CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

Clean Transportation Program

FINAL PROJECT REPORT

Landfill Gas to Renewable Transportation Fuel Project

Monterey Regional Waste Management District

Prepared for: California Energy Commission

Prepared by: Monterey Regional Waste Management District

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PREFACE

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

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

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

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued GFO-15-606 to increase production capacity for low carbon biofuel production facilities. In response to GFO-15-606, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards December 7, 2017, and the agreement was executed as ARV-17-036 on May 23, 2018.

Note: If needed, insert a blank page so that the Abstract begins on the left side in two-page electronic view (same side as the cover page).

ABSTRACT

The Landfill Gas to Renewable Transportation Fuel Project (project) was constructed at the Monterey Regional Waste Management District (MRWMD or district), Monterey Peninsula Landfill (landfill) site in northwestern Monterey County, California. The project captures methane containing biogas generated from decomposing organic material to condition the raw biogas into a renewable natural gas (RNG) for natural gas vehicles used by the district and by the Franchise Waste Collection Contractor's truck fleet for seven of the nine local Member Agency communities on the Monterey Peninsula. The project is designed to receive raw biogas from the landfill (aka landfill gas (LFG)), from an anaerobic digestor (AD) facility located onsite or from the neighboring wastewater treatment plant (WWTP), or from both public entity sources. While the potential to generate renewable energy from AD or landfill biogas is well established in the industry, the landfill is the first publicly owned landfill to install and operate a Biogas-to-RNG facility in California. This project will serve as a prototype for the other publicly owned landfills throughout the state, which will benefit regional vehicle fleets and the populace on a community-scale level.

The priority for the project is generating renewable compressed natural gas (RCNG) for the district's existing CNG truck fueling system. As part of its continued efforts to reduce its reliance on non-renewable resources, reduce onsite emissions, and improve the sustainability of its operations, MRWMD envisioned utilizing its biogas to produce RCNG rather than importing an out-of-state RCNG from the utility pipeline network or using natural gas from non-renewable sources.

Utilizing LFG/AD biogas for the production of RCNG for transportation purposes provides a cost-effective, complete, and scalable system. Furthermore, 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, this demonstrates the application of the project at landfills and/or 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 renewable energy requirements.

Keywords: California Energy Commission, Monterey Regional Waste Management District, Transportation Program, digester gas, landfill, gas conditioning, landfill gas, renewable natural gas, compressed natural gas, CNG, RNG, RCNG

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EXECUTIVE SUMMARY

MRWMD, a California Special District public entity established in 1951, teamed up with Tetra Tech, Inc., and its subsidiaries to produce RNG from biogas created from decomposing organic waste material from the landfill and/or an AD facility onsite or on the adjacent WWTP property. The landfill biogas (aka LFG) is collected by an existing network of horizontal and vertical LFG wells at the wellfield. The bio compressed natural gas (BioCNG™) facility that was installed through this project provides a cost-effective, complete, and scalable system that converts biogas produced from the decomposition of organic matter to RNG for use in transportation vehicles over the long-term.

MRWMD has been using LFG to generate renewable energy since 1983 and has been actively diverting waste organic material from the landfill for more than 20 years. The agency first started a green waste compost program prior to the establishment of Assembly Bill (AB) 939 in 1989. AB939 requires each city or local jurisdiction to implement a plan that diverts solid waste from landfills through source reduction, recycling, and composting activities, 25 percent (%) by 1995 and 50% by 2000. The district constructed a materials recovery facility (MRF) in 1996 and has consistently diverted more than 50% of the unprocessed materials received by the district. The landfill has also been strategically implementing an Integrated Waste Management Plan (IWMP) for several years that incorporates accelerating diversion of organic fractions away from the Landfill in accordance with AB 341, which expands on AB 939 and sets the goal for the state to increase its waste diversion rate to 75 percent by 2020, and AB 32, the California Global Warming Solutions Act. Part of the plan for AB 32 is to keep organic waste out of landfills because of the formation of methane, a greenhouse gas (GHG) emission that has a global warming potential 25 times higher than carbon dioxide. The landfill was the first landfill in the region to initiate a food scrap compost program in 2008. In January of 2012, the district took another pioneering step forward in organics waste management by entering into an agreement with Zero Waste Energy (ZWE) to permit, construct and operate a pilot study facility using the dry fermentation "SmartFerm" AD composting system to manage food scraps and green waste. This was a relatively small facility (~6,000 tons per year +/-) that was contracted for five (5) years of operations. The contract for the small scale pilot study AD facility was extended to a sixth year of operations ending in August 2019. The district is currently assessing the development of its own AD facility at about ten times the throughput capacity and is also collaborating with the adjacent WWTP for processing organic waste slurries to increase biogas production in one or all of their four (4) AD units.

