CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

Clean Transportation Program

FINAL PROJECT REPORT

Blue Line Biogenic CNG Facility

Prepared for: California Energy Commission

Prepared by: Total Compliance Management, Inc.

SOUTH SAN FRANCISCO SCAVENGER COMPANY, INC.

BLUE LINE TRANSFER, INC.

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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 nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-11-601 for the development of new, California-based biofuel production facilities that can sustainably produce low carbon transportation fuels. In response to PON-11-601, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards October 5th, 2012, and the agreement was executed as ARV-12-031 on March 20th, 2013.

ABSTRACT

This Final Report is written to describe the operations and results of a small-scale dry fermentation anaerobic digestion pilot project that was developed for Blue Line Transfer, Inc. in South San Francisco. The pilot project's intent was to demonstrate the ability of a modular anaerobic digestion system that harvests biogas from organic solid waste to fuel a small fleet of waste collection vehicles. Blue Line Transfer and its sister company, South San Francisco Scavenger Company, Inc., are waste processing and collection companies, respectively. Therefore, these companies are in an advantageous position for testing the feasibility of such a waste-to-fuel anaerobic digestion system. The system at Blue Line Transfer consists of eight digestion bays, a gas purification and compression system, a compressed natural gas vehicle fueling station, and two in-vessel composting units for composting the digestate end product.

The goal of this pilot project would be to establish the economic and environmental justifications for similar projects to be replicated throughout the state. Should similar waste-based anaerobic digestion facilities come online and prove successful, California will make significant progress on its climate, solid waste, and energy independence goals.

The details provided in this final report include descriptions of the anaerobic digestion process, summary data regarding incoming feedstock, information regarding the digestate end product, analyses of the biogas production, and assessments of the project benefits.

Keywords: biogas, biomethane, anaerobic digestion, CNG, RNG, South San Francisco, Blue Line, renewable energy, methane, waste-to-energy, pilot project, collection fleet, alternative energy, Eggersmann, Zero Waste Energy, BioCNG, Cornerstone, waste-derived fuels, bioenergy, resource recovery.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Background: Blue Line Transfer, Inc. is a family-owned company that has been collecting and processing solid waste and recyclables alongside its sister company, South San Francisco Scavenger Company, Inc., since 1914. As a solid waste and recycling provider, Blue Line Transfer Inc. is assisting the communities it serves to implement Climate Action Plans and reduce greenhouse gases by transitioning its fleets to low carbon fuel, developing a renewable natural gas fueling station, implementing commercial recycling programs, and developing an anaerobic digestion facility. To facilitate the advancement of greenhouse gas reduction through anaerobic digestion, Blue Line Transfer has established a Pilot and Demonstration Facility that uses small-scale anaerobic digestion to produce vehicle fuel for its fleet.

Purpose: Blue Line Transfer is using a dry anaerobic digestion technology, licensed to Zero Waste Energy, known as *SmartFerm*, which was developed by Eggersmann Anlagenbau Concept GmbH, a Germany company that developed and has implemented this technology in Germany. The purpose of this facility is to process 11,200 tons per year of food and green waste to produce approximately 117,124 diesel gallon equivalents of renewable natural gas to fuel the South San Francisco Scavenger Company's fleet of waste collection vehicles.

The project is designed to demonstrate the use of an entirely modular, small-scale, biofuel production and fueling system, for replication throughout California where it could be co-located at other existing permitted municipal solid waste processing and transfer stations. This project served to establish economic information and best practices to further facilitate the reproduction of similar projects across the state.

In addition to producing information on best practices for these modular dry anaerobic digestion facilities, the project sought to investigate the quality and quantities of the compost and energy outputs of anaerobic digestion. These metrics will help inform future projects and decision makers.

Process: As the owner of the Blue Line Material Recovery Facility where the project is located, Blue Line Transfer Inc. has the necessary infrastructure for the Anaerobic Digestion and Biogenic Compressed Natural Gas Production Facility. Blue Line Transfer has common ownership with South San Francisco Scavenger Company, which has long-term franchise agreements with three local jurisdictions. This arrangement allows Blue Line Transfer access to the 11,200 tons per year of food and green waste required for the project, which equates to approximately 43 tons per day. The biomethane compressed natural gas produced from this feedstock is in turn purified and used to fuel collection vehicles.

The solid by-product of the anaerobic digestion process, digestate, is placed in an in-vessel composter to reduce odors and provide some stabilization prior to being taken from Blue Line Material Recovery Facility to the fully permitted Z-Best Composting Facility in Gilroy. There, the digestate is used as feedstock to produce compost.

Results: The Blue Line Transfer Anaerobic digestion facility successfully began producing vehicle fuel for collection vehicles, and the facility continues to operate without significant interruptions. The methane recovery rate from the biogas for fuel is currently lower than it was at the project outset, a shift from 70 percent recovery to about 50 percent recovery. Once the issue is resolved, production is expected to return to its initial levels. Notwithstanding the

recovery rate, the facility is on track to produce over 50,000 diesel gallon equivalents of renewable natural gas this year, once the facility is back operating at full capacity this number could exceed 100,000 diesel gallon equivalents/year.

Feedstock Processing

South San Francisco's Collection Fleet began collecting food waste and yard trimmings from its clients and delivering the material to its facility. This material is cleaned, loaded into digesters, and ultimately stabilized so it may be furnished as a compost feedstock. Average batches of feedstock are 62 tons and are digested over the course of three weeks. The eight digesters combined process approximately 653 tons of material each month, which is transferred to a compost facility for further processing.

Gas Production

Blue Line Transfer's anaerobic digesters have yielded an average of 2,969 standard cubic feet of biogas for each ton of material placed in them since startup. The methane concentration of this gas varies depending on the nature of the feedstock but averages approximately 55 percent. As South San Francisco Scavenger's collection program matures, more food waste material will be collected which is expected to yield greater biogas generation with higher concentrations of methane.

Gas Upgrading

At the project's beginning, 70 percent of the biomethane produced at the facility was successfully cleaned and upgraded to vehicle fuel. However, due to complications with the purification system, this recovery rate has since dropped to about 50 percent. A solution to this issue is being investigated, and the lessons learned from the process will benefit subsequent projects.

Fueling Station

Gas which is successfully upgraded has been used in South San Francisco Scavenger's fleet without incident since the project's beginning. Trucks refilling at the station are refueled with a biomethane and pipeline natural gas blend that draws from the biomethane tanks preferentially. The operator tested both the renewable blend and pure conventional natural gas in the collection vehicles and have observed no performance differences between the two fuels. Currently 4,441 Diesel gallon equivalents of renewable fuel from this project are being used each month in South San Francisco Scavenger's Fleet. As the biogas upgrading issues are resolved, this amount is expected to rise to the design capacity of 8,787 diesel gallon equivalents per month.

Project Economics

Given the present cost structure of the project, Blue Line Transfer is producing renewable natural gas fuel at the cost of $4.32 per gasoline gallon equivalent, approximately double that of retail natural gas. Although this rate is not yet competitive with current retail fossil fuel compressed natural gas, this fuel is more environmentally friendly than its alternatives. This assists the city of South San Francisco in reducing its greenhouse gas (GHG) footprint. As investment in technologies such as this grow, the economics of biogenic compressed natural gas are expected to improve.

Conclusion

This Blue Line Biogenic compressed natural gas facility is a first of its kind facility that has demonstrated that dry fermentation anaerobic digestion can produce substantial amounts of usable natural gas vehicle fuel from waste materials. As this is a small-scale pilot project implementing a new technology, the gains from this endeavor are more scientific and environmental than economic. However, as lessons learned from Blue Line Transfer are applied, the price point of the technology is expected to improve, thereby facilitating the propagation of similar facilities across the state.

CHAPTER 1: Introduction

This section introduces the dry fermentation anaerobic digestion project at Blue Line Transfer, Inc.

1.1 Project Background

Blue Line Transfer, Inc. has installed and is operating an anaerobic digestion facility that produces compressed natural gas (CNG) for transportation fuel using the biomethane generated by food waste and green waste. These wastes are collected from the cities of South San Francisco, Brisbane, Millbrae, and the County of San Mateo. The anaerobic digestion facility can convert 11,200 tons per year of food waste and green waste into biomethane that is cleaned and compressed to produce CNG for the South San Francisco Scavenger Company's CNG refuse and recycling collection vehicle fleet. With the success of this project, the City of Napa now plans to develop a similar 25,000 tons per year anaerobic digestion facility.

1.2 Project Purpose

This project is the first of its kind. Consequently, the purpose of this project is to address the barriers to commercialization that may arise in subsequent projects. To this end, the following goals were established at the project outset.

- Demonstrate the construction of an entirely modular, small-scale biofuel production and processing system designed to integrate and complement each other.
- Demonstrate the performance of a food waste and green waste anaerobic digestion facility that has been sized such that the tonnage processed and biomethane generated are precisely sized to correspond with a small-scale fuel production and on-site fuel dispensing system.
- Optimize equipment settings to balance biogenic energy generation for fuel production, establishing key operational parameters such as retention time, operating temperature, thermal and electrical loads, water use and wastewater generation, and operational and maintenance requirements.
- Establish economics for this type of small-scale biomethane production facility.

1.3 Project Changes

Several changes to the project have been made since the initial proposal. These changes include:

- The initial proposal included a microturbine for generating electricity from off gas. This microturbine is no longer part of the project. The microturbine was removed due to the expectation that tail gas methane concentrations would not be sufficient to run the microturbine. Pipeline natural gas could have been brought in as a supplement; however, the heat exchanger on the microturbine is not as efficient as the one in the boiler. This would have required higher quantities of pipeline gas to meet the thermal requirements.

- The initially proposed BioCNG 50 unit has been replaced with a BioCNG 100 for greater fuel processing capacity. This expanded capacity is designed to accommodate the increase in throughput from 9,000 tons per year to 11,200 tons per year.
- The fueling station has been expanded such that it may accommodate the entire future CNG fleet for South San Francisco Scavenger Company as the transition from diesel is accomplished by supplementing the biomethane fuel with pipeline natural gas as needed. This expansion can support 40 CNG collection vehicles, enabling the entire fleet to be fueled on-site.

1.4 Project Approach

Blue Line is well situated for establishing an anaerobic digestion facility that converts organic waste into vehicle fuel. Having ownership of both the incoming waste feedstock and a CNG fleet to utilize the final product allows the facility to observe the entire life cycle of the biomethane fuel produced. As such, this project addresses barriers that could be encountered in large scale commercialization at three stages of the process: feedstock acquisition, processing, and use of end products.

1.4.1 Feedstock Acquisition

Blue Line is the owner of the Blue Line Material Recovery Facility where the project is located and where the CNG fleet is parked. This facility has a Full Solid Waste Facility Permit to process organic waste and is the anchor for this project. Furthermore, Blue Line has common ownership with South San Francisco Scavenger Company which has long-term franchise agreements with three local jurisdictions and currently collects food waste and green waste to ensure feedstock delivery. This arrangement is critical to the success of the project as feedstock security is necessary to use the system at full capacity.

Blue Line Transfer and South San Francisco Scavenger engage in ongoing outreach in order to increase organic waste generator participation in the collection programs, and to reduce levels of contamination in the incoming feedstock. As the food waste collection program is still maturing, most of the new inbound tons are green waste.

The collection trucks that collect this material deposit their loads at the same facility that refuels them. Once fueled at the facility, these collection vehicles will once again return to their routes to collect more waste. Each vehicle typically collects eight tons of organic waste each route, and runs two routes per day.

1.4.2 Processing

Blue Line’s Anaerobic Digestion has a capacity of up to 11,200 tons of food and green waste per year. The biomethane produced from this waste is cleaned and converted into biogenic CNG, and then used to refill the same vehicles that collected the waste. The small-scale anaerobic digestion system that makes this transformation is called SmartFerm, which was developed by a German company called Eggersmann Anlagenbau Concept GmbH. Eggersmann has exclusively licensed this dry anaerobic digestion technology to Zero Waste Energy, LLC., a San Jose-based developer of organic waste treatment projects.

The anaerobic digestion facility at Blue Line consists of eight anaerobic digesters, each of which has been receiving 62 tons of organic waste per batch on average since startup. These bays are loaded with feedstock, sealed, and retained for approximately 21 days, during which biogas is collected. During this processing time, the oxygen deprived environment allows the feedstock to emit biogas which is retained in a storage bladder. Biogas generated in the digesters exits to the air space in the percolation tank, from where it flows to the biogas storage bladder. Solid materials are removed at the end of the process and the emptied digesters are then prepared to receive the next batch of feedstock. A detailed timeline of this process is provided in Figure 4.

With the processing time described above, 17.4 batches may be processed by each of the eight digesters every year, thus approximately 139 batches may be processed every year. Given the system's design of 11,200 tons per year, up to 80.6 tons per batch may be processed at design capacity.

