Methane Capture Feasibility Study

City of San Rafael and Central Marin Sanitation Agency

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Executive Summary

ES.1 Food Waste Collected in Central Marin County Now Disposed of by Landfilling

It is estimated that about 50% of the solid waste that is collected in central Marin County and currently transported for disposal in the Redwood Landfill in Novato is food waste. At the landfill, the food waste takes up valuable capacity. It naturally degrades to release methane and carbon dioxide to the atmosphere, adding to greenhouse gas emissions.

To reduce the amount of food waste sent to the landfill, the Marin Sanitary Service (MSS) began a pilot program of separate collection of food wastes from restaurants, markets, and institutions in San Rafael and portions of Ross Valley, along with pilot testing of an in-vessel composting process. The quantity of commercial and institutional food waste within the MSS service area is estimated at 15 tons per day, or approximately the volume of one dumptruck. The City of San Rafael (City) and the Central Marin Sanitation Agency (CMSA) became aware of the possible advantages of diversion of food wastes to the anaerobic digesters at the nearby CMSA Wastewater Treatment Plant (WWTP) to capture the methane biogas and produce electrical power.

ES.2 Food Waste - Methane Capture Feasibility Study

ES.2.1 Exploring Use of Excess Anaerobic Digester Capacity

The CMSA WWTP has used two anaerobic digesters for nearly 25 years to produce methane biogas. This methane biogas is used to operate an engine generator, which in turn produces electric energy to operate pumps, blowers, and other equipment. The anaerobic digesters are underloaded compared to current digester designs, which typically feature improved mixing to enhance volatile organic solids reduction and biogas production. The City commissioned this study to investigate the feasibility of using CMSA’s existing anaerobic digesters to process local commercial food waste to produce renewable, non-fossil-fuel energy.

ES.2.2 Study Objectives

Kennedy/Jenks Consultants worked with the City and CMSA to conduct this food waste study of methane capture feasibility. Kennedy/Jenks investigated potential food waste sources and characteristics, evaluated digester loading capacity and methane biogas production, and then developed conceptual facility design and costs. The key objectives of the study were to:

- Identify the quantity and characteristics of available food wastes
- Identify other agencies that have implemented food waste-to-energy programs
- Determine requirements for pre-treatment of the food wastes
- Identify required modifications to the CMSA WWTP anaerobic digesters
- Determine the methane and solids production from food waste digestion
- Develop project costs and the expected payback period for the project
- Identify permitting issues for the project
ES.3 Existing Food Waste-to-Energy and Composting Programs

ES.3.1 Overview of Programs

Food waste diversion to provide methane gas energy recovery in the U.S. is in its infancy. The only operating facility in the United States exists at EBMUD’s main WWTP in Oakland. A number of U.S. industrial food processing facilities treat their wastes with anaerobic digestion, and the potential exists for food waste processing and methane biogas recovery at these facilities, including more than 150 California municipal WWTPs. There is a great deal of experience in Europe with food waste anaerobic digestion at large municipal facilities, particularly in Denmark and Germany.

An increasing amount of food waste is being diverted from landfills to aerobic composting at a number of locations in the United States, but it still comprises only about 5% of food waste disposal, the remainder of which is done by landfilling. Generally, aerobic composting can be more energy-intensive and more costly than anaerobic digestion.

Compost stabilization of solid wastes requires energy input for air supply to the aerobic bacteria. Carbon dioxide (CO2) and nitrous oxides are emitted to the atmosphere from composting operations.

In short, anaerobic digestion of food waste produces energy, whereas composting consumes energy in an aerobic process. Anaerobic digestion reduces greenhouse gas emissions more than 20 times as much as landfills and eight times as much as composting.

ES.3.2 EBMUD Food-Waste-to-Energy Program

In 2004, the East Bay Municipal Utilities District (EBMUD) constructed a facility to receive and process food waste and high-strength liquid waste at its main WWTP in Oakland, designed for a capacity of 200 tons/day of food waste. It receives food waste transported from the NorCal Jepson Prairie recycling facility in Vacaville. The EBMUD facility processes, stores, and feeds the food waste to anaerobic digesters to produce methane and electric power.

EBMUD has found that the processed food waste readily commingles with the wastewater biosolids and produces a biogas with high methane content. Studies conducted by EBMUD found that the food waste slurry is considerably more digestible by the anaerobic process, in shorter time and higher concentrations, than is municipal wastewater biosolids. The studies also found that the food waste slurry produces more methane gas and lower-residue volumes.

EBMUD has determined that it is preferable to have the municipal solid waste collection company conduct the initial food waste separation, grinding, and screening under an existing California Integrated Waste Management (CIWMB) permit prior to its transport to EBMUD.

The characteristics of the commercial food wastes being collected in the San Rafael area of Marin County closely match those being digested and tested by EBMUD. These wastes are highly biologically digestible and yield greater methane gas production and solids reduction than does municipal wastewater sludge.
ES.4 Feasibility of Converting Food Waste to Energy Through Anaerobic Digestion at CMSA WWTP

This study indicates that diversion of local commercial food wastes from the landfill and processing of this waste with the excess digester capacity at the CMSA WWTP to produce usable methane biogas is feasible. Initially, the food wastes would be received, screened, and ground at a separation facility. Once transported to the CMSA WWTP, the food wastes would be mixed with recycled water into a slurry, further screened and ground up, and fed into the existing anaerobic digester process at the WWTP. The anaerobic digestion process would convert the food waste and biomass into methane biogas. The methane then would be used to produce electricity with an existing engine generator to provide power for the WWTP treatment processes. The CMSA facility would be planned initially at a maximum capacity of 20 tons/day of commercial food waste. The facility would be expandable to handle as much as 40 tons per day in case other food wastes are collected in the future. See Figure ES-1 and the sections below for more detail on the proposed facilities.

The currently collected food waste characteristics are on average 25% solids and 75% water, and the solids portion is approximately 92% volatile. These characteristics make the food waste well-suited for the anaerobic digestion process. Because MSS collects food wastes directly from commercial sources, the waste tends to have fewer contaminants.

The EBMUD facility should be viewed as a prototype for the proposed facility in terms of design, operation, and cost estimates.

ES.5 Benefits of Methane Energy Recovery from Food Waste

The study found that diversion of food waste from the landfill to the CMSA anaerobic digesters for methane energy recovery is an economical alternative that would increase energy recovery and local reuse and would reduce overall greenhouse gas emissions. It would:

- Extend landfill life by diverting commercial food waste from the Redwood Landfill
- Reduce truck traffic from solid waste transport to the landfill
- Capture the energy content of food waste for beneficial use
- Reduce greenhouse gas emissions and reduce the carbon footprint for the City, CMSA, Larkspur, San Anselmo, Fairfax, Ross, and Marin County overall
- Provide more than 50,000 cubic feet per day of methane biogas and 230 kW of renewable energy
- Allow CMSA to achieve greater energy self-sufficiency and to potentially export excess power in the future
- Minimize procurement of natural gas by CMSA
- Produce minimal increase in residuals at CMSA from food waste digestion
- Use existing digesters for food waste digestion; maximize utilization of CMSA’s existing infrastructure
- Conform with the City’s and County’s green initiatives
- Accommodate the future processing of other food waste
ES.6 Key Design and Operational Aspects

ES.6.1 Food Waste Separation at a Solid Waste Collection and Transfer Facility

The food waste needs to be screened of inert, non-biodegradable materials and ground into a paste for introduction into the anaerobic digestion process. The most efficient approach to doing so would be to locate the initial separation and screening facility at MSS or another solid waste collection and transfer facility similar to the NorCal Jepson Prairie facility employed by the EBMUD program.

One reason for this approach is that CMSA does not have the required CIWMB permit to undertake the work, though, like EBMUD, CMSA does have permits to process the food waste as a liquid slurry as part of its NPDES Wastewater Discharge and Air Quality Management Permits. If an agreement to install and operate the receiving and sorting equipment cannot be reached with MSS or another similar facility, CMSA could seek to acquire the necessary permit and conduct receiving and sorting, if necessary.

The proposed equipment for the collection and transfer facility includes a hopper, sort line conveyor, sort line grinder feed conveyor, hammermill grinder, grinder discharge conveyor, and stacking conveyor for loading a truck or bins to transport separated food waste to the CMSA WWTP. The screening facility would remove any large material, rocks, bottles, plastics, metals, etc. and screen the food waste solids down to a size of about 3/4 inch.

ES.6.2 Food Waste Processing Facility at CMSA WWTP

The separated food waste would be transported from MSS or another solid waste collection facility to CMSA for further processing and anaerobic digestion. The food waste processing facility located at the CMSA WWTP would initially be capable of receiving a 20-ton transfer truck about once a day. The processing facility would further grind the food waste, remove any remaining grit, and add water to the food waste to produce a 10% concentration slurry. The slurry tank would be covered and the air space passed through an odor scrubbing system. The slurry would then be pumped into the existing digesters at a controlled rate and blended with biosolids from the CMSA WWTP to produce methane to be used in the existing engine generator, and future generators or fuel cells, for energy production.

ES.7 Recommended Digester Improvements and Expected Methane Gas Production Increase

ES.7.1 Digester Improvements

The addition of up to 15 tons per day of commercial food wastes would increase volatile solids loading to CMSA’s digesters by about a third. With this additional loading, together with fats, oil, and grease (FOG) wastes that CMSA plans to accept in the future, the current desired peak loading with one digester out of service would be exceeded. This is based on using the existing digesters with existing floating covers and mixing system.