The landfill is a nonhazardous municipal solid waste (MSW) landfill, permitted to accept 3,500 tons per day (TPD) and eventually to be built-out to 315 acres (plan area) in size. MRWMD currently collects approximately 300,000 tons annually from surrounding communities in Monterey, San Benito, and Santa Cruz counties. This service is limited to no more than 2,000 vehicles per day of incoming refuse or recyclable materials. The landfill has been operational since 1965 and currently produces approximately 2,400 standard cubic feet per minute (SCFM) of LFG from the active refuse filling airspace. LFG is considered a 'dirty gas' as the quality of the LFG generated (its components) are determined by several factors including, but not limited to, age and type of waste buried at the site, quantity and types of organic compounds within the waste, and moisture content and temperature of the waste. LFG produced at the

landfill is approximately 50% methane produced during the bacterial decomposition of organic matter contained within the waste disposed in the landfill. The focus of this project has been to utilize biogas collected from both an AD system and the landfill. While the project has been designed and constructed for these biogas sources, LFG has been solely utilized as the initial biogas source for the project at this time until there is future expansion or establishment of a larger organic's diversion, AD, and composting facility at the landfill. Also completed for this project was i) an assessment of the condition of existing collection wells, ii) the abandonment of poor quality collection wells, iii) the design and installation of new wells, and iv) investigate whether a subarea of the landfill biogas collection system could be defined and designated as a separate, dedicated collection system for collection of the highest quality landfill biogas that is currently being produced.

The project captures methane containing biogas from decomposing organic material and municipal solid waste to convert and condition it into RNG for use at the district's CNG fueling facility. The project collects LFG from existing and newly installed collection wells with the ability to add additional biogas sources and upsize the system in the future (one or more AD facilities envisioned). The landfill has a permitted capacity of 84 million cubic yards with an estimated closure year of 2161. Considering the process of decomposition at the landfill, and the factors described above that contribute to the composition of biogas, organic waste within the landfill footprint is expected to continue producing a sustainable source of methane over the long-term (e.g., more than 50 years). And lastly, MRWMD is investigating options for increasing the organics diversion to meet the 75% diversion goal established within the state and most recently by SB1383 regulations. This may include installation of a new AD facility on-site or utilization of biogas derived from processing organic slurries in the 'wet' digesters from the adjacent WWTP for use in the BioCNG™ facility at the landfill. This approach is not part of this project's initial operations scope at this time; however, the BioCNG™ facility has been designed and constructed to accomplish this and it will serve as an additional supply of methane for future RNG production to meet future demand for renewable transportation fuel for the region. In January 2022, the Board of Directors of both agencies approved about one million dollars for a joint study to evaluate the highest and best use of wastes and waste byproducts. This study will consider both "wet" and "dry" co-digestion of organic slurries created from food/agricultural product scraps and possibly mixed organic solid wastes. Co-digestion of organic slurries will create a cleaner AD biogas to supply the BioCNG™ facility and the likely expansion to the facility to accommodate the estimated 400 scfm increase in AD biogas production.

GOAL OF THE AGREEMENT

The goal of this agreement is to increase production capacity and address the Clean Transportation Program formerly known as Alternative and Renewable Fuel and Vehicle Technology Program's (ARFVTP) goals of producing sustainable, alternative, and renewable low-carbon fuels in California.

The project utilized biogas derived from decomposing waste organic matter (landfill and/or AD facility) as a feedstock source to create a cost-effective and renewable transportation fuel for vehicle fleets in California. The conversion of organic waste biogas from the landfill and/or AD facility into RNG serves as a local, regional, and statewide solution to future economic growth and the state's energy and environmental goals to meet the demands of climate change and decreasing supplies of non-renewable fuels.

CHAPTER 1:
Introduction: Project Overview

Project Goals and Overview

The project goal is to provide sustainable, alternative, and renewable low-carbon fuels to reduce California's use and dependence on petroleum transportation fuels, increase the use of the alternative and renewable fuels, improve California's Low Carbon Fuel Standard (LCFS) objectives to displace petroleum, reduce carbon, and improve air quality while creating jobs, and stimulate economic development in California.

The design and construction of the project has been successfully completed. The installed BioCNG™ facility has also been operated and tested both manually onsite and remotely offsite on several occasions. These initial testing operations demonstrated that the raw landfill biogas having nearly 50% methane content could be treated and converted to treated gas quality of approximately 83% methane content. While a higher quality treated gas product will be obtained by the BioCNG™ treatment system that has been installed, it will first be necessary to improve the quality of the collected landfill biogas to reduce the presence of oxygen and other gases like nitrogen, carbon dioxide, carbon monoxide which are collectively referred to as balance gas when measuring the quality of a biogas. While testing operations of the installed BioCNG™ treatment system is still ongoing, the goals of the project have been significantly achieved as outlined below.

The project captures LFG or biogas from decomposing organic material in the landfill or an AD facility (future) to convert and condition it into RNG for use by the district and by the franchise waste collection contractor for seven of the nine member agency communities on the Monterey Peninsula. The project has completed construction and is now operational with gas sampling, data collection, and process refinement currently underway. The project, upon completion, will become a critical piece of the landfill operation, providing a consistent local fuel supply to the facility's CNG fueling station.

The BioCNG™ facility comprises of a multi-faceted system of gas conditioning and handling in order to achieve quality fuel to serve MRWMD's vehicle fleet from the LFG sourced from the wellfield. A project of this size requires a lot of funds from inception to completion and due to increased incurred costs throughout the lifespan of the project, the total projected budget increased more than originally budgeted at the inception of the agreement.

The budget originally proposed for the project is shown in Table 1.