1.4.3 Use of End Products

The biogas and solid remnants of the feedstock, known as digestate, are the two main products of the digestion process. The biogas is cleaned to produce a methane rich vehicle fuel. This vehicle fuel, also known as product gas, undergoes a purification that removes moisture, hydrogen sulfide (H_2S), volatile organic compounds, siloxane, and other contaminants. After this purification stage, the fuel gas is then pressurized at the fueling station for use in waste collection vehicles. The fueling station also receives fuel from the natural gas pipeline to assure that all vehicles in South San Francisco Scavenger's CNG truck fleet can be fueled on-site, without being limited to the production of biomethane fuel alone.

The digestate byproduct also undergoes post-digestion processing. When the digestion process is complete, the digestate is removed to free the digester for the next incoming load of feedstock. The digestate is taken to an adjacent in-vessel composting system (IVC), to stabilize the material, meet time and temperature requirements for pathogen reduction, and reduce odors with a retention time of four to five days. The material then leaves the IVC to be shipped out to a composting facility where it may proceed directly to the curing stage of composting.

1.5 Project Timeline

The project has been under development for several years with an official operational start date of March 1st, 2015. Table 1 provides a timeline of milestones.

Table 1: Major Project Milestones

Major Project Milestones	
Notice of Proposed Award	October 5, 2012
Commission Meeting	February 13, 2013
Kickoff & Critical Project Review Meeting	March 21, 2013
Construction Begins	October 2013
Commissioning of Systems	December 2013, January and February 2014
First Waste Placed in a Digester	January 6, 2015
Collection Trucks Operating on Biomethane	February 5, 2015
Official Beginning of Operations	March 1, 2015

Source: Total Compliance Management, Inc.

1.6 Partnerships with Client Jurisdictions

In Blue Line Transfer's service areas of San Mateo County, the City of South San Francisco, the City of Millbrae and the San Francisco Airport, all of these jurisdictions have set concrete GHG reduction goals and sustainability initiatives. As a member of the community, Blue Line Transfer has aligned their own goals with that of their jurisdictions. This ensures that as Blue Line Transfer makes progress toward their own goals and targets, they are assisting their communities in achieving theirs, as well.

Blue Line Transfer has adopted a Sustainability Plan, the first two goals of which are to reduce direct and indirect GHG emissions and to improve fleet efficiency and lower emissions which have negative air quality and GHG impacts. Given that over 80 percent of Blue Line Transfer's GHG emissions are from mobile sources, the on-site production of a biogenic fuel tremendously reduces the overall GHG emissions of their operations.

Recognizing the climate benefits of this project are common to both Blue Line Transfer's and the sustainability goals of the client jurisdiction's, all parties saw the benefit of partnering to make the project a success. The City of South San Francisco agreed to a 20-year franchise agreement with a renewal clause to provide the certainty needed for Blue Line Transfer to make the substantial infrastructure investments required. The support of the client jurisdictions, as well as the California Energy Commission, was critical to the project moving forward.

1.6.1 Ribbon Cutting

In September 2014, a Ribbon Cutting was held for the Blue Line Facility, Figure 1, the nation's first dry anaerobic digestion facility, shown in Figure 2, converting methane gas into compressed natural gas fuel for collection trucks. Blue Line Transfer is excited to pioneer the future of materials management by creating a fuel source for their trucks from the materials collected from local communities. The by-product is composted and applied to soils, promoting healthier production of food and plant materials, that will eventually find themselves back in the anaerobic digester; a closed-loop renewable fueling system. Figures 3 and 4 show the digestion process.

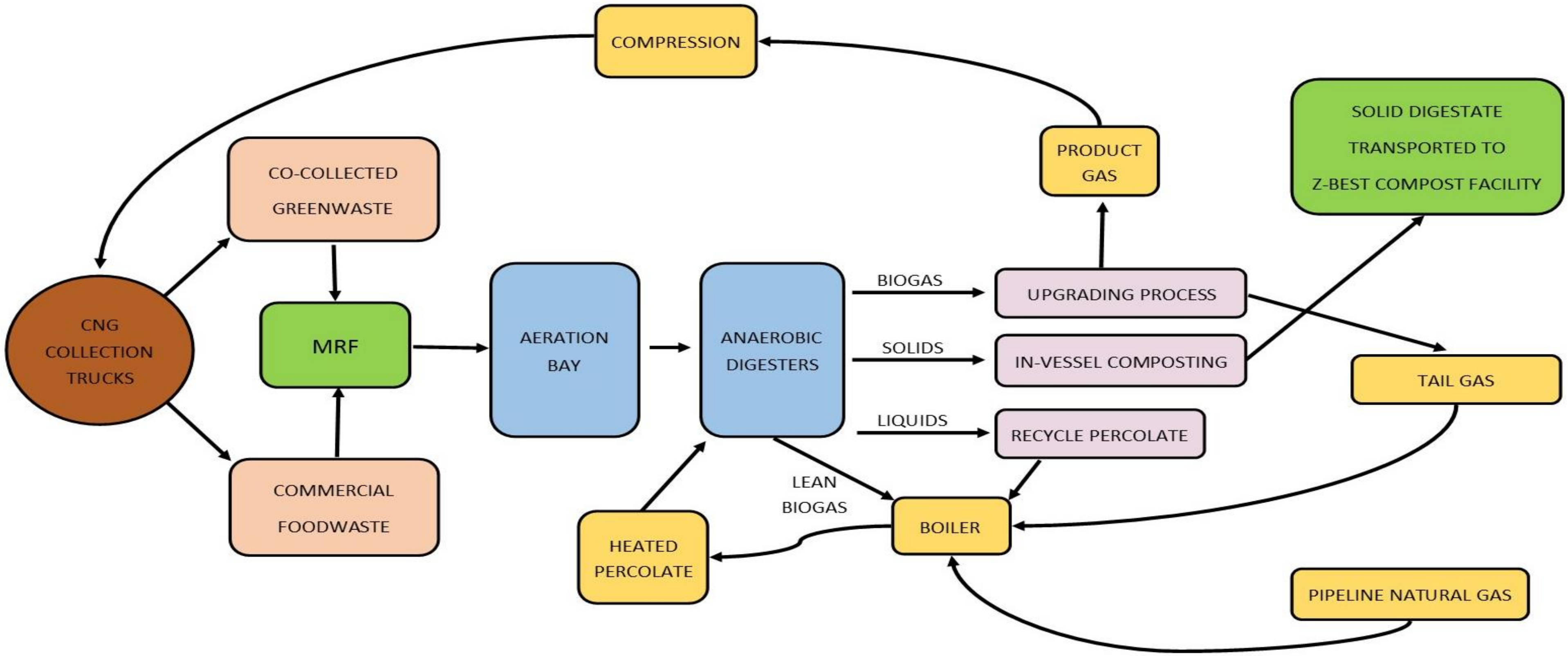
Figure 1: Ribbon Cutting Ceremony

Source: Total Compliance Management, Inc.

Figure 2: Anaerobic Digestion Facility

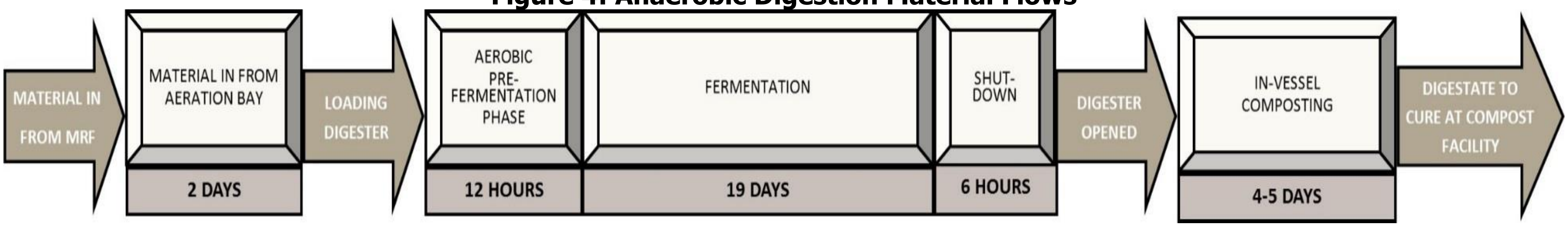
Source: Total Compliance Management, Inc.

Figure 3: Anaerobic Digestion Process Flow Diagram



Source: Total Compliance Management, Inc.

Figure 4: Anaerobic Digestion Material Flows



Source: Total Compliance Management, Inc.

CHAPTER 2: System Configuration

This section is designed to explain each step of the Dry Fermentation Anaerobic Digestion process including the collection of feedstocks, the digestion of materials, the cleaning and treatment of the biogas product, and the final compression and preparation of the gas for vehicle use.

2.1 Waste Receiving and Handling

Organic waste is delivered to the site by the South San Francisco Scavenger Company's fleet of collection trucks. The waste consists of a source separated organic fraction of municipal solid waste collected from households and commercial generators located in the South San Francisco, Millbrae, and Brisbane municipalities, as well as municipal solid waste collected from the San Francisco International Airport.

2.1.1 Feedstock Pre-processing

Feedstock arriving at Blue Line Transfer is delivered to the Material Recovery Facility by the collection vehicles. Materials currently arrive in a mixed state. Some material is bagged, and some material is loose. The bags are opened and removed, and the material undergoes a manual sort where metals, large pieces of wood, and other contaminants are removed by a trained employee working eight hours a day.

After this initial screening process, the green and food waste materials are mixed at the Material Recovery Facility to produce a blend. This optimal ratio of food to green is expected to be 80 percent food and 20 percent green waste. However, due to limited amounts of incoming food material, this ratio has not yet being achieved. The blend currently in use is one loader bucket of food waste for every two buckets of green waste. Once mixed, the material is loaded into a roll off truck, weighed, and deposited in the aeration bay. The aeration bay is forty-five feet long, twenty-five feet wide, and thirty feet high. It is capable of storing 600 cubic yards of material and is adequate to fully accommodate a full digester's capacity of feedstock. Staff is typically able to gauge how much feedstock is unloaded such that all of the receiving bay material is used, while still ensuring adequate material is available to fill a digester.

The aeration bay is under negative air pressure, causing the off gas to go to the acid scrubber and biofilter. This process ensures that hazardous and odorous gases are eliminated from the feedstock material.

2.1.2 Digester Loading

Digester feedstock is moved from the receiving bay to the digesters using wheel loaders, shown in Figure 5. Each digester is twelve feet tall, twelve feet wide, and forty-five feet long. Typically, the back-most six feet of the digester is filled with feedstock such that the feedstock pile slopes up from base level to eight and a half feet high. This pile height is maintained for the next 30 feet of fill as wheel loaders add more feedstock. Finally, the front-most four feet of the digester is loaded such that the material slopes back down to floor level. This arrangement is designed to create a structurally sound feedstock pile that maximizes digester fill and protects the integrity of the rear wall and front door. Once complete, the digester doors are shut, and anaerobic digestion begins.

Figure 5: Digester Loading

Source: Blue Line Transfer

2.2 Anaerobic Digestion

The anaerobic digestion process consists of three stages: start-up, fermentation, and shut down. Material and gas inside the digesters are treated differently in each stage so as to maximize biogas production.

2.2.1 Start-up Stage

Inside the digester, the feedstock is aerated using the in-floor air supply system. This creates aerobic digestion conditions and facilitates the self-heating process of the material. The exhaust air from this phase, as well as that from the aeration bay, are treated in an acid scrubber and biofilter/humidifier to remove ammonia, particulates, volatile organic compounds, and to minimize odor emissions. After twelve hours, the aeration is shut off creating anaerobic conditions, and microbes consume the available oxygen increasing the temperature inside the digester to around 113 degrees Fahrenheit. This is lower than the desired 120-130 degrees Fahrenheit, which is the optimal thermophilic range. This temperature will be increased by increasing gas flow to the boiler to increase thermal energy and operate higher in the thermophilic range. From this phase forward, the waste is sprayed with a fine water mist which percolates through the waste, facilitating decomposition and biogas production. The percolate is collected at the bottom of the digester, solids in the percolate are settled out, and the percolate re-heated by an external boiler and recycled into the digester spray system again.

2.2.2 Fermentation Stage

Percolate flow is managed by parameters built into this system and begins when the digester reaches the 45 degrees Centigrade. The first series of sprays occurs during the pre-fermentation phase and consists of four-minute sprays every 15 minutes. This phase continues until digester methane reaches two percent. At this point the first of the three fermentation phases detailed in Table 2 below begins.

Table 2: Phases of Digestion

Phase	Phase Duration	Spray Duration	Spray Frequency
Fermentation A	3 Days	4 Minutes	Every 15 Minutes
Fermentation B	15 Days	4 Minutes	Every 18 Minutes
Fermentation C	1 Day	2 Minutes	Every 58 Minutes

Source: Total Compliance Management, Inc.