It is possible, however, to increase the capacity of the existing CMSA WWTP digesters by providing fixed dome or membrane gas holder covers to replace the existing floating covers and new digester mixing to increase gas production. This would increase the capacity of the digesters by 50%, which would provide for projected growth of municipal solid wastes and up to 40 tons per day of food waste to well beyond 2030, even with one digester out of service.
**ES.7.2 Expected Methane Gas Production Increase**

Biogas production from the addition of up to 15 tons of commercial food waste is expected to increase from a current level of 180,000 cubic feet/day to 287,000 cubic feet per day by addition of FOG and commercial food wastes. This would nearly double the current CMSA engine generator biogas operation from 12-hour to nearly 24-hour operation – a substantial expansion of a local Marin County energy source. If other food waste is received in the future, a second engine generator, or the addition of fuel cells or microturbines, would be needed to take advantage of the additional methane gas production and to produce additional electricity. This would further reduce electricity used by CMSA. Excess methane or electricity generated could potentially be exported as renewable, non-fossil energy.

**ES.8 Conceptual Capital Cost and Payback Period of Facilities**

Using preliminary layouts of the facilities, vendor quotations, and bid prices from recent similar projects, this study determined conceptual capital costs for the food waste separation and processing facilities. CMSA is planning to refurbish its digesters in the next few years as part of its funded bond capital program, therefore, this study did not include that project’s cost.

The estimated construction cost of a food waste separation facility located in an enclosed space at the MSS Transfer Station would be $1.03 million, with an estimated annual operating cost of $72,900. Projected annual cost savings are $257,000 for transport costs and disposal fees to Redwood Landfill. The net annual cost saving is estimated at $184,500, with a payback period on the capital costs for the separation facility of about 5-1/2 years.

The estimated cost of a food waste processing facility at the CMSA WWTP is $2.7 million, with an estimated annual operating and maintenance cost of $58,000. Projected annual cost savings are $338,900, for avoided natural gas costs due to the additional biogas production sufficient to fuel continuous operation of the existing engine generator. The net annual cost saving is estimated at $338,900, with a payback period on the capital costs for the processing facility of about 8 years.

CMSA should consider a charge or “tipping fee,” similar to EBMUD’s tipping fee, for processing food waste at the CMSA WWTP. This would further reduce the payback period on the estimated capital costs for the processing facility. For a tipping fee range of $10/ton to $50/ton, the net payback period on the capital costs of the processing facility at CMSA would then be reduced to 7 to 5 years, respectively.

The payback period could be further reduced if funding from incentives, grants, or carbon credits can be obtained (described in Section 7 of the report), or if future electricity and/or natural gas costs increase.
Figure ES-1: Food Waste Handling for Anaerobic Energy Recovery and Volume Reduction
Section 1: Background

1.1 Introduction

The City of San Rafael (City), as lead agency, commissioned a food waste Methane Capture Feasibility Study (Study). The main objective of this study is to investigate the feasibility of adding processed food wastes to the Central Marin Sanitation Agency’s (CMSA’s) anaerobic digesters at the Wastewater Treatment Plant (WWTP) to commingle with wastewater biosolids and enhance biogas production. The biogas is primarily methane. It is utilized in an engine generator at the WWTP to produce electric energy and heat for the equipment used in the wastewater treatment processes. The enhancement of biogas production and methane gas capture would enable greater self-sufficiency in energy production and utilization at the WWTP. Excess energy could be provided in the future to the nearby desalination plant being considered by the Marin Municipal Water District (MMWD) and other municipal facilities, or it could be provided to the electric utility as an additional local energy source.

Other objectives include diversion of food waste residues from the Redwood Landfill, which currently receives nearly 50% of the total volume to be landfilled as food wastes. Approximately 1/3 of this food waste is from commercial sources such as restaurants, markets, and institutional kitchens.

The study includes assessments of:

Food waste diversion programs and processing facilities
Food waste quantity, characteristics, and methane capture
Food waste separation and processing to allow food waste to be further processed by CMSA’s anaerobic digesters
The physical space requirements for food waste separation and processing facilities
Digester improvements for processing food waste and fats, oils, and grease (FOG)
The regulatory and permitting oversight requirements
Additional digested biosolids residues and disposition options
Cost estimates for food waste separation and processing facilities and payback periods

Kennedy/Jenks Consultants was authorized to conduct this study by the City in July 2008 with a scope that included the following tasks:

Task 1  Quantify food waste and methane biogas production
Task 2  Conduct food waste reference search and processing facility tours
Task 3  Evaluate digester loading and improvements for processing food waste
Task 4  Prepare conceptual design of food waste separation and receiving facilities
Task 5  Prepare cost estimates, identify funding availability and permitting requirements
Task 6  Prepare methane capture feasibility study report
Task 7  Project coordination, quality control, and meetings

1.2 Background

Over the past 25 years, resource recovery and recycling rather than landfill disposal have been given increased support by government policy and the general public. The issues of sustainability, fossil fuel shortages, energy costs, greenhouse gas reduction, and landfill space...
constraints have made the analysis of energy recovery from solid wastes a focus of activity nationwide.

Food solid wastes have been identified as having the potential for energy recovery, but only recently has there been activity to utilize this resource through landfill gas capture and energy conversion, composting, or use in wastewater treatment plant digesters. Wastewater treatment plant digesters are used for waste solids stabilization, reduction, and methane biogas energy recovery to engine generators or fuel cells. The digesters provide a portion of energy needs for pumps, aeration, and other uses at the treatment plant and often have excess capacity.

Locally, the East Bay Municipal Utility District (EBMUD) has been testing commercial food waste digestion in the existing anaerobic digesters at their Main WWTP in Oakland. In 2004, EBMUD constructed a combined food waste receiving and processing facility together with high-strength liquid waste receiving, storage, and processing facilities. EBMUD began receiving high-strength, biologically reducible liquid wastes to feed directly to their anaerobic digesters. This is the first food waste receiving and processing facility at a municipal wastewater treatment plant in North America. EBMUD encountered some maintenance and operational difficulties with the originally installed processing equipment, which was then replaced by more operationally reliable facilities. The facilities produce a slurry paste from food wastes that can be readily commingled with biosolids produced from municipal wastewater treatment.

EBMUD's acceptance and adoption of food wastes for energy recovery have become known locally and throughout California for the past few years, through presentations by their engineers at California Water Environment Association (CWEA) meetings and conferences and other types of communications.

In 2007, the Environmental Protection Agency, Region 9, funded a research report conducted by EBMUD and published in March 2008, titled "Anaerobic Digestion of Food Waste" (EBMUD, 2008). This report described the highly successful conversion of food wastes to methane and energy by anaerobic biological processes tested both in laboratory pilot plants and full-scale operations.

This report’s Executive Summary reads:

“Food waste is the single largest category of municipal solid waste (MSW) in California, at 5.9 million tons or 16% of total MSW as of 1999. Diverting a portion of food waste from landfills can provide a significant contribution toward achieving EPA, state, and local mandated solid waste diversion goals. In addition, diverting food waste from landfills prevents uncontrolled emissions of its breakdown products, including methane – a potent greenhouse gas. Currently, only about 2.5% of food waste is recycled nationwide, and the principal technology is composting. While composting provides an alternative to landfill disposal of food waste, it requires large areas of land; produces volatile organic compounds (smog precursors), which are released into the atmosphere; and consumes energy. Consequently, better recycling alternatives to composting food waste should be explored. Anaerobic digestion has been successfully used for many years to stabilize municipal organic solid wastes, and to provide beneficial end products, i.e., methane gas and fertilizer. In California, approximately 137 wastewater treatment plants have anaerobic digesters, with an estimated excess capacity of 15-30%. This excess digester capacity could provide
an opportunity to recycle post-consumer food waste while producing renewable energy and reducing greenhouse gas emissions in California."

The City and CMSA became aware of the potential for recovery of methane energy from food wastes by digestion at the WWTF. Locally, the Marin Sanitary Service (MSS) has a contract to collect solid wastes in San Rafael and portions of Ross Valley that are also served by CMSA. MSS estimated that about 50% of what they currently transport for disposal to the Redwood Landfill is food waste. To reduce the amount of food sent to the landfill, MSS began a separate collection of food wastes from restaurants, markets, and institutions in its service area. MSS became aware of the possible advantages of diversion of the food wastes to the anaerobic digesters at the nearby CMSA WWTP, and it has provided food waste samples for analysis and information on quantities of solid waste and food wastes that were used in this study.

In addition, MSS is planning to evaluate by pilot-plant testing an in-vessel composter of 3.2 tons/day capacity for a combination of food wastes mixed with green wastes. This testing program is being evaluated by the Bay Area Regional Air Quality Board for an emission permit and will not operate until that is attained.

In Section 2.3, this study briefly compares composting, which is an aerobic stabilization process, with the anaerobic stabilization process via digestion and methane capture at the CMSA WWTP.

1.3 Acknowledgements

This report was prepared by Kennedy/Jenks Consultants, with contributions from project team members who are listed below.

City of San Rafael
Stephanie Lovette, Economic Development Specialist

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Section 2: Reference Search

This section provides a review of the experience of other agencies with anaerobic digestion of food waste. A search of articles and discussions of similar projects reported in journals, books, and reports over the past 20 years was undertaken. This section also presents information obtained from a tour of EBMUD’s food waste processing facility located at their Main WWTP in Oakland, California, and the Norcal Jepson Prairie Facility (JPF) in Vacaville, California.

The reference search information was provided in a draft technical memorandum (TM) No. 1. Information from the EBMUD facility tour was presented in Meeting Memorandum No. 2. Meeting Memorandum No. 2 and TM No. 1 are included in Appendix A of this report.