Table 1: Projected Budget - Original

Cost Category	Reimbursable Share	Match Share	Total
Direct Labor	$ -	$71,200	$71,200
Fringe Benefits	$ -	$15,664	$15,564
Total Labor	$ -	**$86,864**	**$86,864**
Travel	$ -	$1,200	$1,200
Equipment	$1,816,800	$100,000	$1,916,800
Materials/Miscellaneous	$ -	$ -	$ -
Subcontractors	$ -	$1,643,125	$1,643,125
Total Other Direct Costs	**$1,816,800**	**$1,744,325**	**$3,561,125**
Indirect Costs	$ -	$ -	$ -
Profit (not allowed for grant recipients)	$ -	$ -	$ -
Total Indirect and Profit	$ -	$ -	$ -
Grand Totals	***$1,816,800***	***$1,831,189***	***$3,647,989***

Source: Tetra Tech

Table 2 represents incurred costs as of January 2022 for the project inclusive of all of the BioCNG infrastructure installed, the hydrogen sulfide treatment system, and the LFG wellfield improvements.

Table 2: Cost of Completion

Cost Category	Reimbursable Share	Match Share	Total
Direct Labor	$ -	$	$
Fringe Benefits	$ -	$	$
Total Labor	$ -	**$**	**$**
Travel	$ -	$	$
Equipment	$ 1,816,800	$ 775,160	$ 2,591,960
Materials/Miscellaneous	$ -	$ -	$ -
Subcontractors	$ -	$ 2,924,772	$ 2,924,772
Total Other Direct Costs	**$1,816,800**	**$3,699,932**	**$5,516,732**
Indirect Costs	$ -	$ -	$ -
Profit (not allowed for grant recipients)	$ -	$ -	$ -
Total Indirect and Profit	$ -	$ -	$ -
Grand Totals	**$1,816,800**	**$3,699,732**	**$5,516,732**

Source: MRWMD

Prior to commencement of construction of the project, gas sampling was conducted in order to complete gas analyses and select equipment and media that best addressed the LFG quality at the landfill. One sample was collected on October 25, 2018, at the inlet to the blower skid in accordance with the gas sampling protocol memorandum prepared by Tetra Tech (previously Cornerstone Environmental Group (Cornerstone)). Upon completion of sample collection, the sample and a trip blank (total of two canisters) were sent to Air Technology Laboratory in California for analysis. Table 3 below summarizes the test results.

Table 3: Gas Sampling Laboratory Analytical Results prior to System Installation

Description	Blower Inlet I	Laboratory Blank
Methane (% by volume)	56	Non-Detect
Carbo Dioxide (% by volume)	38	Non-Detect
Oxygen (% by volume)	Non-Detect	Non-Detect
Balance Gases (% by volume)	5.4	Non-Detect
Hydrogen Sulfide (parts per million by volume)	420	Non-Detect
Volatile Organic Compounds (VOC) (parts per million by volume)	9	Non-Detect

Source: Tetra Tech

From these results as well as multiple field evaluations conducted on December 11 and 12, 2018 and January 22 and 23, 2019, multiple recommended modifications were suggested within the gas collection and control system (GCCS) Evaluation Report from June 20, 2019. To best address the wellfield and LFG quality, the project approach was developed into a two-phase plan, summarized below:

- Phase I: Hydrogen Sulfide (H_2S) Treatment System: due to the existing partial hydrogen sulfide (H2S) treatment system limiting the ability to tune and balance the wellfield, a new larger volume, multi-tank system with lower system vacuum losses was recommended to be installed; and repair of existing wells by replacing damaged wellheads with new wellheads and addressing any areas with low points to reduce any obstructions of gas flow. This plan was eventually expanded to include further gas conditioning to remove residual contaminants in the gas stream as well as other equipment necessary in the process of converting LFG to RNG
- Phase II: Wellfield Tuning, Well Abandonments, and Well Installation: wellfield tuning by onsite operations allowed MRWMD to adjust wells to optimize gas collection and better the quality of the LFG across the wellfield; additionally, abandoning poor performing wells and installing replacement wells with deeper perforations to mitigate oxygen and balanced gas intrusion helped to significantly improve the LFG quality and assist with LFG capture efficiency

CHAPTER 2:
RNG System Design

Project Goals and Overview

The BioCNG™ facility is comprised of four H_2S removal tanks to remove H_2S from the gas upstream of the conditioning skid (Figure 5), one polishing vessel to remove any residual contaminants just in front of the conditioning skid (Figure 6), a BioCNG™ 400 gas conditioning skid for the conditioning of the gas for use in the renewable generation equipment (Figure 1) with appurtenant control systems (Figure 2), one booster compressor to compress the gas to the required 240 pounds per square inch (psi) (Figure 3), and a 30,000 gallon storage vessel tank (Figure 4) to store the RNG prior to injecting it to the natural gas pipeline for vehicle usage.

The equipment installed for the project is summarized in Table 4 and in Figures 1 through 6 below.