The fermentation process continues for approximately three weeks, during which biogas product containing 45-65 percent methane and 35-55 percent carbon dioxide is extracted and collected in the bladder storage tanks for later treatment. The amount of methane generated varies depending on the phase. During Fermentation A, methane levels rise quickly to 25 percent to 30 percent, or when the food waste proportion of the feedstock is high, 35-40 percent. This methane concentration peaks at around 56 percent to 59 percent during Fermentation B, and maintains these levels through Fermentation C. The concentration of methane and other components in the gas stored is continuously monitored by a gas analyzer.

2.2.3 Shut-down Stage

As Fermentation C concludes, the digestion stage is terminated with an aeration process where fresh air is pumped through the digested waste from the floor and purged biogas is collected. Once the methane concentration falls below 22 percent, the lean gas is diverted to the burner boiler as auxiliary fuel and combined with pipeline gas and tail gas from the biogas upgrading system described below. Once methane concentration has dropped below 2.5 percent, gas is routed through the biofilter for methane destruction. The digester door remains closed until methane levels have dropped safely below one percent, and H_2S is not detected. Employee-worn portable devices and stationary devices monitor for the presence of hazardous gases.

The residual material, known as digestate, is transferred to one of two in-vessel composting tunnels where residual ammonia is removed by aeration and exhausted to the scrubber and filter system. After a retention time of up to five days, the digestate is transported by truck to an off-site compost facility where it is incorporated into the curing phase, having already undergone pathogen reduction.

2.3 Biogas Collection and Upgrading

Biogas produced from the anaerobic digestion system must be cleaned, treated, and upgraded before it may be compressed into a suitable vehicle fuel. This process involves the removal of H_2S, moisture, siloxane, carbon dioxide, and volatile organic compounds.

2.3.1 Hydrogen Sulfide Removal

H_2S is removed from the biogas at two points in the system. Initially, H_2S is eliminated in the percolate tank through microbursts of air triggered by a parameter-based system which monitors gas composition in the tank. Remaining H_2S is neutralized using a H_2S filter, pictured in Figure 6, and an iron-based treatment media known as "sulfatreat".

Figure 6: H_2S Filter

Source: Blue Line Transfer

2.3.2 Moisture Removal

Biogas that has been cleansed of H_2S is piped to the BioCNG 100 biogas treatment system. This system is capable of processing up to 100 standard cubic foot (SCF) of biogas. The system removes moisture from the biogas flow through a cooling cycle. This system utilizes coolant circulated from a glycol chiller to achieve sufficiently cool temperatures to cause moisture condensate to separate from the gas. The gas is then reheated prior to proceeding to the next stage of the gas upgrading process.

2.3.3 Siloxane Volatile Organic Compounds Removal

After moisture removal, the biogas proceeds through the BioCNG 100 skid to the Siloxane volatile organic compounds removal system. Gas is passed through the system at 100-107 pounds per square inch. This existing gas proceeds to the carbon dioxide removal system.

2.3.4 Carbon Dioxide Removal

The final cleansing unit of the BioCNG 100 skid is the carbon dioxide removal system, shown in Figure 7. Here, two gas flows are generated. These two gases are the methane-rich product gas, and the low-methane tail gas. The product gas has a minimum methane content setting which can be adjusted, but typically remains at about 94 percent. The methane-rich product gas is continuously metered by an Endress-Hauser thermal mass flow meter; while a Siemens Ultramat 23 gas analyzer continuously monitors the CH_4 content prior to the compression stage. The tail gas in the system is routed to the boiler system to contribute thermal energy for the percolation system.

Figure 7: Biogas Upgrade Skid – Biogas Purification

Source: Blue Line Transfer

2.4 Process Heat Production

The gas-fueled boiler, shown in Figure 8 below, is used to generate heat to maintain the optimal temperature in the digesters and heat up the percolate. The boiler is fueled with a mixture of natural gas, digester lean gas, and tail gas from the BioCNG unit. The facility is also equipped with a back-up flare which is used to combust excess supplies of digester gas. The back-up flare does not use any other supply of fuel, neither renewable nor fossil fuel.

Figure 8: Boiler Unit

Source: Blue Line Transfer

2.5 CNG Compression and Fuel Dispensing

The product gas from the biogas upgrading system is stored in a 3,000-gallon buffer tank at approximately 80 pounds per square inch. Two 40 cubic feet per minute, high pressure compressors raise the gas pressure to CNG specification, approximately 3,900 pounds per square inch. The renewable CNG is then stored in a set of high-pressure tanks which supply the truck fueling station. The high-pressure tank set consists of one pipeline natural gas tank, and five renewable natural gas tanks which are used preferentially. A separate utility line provides an auxiliary supply of natural gas to the pipeline natural gas tank to complement the renewable CNG fuel to refuel the trucks as necessary. The utility gas supply is metered separately from the renewable CNG supply line and is converted to CNG using a separate compressor skid and high-pressure storage tank.

2.5.1 Fueling Station

The fuel station consists of 20 dispensing nozzles used to refuel a fleet of 22 municipal solid waste collection trucks. The fuel dispensed is not measured by volume, but by pressure reached in the truck, which is considered full when the pressure reaches approximately 3,700-3,900 pounds per square inch. As described above, the trucks require the auxiliary supply of non-renewable CNG to reach such pressure, shown in Figures 9, 10, and 11 below. The renewable CNG product is continuously measured at the biogas upgrading system output.

Trucks are filled through a slow-fill process, which requires parking the collection vehicles at the fueling station overnight as they are fueled.

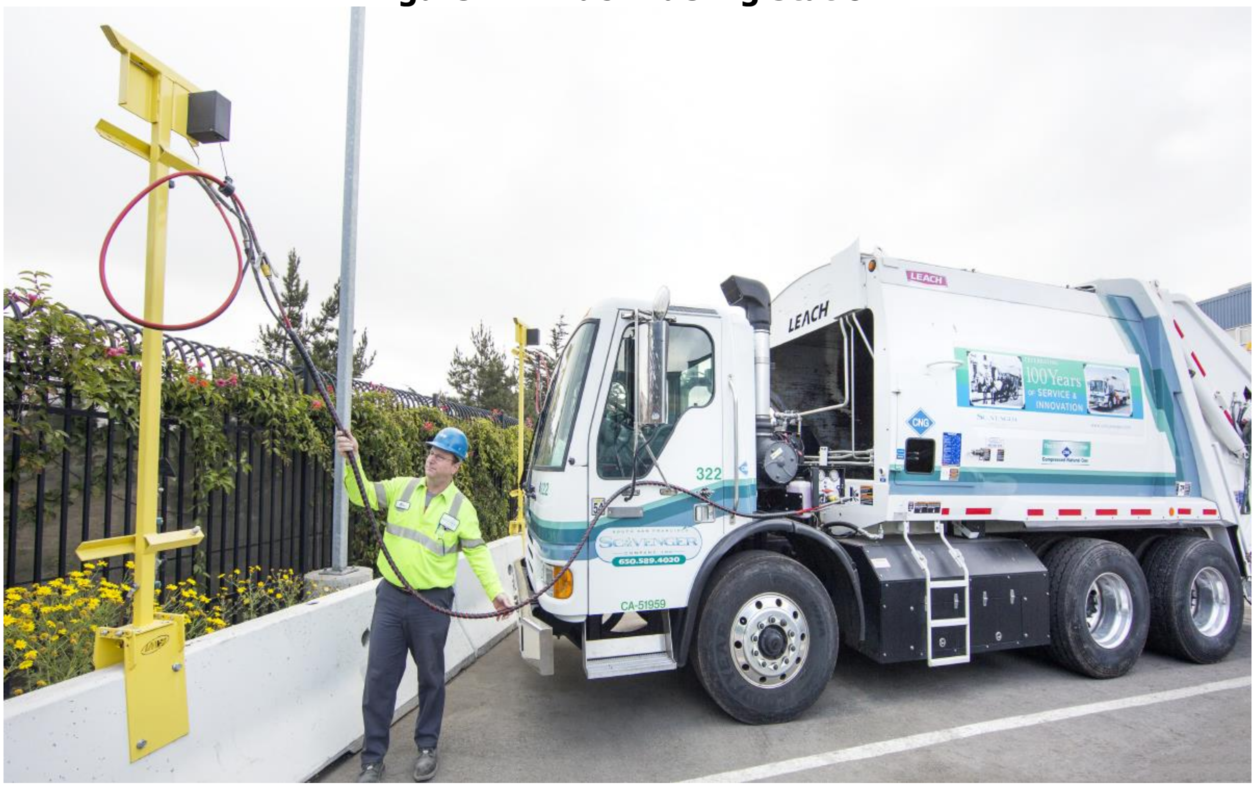
Figure 9: Natural Gas High Pressure Compressor 5-Stage

Source: Blue Line Transfer

Figure 10: Five Renewable Natural Gas and One Pipeline Natural Gas High Pressure Tanks and Blend Line

Source: Blue Line Transfer

Figure 11: Truck Fueling Station



Source: Blue Line Transfer

2.6 Digestate Processing and Removal

After digestion is complete, the remaining material in the digesters undergoes a multi-stage process to transform it to a safe and usable end product. The material, known as digestate, is removed from the digesters once unwanted gases are evacuated and atmospheric conditions within the digesters are at safe levels. At this point, the digester doors are opened and wheel loaders move the digestate to one of two adjacent IVC units. This activity is conducted late at night such that the entire process is complete by 4:00 AM.

Each IVC is forty feet long, twelve feet wide, and has an effective loading height of nine feet. This grants each IVC a holding capacity of 160 cubic yards. This capacity allows the IVCs to receive entire batches of digestate and retain them for three to five days. The IVCs are capable of operating year-round, with biofilter changes resulting in little to no down time, as biofilter media is changed every several years. Plastics are removed from the digestate which is then ground and sent to the composting facility.

2.7 Flare

The biogas storage bladder is routes biogas to the flare once 85 percent of its 800m^3 capacity is filled. The 85 percent tolerance of the biogas varies slightly as a function of ambient temperature. During warm weather, the bladder is more likely to route gas to the flare, and during hot days the flare may come on three to four times a day. Conversely, during cooler times, the flare may only come on once during a four day period. In either event, gas quantities routed to the flare are very small.

2.8 Acid Scrubber, Humidifier, and Biofilter

Aeration bay gas, IVC gas, and lean gas from the anaerobic digesters are all routed to the acid scrubber, shown in Figure 12 below, which removes ammonia and other contaminants from these gases. This acid scrubber utilizes sulfuric acid to treat incoming gas and it is capable of processing 5,500 – 8,000 scm/h. Following the acid treatment, gas passes through a humidifier, and ultimately a biofilter, shown in Figure 13 below, to mitigate emissions. A by-product, ammonium sulfate, may have co-product benefit as a fertilizer, but until that is established the ammonium sulfate is hauled away by the supplier of the sulfuric acid.

Figure 12: Acid Scrubber

Pictured above is the acid scrubber, ammonium sulfide tank, sulfuric acid tank, and emergency eye wash station.

Source: Blue Line Transfer

Figure 13: Biofilter

Biofilter with acid scrubber in background. Biofilter dimensions: length 42.64 feet, width 9.84, height 8.53, with media depth of 6.56 feet.

Source: Blue Line Transfer

2.9 Contractors and Consultants

The equipment and expertise required in the above processes came from the providers listed in Tables 3 and 4 below.

Table 3: Principal Contractors and Consultants

Principal Contractors and Consultants	
Zero Waste Energy	Technology provider, project development, and construction management.
Interstate Grading	Prime Contractor - Construction
JR Miller and Associates	Civil Design
Eggersmann	Process Design
Total Compliance Management	Grant Administration

Source: Total Compliance Management, Inc.

Table 4: Principal Equipment Providers

Principal Equipment Providers	
Marathon Equipment Company	Manufacturer of SmartFerm digesters
BioCNG	Biogas Purification
CPL Industries	Multi-gas industrial boiler
Eggersmann	Exhaust Air System
Likusta	Acid Scrubber - Biofilter
Baur Folien	Biogas Storage Bladder
Abutec Industries	Emergency/ Backup Flare

Source: Total Compliance Management, Inc.

CHAPTER 3: Data and Results

This section discusses the data and findings pertaining to feedstock, gas production, and overall operation of the anaerobic digestion system. The data collection methodology, assumptions, and analysis for each finding are also provided.

3.1 Material Management and Operations

Organic feedstock used in Blue Line Transfer's anaerobic digestion system comes from residential and commercial accounts served by South San Francisco Scavenger Company that are served within a six-mile radius of the facility. Residents combine their green and food waste and deposit it in their green waste container which is collected via automated collection trucks. Commercial food waste is collected by a commercial collection truck from front end loader bins and 96-gallon carts. Materials bound for anaerobic digestion are weighed and recorded.

Data on feedstock weight has been recorded since January 5th, 2015, on a batch-by-batch basis. Similarly, batches of composted digestate have been weighed as they exit the IVC since January 28th.