2.1 EBMUD Food-Waste-to-Energy Facility

EBMUD’s Main WWTP was constructed nearly 40 years ago when there was significant industrial waste loading from food processors and related industries in the service area, which encompassed Albany to San Leandro, including Alameda and the urbanized area between the Berkeley Hills and San Francisco Bay. In recent years, many of these industries have relocated to the Central Valley, which has resulted in excess capacity at the Main WWTP, particularly with the anaerobic digestion process. For the past 10 years, EBMUD has encouraged the receiving and processing of high-strength industrial wastewater. This wastewater is used by anaerobic digestion processes to produce methane and generate electrical energy to satisfy some of the Main WWTP power demands.

EBMUD identified the potential to receive commercial food wastes collected by several Bay Area municipal solid waste handlers. This food waste would have normally been directed to landfills or composted. In 2004, EBMUD constructed a food waste and high-strength liquid waste receiving facility at the Main WWTP (Gray, 2008). The receiving facility included two 20,000-gallon concrete slurry tanks, three liquid receiving tanks with mixers, grit separators, pumps, screens, and odor scrubbers. The facility was constructed at a cost of about $3 million. There were a number of improvements to the facility made by EBMUD to reduce maintenance and improve reliability.

The EBMUD facility was designed for a capacity of 200 tons/day of food waste transported from the NorCal solid waste transfer station in Vacaville. The NorCal Jepson Prairie Facility began receiving commercial food wastes from San Francisco restaurants, markets, and hotels in 1997 for composting adjacent to a landfill situated on 200 acres. This facility began separating and transporting a portion of the food waste to EBMUD in 2005.

In addition, green waste (yard trimmings) is hauled from San Francisco to JPF and mixed with food wastes in a windrow composting operation that occupies 16 acres of the site.

Initially 30,000 tons/year of food wastes were received at JPF; this amount has now grown to 70,000 tons/year of food wastes and 40,000 tons/year of green wastes. These quantities translate to 270 and 155 tons/day, respectively, on a five-day working week basis, and 110 tons/day on a calendar-day basis. Following screening, grinding, and separation processing at JPF, food wastes are hauled back to the EBMUD Main WWTF, where they are anaerobically digested for methane energy recovery.
The present operating permit for JPF is 300 tons/calendar day, which is now being achieved. NorCal would like to double the food and green wastes hauled to and processed at JPF, but because it is located in an air quality non-attainment basin, it must not exceed air emissions beyond the current permit limit. This is a reason why NorCal was amenable to the offer of EBMUD to divert food wastes for the anaerobic digestion at its Main WWTP and thereby effectively allow additional capacity for composting.

A 20 tons/hour processing facility to prepare the wastes received for composting or anaerobic digestion was constructed in 2003 and is considered proprietary by NorCal. It consists of a rotary trammel screen of 4-inch size for separation of larger wood, plastic, paper, bottles, etc., which constitute about 45% of the wastes. There are two grinders in the system, a ¾-inch vertical hammermill for food wastes and a 1 ½-inch star grinder for the larger reject with an air separation for plastics and magnetic separator for metals removal.

Ground food wastes are conveyed from the hammermill grinder to enclosed dump trucks to transport to the EBMUD Main WWTP on their way back to the NorCal transfer sites in San Francisco.

There are some differences in what is proposed for MSS’s San Rafael food waste preparation facility compared to NorCal’s Jepson Prairie facility, as described later. These include manual sorting rather than Trommel screen sorting to achieve a much-greater-than 55% capture of food wastes for digestion. This is now not a problem at NorCal, as most food wastes and all green wastes are composted, but as the need for anaerobic digestion to reduce air emissions increases, a much higher waste capture rate will likely become necessary.

Food wastes are hauled to EBMUD in 30- to 35-cubic-yard covered dump trucks, which contain about 20 tons of food wastes at concentrations of between 20% and 45% total solids. The trucks dump the food waste at the Main WWTP into 20,000-gallon slurry tanks, which are covered and odor scrubbed. Recycled water is added to the slurry tank to produce a slurry with between 6% and 10% solids concentration. Propeller mixers are used to mix the slurry in the 20,000-gallon slurry tank for about 1 ½ hours.

The screened food waste slurry is then discharged through a rock trap/grinder to further reduce the size of the material and remove rocks and metal. The food waste is then pumped by hose pumps through a rotary conveyor screen with 0.06-inch openings to remove grit, plastics, rags, and fibers that are not readily biologically digestible. This rejected material constitutes about 10% of the total food waste.

The food waste paste is then pumped to the anaerobic digesters, and converted into methane gas, where it is used by engines and microturbines at the Main WWTP to produce energy.

Over the past few years, EBMUD staff have made a number of improvements to the facility to reduce operations and maintenance of the equipment. The system now appears robust, simple, and easy to operate. EBMUD is in the process of patenting the process to prevent a commercial patent that would restrict use of the technology. EBMUD will allow other municipalities to use the technology at nominal cost.
2.2 Other Experience

Other than EBMUD’s developmental work, there is limited experience in the United States with food waste by municipal wastewater treatment plants for anaerobic digestion and energy recovery.

Tests were conducted in the Milwaukee, Wisconsin, area since 2005 on restaurant wastes (Zitomer, 2006). The testing was with homogenizers, which are grinding and mixing tanks located within restaurants. The slurry produced by the homogenizers is periodically hauled to the wastewater treatment plant. The homogenizers are produced in Germany with 1,000- and 5,000-gallon capacity, and appear relatively costly (Hendricks, 2005).

Tests of the homogenized food waste at Milwaukee found the food waste to be quite amenable for digestion. The Milwaukee tests were relatively small-scale, with less than 10 tons/day of food wastes being co-digested at the 220 million-gallons-per-day (MGD) Milwaukee South Shore Wastewater Treatment Plant (Zitomer, 2005).

There is more experience in Europe with food waste anaerobic digestion, with rather extensive facilities particularly in Denmark and Germany (Maeng, 1999, Fink, 2007, Cecchi, 1993, and DiPalma, 1999). Usually the food waste is chopped to about 3/8-inch diameter, slurried to 5% to 10% solids concentration, and pasteurized or heat treated at 165°F to 170°F for an hour with municipal wastewater sludge. The treatment and pasteurization process results in a highly digestible material that produces more than 75% volatile solids reduction to methane in anaerobic digesters (Kalago, 2008).

An increasing amount of food waste is being diverted from landfills to aerobic composting (Sherman, 2005). Currently, less than 5% of food wastes in the United States is diverted to aerobic composting (Goldstein, 1998, Brown 2007). Generally, aerobic composting can be more energy-intensive and costly than anaerobic digestion (Jenner, 2007).

Compost stabilization of solid wastes requires energy input for an air supply to the aerobic bacteria (i.e., either tractor turnover of static piles or windrow composting, or electric-driven blowers for in-vessel composters). CO₂ and nitrous oxides are emitted to the atmosphere from compost operations. In contrast, an anaerobic stabilization process produces methane that can be captured and used as a biogas fuel source. CO₂ emissions from methane combustion are less than a quarter of that from composting. If fuel cells are used for methane energy recovery, only a tiny fraction of greenhouse gas is emitted.

The residual biosolids of either an aerobic composting or an anaerobic stabilization process can be recycled to land for plant nutrients and increased CO₂ uptake by photosynthesis to produce a sequestered CO₂ neutral condition. Notably, however, residual solids from an anaerobic stabilization process are about half that from an aerobic composting process. Overall, the anaerobic stabilization process leads to a greater reduction in CO₂ emissions.

There are 10 operating food waste composting facilities in California, including NorCal’s JPF, which currently is the largest in the United States (Pryor, 2008). Another large biosolids composting facility is the Laguna Wastewater Treatment Plant of the City of Santa Rosa.
2.3 Research Testing

The EPA Region 9 sponsored research over the past year at EBMUD on food waste digestion. The research included laboratory pilot-plant and scale testing and was reported in March 2008. It included testing of both mesophilic (96°F to 100°F) and thermophilic (122°F to 126°F) digestion at solids mean cell residence times (MCRT) that varied between 10 and 20 days (Gray, 2008).

The major conclusions of this research were the following (Gray, 2008):

- Food waste pulp appears more biodegradable than municipal sludge because of its higher volatile solids portion (85% to 90% compared to 70% to 80% for municipal sludge) and its higher volatile solids destruction (80% compared to 55% for municipal sludge) under anaerobic digestion.

- Solids production from food waste pulp appears to be half or less than that produced from municipal sludge.

- Methane production from food waste pulp appears to be as high or higher than that produced from municipal sludges. For the same amount of methane produced, results from this study suggest that about half or less digested volume is needed and about half or less biosolids are produced.

- Although food waste cleaning prior to anaerobic digestion has a cost, overall food waste pulp might produce methane at a lower cost than municipal waste does.

- Anaerobic digesters appear to perform slightly better at thermophilic than at mesophilic operating temperatures.