Table 4: Summary of Equipment Installed for RNG System

Equipment	Manufacturer	Model Number	Serial Number
BioCNG™ 400 Skid	Unison Solutions, Inc.	VFS-400-310-HS	N/A
Control Panel	Unison Solutions, Inc.	N/A	VGS-400-310-HS
Low Pressure Storage Tank	Trinity Containers	TK-371	S2000010
Booster Compressor	Corken, Inc	D691-109A	92150SM
Four (4) H_2S Removal Tanks	Unison Solutions, Inc.	FLT-301 – FLT-304	N/A
H2S Polishing Vessel	Unison Solutions, Inc.	FLT-305	N/A
Pad Mount 3PH 500KVa Transformer	T & R Electric, Inc.	TX-21	N/A

Source: Tetra Tech

Figure 1: BioCNG™ Skid and Piping

Installed BioCNG™ 400 conditioning skid and associated piping. The system pressurizes the LFG, removes moisture and contaminants such as CO2, siloxanes/VOCs, and regulates discharge pressure and temperature. (Date of Installation: 10/2/2020)

Photo Credit: Tetra Tech, 2/9/2021

Figure 2: BioCNG™ Skid Control Panel and Piping

Installed control panel for BioCNG™ 400 conditioning skid with associated piping shown at forefront of the photograph. The control panel monitors and controls all parameters of the RNG system. (Date of Installation: 10/2/2020)

Photo Credit: Tetra Tech, 2/9/2021

Figure 3: Booster Compressor (25 HP)

Installed 25 HP Booster Compressor to pressurize gas prior to entry into low pressure storage vessel. (Date of Installation: 10/2/2020)

Photo Credit: Tetra Tech, 2/9/2021

Figure 4: Low Pressure Storage Tank

Installed 30,000-gallon low pressure storage tank to serve as storage for RNG after conditioning has been completed. (Date of Installation: 10/2/2020)

Photo Credit: Tetra Tech, 2/9/2021

Figure 5: Four H_2S Removal Vessels

Installed four H_2S removal vessels to remove H_2S contaminants from the main LFG header pipe. (Date of Installation: 9/28/2020)

Photo Credit: Tetra Tech, 2/9/2021

Figure 6: H_2S Polishing Vessel

Installed H_2S polishing vessel as an addition to the H_2S treatment for the LFG installed in line with the BioGas conditioning skid. (Date of Installation: 10/2/2020)

Photo Credit: Tetra Tech, 2/9/2021

CHAPTER 3:
RNG System Installation and Commissioning

System Construction and Challenges Encountered

The project construction was completed approximately two years and 3 months behind schedule due to multifaceted issues experienced during the project schedule including:

- Time required to select the equipment bidder and develop design constraints took longer than scheduled.
- Equipment drawings were received from Unison approximately a month later than scheduled and equipment delivery was subsequently two months behind schedule.
- State and local orders for the COVID-19 situation also led to additional significant delays due to the shelter in place order.
- Delays in permitting both the air and building permits have contributed further delays in the commencement of construction and start-up of the facility.

Due to the delays discussed, startup of the H_2S treatment system was pushed back pending the revised best available control technology (BACT) analysis submittal that was necessary for the subsequent air permit approval. As a result, the biogas conditioning system start-up was also pushed back approximately nine months behind schedule. Based on this, the original agreement end date was not able to be met. Due to the six-month data collection requirement in Task 7 along with permitting delays, the current agreement date was not able to be met and a revised extension request was submitted to the CEC on October 14, 2021. This was approved by the CEC on October 14, 2021 and the agreement was extended through December 31, 2022.

The project construction was completed and testing operations of the BioCNG™ facility have been conducted during the past year. The BioCNG™ facility testing has demonstrated that the system is fully functional. However, due to poor quality (high oxygen & balance gases) of the raw LFG, the current progress on the project has been focused on ensuring gas quality to be sufficient for the RNG System. Gas sampling and analysis was completed on June 20, 2022 and confirmed the relatively high oxygen and balance gases in the raw LFG compared to the supply gas specification requirements. Most recently, modifications to the wellfield including tuning and other GCCS improvements have been implemented to meet system requirements as there were changes in the gas constituents observed when compared to the original gas sampling results performed in October 2018 as seen in Table 3. Wellfield tuning has been conducted at least once monthly and poor quality, poor performing collection wells have been removed from the wellfield and replaced by new wells collecting from larger waste zones. Additional improvements in the wellfield are also planned to be implemented in early 2023. These improvements will aim to achieve the LFG quality suited for the RNG system sufficient for the vehicle fleet. Previous GCCS improvements, which were independent of the grant and project construction, greatly improved the project's efficiency and steady generation of LFG of sufficient quality for the BioCNG™ skid, which aided in eliminating potential shutdowns or fluctuations in the RNG production.

Data Collection and Analysis

The BioCNG™ facility system operation and related data collection plan commenced by initially operating two days a week during business operating hours at the landfill starting in April 2022 and operational data collection began while system testing was performed. The collection plan incorporated part-time operation during the initial testing and sampling of the BioCNG™ skid and related gas quality. During operation, a faulty component with the glycol chiller was discovered and required replacement prior to resuming operation of the system. Following this, subsequent sampling result from Atmospheric Analysis & Consulting, Inc. identified that there was an unexpected increase in the amount of VOCs in the inlet gas stream (i.e. raw LFG) compared to the initial sampling event, Table 5 below summarizes the sampling result. As a result, the system was and has been temporarily shut down until gas quality improvements can be made to reduce VOCs. These improvements are currently underway. Should the continued wellfield improvements not produce the LFG quality needed for RNG production, additional improvements may utilize a dedicated LFG pipe from the facility to the wellfield and only to related wells containing high quality gas to allow the site to meet the performance objectives.