3.1.1 Inbound Feedstock

Anaerobic digestion feedstock undergoes several processes before being weighed. First, materials are delivered to the Material Recovery Facility where some sorting and blending occurs. At the facility, contaminants are removed from the food waste stream, amounting to approximately 50 percent of the inbound volume. Some typical contaminants that are removed at this stage include plastic bags, metals, large pieces of wood, and other large obvious contaminants. Currently, this is achieved through a manual sort with a trained employee for eight hours a day.

Following the removal of large contaminants at the Material Recovery Facility, feedstock is taken to the aeration bay, where the air space is evacuated by a blower to ensure that the atmosphere is safe. Material is weighed as it is placed in the digester. No feedstock material is added to or removed from the batch once digestion begins.

On average, batches placed in a digester have weighed 62 tons. As calculated in 1.3.2, the digesters have a design capacity of 80.55 tons per batch. The lower-than-design inbound weights may be attributed to low density of inbound material. Food waste tends to be denser than green waste. Weights of 1,000 to 1,200 pounds per cubic yard for food waste and 550 to 650 pounds per cubic yard of green waste are typical. Since South San Francisco Scavenger's food waste collection and outreach program is still new and developing, inbound food waste feedstock is not yet sufficient to reach the intended 80 percent food waste 20 percent green waste blend targeted for the system. Furthermore, because material loaded into the digester slopes on the near and far ends, not all 8.5 feet of clearance is used in all parts of the digester. Thus the capacity to store feedstock is 157 cubic yards of the 170 cubic yard total volume. Given the densities provided above, the average weight of digester batches, and the volume of the batches currently being processed, the proportion of food waste to green waste can be estimated as shown in Table 5. The resulting estimated density of each digester is 790 pounds per cubic yard. Given a food waste density of 1,100 lbs/cubic yards and a green waste density of 650 lbs/cubic yards, the facility is receiving 31 percent of its material from food waste.

Table 5: Design and Observed Densities

	Design	Current Operation
Tons Per Batch	80.55	62.00
Pound Per Batch	161,100	124,000
Available Digester Capacity cy	157	157
Density – lbs/cy	1,026	790
% Food Waste at 1,100 lbs/cy	68%*	31%
% Green Waste at 650 lbs/cy	32%*	69%

Original Design Calculations based off of 1,200 lbs/cy density for food waste, however observations of load volumes suggest an actual density of 1,100 lbs/cy.

Source: Blue Line Transfer

February was the first full month of recorded inbound tonnages. Since then, the eight digesters combined have received an average of 653 tons per month of feedstock. Each month's total inbound feedstock tons are summarized in Table 6 below.

Table 6: Inbound Feedstock (Tons)

FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
704	712	520	656	626	757	674	568

Source: Blue Line Transfer spreadsheets.

3.1.1.1 Digestion Process: Start Up Phase

In the start-up phase, the digesters are sealed and the waste is initially treated aerobically using an in-floor aeration system, which is activated immediately after the digester door is sealed. The aeration system distributes air into the organic waste material which creates aerobic conditions to allow the material to self-heat up to process temperatures. Temperature is measured with thermocouple devices located in each digester. During this phase, no biogas is produced and exhaust air is treated in an acid scrubber and then a biofilter, which is equipped with a humidifier that prevents drying of the wood chip media in the biofilter. The air is first treated by the acid scrubber, removing ammonia, followed by the humidifier then finally the biofilter which removes the particulate material, methane, volatile organic compounds, and odor causing compounds. When desired temperatures are reached, aeration ceases, percolation begins, and anaerobic conditions are created as the aerobic microbes consume the remaining oxygen in the digester. This initial startup phase of the process lasts for approximately twelve hours.

3.1.1.2 Digestion Process: Fermentation Phase

Following the initial aeration of the organic waste material, percolation begins and thermophilic anaerobic conditions are established; this is known as the fermentation phase. Under anaerobic conditions, the organic waste is finely sprayed with conditioned process water containing the thermophilic micro-organisms ("percolate") that decompose the waste and produce biogas. This percolate is pumped in a closed loop between the digesters and the insulated percolate tank, which is located underground beneath the digesters. Percolate is sprinkled on the material on a daily basis for approximately 20 days, facilitating the production of biogas. Percolate is collected in a drainage system, screened for solids in a specially designed weir called a "sandtrap", and gravity flows to the percolate tank. In addition, high quantities of organic acids, which arise during the beginning of the process, are stored and degraded in the percolate tank to ensure proper pH balance. Biogas generated in the percolate tank is also stored in the biogas storage bladder. The thermophilic process temperature in the digesters is maintained through accurate process control of temperature and flow of percolate.

The production of biogas begins quickly after percolation. Biogas is primarily composed of approximately 45 to 65 percent methane and 35 to 55 percent carbon dioxide (CO_2) depending on feedstock material composition. In addition, biogas will contain small quantities of hydrogen sulfide, oxygen, nitrogen, and other trace gases. The biogas is collected in an exhaust port on the back wall of each digester and piped into the below ground percolate tank. From there, it is then piped to the bladder located on the roof of the SmartFerm dry fermentation anaerobic digestion system. Stored biogas flows to the BioCNG purification unit.

3.1.1.3 Digestion Process: Shutdown Phase

After approximately 21 days of anaerobic digestion, the shutdown process is initiated. The shutdown or "termination phase" of a digester generally commences six hours before the digester hatch is opened. The process is as follows:

1. Percolation is gradually reduced and eventually ceased.

2. Fresh air is introduced through the in-floor aeration system to terminate anaerobic digestion and create an environment safe for digestate removal.

3. Purged air and biogas mixture are removed via a dedicated fan located in the mechanical room.

Exhausted lean biogas is collected in the biogas collection system until methane content reaches approximately 22 percent at which point the biogas is sent to the burner/boiler system where it is combined with tail gas from the biogas upgrading system and natural gas from the pipeline. When the methane content of the digester purge air decreases to 2.5 percent, the air is routed to the acid scrubber, humidifier, and then to the biofilter.

3.1.2 Outbound Digestate Data Collection

After the digestion process is complete, biogas is removed from the digester and fresh air is introduced. Once atmospheric conditions within the digester tunnel are safe, a wheel loader will move the digestate to one of the two IVCs for composting. The in-vessel composting process typically takes three to five days.

3.1.2.1 Digestate Amounts

Digestate is not weighed upon leaving the digester, but rather is weighed as it leaves the IVC. This material is then sent to a compost facility for further stabilization prior to being sold as a soil amendment. Outbound material weights from the IVC system are typically about 52 percent of the weight of the initial feedstock loads entering the digesters.

February was the first full month of recorded tonnages leaving the IVC. Since then, the total outbound material has averaged 363 tons per month. Each month's total outbound IVC material tons are summarized in Table 7 below.

Table 7: Inbound Feedstock and Outbound IVC Tons

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Inbound Digester Feedstock	511	704	714	620	565	626	757	674	568
Outbound IVC Digestate	62	340	408	445	259	314	405	249	486
% of Original	12.2%	48.2%	57.2%	71.8%	45.8%	50.1%	53.5%	36.9%	85.5%

January was a partial month for IVC data and is excluded from monthly estimate.

Source: Total Compliance Management, Inc.

3.1.2.2 Ammonium Sulfate

The acid scrubber uses sulfuric acid to cleanse the IVC gases, lean gas, and aeration bay gases of ammonia. The by-product is ammonium sulfate. At present, ammonium sulfate produced at the facility is removed by the company that provides the sulfuric acid. This ammonium sulfate by-product may have a co-product use as a fertilizer, and this possibility is being investigated.

3.1.2.3 Digestate Compost Properties

The properties of this digestate have been tested by Control Laboratories in Watsonville, California. The results from this test, performed in March of 2015, are summarized in Table 8 and 9 below.

Table 8: Digestate Properties - Metals

Metals		Result	Units (dry weight)	MDL	% Recovery	Date Tested
Arsenic (As)		2.8	mg/kg	1.0	110.8	12 Mar. 15
Cadmium (Cd)	Less than	1.0	mg/kg	1.0	98.9	12 Mar. 15
Chromium (Cr)		41	mg/kg	1.0	104.1	12 Mar. 15
Copper (Cu)		67	mg/kg	1.0	90.3	12 Mar. 15
Lead (Pb)		130	mg/kg	1.0	102.3	12 Mar. 15
Mercury (Hg)	Less than	1.0	mg/kg	1.0	105.7	12 Mar. 15
Molybdenum (Mo)		1.5	mg/kg	1.0	87.8	12 Mar. 15
Nickel (Ni)		20	mg/kg	1.0	100.0	12 Mar. 15
Selenium (Se)	Less than	1.0	mg/kg	1.0	114.7	12 Mar. 15
Zinc (Zn)		180	mg/kg	1.0	89.3	12 Mar. 15
Cobalt (Co)		3.2	mg/kg	.50	101.9	12 Mar. 15
Total Solids		41	%	.05	NA	06 Mar. 15

Source: Total Compliance Management, Inc.

Table 9: Digestate Properties - Bacteria

Bacteria		Result	Units (most probable number)	Date Tested
Fecal Coliform		25	g dry weight	06 Mar. 15
Salmonella	Less than	3	4g dry weight	06 Mar. 15

Source: Total Compliance Management, Inc.

California Code of Regulations Title 14 stipulates that compost products containing metal or pathogens in excess of maximum predefined limits, must undergo further processing or be disposed. The test of the digestate product of the dry fermentation anaerobic digestion system indicates that all metal and pathogen levels are below these thresholds. A list of these thresholds, as they appear in Title 14, Sections 17868.2 and 17868.3, is provided in Table 10. A discussion of the costs and benefits of managing this digestate is provided in Chapter 4.

Table 10: Title 14 Maximum Acceptable Concentrations

Constituent	Maximum Concentration	Units
Arsenic	41	Mg/kg dw
Cadmium	39	Mg/kg dw
Chromium	1200	Mg/kg dw
Copper	1500	Mg/kg dw
Lead	300	Mg/kg dw
Mercury	17	Mg/kg dw
Nickel	420	Mg/kg dw
Selenium	36	Mg/kg dw
Zinc	2800	Mg/kg dw
Fecal Coliform	1,000	MPN/g dw
Salmonella	3	MPN/4g dw

Source: CalRecycle

3.2 Biogas and Fuel Production

Multiple meters throughout the facility record flows, composition, and other information about the anaerobic digestion system's gas inputs and outputs as provided in Table 11 and shown in Figure 14 below. These flows measure methane fuel production, tail gas, lean gas, as well as amounts of pipeline natural gas used that is used to supplement the biomethane fuel and heat percolate.

Table 11: Summary of Meter Data Sources

Meter Name	Unit of Measurement	Method of Measurement
Product Gas CH_4	Percentage	Automatic Sensor
Product Gas CO_2	Percentage	Automatic
Product Gas Flow	Standard Cubic Feet/Minute	Automatic
Boiler CNG	Cumulative SCF Flow	Manual Reading
Boiler Tail Gas	Cumulative SCF Flow	Manual Reading
Boiler Lean Gas	Cumulative SCF Flow	Manual Reading
BioCNG Product Gas	Cumulative SCF Flow	Manual Reading
PG&E Gas Meter EC38	Cumulative SCF Flow	Manual Reading
Bladder CH_4 %	Percentage	Automatic
Flare Flow	Cumulative SCF Flow	Automatic

Source: Total Compliance Management, Inc.

Figure 14: Supplemental Natural Gas Meter –PG&E Gas Meter EC38

Source: Total Compliance Management, Inc.

3.2.1 Biogas Generation and Fuel Production

The purpose of this sub-section is to provide data and summaries of the important methane and fuel gas production metrics recorded during this pilot project. Production metrics are roughly what was projected at the time of the proposal submittal. However, data available following proposal submittal indicates that higher percentages of food waste are feasible, resulting in higher biogas generation and methane concentrations. As food waste content of the feedstock blend increases, the project is expected to exceed current metrics from the first six months of the project.

3.2.1.1 Feedstock Conversion to Biogas

During the period 03/01/2015 – 09/30/2015, a total of 4,522 tons of feedstock were processed through the digesters, and 13,327,510 scf of biogas was produced, as shown in Table 12. This suggests an average biogas yield of approximately 2,969 scf per ton of feedstock, or seven diesel gallon equivalent (DGE) per ton. This is only an approximation, as biogas production from a given batch may occur over two months.

Table 12: Feedstock Tons and Biogas Production

	MAR	APR	MAY	JUN	JUL	AUG	SEP
Feedstock Tons	712	620	565	626	757	674	568
Biogas scf	1,878,266	1,798,943	1,716,405	1,610,934	2,143,617	2,016,502	2,162,844
Biogas scf/Ton	2,639	2,904	3,039	2,572	2,831	2,992	3,807
% CH_4	55.9%	55.9%	55.8%	54.6%	55.1%	55.0%	54.9%
CH_4	1,049,951	1,005,609	958,011	879,368	1,180,853	1,109,556	1,187,795
DGE	7,924	7,590	7,230	6,637	8,912	8,374	8,965

Source: Total Compliance Management, Inc.