Table compares food waste to municipal solid waste digestion.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>Food Waste</th>
<th>Municipal Sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Volatile Solids</td>
<td>%</td>
<td>85 - 90</td>
<td>70 - 80</td>
</tr>
<tr>
<td>Volatile Solids Loading</td>
<td>lb/ft³/d</td>
<td>0.60+</td>
<td>0.20 max</td>
</tr>
<tr>
<td>COD Loading</td>
<td>lb/ft³/d</td>
<td>1.25+</td>
<td>0.06 - 0.3</td>
</tr>
<tr>
<td>Total Solids Feed</td>
<td>%</td>
<td>10+</td>
<td>4 - 6</td>
</tr>
<tr>
<td>Total Solids Digested</td>
<td>%</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Minimum MCRT</td>
<td>Days</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Volatile Solids Destroyed</td>
<td>%</td>
<td>80+</td>
<td>55</td>
</tr>
<tr>
<td>Methane Gas Produced</td>
<td>CF/lb VS</td>
<td>13</td>
<td>12.5</td>
</tr>
<tr>
<td>Destroyed(1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>% of Sludge Gas</td>
<td>65 - 70</td>
<td>60 - 65</td>
</tr>
<tr>
<td>Digested Solids Produced</td>
<td>% of Feed Solids</td>
<td>0.28</td>
<td>0.55</td>
</tr>
</tbody>
</table>

1 - CF/lb VS destroyed = cubic feet per pound volatile solids destroyed
A study of California municipal wastewater treatment plants found that over two thirds had excess digester capacity when provided with high-rate mixing and would have capacity to accept community food wastes (Shang, 2006).

### 2.4 Food Waste Quantities

Food wastes are typically in the range of 10% to 16% of total municipal solid wastes, with a recoverable commercial portion of about \( \frac{1}{4} \) pound per capita and currently a mostly non-recoverable portion of \( \frac{3}{4} \) pound per capita. Institutions, schools, and prisons can provide over \( \frac{5}{3} \) pound of food waste per capita (Tchobanoglous, 2002). The portions in the MSS service area generally are in line with these quantities.

Commercial food wastes from restaurants and institutions are composed of untreated food scraped from plates and overage food, peelings, etc. There is also a substantial quantity of food waste from supermarkets, food preparers, and suppliers (Jones, 2005, Newel, 1993).

Some portion of domestic food waste is backyard-composted, but it is a relatively small portion at less than 25% of the total (Sherman, 2005).

Anaerobic digestion of food waste recovers energy, while composting uses energy. Also, greenhouse gas production can be lower with anaerobic digestion (Jenner, 2007). Anaerobic digestion and composting may actually reduce greenhouse gas carbon emissions if residues are added to soil to increase plant growth, which absorbs and sequesters more CO\(_2\) from the atmosphere (U.S. EPA, 1998).

### 2.5 Energy Recovery

There are three basic types of cogeneration options that can use methane to generate electricity: internal combustion engines (IC engines), fuel cells, and microturbines. In addition, Stirling Engines are in the field testing stage of development and hold great promise for digester gas energy recovery. The Oregon Association of Clean Water Agencies (ACWA) Energy Independence Study (Kennedy/Jenks, 2008) shows that IC engines have the lowest costs, were rated the best overall cogeneration technology for WWTPs, but can be difficult to site for air quality concerns. A lean burn engine was, however, recently installed at the CMSA WWTP.

The ACWA study showed that microturbines are the next best cogeneration alternative, followed by fuel cells. This comprehensive study, which assessed all three technologies, scored the IC engines with 82 points out of 100 possible, microturbines with 81 points, and fuel cells with 70 points. IC engines had the lowest capital and operating cost of the three technologies. The analysis showed capital costs of 385 kW of IC engines at $1.5 million, 400 kW of fuel cells at $2.4 million, and 390 kW of microturbines at $2.9 million. Life cycle costs, or real levelized costs, were 2.9 cents/kWh for IC engines, 4.9 cents/kWh for microturbines, and 7.9 cents/kWh for fuel cells. A distinct advantage of fuel cells is their almost complete elimination of greenhouse gas emissions.

The waste heat produced by IC engine generators is used in North America and in Europe to provide heat treatment of all sludge to be digested, to increase municipal wastewater sludge volatile solids reduction from 55% to 75% (with nearly 150% more methane from municipal sludge), and to reduce solids residues. Reuse of waste heat is common here and in Europe to...
maximize energy recovery and greenhouse gas reduction (Kelleher, 2007). Other possibilities for waste heat energy utilization are to convert digesters to thermophilic operation and/or to dry and pelletize all digested solids (McDannel, 2008).

The rapid response of food waste anaerobic digestion to produce sludge gas can allow storage and pumping of food waste at night during off-peak periods. This can dramatically increase the amount of methane created to generate additional electricity, minimize the need for significant gas storage, and equalize gas availability for continued relatively uniform energy recovery (Gray, 2008).

Currently, other food waste to energy studies are being undertaken on the West Coast, including two by Kennedy/Jenks Consultants at Roseville and Thousand Oaks California. It is expected that this concept will rapidly accelerate as proposed studies and plans are underway at Boston; Hartford; Champaign, Illinois; and Toronto (Connecticut 2001, Goldstein 2007, Erickson 2005, Haynes 2005, Wirth 2005). The triple bottom line of economic, environmental, and social advantage is quite favorable for food waste to energy projects.

2.6 Greenhouse Gas Reduction

Landfill gas (LFG) is a combination of 50% methane gas and 50% carbon dioxide (CO₂), which is either captured in a collection system, or in some instances vented directly to the atmosphere. (Methane is a much more harmful greenhouse gas [GHG]). While carbon dioxide has a global warming potential of one, methane has a global warming potential of 21. Most landfills are subject to EPA’s New Source Performance Standards (NSPS) and a LFG collection system is required. The collected LFG is either flared or used to generate electricity. In either case, these GHGs are considered biogenic (non-fossil fuel and non-human caused), rather than anthropogenic (fossil-fuel or human generated GHGs). Use of LFG or digester gas to generate electricity therefore is considered to involve biogenic GHGs and are not counted as GHG reduction projects in the GHG reduction calculation.

The rationale is that carbon dioxide emitted during combustion represents the carbon dioxide that would have been emitted during natural decomposition of the solid waste. Emissions from the landfill gas control system do not yield a net increase in atmospheric carbon dioxide because they are theoretically equivalent to the carbon dioxide absorbed during plant growth.

If the LFG or digester gas is used to displace fossil-based grid-delivered electricity or natural gas, however, it can be counted as a GHG reduction project. This is classified as an indirect emission reduction activity, because the change in GHG occurs from sources owned and controlled by the power producer or the end user of the natural gas. Capturing and using methane to displace fossil-based electricity on the grid or natural gas in gas transmission and distribution systems is therefore generally considered to constitute a GHG reduction project. The amount of the GHG reduction credit is calculated by multiplying the amount of generated electricity (MWh) by the local utility emissions factor (pounds of CO₂e per MWh) to yield metric tons of carbon dioxide equivalent (CO₂e).

Even with landfill retrofit to capture and generate electricity, the efficiency of methane capture is usually less than 85%. That still equals landfill emission of over eight times the amount that occurs through anaerobic digestion (USEPA, 1998, Meissel, K., 2007).
There are other greenhouse gas factors to consider, such as the fuel for transportation, the energy for aerating aerobic composting, and the deposition of compost or digestion residues to land, which can sequester CO₂ from the atmosphere (Jambeck, 2006). All of these factors vary in site-specific and residue-specific situations. Still, overall, anaerobic digestion and energy production from food wastes is quite favorable (Bilek, 2006).
Section 3: Food Waste Quantity and Characterization

The quantity and characteristics of food wastes collected by MSS in the City of San Rafael and adjacent areas were determined. This information was used to evaluate the capacity of the CMSA WWTP to receive and handle the additional loading from food waste to produce methane and energy, and to process the food waste anaerobic biosolids residues.

Testing of the characteristics and biological digestibility of commercial food wastes was done by EBMUD and was reviewed as part of this study (EPA, 2008). Samples of food wastes collected by MSS from restaurants were also tested by CMSA to verify the quantity and characteristics of the food wastes in comparison to EBMUD test results.

3.1 Food Waste Quantity

MSS conducted a recent study of the quantities by type of waste collected and processed for recycle or disposal (Cal Recovery, 2008). The data pertinent to food wastes are shown in Table 2.

Table 2: Quantity and Proportion of Food Wastes Received by MSS

<table>
<thead>
<tr>
<th>Category</th>
<th>Container</th>
<th>Tons/Year</th>
<th>Tons/Day (1)</th>
<th>Proportion of total waste % (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Commercial</td>
<td>Debris Box</td>
<td>2,862</td>
<td>11.00</td>
<td>2.0</td>
</tr>
<tr>
<td>2 Debris Box Sort Line</td>
<td>Residue</td>
<td>551</td>
<td>2.12</td>
<td>0.4</td>
</tr>
<tr>
<td>3 Commercial</td>
<td>Sort Line Residue</td>
<td>312</td>
<td>1.20</td>
<td>0.2</td>
</tr>
<tr>
<td>4 Residential &amp;</td>
<td>Rear Loaders</td>
<td>10,286</td>
<td>39.56</td>
<td>7.0</td>
</tr>
<tr>
<td>Commercial(3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Food Waste</td>
<td></td>
<td>14,001</td>
<td>53.88</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Notes:
(1) Processing 260 days/year
(2) MSS total waste – 145,436 tons/year
(3) Residential & Commercial includes commercial food waste MSS receives from restaurants and food markets

MSS indicated that the estimated quantity of commercial food wastes received and potentially available for methane capture is up to 15 tons/day. This estimated quantity is similar to the quantity estimated in the 2008 Cal Recovery Report survey. The food wastes MSS receives are from about 237 restaurants and from about 12 food markets.