Table 5: Gas Sampling Laboratory Analytical Results Following System Installation

Description	Raw Inlet
Methane (% by volume)	53
Carbon Dioxide (% by volume)	39.3
Oxygen (% by volume)	0.65
Balance Gases (% by volume)	7
Hydrogen Sulfide (parts per million by volume)	477
Volatile Organic Compounds (VOC) (parts per million by volume)	68.66

Source: Tetra Tech

Once these improvements are made, the system is then anticipated to gradually ramp up production from initial operation while the remainder of outstanding wellfield tuning is completed to optimize LFG quality and quantity per the system operational plan. The anticipated full-time operation will occur when the feedstock supply reaches 400 SCFM for the system resulting in the maximum capacity of the new fuel production system reaching 1,431 diesel gallon equivalents (DGE) per day of RCNG. Currently, the landfill has significantly greater than the maximum feedstock supply requirements for full-time system operation. An improvement in LFG quality or incorporation of a supplemental biogas source will aid in meeting the system requirements from a gas composition standpoint. All waste gas (waste produced from production processes, both off-gas and condensate from the BioCNG™ skid are collected and transferred to the existing control and destruction devices at the landfill. Off-gas flow is measured in SCFM while condensate from production is not measured.

Data collection on the BioCNG™ skid occurred from April 8, 2022 through June 29, 2022 during business hours at the landfill. The collection parameters for the samples taken from the gas in the system included the flow rate (in SCFM), pressure (in psi), gas composition (in

percent by volume of methane, carbon dioxide, and oxygen), and temperature readings (in degrees Fahrenheit) of the samples.

Given the extensive amount of data collected every minute by the system for multiple months, the following data in Table 6 summarizes the operational data collected as averages for each day of operation. While the facility is capable of operating regularly per the operational plan discussed previously, the composition of the raw LFG data included high amounts of oxygen, balanced gas, and VOCs. Due to the VOC intrusion, the lifespan of the system's media was drastically shortened during the operational period, causing a temporary system shutdown and cease in operation to occur for changeout of the media. The related constituents in the gas, which varied from the quality at the start of the project, posed challenges to complete Task 7 within the duration as improvements to the gas system to better the overall gas quality from the wellfield were necessary to operate the system and collect a sufficient amount of data for Task 7.

Due to additional necessary wellfield improvements needed to improve the feedstock LFG quality and quantity, various iterations of construction events were required. This provided multiple jobs to contractors and operations and maintenance workers at the landfill. Additional information regarding specific jobs and economic development resulting from this project and projections on potential job creation, economic development, and increased state revenue because of expected future expansion are further discussed in Chapter 4 of this report.

Aside from the delay in meeting the six-month data collection schedule, the unexpected increase of VOCs being introduced to the LFG stream, and subsequent delays as a result, has resulted in the difficulty of acquiring several items that were listed under Task 7 in the initial agreement. Data and evaluation related to the impact of the operational project has to date been unable to be obtained as a gas sample must be obtained that meets the fuel requirements followed by EPA approval prior to full operation and displacement of brown gas from the vehicle fleet can commence. As the gas quality at the inlet is not currently within the range needed to produce such a result, the data for gallons of gasoline and/or diesel fuel displaced cannot be calculated. It is anticipated that once the system resumes operation per the operational plan, the gallons of gasoline and diesel fuel required to fuel MRWMD vehicle fleet will be displaced entirely by the RCNG that is produced from the system through the conversion of the feedstock LFG. For further details on the current and planned use of renewable energy at the facility from the installed system, see Chapter 6 of this report.

The reduction in air emissions once the facility is fully operational is detailed in the below table. It is anticipated that once the full-time operation occurs and the feedstock supply reaches 400 SCFM, the reduction in the estimated sitewide emissions for in sulfur dioxide (SO_2) could be up to 3.7 tons per year (TPY). This is due to the hydrogen sulfide treatment before and after the RCNG treatment skid. There also is an anticipated reduction in volatile organic compounds (VOCs) from the removal of siloxanes of approximately 10% or 1.54 TPY as a result of the post treated gas from the RCNG skid. Additionally, the reduced LFG combustion emissions and diesel fuel replacement reduction have caused a reduction to the greenhouse gases (GHG) as depicted below as a reduction of carbon dioxide equivalent (CO_2e).

Table 6: Summary of Expected Air Emissions Reduction in Tons Per Year (TPY)

Source	NO_x	SO_2	PM_{10}[1]	VOC	CO_2e (GHG)
Total Post-Project Potential Emissions	26.76	33.41	9.46	14.23	120,485
Calculated Potential to Emit Pre-project	26.81	37.11	10.51	15.77	121,617
Net Reduction of Emissions	**(0.05)**	**(3.70)**	**(1.05)**	**(1.54)**	**(1,132)**

NOx – Nitrogen Oxide; CO – Carbon Monoxide; SO_2 – Sulfur Dioxide; PM10 - particulate matter 10 micrometers or less; VOC - Volatile Organic Compounds; A – Attainment; NA – Nonattainment; LPG – Liquified Petroleum Gas
Source: Tetra Tech

The following list of items are unable to be provided at this time due to the unprecedented issues encountered during the project including significant project delays and gas quality issues:

- Duty cycle of the current fleet and the expected duty cycle of future vehicle acquisition;
- Finished fuel price in terms of dollar per DGE at the time of the final report;
- Analysis of total facility costs, operation and maintenance costs, marginal abatement costs;
- Completion of CEC Form M810E and CEC Form M13 monthly for submission to the California Energy Commission's PIIRA Data Collection Unit;
- Written record of registering with the Low Carbon Fuel Standard and Renewable Energy Commission's PIIRA Data Collection Unit; and
- Energy efficiency measures used in the facility that may exceed Title 24 standards in Part 6 of the California Code of Regulations.
- Provide a quantified estimate of the project's carbon intensity values or provide an Air Resources Board approved pathway carbon intensity.

