNG) time-fill fueling station was also provided as part of the BERS to provide for the utilization of a portion of RNG to fuel compressed natural gas (CNG) vehicles that the District will acquire over time.

System Components

While the equipment that was specified for the project is all commercially available, the configuration of the equipment as a total system makes this project unique. Furthermore, this project set out to determine if 100 percent utilization of methane could be achieved through the use of a closed-loop gas conditioning skid, meaning that no tail gas would be flared from conditioning of the digester gas to RNG quality.

All of the equipment that was specified had been used in biogas utilization projects across the country and are proven technologies in the biogas to electricity/RNG industry. The unique aspect of this project is the purpose each piece plays in the overall system and the full utilization of methane. Each piece of equipment is available through a known and credible manufacturer and can be obtained through initiating orders of equipment through website contacts or local distributors. All equipment is available in a range of different sizes, therefore production of another BERS system at a different WWTP would be largely dependent on system sizing to match biogas output. Each piece of equipment, its function in the overall system, and its available sizes are discussed below.

Gas Conditioning Skid – BioCNG 50 System

The digester gas is conditioned by a BioCNG 50 gas conditioning skid which was designed by BioCNG and Unison Solutions and fabricated by Unison Solutions. The BioCNG unit is a skid mounted system with a single free-standing hydrogen sulfide removal vessel used for "upgrading" biogas for use in microturbines, boilers, and vehicle fuel. The procurement of a system includes the fabrication, materials, delivery and start-up services for the equipment. The BioCNG system was sized to treat up to 50 standard cubic feet per minute (scfm) of raw, unconditioned biogas from the digesters. The BioCNG 50 System is one of the four standard sizes manufactured by BioCNG. BioCNG guarantees that the biogas produced meets SAE J1616 vehicle fuel quality standards (SAE International, 2024). The system is beyond the research and development stage, and there are currently multiple BioCNG systems in operation across the country in both landfill and wastewater treatment plant (WWTP) operations.

Using several pieces of equipment all interconnected to produce the necessary output, the BioCNG conditions the digester gas through: the removal of particulates, moisture, hydrogen sulfide, siloxane, volatile organic compounds (VOCs), and carbon dioxide. The conditioned digester gas (CDG) is also compressed and cooled prior to delivery to the microturbines. A portion of the CDG continues on to the carbon dioxide removal membranes for further refining to RNG quality.

The BioCNG 50 System utilizes a closed loop system that captures 100 percent of the methane produced by the digesters. During conditioning of the digester gas to RNG, BioCNG uses membranes for the removal of carbon dioxide, whereby tail gas is generated. During the removal of carbon dioxide, a percentage of methane is removed with and enters the carbon dioxide tail gas stream as well, generating a tail gas that has a potential concentration as high as 30 percent methane. In the BERS, the waste gas produced is returned to the front-end of the system for biogas conversion and the methane that was removed by the carbon dioxide membranes is circulated back to the front of the process train. Through on and off cycles of RNG production, where in during the off cycle all digester gas entering the system is conditioned and directed to the microturbines and destroyed, the system maintains a relatively consistent incoming digester gas composition despite the recirculation of the tail gas during on cycles for RNG production. Therefore, the existing on-site flare is only needed for emergency situations; there is no utility flare installed as part of this system.

This closed loop system benefits the District by reducing energy costs and improving energy efficiency through the elimination of an ancillary flare and 100 percent utilization of methane generation. Not only does the closed loop system reduce capital and operating costs that in return lower the cost to the ratepayer, but it also reduces methane emissions to help meet the requirements of California State bill SB605 (Short-Lived Climate Pollutants) and assembly bill AB32 (Global Warming Solutions Act).

The system is mounted on two skids, with a single free-standing vessel:

- Hydrogen sulfide removal vessel – the vessel is filled with commercially available media that is selected based on the level of hydrogen sulfide in the raw digester gas.

Skid 1 includes:

- **Glycol chiller** – This equipment is used to lower the dew point of the conditioned digester gas;

- **Control panel** – Motor starter and process logic controller for the control and operation of the system, including the microturbines; and
- **Siemens gas analyzer** – This equipment obtains small samples off the RNG gas stream to confirm that the gas parameters are sufficient for use in the CNG vehicles.

Skid 2 includes:

- **Compressors** – capable of creating at least a 100 pounds per square inch gauge (psig) at 50 scfm to provide sufficient inlet pressure to the microturbines;
- **VOC/Siloxane removal media** – carbon-based commercially available media is used for the removal of VOCs and siloxanes;
- **Carbon dioxide removal membranes** – The membranes are provided by Air Liquide and are used to remove carbon dioxide from the gas stream; and
- **Mercaptan odorization system** – to re-odorize the RNG after it has been cleaned.

The lead time from the approval of equipment submittal to on-site delivery was approximately 24 weeks.