The proportion attributable to the City of San Rafael is a substantial portion of the total MSS service area. For purposes of an overall estimate of methane capture, the total MSS service area should be considered as the CMSA service area of San Rafael, Ross Valley, and Larkspur; Corte Madera is in CMSA’s service area, but not MSS’s. A map of the service areas of CMSA and MSS is shown in Figure 1; they have substantial overlap.
There is a long-range potential to divert much more overall food waste from landfills than just beyond that from commercial sources. This inclusion, however, would require a significant change in collection and handling procedures, which have little precedent in practicality or practice in North America (Goldstein, 2007 and Brown, 2007).
Approximately half of the solid waste that is currently transported and disposed of at the Redwood Landfill by MSS is food waste. The commercial portion of this food waste is approximately one eighth.

A comparison of the proportion of food wastes collected by MSS of 9.6% to the United States average shows that they are quite close, at 13.1% by weight of total municipal wastes (Tchobanoglous and Keith, 2002) or 11.1% from the EPA (U.S. EPA, 2006). The volume of food waste is only 5.1% of total waste volume, as food waste has a higher density than other municipal wastes such as paper. The average density of food wastes is 2,000 pounds per cubic yard (U.S. EPA, 2006).

### 3.2 Food Waste Characteristics

Test results from samples of food wastes collected from three restaurants and a market were obtained in August 2008. The total solids moisture and proportion of volatile solids were determined by the CMSA laboratory. It was found that the average total solids was 25%, with a moisture content of 75% and a volatile solids portion of 92%.

Comparison of these characteristics can be made to those compiled by EBMUD for the past several years. EBMUD has found that the total solids (TS) concentration of food waste varies from less than 25% to more than 40% solids, with an average of about 28% (Gray et al. 2008).

The volatile solids (VS) proportions of total suspended solids range from 87% to 95%, with an average of 90%. These values are close to those in the MSS food waste test results.

### 3.3 Food Waste Solids Loading

There is a potential of 15 tons/day of commercial food wastes from MSS that could be directed to CMSA for methane capture, or 3,900 tons/year.

Of relevance in estimates of loading is the loss in processing at EBMUD through the paddle finisher conveyor screen of about 10% of the total, which comprises poorly digestible rags, plastics, and other fibrous materials (EBMUD, 2008). These relatively biologically inert organic materials would be taken to landfill, however in the future, converting this material to energy by combustion or pyrolysis could be explored. The material could possibly be diverted with wood wastes for combustion and power generation.

The quantity of total and volatile solids to the digester can be determined, based on the daily tonnage less reject, as 13.5 tons/day and an average of 92% VS content. The VS loading to the digester would be:

\[
13.5\text{ tons/day} \times 25\% \text{ TS} \times 92\% \text{ VS} = 6,200 \text{ lb VS/day}
\]

In the future, an additional 39.5 tons/day of food waste could be collected; after processing and removal of reject, this would total 35.5 tons/day. The potential of total food wastes for anaerobic digester would be:

\[
49\text{ tons/day} \times 25\% \text{ TS} \times 92\% \text{ VS} = 22,500 \text{ lb VS/day}
\]
It would appear that the initial food waste handling facilities for commercial sources should be sized for a maximum of 20 tons/day and should be expandable to a future capacity of 40 tons/day.
Section 4: Food Waste Conceptual Design

MSS initiated a pilot program to collect commercial food waste in bins from markets and institutions and in portable carts from restaurants. The food waste is transported to the material recovery facility on Andersen Drive in San Rafael. At this facility the food waste is mixed with shredded yard waste and composted with an in-vessel composting system. The MSS material recovery facility is permitted by the California Integrated Waste Management Board (CIWMB).

It is recommended that the receiving, sorting and processing of solid food wastes continue at a solid waste transfer facility as it does not appear practical to do this at CMSA and CMSA does not have the required CIWMB permit to undertake the work. This is similar to the EBMUD food waste processing facility where the waste haulers (NorCal and Allied) have a CIWMB permit that allows them to separate and grind the solid food waste at their transfer stations and EBMUD has permits for processing the liquid food waste with their NPDES Wastewater Discharge and Air Quality Management Permits.

This section presents the conceptual design of the food waste separation facility and the food waste processing facility.

4.1 Food Waste Separation Facility

The food waste requires separation prior to transport to CMSA for processing and digestion. The separation facility would be located at a solid waste collection facility and would separate the food waste as is done at the NorCal Jepson Prairie Facility in Vacaville. The separated food waste would be transported from the solid waste collection facility to the CMSA WWTP.

To reduce transportation costs, adding water and pumping separated food waste in a slurry from a solid waste collection facility to the CMSA WWTP was investigated. Use of an existing abandoned 6-inch PVC pipe located beneath Andresen Drive between MSS and CMSA was reviewed to pump the slurry to CMSA. A preliminary hydraulic analysis to pump a food waste slurry at 10% solids concentration between MSS and CMSA indicates a pipe friction loss as high as 800 psi. This would require a pumping head that would be much higher than the maximum working pressure of the existing PVC pipe. Due to the high operating pressures, and the risk of failure, pumping a separated food waste slurry from a solid waste collection facility to CMSA is not recommended and was not investigated further as part of this study.

A third option is to do all of the food waste processing at the CMSA WWTP. This would require CMSA to apply and receive a permit from the CIWMB for solid wastes handling, which EBMUD has avoided and is difficult to obtain and maintain. CMSA would also have to employ additional personnel for solid waste handling and sorting. This does not appear either economical or practical at this time. However, it could become necessary in the event MSS or another solid waste handler declined to participate. Then the sorting and grinding equipment as now proposed to be located at the MSS Transfer Facility would either have to be relocated or replaced and installed at the CMSA WWTP. Overall, this alternative is not developed further.
4.1.1 Design Criteria

It was found that the food waste separation equipment at the NorCal Jepson Prairie Facility was provided by West Salem Machinery Company (Goldstein 2008). West Salem Machinery Company was contacted and they provided a proposal for a 20 ton/hour facility to separate and grind the food waste to a size of ¾-inches or less (Foti 2008 and West Salem 2008).

4.1.2 Equipment

The proposed equipment for the separation facility includes a hopper, sort line conveyor, sort line grinder feed conveyor, hammer mill grinder, grinder discharge conveyor and stacking conveyor for loading a truck or bins to transport separated food waste to CMSA WWTP.

There are several types of screening equipment used in solid waste handling facilities. Most common are rotary drum (Trommel) screens, disc screens, and vibrating screens. MSS currently uses a vibrating screen in processing wood waste but this equipment is unavailable for food waste separation.

A Trommel screen was used for the NorCal facility in Vacaville but West Salem Machinery did not recommend this equipment for the separation facility because the NorCal facility separates much larger volumes of green waste.

West Salem indicated that the Trommel screen was not necessary and may be even disadvantageous as it would reject large objects like head lettuce, bones, bread, rolls, melon rinds, etc. These items would be considered suitable for food waste digestion after further processing by grinding and screening.

Trommel screens are high output units where material to be separated is fed into one end of a tubular rotating screen with a downward slope (about 5%), so that the material will flow down the screen as it is dropped and tumbled. Lifters are often placed inside the screen to increase tumbling of the material. Oversize material is rejected at the exit while materials below a certain size are dropped through the screen onto the loading conveyor. There are many manufacturers of Trommel screens besides West Salem (Yepsen and Goldstein 2008, Coker 2007 and Spencer 2007). These screen manufacturers are listed in Appendix D.

West Salem Machinery advised that prior to grinding, the food waste should be free of plastic. Sheet plastic such as grocery bags, bread wrappers, and plastic wrap for meat and vegetables will plug up the grinder screens. This material would be removed manually on a sort line and MSS confirmed that two people working for about two hours would be necessary to remove material from one truck load of food waste.

Several types of equipment are utilized to rip, cut or pulverize solid wastes (Technobanogalous 2002). These include hammermills, flail mills and rotary grinders that operate at a relatively high rate of speed to shear softer material like food wastes and wood. A horizontal hammermill is proposed for the separation facility at MSS or other solid waste transfer station.
Material is fed through a feed conveyor into the hammer grinder. The hammers which are attached to a rotor or shaft, impact the feed material, breaking it into smaller pieces. Below the hammer circle is a series of cast grates. The material remains inside the hammermill and is crushed or torn between the hammers and grates until its size is sufficiently reduced to pass through the grates where it is discharged onto a conveyor below.

The hammermill grinder is constructed of steel with alloy steel hammer pins and abrasion resistant liners. The grinder proposed by West Salem Machinery rotates at 1,800 RPM, is powered by a 200 hp motor and weighs over five tons.

As with screens, there are many manufacturers of grinders (Yepsen and Goldstein 2008, Coker 2007 and Spencer 2007) and these are listed in Appendix E.

The equipment budgetary costs (2008 pricing) and horsepower from the West Salem Machinery quotation are:

- Hopper, sort line conveyor and sort line $95,000 2 hp
- Grinder feed conveyor $26,000 2 hp
- Hammermill grinder $90,000 200 hp
- Grinder discharge conveyor $24,000 2 hp
- Stacking conveyor $44,000 3-5 hp

**$279,000 211 hp**

The estimated construction cost for the separation facility including shipping, taxes, foundations, painting, plumbing, and electrical with contractor’s overhead and profit, contingency and engineering is presented in Chapter 6.

West Salem Machinery can provide a field technician to advise a construction contractor on installation of the equipment. West Salem is available on-site for field testing, startup, training and trouble-shooting but they do not have construction capabilities so a general contractor would need to be retained to install West Salem’s equipment or other equivalent units.

A tour of the NorCal Jepson Prairie Facility indicated differences in the processing line they acquired from West Salem and that proposed at MSS. The primary difference is a Trommel screen at the NorCal facility rather than a sort line before the grinder as proposed at MSS or other solid waste transfer station.