Table 7: MRWMD GCCS Operational Data

Date	Inlet Flow	Carbon Dioxide	Methane	Oxygen	Inlet Pressure	Outlet Pressure	Off-Gas Pressure	Temperature
YY/MM/DD	SCFM	%	%	%	PSI	PSI	PSI	°F
22/04/08	400	6.97	77.80	0.30	-0.77	94.57	0.64	74.37
22/04/09	400	8.15	77.00	0.28	-1.04	94.37	0.48	73.26
22/04/10	400	8.02	77.13	0.27	-0.91	94.21	0.57	73.69
22/04/11	400	8.52	76.44	0.25	-1.04	94.39	0.43	70.21
22/04/12	400	9.15	76.91	0.21	-1.32	94.92	0.25	68.48
22/04/13	400	8.51	74.94	0.46	-1.34	94.66	0.22	68.63
22/04/14	400	8.06	75.43	0.48	-1.20	94.41	0.33	70.17
22/04/15	400	7.74	76.07	0.47	-1.00	94.13	0.52	71.29
22/04/16	400	8.14	78.74	0.21	-1.04	93.91	0.48	70.65
22/04/17	400	4.71	45.70	9.14	-1.24	89.36	0.33	63.60
22/04/20	400	1.30	11.69	18.02	-1.05	78.21	0.44	66.93
22/04/21	400	5.85	49.39	8.00	-0.89	93.16	0.57	68.87
22/04/22	400	7.61	78.31	0.24	-1.08	94.47	0.42	70.58
22/04/23	400	7.79	77.22	0.29	-1.16	94.15	0.33	70.33
22/04/24	400	7.75	78.26	0.22	-1.12	93.96	0.38	70.66
22/04/25	400	7.78	78.25	0.21	-1.09	93.82	0.41	71.09
22/04/26	400	7.76	78.31	0.20	-1.04	93.75	0.44	71.41
22/04/27	400	7.97	77.80	0.20	-1.08	93.68	0.35	70.91
22/04/28	400	7.97	77.25	0.22	-1.12	93.69	0.35	70.73
22/04/29	400	8.21	78.13	0.17	-1.16	94.23	0.31	69.54
22/04/30	400	7.91	78.49	0.18	-1.08	93.80	0.39	70.95
22/05/01	400	8.10	78.60	0.16	-1.04	93.75	0.42	72.03
22/05/02	400	8.06	78.70	0.15	-1.04	93.77	0.42	72.11
22/05/03	400	8.40	78.17	0.18	-1.13	93.70	0.33	71.92
22/05/04	400	8.03	79.24	0.11	-0.81	94.05	0.58	74.23

22/05/13	400	8.78	77.90	0.60	-1.18	95.04	0.29	71.06
22/05/14	400	3.79	40.55	10.41	-1.00	89.74	0.46	67.94
22/05/17	400	4.78	44.19	9.99	-1.08	85.26	0.39	67.19
22/05/18	400	1.16	45.33	10.02	-1.14	85.13	0.37	64.05
22/06/03	400	0.19	5.47	19.71	-0.98	1.69	0.50	69.37
22/06/04	400	1.54	67.80	3.65	-0.81	81.17	0.63	72.75
22/06/08	400	0.84	39.51	11.67	-0.99	80.90	0.42	69.00
22/06/09	400	1.85	76.72	2.18	-0.91	90.32	0.50	77.00
22/06/10	400	0.42	41.50	11.09	-0.81	77.04	0.54	71.26
22/06/14	400	1.06	75.82	2.69	-1.03	84.94	0.40	76.29
22/06/15	400	1.26	87.07	0.03	-0.99	88.54	0.42	76.44
22/06/16	400	1.38	86.63	0.04	-0.99	90.44	0.42	76.29
22/06/17	400	1.49	88.23	0.03	-0.95	92.61	0.43	76.56
22/06/18	400	1.31	87.08	0.03	-0.94	91.66	0.44	76.31
22/06/19	400	1.52	86.06	0.03	-1.04	94.00	0.34	76.44
22/06/20	400	1.83	86.18	0.03	-1.07	95.03	0.34	76.28
22/06/21	400	1.11	68.79	4.90	-0.92	87.05	0.45	70.03
22/06/23	400	1.37	70.53	0.19	-0.68	88.56	0.62	81.91
22/06/24	400	2.19	84.27	0.21	-0.96	95.01	0.42	77.70
22/06/25	400	2.38	83.87	0.23	-0.96	95.05	0.42	78.86
22/06/26	400	2.58	83.32	0.25	-1.00	94.98	0.38	78.11
22/06/27	400	2.68	83.23	0.24	-1.02	95.04	0.37	78.58
22/06/28	400	3.10	83.08	0.27	-1.07	95.05	0.35	78.76
22/06/29	400	1.91	55.45	7.24	-1.01	85.59	0.39	70.71

Source: Tetra Tech

CHAPTER 4:
Economic Benefits

While projects of this type have the potential for job creation, no permanent full-time jobs have been specifically developed at the landfill for the project's operation. The existing on-site personnel are in the process of being trained to operate the system and provide equipment modifications through the system control panel and it is anticipated that operations and maintenance (O&M) services for the facility will be required on a part time basis.