DGE calculated assuming 962 British Thermal Units (BTU) per scf of methane, and 127,464 BTU per scf of diesel.

3.2.1.2 Biogas Storage

The bladder is the canopy-like structure above the digesters which stores the biogas produced by the digestion process. Biogas accumulates in the bladder prior to being purified and compressed for processing as vehicle fuel. Since April 24th, measurements of the methane content of the biogas in the bladder have been taken. Since then, methane levels have typically stayed between 52 percent and 57 percent. The mean methane content of the bladder from this date until the end of August, 2015, is 55.11 percent, with a standard deviation of 2.58 percent. Below is a summary in Table 13 of the average monthly methane content of the bladder biogas that is routed to the BioCNG.

Table 13: Total Biogas Methane (scf)

	MAR	APR	MAY	JUN	JUL	AUG	SEP
Total Biogas	1,878,266	1,798,943	1,716,405	1,610,934	2,143,617	2,016,502	2,161,844
Lean Gas	103,567	100,202	101,351	73,178	104,914	105,891	102,855
Flare	6,741	5,394	1,342	3,379	1,054	2,298	1,609
Biogas to BioCNG*	1,767,958	1,693,347	1,614,712	1,534,377	2,037,649	1,908,313	2,058,380
CH_4 %	55.9%*	55.9%	55.8%	54.6%	55.1%	55.0%	54.9%
BioCNG CH_4	988,289	946,581,	900,693	837,578	1,122,479	1,050,027	1,1,30,425

Source: Total Compliance Management, Inc.

Biogas to BioCNG is total bladder biogas minus the lean gas and flared portions. March CH_4 percent unknown, April's percent is used as a proxy.

3.2.1.3 Methane Content of Product Gas

The biogas from the bladder is eventually moved through a purification system designed to remove contamination and produce a methane-rich gas for transportation fuel. This gas is eventually pressurized and made accessible to Blue Line's vehicle fleet through its fueling station. Methane content of this product gas is recorded daily, as is its carbon dioxide content. On average, the product gas consists of about 93 percent methane and 6-7 percent carbon dioxide. Below is a summary in Table 14 of the average methane concentrations of this gas.

Table 14: Average Methane Content of Product Gas

FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
94.5%	92.9%	93.7%	93.7%	93.0%	93.3%	91.5%	90.6%

Source: Total Compliance Management, Inc.

3.2.1.4 Quantities of Product Gas Flow

Product gas production from the BioCNG unit is measured on a meter that records cumulative total flow in standard cubic feet. This difference in one day's reading and the next day's reading is the flow for one day. Similarly, the reading at the end of the month minus the reading at the end of the previous month is assumed to be one month's production (allowing tolerance for variation in the time of day of a reading). Readings are taken daily, except for weekends and holidays. Should the end of a month fall on a day where no reading was taken, the reading is estimated as a time weighted average of the previous reading and the next reading.

This product gas flow started being recorded on February 27th 2015. Since then, this flow has averaged approximately 634,380 SCF per month, or 21,146 SCF per day. Methane concentrations of this flow, which are also recorded daily, average approximately 93 percent CH_4, with some variance. Due to the varying methane concentrations of this product gas, the final methane equivalencies of this product gas vary as well. The methane available for fuel energy is calculated as follows:

$$\textit{Product Gas} \times \textit{Methane Concentration} = \textit{Fuel Methane}$$

This calculation is performed each day, and then summed to provide an estimate of each month's fuel methane production, as shown in Table 15 below.

Table 15: Monthly Product Gas Production (SCF)

	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
Product gas (scf)	731,790	723,467	635,742	503,497	631,529	620,369	594,265	4,440,659
CH_4%	94.5%	92.9%	93.7%	93.0%	93.3%	91.5%	90.6%	93% avg.
Methane (scf)	690,762	672,708	595,279	466,338	588,806	566,912	538,111	4,118,916

Source: Total Compliance Management, Inc.

The amount of biomethane recovered per ton is a function of how efficiently biomethane sent to the BioCNG unit is captured, upgraded, and processed into vehicle fuel. This recovery rate is calculated as the ratio of methane that becomes vehicle fuel to total methane sent to the upgrading system. Due to difficulties with filtration membranes, the recovery ratio has declined since the outset of the project. The reduction in recovery ratio has in turn resulted in less product gas per ton of feedstock. A table summarizing the trends in recovery rate is provided below.

The amount of methane being recovered for vehicle fuel has been declining, while at the same time methane in the tail gas and tail gas quantities have been increasing. This trend is presented in Table 16 below.

Table 16: Methane Recovery Rate

	MAR	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**
CH_4 to BioCNG	988,289	946,581	900,693	837,578	1,122,479	1,050,027	1,130,425
Product CH_4	690,762	672,708	595,279	466,338	588,806	566,912	538,111
Recovery Rate	70%	71%	66%	56%	52%	54%	48%
Tail Gas scf	1,036,168	969,880	977,969	1,030,881	1,406,120	1,287,944	1,464,115
Tail Gas CH_4 %	28.7%	28.3%	31.2%	35.8%	31.7%	37.4%	40.4%
Tail Gas CH_4 scf	297,151	274,151	305,291	369,305	533,673	482,189	591,981

Source: Total Compliance Management, Inc.

As indicated in the table above, methane production was significantly lower in the month of June. During this time, staff was working to resolve issues with the biogas purification system that adversely affected fuel gas production. Methane recovery rates have declined over time, and different approaches to bringing the methane recover rate up to at least 70 percent, as it was initially, are underway, and are described below.

3.2.1.5 Differences between Anticipated and Observed Methane Recovery

This reduction is believed to be at least partially caused by higher than anticipated volatile organic compounds in the biogas stream, which has caused the membranes to operate less efficiently. As purification is impeded, more gas is routed through as tail gas and less product gas is produced. Resolution is currently underway as different filtration media are being investigated.

Another approach to increasing methane recovery that is also being investigated is to lower the reheating temperature of gas exiting the chiller for moisture removal. At cooler temperatures, the methane recovery rate through the membrane filters increases.

Another potential improvement to the system could be to increase the percentage of food waste feedstock entering the system. Feedstock batches high in food waste are expected to be denser and produce more methane under digestion. As food waste becomes an increasingly larger fraction of feedstock, biogas methane concentrations are expected to reach 60 percent.

At higher levels of methane concentration, the membranes responsible for purifying operate more efficiently. This efficiency, will in turn, increase the proportion of gas passed through as product gas.

3.2.1.6 Conversion to Diesel Gallon Equivalents

Knowing methane quantities allows for useful conversions to energy equivalents such as BTUs or Diesel Gallon Equivalents, as shown in Table 17. As this energy is used to power collection vehicles, these measurements provide insight into the amount of fossil fuel that has been conserved through the use of the anaerobic digestion system. The following conversion factors are used to make conversions of CNG to DGE, and ultimately diesel gallons saved.

Table 17: Conversion Factors Used to Calculate Diesel Gallons Conserved

BTU per Cubic Foot of CH_4	962
BTU per Gallon of Ultra Low Sulfur Diesel	127,464
Energy Economy Ratio*	0.9

Source: Total Compliance Management, Inc.

* Energy Economy Ratio is used to reconcile the differences in performance of Diesel and CNG engines.

$$\text{Fuel Methane} \times \frac{962}{127{,}464} \times 0.9 = \text{Diesel Gallons Saved}$$

$$4{,}118{,}916\ \text{scf} \times \frac{962}{127{,}464} \times 0.9 = 27{,}978\ \text{Diesel Gallons Saved}$$

A total of 4,118,916 scf of product gas fuel methane have been produced from March 1st 2015, to September 30th 2015. Using the above conversion factors, this equates to a total of 31,086 DGEs, or a savings of 27,978 diesel gallons (the difference between DGE and diesel gallons saved is a result of energy efficiency differences between CNG and diesel engines).

On average, 4,441 DGEs (3,997 diesel gallons savings) are produced each month at the Blue Line dry fermentation anaerobic digestion facility. At this rate, the facility can be expected to produce 53,291 DGEs in the first year of operations. A comparison of the costs and costs savings of the alternative fuel produced by the dry fermentation anaerobic digestion system is provided in Chapter 4.

3.2.1.7 Comparison to Anticipated Annual Production at Capacity

Prior to start-up of the facility, projections were made as to the final DGE production of the dry fermentation anaerobic digestion system. The following parameters were used to predict final production in Table 18.

Table 18: Fuel Gas Parameters from Proposal

	Cubic Feet/Minute	Methane Content	Methane CF/M
Biogas	50	60%	30.00
Fuel Gas	16.5	99%	16.34
Waste Gas	33.5	40%	13.40

Source: Total Compliance Management, Inc.

Figures are from the initially proposed system which would process 9,000 tons of feedstock per year, and would have a BioCNG unit capable of processing 50 cubic feet per minute.

With an anticipated fuel gas flow of 16.34 cubic feet of methane per minute, 8,585,676 cubic feet of methane would be produced in a year. Given the same conversion factors listed above, this would result in the production of 65,453 DGE, or the replacement of 58,318 diesel gallons.

3.2.1.8 Projected Production at Capacity

As output-constraining factors are resolved, renewable compressed natural gas production is expected to increase. South San Francisco's organics collection program will mature with time, and yield increasing amounts of food waste. Higher concentrations of food material may produce, on average, 3,300 scf/ton of biogas at a concentration of 60 percent methane.

Once the BioCNG unit is able to process this gas at full capacity, 70 percent of this methane will be recoverable for transformation to vehicle fuel. Given this, energy production is expected to be:

3,300 scf biogas/ton × 11,200 tons per year = 36,960,000 scf biogas/year

36,960,000 scf biogas/year at 60 percent *methane = 22,176,000 scf* CH_4 */year*

22,176,000 scf CH_4 */year at 70* percent *recovery = 15,523,000 scf* CH_4 *recovered annually*

Using the same conversion from CH_4 to DGE as before, 15,523,000 scf of CH_4 is equivalent to 117,157 DGE or 105,441 diesel gallons displaced. Table 19 shows a summary of the gas flows.

Table 19: Original, Current, and Design Product Gas Flows

Table 19: Original, Current, and Projected Product Gas Flows	Original Proposal	Current Operations	Design
CH_4 cubic feet per minute	16.34	13.43	29.53
Annual CH_4 CF	8,585,676	7,061,002	15,523,000
DGE	65,453	53,291	117,157
Offset Diesel Gallons	58,318	47,964	105,441

Source: Total Compliance Management, Inc.

3.2.2 Boiler Gas

In order to facilitate the anaerobic digestion process, heated percolate is added to the digesters during the fermentation stage. The percolate is heated using a multi-gas industrial boiler. This boiler is fueled with tail gas from purification, the lean gas from the anaerobic digestion system, and conventional natural gas from a PG&E pipeline.

3.2.2.1 Tail Gas Flow

Tail gas is the portion of biogas from the purification process that does not become vehicle fuel. Because the membrane filters don't recover all of the biogas methane for vehicle fuel, there is a tail gas flow that is generally about 30 percent methane and 70 percent carbon dioxide that is metered cumulatively in standard cubic feet. Every day since February 25th, excepting holidays and weekends, the tail gas flow readings have been recorded. As with product gas, tail gas monthly flows are calculated by the reading at the end of one month minus the reading at the end of the previous month. Summarizing the monthly tail gas readings is provided in Table 20 below.

Table 20: Tail Gas Flows (SCF)

	MAR	APR	MAY	JUN	JUL	AUG	SEP
Tail Gas	1,036,168	969,880	977,969	1,030,881	1,406,120	1,287,944	1,464,115
Avg. CH_4%	29.36%	28.27%	31.22%	35.82%	31.67%	37.44%	40.43%
CH_4 scf	304,169	274,151	305,291	369,305	533,673	482,189	591,981
MMBTU	293	264	294	355	428	464	569

Source: Total Compliance Management, Inc.

Assuming 962 BTU per standard cubic foot of methane. Monthly increases in tail gas methane levels are attributable to membranes operating below capacity.

As discussed previously, the amount of tail gas and methane content of the tail gas has increased overtime. This is the inverse of the methane recovery rate for fuel, previously discussed

3.2.2.2 Lean Gas Flow

Lean gas is biogas from the dry fermentation anaerobic digestion that contains less than 22 percent methane. This gas, which results from the start up and shut down processes described in 3.1.1, does not have a high enough methane content to become vehicle fuel. This gas is used to heat the percolate in the boiler along with the tail gas. When methane concentrations drop below 2.5 percent, lean gas is flared off. Lean gas methane concentrations range between 2.5 percent and 22 percent. Assuming an average methane concentration of 15 percent, and using known flows, it is possible to estimate the amount of methane in the lean gas, as shown in Table 21. This amount is a relatively small fraction of all the methane in the system, typically less than 1 percent.