As discussed previously the Trommel rejects over 45% of the food wastes, as well as processing a much higher capacity 300 tons/day of covered food and green wastes of which only about 10% are presently diverted to anaerobic digestion.

An automatic non-manual sorting is apparently advantageous to this much larger facility; as the Trommel screen reject is passed to another separator grinder made by Komptech, which grinds the reject to 1½-inch size for composting. This in effect captures most of the reject from the initial Trommel screen for composting except for plastics, metals and glass, which are diverted into separate bins.
The food waste separation system proposed at MSS or other solid transfer station is significantly smaller and has a minimal reject rate for anaerobic digestion.

However, it may be desirable to change some of the equipment and or configuration based upon initial operations testing or acceptance of additional food wastes in the future.

### 4.1.3 Facility Location and Layout

A conceptual layout of the separation facility proposed by West Salem Machinery Company as part of their proposal of 22 September 2008 (Foti 2008) is shown in Figure 2. The total dimensions of the separation facilities are 151’2” L x 12’ W x 17’3” H.

A tour of the MSS facility with their staff on 29 September 2008, found that this facility could be located along the west side of the transfer station building were there appears to be sufficient space although MSS would need to find an alternative location for haul truck parking (see Figure 3).

**Figure 3: Proposed Location of Separation Facility**

The transfer station building is more than 300 feet long, 100 feet in width and over 30 feet high. The station operation is permitted by the CIWMB. Collection trucks would enter the south side of the building, pass along State Certified scales and be weighed, and dump food waste into the separation facility hopper. A transfer truck would be parked on the north side of the separation facility to collect the separated food waste from the stacking conveyor. The separation facility equipment would be placed on the concrete floor and enclosed by a curb to contain liquid drips and drains. A floor drain system would be constructed to drain to a sewer. The abandoned pipe on Anderson Drive possibly could be used to convey process drainage to the CMSA WWTP and this could be investigated further during detailed design.

The separation facility could also be located at other solid waste collection facilities but the MSS appears to be most advantageous because of its close proximity to the CMSA WWTP.
4.1.4 Facility Operation and Operating Costs

The separation facility would normally be operated by two persons for a two hour shift each day. Carts from restaurants would be dumped onto the loader conveyor, while bins from markets would be dumped from forklifts. The plastic and other debris from the sort lines would be dumped into other bins for removal. The stacking conveyor would be 17 feet high to allow discharge into transfer trucks or bins, which would then be weighed at MSS and then hauled that day to the CMSA WWTP for processing and digestion. Rejected materials including plastic, rags, fibers, grit and metal from the separation processes would be returned to the transfer station for further recycling or disposal with other solid wastes.

It is expected that the operating crew would clean the equipment with hoses each day following its use. Operating costs would include one hour of operation of the equipment and two hours each working shift to start, stop and clean equipment.

The estimated annual operating costs are as follows:

\[
\begin{align*}
212 \text{ hp} \times 0.746 \text{ kW/hp} \times 0.9 \text{ power factor} &= 176 \text{ kW} - 1 \text{ hour (hr)} \\
\text{Cost/day @ 15¢/kWH} &= \$26.40/\text{day} \\
176 \text{ kW-hr} \times 0.15 &= \$200/\text{day x 260 days/year} \\
\text{Annual Energy Cost} &= \$6,900 \\
\text{Personnel Cost @ $50/hour} &= \$200/\text{day x 260 days/year} \\
4 \text{ hours} \times $50 &= \$14,000/\text{year} \\
\text{Equipment Maintenance @ 5\%} &= \$279,000 \times 0.05 = \$14,000/\text{year} \\
\text{Annual Operating Cost} &= \$72,900
\end{align*}
\]

4.2 CMSA Processing Facility

The food waste receiving and processing facility located at CMSA WWTP would initially be capable of receiving a 20-ton transfer truck delivery about once a day. The processing facility would produce a slurry to a maximum 10% concentration and would grind, remove grit and screen the food waste before it is pumped into the existing digesters at the WWTP.

4.2.1 Design Criteria

Design criteria for the food waste receiving and processing facility was developed from information collected at the EBMUD WWTP site tour and through discussions with equipment vendors. The facility would receive one to two truck loads per day and would be sized to process 20 tons/day of food waste initially and would be expandable to 40 tons/day in the future.
4.2.2 Equipment

The equipment consists of a slurry tank, a slurry tank mixer, a grinder/rock trap, screen feed pumps, a rotary screen, digester feed tank and digester feed pumps and odor control system. A schematic of the equipment is shown on Figure 4. The design criteria for the processing facility is shown in Table 3.

<table>
<thead>
<tr>
<th>Table 3: Processing Facility Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>Slurry Tank</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Slurry Tank Mixer</td>
</tr>
<tr>
<td>Grinder/Rock Trap</td>
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<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Screen Feed Pumps</td>
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<td></td>
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<tr>
<td>Conveyor Screen</td>
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</tr>
<tr>
<td>Digester Feed Tank</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td>Digester Feed Tank Mixer</td>
</tr>
<tr>
<td>Digester Feed Pumps</td>
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<tr>
<td>Odor Control</td>
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</tbody>
</table>
### 4.2.3 Processing Facility Location and Layout

Three sites at the CMSA WWTP were identified as potential food waste receiving and processing facility locations as shown in Figure 5.

A site northeast of the existing contact tanks and a site near the future FOG facility appear to have sufficient space to construct a processing facility. Access to these locations would require that food waste transfer trucks drive through much of the wastewater plant site. However, these two sites are closer to the existing digesters so less interconnection piping would be required and the distance for pumping the food waste slurry to the digesters would be shorter saving material and operation and maintenance costs. These sites are also more remote from potential odor receptors.

The site adjacent to the future FOG facility is closest to the existing digesters and would be located along the hillside. This site would not require a pile foundation, however some rock excavation and installation of a retaining wall would be required. The site adjacent to the chlorine existing contact tanks is relatively flat and open for construction but a pile supported foundation would likely be required.

#### Figure 5: CMSA Processing Facility Location

A third site in the paved parking area adjacent to the Maintenance Building appears also feasible for the processing facilities. The site has sufficient space for the receiving and processing facility and is closer to the controlled plant entrance gate. This site would allow easier monitoring of the movement of the food waste transfer trucks at the plant site and better
access for plant staff to assist with the food waste dumping operations. However, from geotechnical data provided by Fugro (Fugro, 2005) it appears that the area around the Maintenance Building is located on bay mud. It is likely that the structures at this location would need to be constructed on piles to prevent settlement.

Sites closer to the existing digesters could be a several hundred thousand dollar cost advantage in foundation and utility infrastructure savings. However, the more costly site near the Maintenance Building is used to provide a conservative construction cost estimate for the processing facilities. Further evaluation and cost analysis would be provided during predesign to determine the overall best site and facility location.

A layout of the food waste receiving and processing facility with plan and section is shown on Figure 4. The slurry and digester feed tanks would be located at grade and access hatches for food waste dumping would be provided to both tanks.

The process piping would be configured to allow dumping into the digester tank and storage for 24 hours when the slurry tank is shut down for maintenance and cleaning. The configuration would be similar to the EBMUD facility shown on Figure 6.

**Figure 6: EBMUD Facility Slurry Tank**

![EBMUD Facility Slurry Tank](image)

The grinder/rock trap, screen and digester feed pumps would be located below grade in a vault with stair access and safety guardrails around the perimeter of the vault. The odor control system would be located at grade adjacent to the slurry tanks. The rotary screen, convey and reject collection bin would be located under a shelter near the tanks.

The slurry is drained from near the bottom of the tank and first passes through a rock trap grinder to remove large grit, metals, etc. These materials are periodically drained from the bottom of unit for disposal.
The slurry is then pumped with hose pumps to the rotary (paddle finisher) screen which has fine (0.06-inch) perforated openings which extrude a paste of food waste which is discharged to the digester feed tank. The food waste paste is pumped again with hose pumps from the smaller digester feed tank to the digesters.

All of the tanks would be covered and the hood space air exhausted and processed through a biological scrubber followed by a GAC scrubber for odor control removal of sulfurous, sour, and nitrogenous compounds.

4.2.4 Processing Facility Operation and Costs

The food waste would be transported from the separation facility in sealed covered tilting dump trucks, which contain about 20 tons of food waste. Typically one truck would be received a day, and emptied into the mixed slurry tank.

Prior to adding food waste to the slurry tank, CMSA staff would add recycled water to the tank and operate the mixer. CMSA staff would open the hatch and monitor the food waste dumping operation. From the experience at the EBMUD facility, the slurry is well homogenized in about 90 minutes after receiving the food waste, and can then be screened and pumped to the digesters (EBMUD, 2008). It would be desirable to store the load so that the slurry is fed to the digesters during the night-early morning off peak hours to provide for more uniform daily feed, gas production and minimize the need for gas storage as well as maximize energy recovery.

With a 20,000 gallon slurry tank, the waste concentration would be approximately a 6.25% concentration, and at an average 50 gpm pumping rate it would take approximately 7 hours to empty the slurry tank between 10 PM and 5 AM. If the food waste collection system is expanded to include other food waste sources, then two or three 20 ton loads could be received and dumped into the slurry tank, once in the morning and then again several in the afternoon. The same processing equipment could be used to process the higher concentration slurry paste of 12.5%, which when mixed with the 5% concentration of municipal waste sludge, would result in a total solids concentration of about 8% to be fed to the existing digesters, which remains within an acceptable range.