As part of the construction activities, there were temporary jobs created. The general contractor was BSE General Engineering, Inc. (system installation), Monterey Peninsula Engineering (grading and foundations), and Unison Solutions, Inc. (system supplier). The total equipment cost was more than $2,580,000 inclusive of the hydrogen sulfide treatment system and construction cost was more than $2,920,000 (inclusive of well collection field improvement costs). 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 2020; excludes benefits) there were approximately 32,863 hours of labor time for the project. 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.

Furthermore, the additional efforts that are currently improving the wellfield have increased job opportunities and economic growth. Temporary jobs are created for contractors such as BSE General Engineering, Inc., Sacramento Drilling, and Alliance Diversified Enterprises, Inc., and operations and maintenance staff at the landfill. Job opportunities will continue as the biogas skid is operational full-time.

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 via an application process. For this project, more than $181,500 in sales taxes were generated through the purchase of materials and state revenue was also generated through income taxes received on the construction labor, CQA and engineering efforts, and permitting fees.

CHAPTER 5:
Community Benefits

The priority for the project was to generate RCNG for the district's CNG truck fueling system. The previously utilized natural gas utility pipeline to the fueling station allows for the use of natural gas generated by non-renewable sources and contracted RNG sources. By transitioning the vehicle fleet to RCNG sourced onsite from conditioned LFG, this directly benefits the local community by reducing the amount of harmful pollutants generated from non-renewable vehicle fuel sources such as diesel vehicles and beneficially utilizing the LFG that is generated from community's waste materials that are disposed in the landfill.

LFG for the production of RCNG for transportation provides a cost-effective, complete, and scalable system. Furthermore, the importance of LFG utilization to reduce methane emissions in California is substantial, and the project aids this goal directly. Since capturing and beneficially using LFG is the best way to mitigate methane emissions from landfills, the project demonstrates the application of the project at landfills 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 renewable energy requirements.

The current biogas conditioning facility faces numerous obstacles when attempting to meet the primary objective of the initial agreement to convert and upgrade up to 400 SCFM of LFG to 1,431 diesel gallon equivalents (DGE) per day. This is due to multiple operational issues including unexpected gas intrusion from the wellfield. The resulting product is LFG with a high nitrogen content and VOC concentration which has caused the facility to temporarily suspend operation with the concern of potential harm the gas could cause to the media within the treatment system. The gas intrusion is currently being addressed through various methods of improvements and the system is expected to resume normal and regular operation once improvements are implemented.

To overcome these issues, improvements and modifications are actively being implemented on the site currently. Gas extraction wells with elevated VOCs are in the process of being abandoned or removed from the wellfield which has and will continue to significantly decrease the VOC concentration of the wellfield. Additionally, wells that have high flow, great gas quality, and low VOC concentration have been added to the inlet stream of the system in an effort to reduce the VOC concentration for the LFG down to an operational level for the conditioning system, thus increasing the lifespan of the designed media. Despite the difficulty the project had in meeting the timeline, the system is currently in progress to meet the objectives set forth in the initial agreement due to improvements that are currently underway.

CHAPTER 6:
Conclusion: System Usage and Emission Reductions

6.1 Challenges

As previously discussed in Chapter 3, several factors have delayed the timeline for this project and its completion of the goals set out at the conception when the agreement was executed as ARV-17-036 on May 23, 2018. Some of the factors that contributed to the delay include the additional time required to select bidders and receive equipment drawings/deliveries, state order for COVID-19 causing issues, and delays with obtaining permits. Due to the several causes listed above, the project was completed approximately two years behind schedule.

Aside from the delays, the project also encountered delays during startup and commissioning due to an equipment failure and a change in gas constituents within the LFG resulting from increased VOC concentration in the wellfield. This required a shift in focus of the project from system startup to ensuring sufficient quality LFG for operation of the RNG System. The poor performing wells have been removed from the wellfield and are currently being replaced by new wells collecting from larger waste zones with newer waste for quality gas collection. However, the six months of data collection requested cannot be completed by the closure of the project due to the VOC intrusion into the landfill's wellfield.

6.2 Successes

The BioCNG™ facility has been installed and operationally tested during the past year to demonstrate that the gas conditioning system is functioning as designed. Once the quality of the incoming raw LFG has been achieved to align with the requirements of the installed equipment, the system will commence regular operation to supply RCNG to the onsite CNG fueling facility. About 40 medium-duty to heavy-duty on-road trucks are fueled using the onsite CNG fueling facility. Those vehicles replaced diesel fired engines and are achieving emission reductions through their use in the community collecting solid waste and recyclable materials. Five new vehicles are being purchased in 2023 by MRWMD that will replace trucks with diesel engines and will result in new, additional reductions in emissions. This is the objective of agreement ARV-17-036, for local waste collection vehicles to be fueled by RCNG that is produced from the biogas generated by the wastes in the landfill that were originally disposed by these same waste collection vehicles.