Microturbines

Based on the anticipated flow rate (approximately 32 scfm) and methane concentration of the conditioned digester gas (approximately 61 percent methane), two 65 kw microturbines were selected for installation. Cornerstone specified that Capstone microturbines were to be procured. Capstone has demonstrated reliability in the WWTP biogas utilization industry and has continued to improve their product over time. In addition, a distributor/service representative is located relatively close to the site.

The microturbines selected were CR65-ICHP renewable fuel model, which is commercially available and have been involved in multiple case studies which are available for review on the Capstone website. The benefits of selecting commercially available and industry proven technologies include a reduction in purchasing costs and minimization of operational and maintenance issues that have been remedied during the years of the equipment being in service.

The ICHP (internal combined heat and power) model is equipped with a heat recovery unit that is placed on the top of the microturbine and does not require any additional footprint. The heat recovery unit operates as a heat exchanger to heat up incoming water with the exhaust heat generated from conditioned digester gas combustion. The hot water loop in the digester room is connected to the heat recovery loop off of the microturbines. The majority of heating demand for the digester hot water loop is met through the microturbine’s heat recovery capabilities.

The microturbines meet the California Air Resource Board (CARB) emissions requirements without any additional emissions control equipment, which helped to decrease air permitting timelines (CARB, 2024).

Some additional characteristics that supported the decision for the selection of Capstone microturbines instead of an IC engine:

- Low maintenance and downtime;
- No lubricant or coolant needed – meaning no storage of lubricants or additional materials onsite;
- Small design for easy, low cost installation with minimal footprint;
- Electrical efficiency of 29 percent;
- 251,000 Btu/hr of heat recovery; and
- UL2200 and UL 1741 classified for raw natural gas and biogas operation.

The lead time from the approval of equipment submittal to on-site delivery is approximately 24 weeks.

Time-fill Fueling Station

To distribute on-site RNG, Cornerstone specified a time-fill fueling station manufactured by Verdek-Greenline. Verdek-Greenline has shown reliability for time-fill fueling station design and has installed over 2,000 fueling stations worldwide. A time-fill fueling station was selected (as opposed to a fast-fill station) to eliminate the need for on-site storage of high-pressure RNG. It was also selected because it allows for the CNG trucks to fuel overnight as the BioCNG skid produces RNG while continuing to operate the microturbines with no interruptions. In addition, because of the recirculation of tail gas in the system, the microturbines must be operating during RNG production for combustion of the lower heating value fuel that the microturbines are able to utilize. The microturbines are able to seamlessly operate during fluctuations in heating value of the incoming fuel, which allows the tail gas generated from RNG production to be combined with the incoming digester gas. The temporarily lower heating value fuel is utilized by the microturbines and allows the RNG production to continue to produce RNG that meets the proper heating value for the CNG vehicles.

The time fueling station selected is a commercially available product. The purchaser provides the specification for operation to the manufacturer, and a quote for the equipment being produced based on the information is provided. The parameters for fueling either in a time-fill or fast-fill scenario are relatively set at this point in the industry, so there are minimal site-specific modifications needed, if any at all.

Specifically, for this project, the time-fill station was programmed to ensure that RNG would not be distributed to CNG trucks if the hydronic boiler needed the RNG for supplemental heat. The priority of digester gas usage was to the microturbines, RNG to the hydronic boiler, and then RNG for truck fueling. The fueling station process logic controller assists in prioritizing the RNG supply while also supplying the estimated demands of the CNG truck.

Some additional characteristics that supported the decision for the selection of Verdek-Greenline time-fill stations are the small compact design that it provided and the commercial availability and experience of Verdek.

RNG Hydronic Boiler

The existing boiler at the WWTP is too large to operate in conjunction with operating the microturbines at full capacity. Cornerstone selected a small hydronic boiler be installed to operate with the microturbines. Cornerstone specified that Brute Elite hydronic boiler be procured. The small hydronic boiler selected is model number BNTH-500. It is a commercially available product, with many models installed nationwide. The general contractor was able to procure the boiler from a local distributor. The hydronic boiler is intended to operate off of natural gas, and therefore, it is capable of operating off of the RNG produced by the BioCNG skid. The flexibility of the BERS to provide supplemental heat from the RNG boiler eliminates the need for supplemental fuel from an off-site source.

The hydronic boiler has a 5:1 turndown which helps meet the flexibility needs of the system. It has up to 96.6 percent efficiency with a maximum input of 500,000 British Thermal Unit (BTU)/hr. With the hydronic boiler installed, the existing boiler remained in place as back-up and can operate off raw digester gas should there be a shutdown of the BERS.

Some additional characteristics that supported the decision for the selection of Brute Elite hydronic boiler:

- Available for both natural gas or propane models;
- High efficiency, condensing design;
- Thermal efficiency of 95%;
- Fully automated;
- Operates at low gas pressure; and
- Meets the heating and flow demands for the hot water loop.

Attachments:

- Product Specification Sheets