It is expected that annual removal of grit from the tanks would be required and daily removal of rocks from the rock/trap grinder. The hose pump hoses would also require replacement depending on wear. The bins with reject material from the rotary screen would require pick-up and removal to MSS for disposal. Operators would also be required to perform general clean up of the facility and maintenance of the hose pumps, mixers, rock trap and rotary screen.

It is estimated that one operator would be required at the facility for 1 hour per day. The estimated annual operating costs of the processing facility are as follows:

\[
130 \text{ hp} \times \frac{0.746 \text{ kW/hp}}{0.9 \text{ power factor}} = 108 \text{ kW} \times 7 \text{ hours} = 756 \text{ kW}
\]

\[
\text{Cost/day @ 15¢/kWh} = 756 \text{ kW-hr} \times 0.15 = $113.40/\text{day}
\]

\[
\text{Annual Energy Cost} = 260 \text{ days/year} \times $113.40/\text{day} = $29,500
\]
Personnel Cost (no additional cost)

Equipment Maintenance @ 5%
$569,000 x 0.05 = $28,500/year

Annual Operating Cost = $58,000
Section 5:  Digester Improvements

5.1  Evaluation of Digester Performance

The purpose of this evaluation is to determine the existing capacity of the anaerobic digestion system at the CMSA WWTP to receive additional loading from FOG and food waste. Volatile solids loading, hydraulic loading, residual solids production, gas production, digester mixing, and digester covers will be discussed in this section.

There are two 80-foot-diameter digesters at the CMSA WWTP. The digesters are equipped with floating covers and have a side water depth of 26 feet. The digester cone depth is 8 feet. Excluding the cone volume, the digester volume is approximately 130,700 cubic feet (978,000 gallons). To provide a conservative approach in evaluating digester capacity, the cone depth is not typically included in the digester volume The digesters were constructed in 1984 for an average volatile solids loading of 14,570 pounds/day and a peak loading of 28,650 pounds/day, which translate to unit volumetric loadings of 0.056 and 0.11 pounds/day, respectively. According to plant staff, the digesters are typically taken out of service for cleaning and maintenance approximately once every 10 years.

Each digester is equipped with a vertical gas mixing system. This mixing system is not optimum for digestion of FOG or food waste as this type of vertical mixing energy will often promote formation of a grease and scum mat at the surface of the digester liquid and grit accumulation at the bottom of the digester which significantly reduces digester volume and efficiency.

Based on discussions with WWTP staff, there is adequate heating and heat transfer capacity to maintain the digester temperature in the mesophilic range throughout the year. No further evaluation of this system was made for this study.

5.1.1  Volatile Solids Loading

Current design criteria for a well mixed and heated digester, the recommended volatile solids loading is in the range of 0.10 – 0.30 lbs/cf/d (WEF MOP 1998). Based on CMSA WWTP data from July 2007 through June 2008, the average volatile solids loading of the existing digesters is currently 0.063 pounds per cubic feet per day (with two digesters in service). For the purposes of this evaluation it was assumed that the digester mixing systems would be upgraded to pumped mixed system. The corresponding volatile solids loading with the new mixing system would be 0.2 lbs/cf/day.

Additional data were provided by CMSA for the period beginning in 2006, but these data were not used because they did not include cogenerator operation time. The year’s worth of data from July 2007 through June 2008 was considered to be representative of typical loading and to be appropriate for the evaluation of digester capacity. Table 4 summarizes municipal waste loading to the CMSA digesters and resultant gas production.
### Table 4: CMSA Digester Loading, Volatile Solids Reduction Sludge Gas Production and Cogeneration Engine Operation (1)

<table>
<thead>
<tr>
<th>Date</th>
<th>TS. (2) gpd</th>
<th>TS %</th>
<th>TS. (1) lb/d</th>
<th>V.S. (3) lb/d</th>
<th>Digester Load lb/cf/d</th>
<th>VS Red. %</th>
<th>VS Red lb/d</th>
<th>Bio Gas cf/d</th>
<th>Methane %</th>
<th>Therms per day</th>
<th>Cogen Run time</th>
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<td>Jul 07</td>
<td>44,300</td>
<td>5.12</td>
<td>18,916</td>
<td>15,133</td>
<td>0.058</td>
<td>53.1</td>
<td>8034</td>
<td>147,333</td>
<td>63</td>
<td>974</td>
<td>9.7</td>
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<tr>
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<td>5.44</td>
<td>19,331</td>
<td>15,465</td>
<td>0.059</td>
<td>55.8</td>
<td>8,071</td>
<td>108,162</td>
<td>63</td>
<td>661</td>
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<td>Sept 07</td>
<td>40,690</td>
<td>5.83</td>
<td>19,785</td>
<td>15,827</td>
<td>0.061</td>
<td>57.9</td>
<td>9,654</td>
<td>135,973</td>
<td>63</td>
<td>899</td>
<td>11.6</td>
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<tr>
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<td>5.55</td>
<td>18,748</td>
<td>14,999</td>
<td>0.057</td>
<td>55.6</td>
<td>8,339</td>
<td>114,234</td>
<td>63</td>
<td>755</td>
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<td>21,206</td>
<td>16,965</td>
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<td>9,806</td>
<td>128,950</td>
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<tr>
<td>Dec 07</td>
<td>50,425</td>
<td>6.25</td>
<td>26,200</td>
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<td>0.081</td>
<td>51.3</td>
<td>10,752</td>
<td>142,380</td>
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<td>11.9</td>
</tr>
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<td>Jan 08</td>
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<td>19,430</td>
<td>15,549</td>
<td>0.059</td>
<td>49.5</td>
<td>8,536</td>
<td>136,201</td>
<td>63</td>
<td>900</td>
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<td>23,114</td>
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<td>9,587</td>
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<tr>
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<td>51.7</td>
<td>8,197</td>
<td>115,025</td>
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<td>Jun 08</td>
<td>43,200</td>
<td>5.55</td>
<td>19,995</td>
<td>15,997</td>
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<td>6,990</td>
<td>105,549</td>
<td>63</td>
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<td>10.6</td>
</tr>
<tr>
<td>Avg</td>
<td>50,535</td>
<td>4.92</td>
<td>20,500</td>
<td>16,400</td>
<td>0.063</td>
<td>53.7</td>
<td>8,900</td>
<td>126,480</td>
<td>63</td>
<td>836</td>
<td>11.2</td>
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<tr>
<td>Max</td>
<td>68,880</td>
<td>6.25</td>
<td>26,200</td>
<td>20,960</td>
<td>0.081</td>
<td>62.0</td>
<td>10,750</td>
<td>136,515</td>
<td>63</td>
<td>974</td>
<td>12.4</td>
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<tr>
<td>Min</td>
<td>40,505</td>
<td>3.50</td>
<td>18,750</td>
<td>15,000</td>
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<td>43.7</td>
<td>6,990</td>
<td>105,850</td>
<td>63</td>
<td>661</td>
<td>10.4</td>
</tr>
</tbody>
</table>

**Notes:**
1. CMSA records of July 2007 through June 2008
2. All data from combined primary and secondary sludge
3. Volatile solids calculated at 80% of total solids
5.1.1.1 Volatile Solids Loading Capacity

To understand when the existing digesters could reach a maximum reliable volatile solids loading capacity criterion of 0.2 pounds per cubic feet per day (assuming an external pump mix system was installed for the digesters), the following loading assumptions were made:

1. Volatile solids from influent wastewater derived solids (primary and secondary sludge) might increase at a compound average annual rate of 0.5%. This assumption is based on an historic growth rate of the CMSA service area and solids loading.

2. FOG receiving would start in 2010 at 700 gallons/day and increase linearly to 1,425 gallons/day. The maximum FOG loading rate of 1,425 gallons per day is based on a FOG Management Feasibility Study that was prepared by Brown and Caldwell for CMSA in March 2007 (Brown and Caldwell, 2007).

3. Food waste may suddenly increase linearly from 15 tons/day to 40 tons/day if additional food waste were separated from other sources. Maximum food waste loading of 16.5 tons/day was used for capacity evaluation and represents the volume of food waste anticipated from commercial sources.

The existing digesters with the gas holder covers and vertical mixing system were designed for an average volatile solids loading of 0.056 lbs/cf/d and a peak of 0.112 lbs/cf/d.

As illustrated in Figure 7 with one digester out of service for maintenance, the plant has already reached the target volatile solids loading criterion. This means that the current available digester volume is not adequate to provide firm capacity for the addition of FOG and food waste receiving. If two digesters are in operation, FOG and food waste can be accommodated for the twenty year planning period before additional digester capacity is required. Operational experience with combined food and municipal solid waste may indicate that a higher unit loading rate is feasible as shown in the EBMUD pilot testing (Gray, 2008).
Figure 7: Volatile Solids Digester Loading (Existing Floating Covers & Mixing System)

It is readily seen that with one digester out of service and with the existing floating covers and vertical mixers, the peak volatile solids loading of 0.11 pounds/cubic feet per day is exceeded with wastewater derived solids loading alone. More digester capacity and a change to better mixing are necessary to accommodate FOG and food wastes.

It is possible to increase the available digester volume by converting the existing floating covers to fixed or membrane gas holder covers and using more of the existing wall height. The volume of the digesters can be increased from 130,700 cubic feet to 213,600 cubic feet. If digester volume is increased in this manner, firm digester capacity for digestion of wastewater solids, FOG, and food waste addition at the anticipated loading rates will be sufficient. With two digesters in service the target criterion of 0.2 pounds per cubic feet per day is also not reached during the 20 year planning period including both FOG and food waste addition and for a short term peak (3 months +/-) loading of one digester at a maximum rate of 0.3 pounds per cubic feet per day. The volatile solids loading versus time plot for the larger digester volume is illustrated in Figure 8.
5.1.2 Hydraulic Retention Time

The U.S. Environmental Protection Agency (EPA) 503 regulations for Class B biosolids are based on a Time/Temperature relationship that corresponds with pathogenic organism deactivation. The second criterion, required retention time for Class B biosolids, is 15 days at 95°F. The minimum allowable retention time at any temperature is 15 days.