6.3 Next Steps

The project's installed biogas conditioning facility will convert and upgrade up to 400 SCFM of LFG and/or AD biogas (e.g., methane) to approximately 1,431 diesel gallon equivalents per day of RNG. The project has been designed, installed, and has commenced preliminary operation to meet this goal. In order to accomplish continuous operations, further reduction of constituents in the raw LFG from the wellfield (reduce and/or eliminate oxygen & balance gases to improve raw biogas quality) is currently underway with further wellfield tuning, well abandonment and replacement, and newly planned GCCS improvements to help meet these

goals. Additional measures such as i) modifying the treatment media in the polishing tank to include VOC treatment media in addition to H_2S treatment media, ii) a dedicated group of high-quality LFG collection wells on a separate transmission pipeline to the BioCNG™ facility, or iii) new biogas sources from an onsite AD or the adjacent WWTP AD facility will be utilized if improvements in the raw biogas quality is not achieved in the near future. The AD biogas supply opportunity is being evaluated by a joint study with MRWMD and the adjacent WWTP agency in 2023.

Once the raw LFG quality is improved and the system's specified product gas quality is approved by CalRecycle and the Environmental Protection Agency (EPA), the system will commence full-time operation and produce RCNG from LFG on a continuous basis. RCNG will then be sent to the vehicle fleet as a renewable fuel source to the California transportation sector which will further the economic and community benefits accomplished by the project. Supplying RCNG to the district's existing CNG truck fueling system for use in collection of the community's solid wastes completes the cycle of beneficial reuse of landfill and/or future AD biogas generated from those waste materials.

GLOSSARY

GLOBAL WARMING SOLUTIONS ACT (AB32) – The 2006 Act that aims to reduce global warming by requiring in law a sharp reduction of GHG emissions so that California could set the stage for its transition to a sustainable, low-carbon future. AB 32 requires California to reduce its GHG emissions to 1990 levels by 2020 — a reduction of approximately 15 percent below emissions expected under a "business as usual" scenario.

ANAEROBIC DIGESTER (AD) – a sequence of processes by which microorganisms break down biodegradable material in the absence of oxygen.

ALTERNATIVE AND RENEWABLE FUEL AND VEHICLE TECHNOLOGY PROGRAM (ARFVTP) – also known as the CEC's Clean Transportation Program, it invests up to $100 million annually in a broad portfolio of transportation and fuel transportation projects throughout the state. The Energy Commission leverages public and private investments to support adoption of cleaner transportation powered by alternative and renewable fuels.

BEST AVAILABLE CONTROL TECHNOLOGY (BACT) – a type of technology that is one of the pollution control methods covered by the U.S. Clean Air Act. Title 1 of the Act promotes air quality, protects the ozone and places limitations on emissions.

BIO COMPRESSED NATURAL GAS (BioCNG) – a Tetra Tech Company's technology for the biogas conditioning system, which economically produces biogas-based fuel for CNG vehicles.

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

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

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

ENVIRONMENTAL PROTECTION AGENCY (EPA) – an independent executive agency of the United States federal government tasked with environmental protection matters.

GAS COLLECTION AND CONTROL SYSTEM (GCCS) – network of minor and major components of landfills to help LFG migration, odor control, control of non-methanogenic organic compounds, provide LFG to energy projects, and meet EPA regulations.

GREENHOUSE GAS (GHG) – a gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

HYDROGEN SULFIDE (H_2S) – Hydrogen sulfide is a gas that naturally occurs in the environment in crude petroleum, natural gas, volcanic gases and hot springs. It can also be produced from bacterial breakdown of organic matter. It is flammable, colorless and noticeable by its rotten egg odor.

INTEGRATED WASTE MANAGEMENT PLAN (IWMP) – under AB 75, each state agency and large state facility was required to develop an integrated waste management plan by July 1, 2000. The plan was to lay out how the agency or facility would divert at least 25 percent of its solid waste from landfills or transformation facilities by January 1, 2002, and 50 percent by January 1, 2004.

LOW CARBON FUEL STANDARD (LCFS) – a program in California designed to decrease the carbon intensity of California's transportation fuel pool and provide an increasing range of low-carbon and renewable alternatives, which reduce petroleum dependency and achieve air quality benefits.

LANDFILL GAS (LFG) – a mix of different gases created by the action of microorganisms within a landfill as they decompose organic waste, including methane, carbon dioxide, nitrogen, hydrogen sulfide, and VOCs.

MONTEREY REGIONAL WASTE MANAGEMENT DISTRICT (MRWMD) – waste management services in Monterey County, California and is the location of the project.

MUNICIPAL SOLID WASTE (MSW) – a waste type consisting of everyday items that are discarded by the public.

PUBLICLY OWNED TREATMENT WORKS (POTW) – a sewage treatment plant owned, and usually operated, by a government agency. In the U.S., POTWs are typically owned by local government agencies, and are usually designed to treat domestic sewage and not industrial wastewater.

POUNDS PER SQUARE INCH (psi) – unit to measure pressure

RENEWABLE NATURAL GAS (RNG) – a pipeline-quality gas that is fully interchangeable with conventional natural gas and thus can be used in natural gas vehicles.

STANDARD CUBIC FEET PER MINUTE (SCFM) – unit to measure flow rate of gas under standard pressure and temperature conditions

TONS PER DAY (TPD) – unit to measure rate of waste in weight on a daily basis

TONS PER YEAR (TPY) - unit to measure rate of waste in weight on a yearly basis

VOLATILE ORGANIC COMPOUND (VOC) – organic chemicals that have a high vapor pressure at room temperature. High vapor pressure correlates with a low boiling point, which relates to the number of the sample's molecules in the surrounding air, a trait known as volatility.

ZERO WASTE ENERGY (ZWE) – the conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without

burning and with no discharges to land, water, or air that threaten the environment or human health.