Table 21: Lean Gas Flows (SCF)

	MAR	APR	MAY	JUN	JUL	AUG	SEP
Lean Flow (scf)	103,567	100,202	101,351	73,178	104,914	105,891	102,855
Estimated CH_4 Concentration	15%	15%	15%	15%	15%	15%	15%
Estimated CH_4 (scf)	15,535	15,030	15,203	10,977	15,737	15,894	15,428

Source: Total Compliance Management, Inc.

3.2.2.3 Conventional Natural Gas Flow

Conventional natural gas is brought into the boiler to supplement the thermal energy provided by the lean gas and tail gas. Like the other two gases, the usage of this gas is metered cumulatively and recorded daily. Usage of conventional natural gas is summarized in Table 22 below.

Table 22: Conventional Natural Gas Flows (SCF) to Boiler

	MAR	APR	MAY	JUN	JUL	AUG	SEP
SCF	317,100	332,430	236,400	216,811	325,182	369,271	325,891
MMBTU	305	320	227	209	313	355	314

Source: Total Compliance Management, Inc.

Assuming 962 BTU per standard cubic foot of methane.

A comparison of the energy equivalencies of the boiler fuels is provided in Table 23 below.

Table 23: Comparative Energy of Tail Gas and Pipeline Gas to Boiler (MMBTU)

	MAR	APR	MAY	JUN	JUL	AUG	SEP
Tail Gas	293	264	294	355	513	464	569
Conventional CNG	305	320	227	209	313	355	314
% Tail Gas	49%	45%	56%	63%	62%	57%	64%

Source: Total Compliance Management, Inc.

Assuming 962 BTU per standard cubic foot of methane for both pipeline and tail gas.

3.2.3 Flare Gas

The flaring process is designed to mitigate the potential for air pollution of methane gas when the storage capacity of the bladder is close to full. Flaring occurs when the bladder is over 85 percent full. Measurements of flare flows have been recorded beginning February 27th and are summarized in Table 24 below; they are very small relative to other gas flows.

Table 24: Flare Gas Flows (SCF)

MAR	APR	MAY	JUN	JUL	AUG	SEP
6,741	5,394	1,342	3,379	1,054	2,298	1,609

Source: Total Compliance Management, Inc.

3.2.4 Natural Gas Supplement

In order to provide CNG for its entire future collection fleet, Blue Line Transfer's fueling station is designed for 40 vehicles. Blue Line's current CNG fleet size is 22. As the fuel demand for the future CNG fleet is greater than the projected biomethane production, pipeline natural gas from PG&E is used to supplement the anaerobic digestion fuel.

Once the dry fermentation anaerobic digestion to fuel system is operating at capacity, biomethane compressed natural gas should be sufficient to fuel 22 vehicles without a pipeline supplement. As collection vehicles continue to be transitioned from diesel to CNG and renewable natural gas (RNG), the supplemental pipeline natural gas will assure sufficient fuel flows to fuel the entire fleet on site. Fleet fuel needs are calculated based of DGEs purchased in 2014 (before the addition of the renewable fueling station). Table 25 detals fuel needs, biofuel production, and supplemental natural gas below.

Table 25: Fleet Usage of Renewable and Pipeline Natural Gas

	2014 22 Vehicles Fueling	Current Operation with 22 Vehicles	Full Capacity with 22 Vehicles	Projected Full Capacity with 40 Vehicles
DGE/Month Required	8,462	8,462	8,462	15,386
Renewable Natural Gas (DGE/Month)	0	4,441	8,787	8,787
Pipeline Natural Gas Supplement (DGE/Month)	8,462	4,021	0	6,599
% RNG	0%	52%	100%	57%
% Conventional NG	100%	48%	0%	43%

Source: Total Compliance Management, Inc.

Current production is 53,291 DGE/year, which is 4,441 DGE/Month.

3.2.5 Operating Time

Typically, seven to eight digesters are loaded and sealed at any given time. A digester will only be vacated to unload processed digestate, a process that takes place from midnight to 4:00 AM to mitigate odor concerns. That digester is then used to process the next incoming batch of feedstock. The only other time a digester is vacant is when it is undergoing cleaning, inspection, or other maintenance.

As most digesters are full at any given time, digestion is constantly occurring. Consequently, methane from the digestion process is always being captured. If other project components experience down time and biogas is stored in the bladder and unable to proceed to purification, the flare will oxidize any biogas generated in excess of the bladder capacity.

The BioCNG is capable of close to continuous operation under normal circumstances. Media changes require about three hours of shutdown, and membrane rotation, and other routine maintenance may be performed without shutting down the system. Under routine operating conditions, the BioCNG is taken offline less than once a month.

3.2.5.1 Boiler Downtime

Gas from the anaerobic digestion system is utilized in the multi-gas boiler system to heat percolate. The boiler itself is not in constant use, and experiences periods of downtime due to maintenance or repairs. Most days the boiler does not experience downtime. On days where the boiler is down, the average time spent out of operation has been about 65 minutes. Most of the downtime for the boiler has been during commissioning and start up and occurred principally in the first several months. Generally, the boiler unit requires little to no maintenance.

3.2.5.2 Flare Run Time

A total of 442 hours of run time to date have been logged on the flare meter. Over the course of the 185-day recording period, this indicates a 2.4 hours per day average flare run time, with many days having no flare activity at all. Flare activity is generally a result of the boiler or the BioCNG being offline. Now that the boiler is no longer undergoing commissioning and start up; flare run time and frequency will reduce.

3.2.5.3 Flare Purpose

The flare is meant to operate only as needed, when other outlets for the biogas are not available. If the bladder reaches 85 percent of capacity the excess methane is safely flared off.

3.3 Vehicle Performance Using Renewable Natural Gas Fuel

South San Francisco Scavenger has been successfully operating its fleet using the renewable natural gas blend produced at the anaerobic digestion facility since February 2015. Both vehicle operators and maintenance personnel have noted no significant performance differences between the biogenic natural gas blend fuel and conventional natural gas fuel. In October of 2015, a comparative test was performed in which a collection vehicle was filled with both types of fuel and then sent to perform a typical collection route. The 100 percent pipeline natural gas was fueled at a retail CNG fueling facility to provide a control fuel, whereas the renewable blend was filled on a Monday to maximize the biogenic portion of the fuel. The results, measured in terms of tank pressure (in pounds per square inch) are provided in Table 26.

Table 26: Vehicle Performance Comparison

	Date	Miles	Start	End	Used
Renewable Blend	10/12/2015	27.1	3800	2000	1800
100% Pipeline CNG	10/19/2015	28.5	3100	1500	1600

Source: Total Compliance Management, Inc.

Both samples were done by the same driver, in the same truck, on the same route. Biofuel portion of gas estimated based off of PG&E meter data compared to product gas production.

In general, drivers have reported that there is no discernable difference in vehicle performance since switching to a blend of biomethane and conventional CNG from using 100 percent conventional CNG.

3.4 Carbon Intensity of Blue Line Transfer's Renewable Natural Gas

The California Air Resources Board (CARB) manages the Low Carbon Fuel Standard (LCFS) Program, which provides carbon credits for transportation fuels that have lower carbon intensities than a reference fuel, which is established in the LCFS regulation. CARB requires that a specific model be used to calculate carbon intensity of fuels, the California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model.

CARB has developed a model spreadsheet for fuel produced from high-solids anaerobic digestion with biogas purification to vehicle fuel, which resulted in a carbon intensity of -22.93 grams carbon dioxide equivalent (CO_2e) /MJ of fuel produced. This spreadsheet is made available for modification for facilities using similar types of fuel production processes and is then submitted to CARB for review. The carbon intensity of Blue Line Transfer's renewable natural gas transportation fuel was estimated using the model by the consulting firm ICF International. Blue Line Transfer has registered with CARB as a Biofuel Production Facility and submitted the model spreadsheet to CARB for review. Blue Line Transfer has requested that CARB allow them to simply use the default carbon intensity of -22.93 grams CO_2e/MJ, with the option of following a more in-depth and time-consuming process later to register with a site-specific carbon intensity.

If a fuel production process with a reference fuel pathway that has already been developed by CARB uses the reference pathway to demonstrate that the carbon intensity of the fuel produced is less than that of the CARB pathway, then CARB will allow the default carbon intensity to be used. In the case of Blue Line Transfer, the carbon intensity was found to be negative 37.1 grams CO_2e/MJ, much less than the CARB default carbon intensity for that process of negative 29.5 grams CO_2e/MJ.

This analysis was developed by modifying ARB's high solids anaerobic digestion Pathway spreadsheets to reflect biomethane production processes. The Blue Line data inputs outlined below are based on 29 days of Blue Line anaerobic digestion Daily Data (Aug 13th - Sept 11th, 2015) and were annualized assuming 360 days/year.

The key differences between these two pathways include:

1. Feedstock - the Blueline facility's incoming feedstock has a higher percentage of organic food wastes compared to the ARB modeled pathway and does not include FOGs.

2. Biomethane capture efficiency - the Blueline high solids anaerobic digestion production facility is 49 percent less efficient at capturing CH4 than the ARB modeled pathway therefore theoretical yields were used and a 70/30 FW/GW feedstock split.

3. Process efficiency - the Blueline biogas upgrading process is significantly more energy intensive than the ARB modeled pathway.

4. Transport and distribution - Blueline biomethane is compressed into storage tanks on-site and used a vehicle fuel for refuse trucks; there is no pipeline connection or transportation emissions, as modeled in the ARB pathway; digestate is transport from South San Francisco to Gilroy, Ca., for composting.

Table 27 presents a comparison of the Blue Line and CARB high solids anaerobic digestion modeled pathway results.

Table 27: Carbon Intensity of Blue Line's Anaerobic Digestion Fuel

Parameter	**ARB high solids anaerobic digestion Pathway**		**Blueline high solids anaerobic digestion Pathway**	
	gCO_2e/MJ	**gCO_2e/ton waste**	**gCO2e/MJ**	**gCO_2e/ton waste**
Process GHG Emissions	71.1	200,444	54.3	185,178
Process Heat Loading Requirements	1.0	2,743	10.0	34,059
Compost GHG Emissions	52.2	147,065	30.5	104,059
Wastes Loading Fossil Fuel Use & Emissions	0.6	1,741	0.5	1,833
Compost Fossil Fuel Use & Emissions	1.9	5,453	1.0	3,427
Plant Load & Composting Fossil Fuel Energy Use	2.6	7,195	1.5	5,260
Total Fuel Cycle Electric Emissions:	*8.8*	*24,690*	*14.4*	*49,163*
Total No. 2 Diesel WTT Emissions:	*0.8*	*2,171*	*0.5*	*1,587*
Total Process Emissions	136.4	384,307	111.2	379,307
GHG Emissions from CNG Combustion in HDV (TTW)	60.7	171,010	60.7	207,012
Less Carbon Credit from "MODEL"	196.6	553,989	188.6	643,444
Less Compost Emissions Reduction Factor (CERF)	23.4	65,953	20.4	69,424
Net Annual GHG Emissions	(22.9)	(64,624)	(37.1)	(126,549)
Proposed High Solids Anaerobic Digestion Pathway Carbon Intensity	(22.9)	(64,624)	(37.1)	(126,549)

Source: Total Compliance Management, Inc.

CARB requires two years of operational data upon which to base a fuel’s carbon intensity. However, they will grant provisional carbon intensity with the qualification that additional data must be periodically submitted substantiating that the actual carbon intensity does not exceed the provisionally granted carbon intensity.

CHAPTER 4: Project Benefits

4.1 Environmental Benefits

The primary benefits of the Blue Line Transfer anaerobic digestion facility are environmental. These benefits are multifaceted as the processing of organic waste into an alternative fuel produces a variety of benefits. These benefits are identified one by one below, and their respective positive impacts are identified using the best available evaluation methods.

4.1.1 Provision of a Low Carbon Fuel

The biomethane fuel produced from the anaerobic digestion process is used in lieu of pipeline compressed natural gas and other transportation fuels, such as diesel. Fossil fuels, such as those displaced by biomethane are linked directly with a variety of deleterious environmental impacts. The extraction, processing, and use of these fossil fuels are known to contribute to greenhouse gases.

4.1.1.1 Amount of Fuel Displaced

By converting the energy value of the biomethane into diesel gallon equivalents and adjusting for differences in engine efficiency, the amount of diesel fuel displaced can be calculated. The amount of diesel fuel being currently displaced, as well as the diesel fuel that will be replaced once the system is operating at capacity, is shown in Table 28 below.

Table 28: Diesel Fuel Displacement at Current Operations and Capacity

	Current Operations Projected Annually	Annual Operations at System Capacity
DGE produced	53,291	117,157
Energy Economy Ratio	0.9	0.9
Diesel Gallons Displaced	47,964	105,441

Source: Total Compliance Management, Inc.

4.1.1.2 Greenhouse Gas Impacts of Anaerobic Digestion Derived CNG

In 2014, the California Air Resources Board (CARB) published *Low Carbon Fuel Standard Pathway for the Production of Biomethane from High Solids Anaerobic Digestion of Organic (Food and Green) Wastes.* This report estimated the life-cycle emissions of producing a biogenic transportation fuel from a process very similar to the one used at Blue Line Transfer's dry fermentation anaerobic digestion. The conclusion of this report is that the carbon intensity of transportation fuel derived from high solids anaerobic digestion is negative 22.93 grams of CO_2e/MJ of fuel. Using this carbon intensity value, or "CI", it is possible to estimate the amount of greenhouse gases avoided by substituting this biogenic fuel for diesel.

The emissions avoided during the production of the biomethane fuel, relative to a baseline of landfilling the organic feedstock, are shown in Tables 29 and 30 below.

Table 29: Current Operations: Greenhouse Gas Emissions from Fuel Production (CARB)

Month	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL:
CH_4 scf	690,762	672,708	595,279	466,338	588,806	566,912	538,111	4,118,916
Btu/scf*	962	962	962	962	962	962	962	
MMBTU	665	647	573	449	566	545	518	3,962
BTU/MJ	947	947	947	947	947	947	947	
Total MJ	701,098	682,774	604,187	473,316	597,617	575,395	546,635	4,180,550
gCO_2e/MJ	-22.93	-22.93	-22.93	-22.93	-22.93	-22.93	-22.93	
$MTCO_2e$	-16.08	-15.66	-13.85	-10.85	-13.70	-13.19	-12.52	-95.9

Source: Total Compliance Management, Inc.

Table 30: Annual Operations at Capacity: Greenhouse Gas Emissions Avoided by the Use of Biogenic CNG at Blue Line Transfer

CH_4 scf	15,523,200
BTU/scf	962
MMBTU	14933
BTU/MJ	948
TOTAL MJ	15,755,485
gCO_2e/MJ	-22.93
$MTCO_2e$	-361.27

Source: Total Compliance Management, Inc.

In total, the estimated greenhouse gas avoidance from the dry fermentation anaerobic digestion project from the seven months of data has been -95.9 metric tons of carbon dioxide equivalent, or about 13.7 metric tons a month. Over the course of a year, this equates to a -164.3 $MTCO_2e$. This is the lifecycle impact of producing and using biomethane from a high-solids anaerobic digestion process as a CNG vehicle fuel, relative to a landfilling baseline.

Using a similar life cycle analysis, CARB has also established a carbon intensity estimate for diesel fuel, and this carbon intensity is currently set at 102.01 gCO_2e/MJ of diesel use. By applying this carbon intensity factor to the 47,964 diesel gallons displaced, it is possible to arrive at an estimate of avoided diesel emissions. This estimate is shown in Table 31.

Table 31: Current Operations: Annual Greenhouse Gas Savings from Avoided Diesel Use

	Current Operations	**Operations at Capacity**
Annual Diesel Fuel Displaced	47,964	105,412
BTUs/Diesel Gallon	127,500	127,500
Total Diesel MMBTU	6,115	13,440
BTU/MJ	947.81	947.81
TOTAL MJ Diesel	6,452,099	14,179,936
gCO_2e/MJ	102.01	102.01
Total $MTCO_2e$ of Displaced Diesel	663.4	1,458.0

Source: Total Compliance Management, Inc.

Diesel fuel displaced has already been adjusted for EER

The total combined greenhouse gas savings from creating an organics derived fuel (164.3 $MTCO_2e$), and displacing 47,964 gallons of diesel fuel (663.4 $MTCO_2e$) is:

164.3 + 663.4 = **827.7 Avoided $MTCO_2e$**

Once the facility is operating at full design capacity, renewable natural gas production will increase. At this higher level of production, the total combined annual greenhouse gas savings from creating an organics derived fuel (361.2 $MTCO_2e$), and displacing 105,412 gallons of diesel fuel (1,458 $MTCO_2e$) is:

361.2 + 1,458 = **1,819.2 Avoided $MTCO_2e$**

4.1.2 Reduction of Criteria Pollutant Emissions

Criteria pollutant emissions are generated during the fuel production process (well to tank, WTT) and during the combustion in a vehicle (tank to wheel, TTW). The analysis of these emissions utilizes the reference document "August 2007 Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts, CEC-600-2007-004-REV". Information for diesel fuel emissions are calculated from vehicle models year 2010 and newer. Information for CNG fuel emissions are taken assuming vehicle model year 2010 and newer.

The proposed RNG fuel would have essentially the same criteria pollutant emissions profile on a TTW basis as fossil fuel CNG currently in use, which are compared to diesel using the "Urban" category from the referenced document as shown in Table 32.

Table 32: TTW Criteria Pollutant Emission Comparison

Pollutant	ULSD: 2012 (g/mile)	CNG, North American Natural Gas (g/mile)
volatile organic compounds	0.168	0.048
CO	0.901	0.907
Nox	0.714	0.687
PM10 (x10)	0.677	0.672

Source: Total Compliance Management, Inc.

Therefore, based on the cited CEC document, less criteria pollutants are emitted from the combustion of CNG than diesel, with the exception of carbon monoxide, which is slightly higher than diesel (0.7 percent).

WTT criteria emissions for the RNG from the proposed project are significantly different than those provided in the CEC document for fossil fuel CNG. To make a comparison, the WTT criteria pollutant emissions for ULSD are converted from grams per mile to grams per MJ. The WTT energy use is given as 7.34 MJ/mile and the diesel criteria pollutant emissions are adjusted by dividing each emission factor in g/mile by the WTT energy use in MJ/mile to arrive at units of g/MJ for comparison with the proposed RNG fuel. The CNG fuel criteria emissions for WTT are put into similar units by calculating the total annual emissions of each constituent during fuel production and then dividing by the total energy content of the fuel produced per year. Further, the emissions are increased by dividing by the energy economy ratio of 90 percent. The WTT emissions for diesel are assumed to be the difference between the urban emissions and the total emissions. The criteria pollutant profile for the WTT pathway is shown in Table 33 below.

Table 33: WTT Criteria Pollutant Emission Comparison

Pollutant	ULSD: 2012 (g/MJ)	Biomethane CNG (RNG) from Anaerobic Digestion (g/mile)
volatile organic compounds	0.0357	0.006
CO	0.0787	0.022
NOx	0.2625	0.0124
PM10 (x10)	0.1925	0.004

Source: Total Compliance Management, Inc.

As can be seen, the WTT emissions for the proposed RNG fuel are significantly lower than diesel for all constituents.

4.1.3 Provision of a Compost Feedstock

The digestate end product of the anaerobic digestion process is placed in an in-vessel composting system after the digestion phase is concluded. The in-vessel composting process removes some of the adverse properties of the digestate such as its odor and some volatile organic compounds. The treated digestate is sent from the facility to a permitted composting operation where it is screened and further stabilized for use as a soil amendment.

The environmental benefits of compost use are well-established, and include erosion control, increased water retention in soil, reduced dependence on chemical fertilizer, and carbon sequestration. CARB has estimated that the greenhouse gas reduction benefits of compost application to be .42 metric tons of carbon dioxide equivalents ($MTCO_2e$) reduced for each ton of organic feedstock used. This factor is likely conservative, as the compost emissions base line used in this study are under windrow composting conditions. As Blue Line Transfer is using a combination of anaerobic digestion and in-vessel composting, emissions are better controlled than they would be if the material were processed in a windrow.

Using the factor of .42 $MTCO_2e$ avoided for each ton of compost feedstock, it is possible to estimate the greenhouse gas benefit from Blue Line Transfer's provision of digestate for compost uses. To date, Blue Line has processed 5,121 tons of anaerobic digestion feedstock. Under CARB's emission factor this equates to avoiding an estimated 2,151 $MTCO_2e$. Note that the emissions reduction from producing compost is also included in the CARB's -34.7 CO_2e/MJ pathway, and therefore cannot be counted as additional to the reduction from 3.1.1.

4.1.4 Reduction of Landfilled Waste

Independent of its value as a compost feedstock, the diversion of organic materials from landfills has its own inherent environmental value. Under landfill conditions, these materials would have decomposed anaerobically. However, the anaerobic decomposition in a landfill is much less controlled than in an anaerobic digester. In a landfill, a portion of resulting methane gases would have escaped into the atmosphere. This fugitive methane gas over a 100-year time period is 21 times more powerful than methane.

4.2 Cost Effectiveness

This section details the costs associated with the construction and development of the project.

4.2.1 Non-Recurring Costs

$10,573,666 has been spent on the direct fixed costs associated with this project as shown in Table 34.

Table 34: Fixed Expenses

Item	Amount
CEC Reimbursable	$2,590,929
Match Funding	$7,175,798
50% Expense of Fueling Station	$806,939
TOTAL:	$10,573,666

Source: Total Compliance Management, Inc.

4.2.2 Operational Expenses

The dry fermentation anaerobic digestion system at Blue Line Transfer has approximate annual operations and maintenance costs of $1,159,049. A summary of these costs is provided below in Table 35.

Table 35: Operations and Maintenance Annual Expenses

Expense	Unit Cost	Unit	Annual Cost
Electricity	$0.15	KwH	$139,648
Media Replacement	$50,000	Annual Replacement	$50,000
Sulfuric Acid	$7,000	Annual Replacement	$14,000
Ammonium Sulfate Disposal	$8,400	Annual Removal	$16,800
Boiler Natural Gas	$0.95	Therm	$33,231
Digestate Tipping Fee	$45	Ton	$196,098
Digestate Transportation	$37	Ton	$161,236
Labor	$450,000	Annual Expenditure	$450,000
TOTAL:			$1,159,049

Source: Total Compliance Management, Inc.

4.2.3 Revenue and Savings

The dry fermentation anaerobic digestion system at Blue Line Transfer provides several sources of savings as well as certain revenue streams. The offset vehicle fuel provided by the system is the largest source of savings; whereas the ability to collect a tipping fee for food waste along with green waste is the greatest source of new revenue. Additional savings are produced from the reduction of mass that needs to be managed and labor hours required for fueling off-site. Additional new sources of revenue include the receipt of Renewable Identification Numbers (RINS), LCFS credits, and the potential sale of ammonium sulfate as a fertilizer. A summary of these annual revenues and savings is provided in Table 36.

Table 36: Annual Revenue and Savings

	Revenue/Savings per Unit	Annual Units	Amount
Tipping Fee	$81 per ton	11,200 tons	$907,200
Vehicle Fuel Savings	$2.15 per GGE	131,803 GGE	$283,377
RINS	$0.50 per 77,000 btu	14,933,318,400 btu	$96,969
LCFS	$40 per credit ($MTCO_2e$)	1,691 credits	$67,653
Time Savings	$60 per hour	2,860 hours	$171,600
TOTAL:			$1,526,773

Source: Total Compliance Management, Inc.

Tonnage processing and fuel processing amounts based on system design parameters. Prices for RINs and LCFS subject to change; values for these are listed as estimated averages of prices. Gasoline gallon equivalent price for CNG taken from South San Francisco International

Airport. Time savings including worker's compensation and other expenses estimated to be $60 an hour. Estimated time savings from not going off-site to refuel is a half hour a truck a day for 260 operating days. LCFS revenue modelled to expire in 2020.

4.2.4 Return

Annual expenditures associated with the anaerobic digester to fuel system are $1,159,049 whereas revenue and savings from the system are $1,526,773. Comparing these two cash flows reveals a positive net savings of $367,723 per year.

4.2.4.1 Net Present Value

Assuming a 5 percent interest rate, price escalation of 2.5 percent, $10,573,666 in initial capital costs, and an equipment lifespan of 20 years, the net present value of the dry fermentation anaerobic digestion system is -$6,868,393.

4.2.4.2 Internal Rate of Return

Using the same parameters described above, the internal rate of return for this investment is -4.3 percent.

4.2.4.3 Unit Fuel Costs

If fuel savings are excluded from the net present value calculations, the project's net present value is -$11,376,3487. At design capacity, the dry fermentation anaerobic digestion system will produce 131,803 gasoline gallon equivalent per year, or 2,636,067 gasoline gallon equivalent over a 20-year lifespan. Unit fuel costs for the dry fermentation anaerobic digestion renewable natural gas are $4.36 per GGE.

4.2.4.4 Unit Fuel Cost Comparison

A unit price of $4.36/ Gasoline gallon equivalent for RNG is higher than current prices for other fuels. Table 37 compares prices of RNG from this project, conventional CNG, and diesel. All values are converted into DGE.

Table 37: Fuel Price Comparison

Fuel Price Comparison ($/DGE)		
Project RNG	Conventional CNG	Diesel
$4.36	$2.45	$2.81

Source: Total Compliance Management, Inc.

Prices taken from U.S. Energy Information Administration, October 19th, 2015.

4.2.4.5 Marginal Abatement Costs

A marginal abatement cost is the amount of incremental cost that would be incurred to reduce one unit of pollution, in this instance, a metric ton of carbon dioxide equivalent ($MTCO_2e$). Under alternative production parameters and cost structures, the Blue Line Transfer Anaerobic Digestion Facility could reach two different benchmark efficiencies. The first benchmark, achieving a net present value of zero, is the point at which the project would be financially viable independent of other project benefits. At this point, the marginal abatement cost would be zero. The second benchmark, would be achieving a marginal abatement cost of under $100/MTCO_2e, this is provided in Table 38 below. This value has been identified in a Precourt

Institute for Energy Efficiency Paper Titled *"Analysis of Measures to Meet the Requirements of California's Assembly Bill 32,"* as a guideline for determining which abatement strategies would be cost-effective given the greenhouse gas targets of California's Global Warming Solutions Act of 2006.

Table 38: Net Present Value and Marginal Abatement Costs

	70% CH_4 Recovery	**90% CH_4 Recovery**
Net Present Value with Existing Cost Structure	-$6,745,689	-$4,965,931
Marginal Abatement Cost with Existing Cost Structure ($/MT$CO_2$e)	$189.97	$103.58
Maximum Fixed Costs For Net Present Value of Zero	$3,700,000	$5,600,000
Maximum Fixed Costs to Achieve a Marginal Abatement Cost of Less Than $100/MT$CO_2$e	$7,500,000	$10,200,000

Source: Total Compliance Management, Inc.

Analysis assumed a 5 percent discount rate, a 2.5 percent price escalator, and a 20-year life expectancy for the facility. All other costs and parameters are held fixed.

4.3 Economic Benefits

The purpose of this section is to quantify the economic benefits of this project. These benefits include the creation of temporary and permanent jobs, an increase in State and local tax revenue, economic growth, and direct benefit to economically distressed areas.

4.3.1 Direct California Jobs

The on-going jobs created by operating an 11,200 tons-per-year facility are at Blue Line are 3.5 fulltime equivalent positions. The jobs will be classified as prevailing wage union jobs for equipment operators, facility foremen, mechanics, and laborers.

From a systems wide approach, the Tellus Institute estimated job creation in their recent report, More Jobs, Less Pollution: Growing the Recycling Economy in the U.S. The collection of organic creates 1.67 jobs for every 1,000 tons handled, creates 0.5 processing jobs for every 1,000 tons, and 0.5 manufacturing jobs for every 1,000 tons handled. With 4.2 million tons of organics heading towards anaerobic digestion facilities by 2020 to meet the adopted AB 32 Scoping Plan measures, it is estimated that 11,200 full-time operating jobs will be phased in over the next eight years as 4.2 million tons of organics are collected, processed at anaerobic digestion facilities, and composted.

4.3.2 State and Local Taxes

The creation of direct project jobs and ancillary full-time organic system-wide jobs will create positive roll-over effects for state and local taxes. The CNG use will be internalized for the existing CNG fleet and will not be sold to the general public and would be considered a wholesale transaction. The statewide commercialization of projects of this type could yield 23,500,000 million diesel equivalent gallons per year by 2020, or enough fuel for 1,800 CNG fueled refuse and recycling fleet. Today, there are over 15,000 refuse and recycling collection vehicles, with over 2,000 CNG collection vehicles on pipeline. Most likely, the CNG fuel use will be internalized to the existing fleet and will not be sold to the general public to create state or local taxes. As a replacement to diesel, that state would lose 18 cents per gallon, and locals would lose an average of 1.25 percent sales taxes, which could result in a loss of $4.23 million in state taxes per year in 2020, and a loss of $600,000 in local taxes in 2020.

4.3.3 Other Economic Impacts

CNG would replace more expensive diesel fuel that have volatile costs that have been as high as $5 per gallon. There would be loss in landfill revenues from foregone tipping fees that average $40 per ton. With 23,500,000 million diesel equivalent gallons per year produced by 2020, $117 million in lost diesel sales could occur. With 4.2 million tons of organic waste diverted from landfills, the solid waste disposal industry would lose $168 million in 2020. The amount of compost produced statewide could be 2.2 million tons in 2020, where compost sales average $10 per ton for bulk compost; the value is estimated to be $22 million.

CHAPTER 5: Conclusion

The Blue Line Transfer Biogenic Energy Project has demonstrated the construction of a modular anaerobic digestion system coupled with a biogas purification unit and vehicle fueling facility on a small footprint at an existing waste management facility. A combined biomethane and pipeline natural gas fueling facility, guaranteeing sufficient fuel for a 40-truck fleet while preferentially using biomethane, has been successfully implemented. The operation of waste collection vehicles on renewable CNG without any detrimental performance issues is ongoing. The composted digestate has been shown to be suitable as a soil amendment, being virtually identical to compost created entirely under aerobic conditions. The carbon intensity of fuel produced at high-solids anaerobic digestion facilities of this scale and type has been calculated using the California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model developed by the California Air Resources Board. Critical performance metrics have been established, many being better than anticipated at the time of the original proposal to the California Energy Commission.

Although the economics of this project indicate that the cost per unit of renewable natural gas is greater than that of pipeline fossil natural gas, the greenhouse gas reductions and contribution to environmental sustainability goals are substantial. The alignment of those goals between the service provider and client jurisdictions engendered a partnership that enabled substantial infrastructure investments. This technology ties together business, local and State sustainability goals. This project demonstrates the concept of distributed production of renewable transportation fuel, located to meet local needs and insulate users from market volatility and controversial extraction methods.

GLOSSARY

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

CALIFORNIA AIR RESOURCES BOARD (CARB)— The state's lead air quality agency consisting of an 11-member board appointed by the Governor, and just over thousand employees. CARB is responsible for attainment and maintenance of the state and federal air quality standards, California climate change programs, and is fully responsible for motor vehicle pollution control. It oversees county and regional air pollution management programs.

CARBON DIOXIDE EQUIVALENT (CO_2e)—A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.

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 CEC'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.

Funding for the CEC's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account, and other sources.

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

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

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

HYDROGEN SULFIDE (H_2S)—A highly flammable, explosive gas. H_2S burns and produces other toxic vapors and gases, such as sulfur dioxide.

IN VESSEL COMPOSTING (IVC) — Processing large amounts of waste by feeding organic materials into a drum, silo, concrete-lined trench, or similar equipment.[1]

LOW CARBON FUEL STANDARD (LCFS)—A set of standards designed to encourage the use of cleaner low-carbon fuels in California, encourage the production of those fuels, and therefore reduce greenhouse gas emissions. The LCFS standards are expressed in terms of the carbon intensity of gasoline and diesel fuel and their respective substitutes. The LCFS is a key part of a comprehensive set of programs in California that aim cut greenhouse gas emissions and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options.

RENEWABLE NATURAL GAS (RNG)—Or biomethane, is a pipeline-quality gas that is fully interchangeable with conventional gas and thus can be used in natural gas vehicles. RNG is essentially biogas (the gaseous product of the decomposition of organic matter) that has been processed to purity standards. Like conventional natural gas, RNG can be used as a transportation fuel in the form of compressed natural gas (CNG) or liquefied natural gas (LNG).

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

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[1] Types of Composting and Understanding the Process | US EPA https://www.epa.gov/sustainable-management-food/types-composting-and-understanding-process#:~:text=In-vessel%20composting%20can%20process%20large%20amounts%20of%20waste,a%20drum%2C%20silo%2C%20concrete-lined%20trench%2C%20or%20similar%20equipment.

APPENDIX A
Ribbon Cutting

RIBBON CUTTING CEREMONY

Blue Line Transfer, Inc. will be having an Anaerobic Digestion Facility Commissioning Ribbon Cutting Event on September 19, 2014 at their material recovery facility located at 500 E. Jamie Ct, South San Francisco, CA 94080 at 11:00am. The project, ARV-12-031: "Blue Line Biogenic CNG Facility", is to develop and build a pilot anaerobic digestion facility in South San Francisco, CA. The facility will demonstrate Blue Line Transfer's ability to produce biomethane from food and plant feedstocks. The facility is expected to produce the equivalent of 120,000 diesel gallons per year of biomethane to be used by fifteen compressed natural gas (CNG) waste and recycling collection vehicles.

The facility will utilize 11,200 tons of feedstock per year, or about 43 tons per day, consisting of 2/3 source separated food scraps and 1/3 yard trimmings. The collection of source separated yard trimmings is an established practice, and Blue Line Transfer is expanding their already successful commercial food scraps program as part of this project and implement the program in residential areas, as well. The food scraps feedstock will be collected from the company's service area, including South San Francisco, Brisbane, Millbrae, and San Francisco International Airport.

The anaerobic digestion process results in biogas production, of which about 60 percent is methane, the principal component of natural gas. A purification system cleans the biogas and produces a flow of fuel quality biomethane sufficient to continually operate 15 heavy duty collection vehicles. In fact, the organic feedstock collected by one collection vehicle produces more than enough biomethane to operate two collection vehicles. Blue Line Transfer's system, made by Zero Waste Energy, LLC, is the first dry anaerobic digester in the country to produce CNG transportation fuel.

The natural gas fueling system is designed to have sufficient capacity to fuel up to 40 CNG vehicles, although the initial phase will include fueling posts for 20 vehicles. This allows for easy expansion of the fueling posts as the diesel fleet is progressively replaced by CNG vehicles. Biomethane CNG and natural gas from the utility pipeline are blended together to continually assure sufficient CNG fuel for the entire fleet while prioritizing the use of biomethane. Even pipeline natural gas has significantly less greenhouse gas impact than diesel fuel, while the biomethane CNG is a carbon negative fuel, as determined by the California Air Resources Board.

Operation of the facility will result in the creation of 2.5 full-time equivalent positions. The organic feedstock, after the biomethane has been extracted from it, is further processed in in-vessel composting chambers to produce nutrient-rich compost that will be certified as an organic soil amendment.

FOR IMMEDIATE RELEASE
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South San Francisco Scavenger Company to Turn Food Scraps into Fuel for Collection Fleet

Cutting-Edge Technology Keeps Waste Out of Landfill, Reduces Emissions

South San Francisco, CA—South San Francisco Scavenger Company (SSFSC) and Blue Line Transfer, the facility that handles SSFSC's recycling and disposal is launching an onsite system to convert food scraps and yard waste into transportation fuel and compost. The new facility uses dry anaerobic digestion technology to generate clean-burning compressed natural gas (CNG), that will power the company's collection fleet. The fully enclosed system is set to process 11,200 tons of material per year, including food scraps and food soiled paper collected from businesses in the company's service area, including South San Francisco, Brisbane, Millbrae, and San Francisco International Airport.

"We're excited about the new digester because it allows us to turn compostable food scraps into fuel for the very trucks that collect those materials. It's a truly closed loop system," said Doug Button, president of South San Francisco Scavenger Company and Blue Line Transfer. "Plus, the process keeps organic waste out of the landfill and cuts greenhouse gas emissions—benefitting the communities we serve, the environment and our company."

Anaerobic digestion is a process that uses microorganisms to break down biodegradable material in the absence of oxygen, resulting in methane gas. Most anaerobic digesters currently online in California generate electricity from methane. Blue Line Transfer's system, made by Zero Waste Energy, LLC, is the first dry anaerobic digester in the country to produce CNG transportation fuel. Besides producing up to 500 Diesel Gallon Equivalents (DGE) per day of carbon negative biogenic (renewable) CNG, the process provides digestate, a nutrient-rich substance that will be matured into certified organic compost. Compared to traditional composting, the dry anaerobic digestion process reduces greenhouse gas (GHG) emissions and other air pollutants.

The launch of the facility is part of South San Francisco Scavenger Company's expanded business collection program for food scraps and food soiled paper. A campaign is currently underway to increase the number of commercial customers participating in the program. The company plans to expand the food scrap collection program to residents as well.

Founded in 1914 as a collection company, the South San Francisco Scavenger Company has a history of meeting and exceeding industry standards and providing excellent customer service throughout its service area.

The cornerstone of their efforts has been innovation. As regulations have become more rigorous and complex, the South San Francisco Scavenger Company has always found cost-saving, innovative disposal methods that allow for greater recycling and diversion of waste from landfills. Some examples of their efforts include: being one of the first companies to implement waste reduction and resource recovery technologies, including curbside collection of recyclables and advanced household hazardous waste programs.

A significant accomplishment taking place in their 100th year is the launching of an anaerobic digestion facility, which will transform 11,200 tons of food and green waste per year into compost, and biogenic compressed natural gas (CNG), a carbon negative fuel for use in their collection fleet which will be delivered from the new onsite slow fill CNG fueling station.

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