5.1.2.1 Hydraulic Loading Capacity

To understand when the existing digesters would reach a hydraulic loading capacity criterion of 15-days hydraulic retention time, the following loading assumptions were made:

1. Solids from influent wastewater derived solids (primary and secondary sludge) would increase at a compound average annual rate of 0.5%. This assumption is based on an assumed growth rate of the CMSA solids loadings. The current solids flow rate to the digesters is approximately 50,500 gallons/day.

2. FOG receiving would start in 2010 at 700 gallons/day and increase linearly to 1425 gallons/day. The maximum FOG loading rate of 1,425 gallons/day is based on a FOG Management Feasibility Study that was prepared by Brown and Caldwell for CMSA in March 2007 (Brown and Caldwell, 2007).
3. Food waste receiving would increase linearly from 9,000 gallons/day to by 0.5% per year.

As illustrated in Figure 9, with one digester out of service for maintenance, hydraulic capacity for the digesters will be reached around 2024. This means that the current available digester volume will just provide firm capacity for the projected addition of FOG and food waste. If two digesters are in operation, FOG and food waste can be accommodated beyond the 20-year planning period.

**Figure 9: Digester Hydraulic Loading (Existing Floating Covers)**

If digester volume is increased by the replacement of the floating covers with fixed or membrane covers, firm digester capacity is not reached (including FOG and food waste loading). With two digesters in service, the digester hydraulic retention time criteria of 15-days is also not reached within the 20-year planning period (with FOG and food waste loading included). The hydraulic loading versus time plots for using fixed dome or membrane covered digesters is illustrated in Figure 10.
5.1.3 Solids Production

It is not anticipated that the addition of FOG and food waste to the digesters could adversely impact the solids handling capacity of the existing solids dewatering facilities. Based on existing record drawings, the current capacity of the sludge dewatering facilities is 21,440 lbs/day.

Solids loading projections were made based on the same loading assumptions for food waste and wastewater solids that were used for the volatile solids and hydraulic loading evaluations. Solids loading versus time is illustrated in Figure 11. It was assumed that 60% of the wastewater volatile solids fed to the digester would be destroyed and converted to digester gas. It was also assumed that 85% of the food waste volatile solids fed to the digester would be destroyed and converted to digester gas, which is consistent with the volatile destruction rates reported in the food waste study performed by EBMUD (Gray et al 2008).

It is important to note that the co-digestion of FOG waste has been shown to improve solids destruction and reduced hauled weight of residual solids from facilities by as much as 30% (York et al. 2008). This phenomenon was not taken into account as a conservative means of evaluating when a solids dewatering bottleneck would occur. Instead, a conservative assumption was made that FOG waste addition would result in no net residual solids increase.
As indicated in Figure 11, it is anticipated that food waste will generate additional residual solids and this will add a marginal load to the solids dewatering facilities. Based on an 85% volatile solids destruction rate in the digester for food waste, the estimated residuals solids for a 15 ton load of food waste (wet weight) would be approximately 1,600 lbs.

5.1.4 Gas Production

Digester gas production is anticipated to increase dramatically when FOG waste and food waste are introduced to the digesters. Initial gas production estimates based on anticipated FOG and food waste addition is summarized in the Table 5.
Table 5: Gas Production Estimate

<table>
<thead>
<tr>
<th></th>
<th>Quantity of Waste</th>
<th>Volatile Solids</th>
<th>% Volatile Solids Destroyed in Digester</th>
<th>Gas Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW Solids</td>
<td>25,000 lbs</td>
<td>20,000 lbs</td>
<td>60%</td>
<td>180,000 CF</td>
</tr>
<tr>
<td>FOG</td>
<td>1,425 gallons</td>
<td>2,000 lbs</td>
<td>90%</td>
<td>27,500 CF</td>
</tr>
<tr>
<td>Food Waste</td>
<td>13.5 tons</td>
<td>6,200 lbs</td>
<td>85%</td>
<td>79,000 CF</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>28,200 lbs</strong></td>
<td><strong>67.4%</strong></td>
<td><strong>287,000 CF</strong></td>
<td></td>
</tr>
</tbody>
</table>

Assumptions:
- Digester gas production = 15 CF per pound of VS destroyed in the digester.
- WW solids quantity is an average value for current (2008) biosolids from primary and WAS.
- Grease content in FOG is 18% by weight. 95% of grease is volatile.
- Food waste – 90% processed at 25% total solids for digestion at 92% volatile solids.

It is anticipated that influent wastewater and incoming food waste to the plant will increase. Using the same loading assumptions for food waste and wastewater solids that were used for the volatile solids and hydraulic loading evaluations. Figure 12 shows how gas production will increase over time.

**Figure 12: Gas Production Estimate vs. Time**

Assumptions:
- Fog starting in 2010 at 700 gal/day and increasing to 1425 gal/day
- 0.5% growth rate for WW solids
- Incoming net food waste varies from 15 to 18.5 tons

Engine Capacity: 75 therm/hr

City of San Rafael – CSMA Methane Capture Feasibility Study
As indicated in Figure 12, the existing reciprocating engine that is used for cogeneration has a capacity of approximately 75 therms per hour, which is equivalent to approximately 300,000 cubic feet per day of digester gas (600 BTU per cubic foot energy content). The cogenerator capacity will nearly be reached if CMSA receives the projected 1,425 gallons per day of FOG waste and 16.5 tons/day of food waste and may be after 2020.

5.1.4.1 Improvements to Gas Handling

The digester gas production that will result from FOG waste and commercial food waste receiving and co-digestion is not expected to reach the capacity of the existing digester gas handling system. This conclusion is based on the size of the current gas treatment and cogeneration system. It is not anticipated that improvements to the existing gas handling system will be required during the 20-year planning period for this project.

5.2 Digester Improvements

5.2.1 Digester Mixing

Based on long term operation of other trucked waste receiving stations at other wastewater treatment facilities, high shear horizontal circumferential mixing would be the most appropriate for FOG and food waste co-digestion at the CMSA RWTF. This would consist of an external pump mixing system with intake pipes and discharge nozzles mounted inside the digester.

In an externally pumped mixing system, sludge is drawn through a pipe from the center of the digester to a pump that discharges the sludge back into the digester through a nozzle along the exterior wall. The discharge nozzle is installed at the proper angle to create a circular swirling motion within the digester. Dual suction and discharge pipes are provided to allow draw-off from either the top or bottom of the digester and discharge to either the top or the bottom of the tank. The upper and lower suction and discharge piping is periodically alternated to prevent the buildup of grit on the bottom and scum on the top.

The mixing mechanism associated with the proposed externally pumped mixing system is illustrated in Figure 13. Externally pumped mixing systems are characterized by highly uniform mixing. The high velocities that are developed at the discharge nozzles create a swirling motion, or spiral vortex and also create shear forces on the solids. This shearing action reduces the size of the solids particles, and subsequently increases the surface area exposed to the microbial culture in the digesters, resulting in higher volatile solids destruction and increased gas production.
5.2.1.1 Benefits of Effective Mixing

Efficient digester mixing is required for exposure of the active biomass to the digester food source. Efficient mixing translates directly to swift exposure and rapid destruction of volatile solids, which reduces the required detention time and effectively increases digester capacity. Some of the benefits that can be realized from a more efficient, externally pumped digester mixing system include the following:

1. **Increased gas production** - Improved digester mixing can result in higher digester gas production as a result of better volatile solids destruction.

2. **Increased effective digester capacity** - Improved digester mixing will result in full utilization of the tank volume for active digestion and shorter digestion periods due to improved exposure of the biomass, which equates to increased digester capacity.

3. **Better digestion of FOG and food waste** - A pump mixed digester is better able to address the special challenges of mixing oil and grease with the active biomass and process the additional loading from FOG and food waste addition.

4. **Reduced grit and scum buildup** - A thick scum blanket can accumulate in poorly mixed digesters. This blanket reduces the active volume of the digester. A well mixed digester tends to have less buildup of scum and grit which will extend the period between digester cleanings and increase active volume.

5. **Improved heat distribution** - Improved digester mixing results in a more rapid distribution of the heat that is added, and thus, a more uniform temperature throughout the digester.

An externally pumped mixing system is favored over other mixing systems due to the reliability and maintenance accessibility of mechanical pumps, availability of a standby pump, and lack of any critical operating facilities within the digesters. There is no need to take the digesters out of service for mixing system maintenance. Additional features are that the dual piping system allows flexibility in operating the mixing system, and the effects of shock loading are minimized.
5.2.1.2 Mixing System Components

A conceptual section view of the proposed mixing system is shown in Figure 14. The system would likely consist of a dedicated mixing pump for each digester, large diameter upper and lower suction and discharge piping, and associated valves and fittings. Discharge to each digester is through one of two nozzles located near the top and bottom of the digester. Alternative suction and discharge pipes are provided so that the mixing patterns in the digester can be rotated periodically.

**Figure 14: Digester Mixing Section View**

![Digester Mixing Section View Diagram](image-url)
It is anticipated that each digester would require a 10,000 gpm pump to provide the recommended 8.5 to 9 digester turnovers per day. This is assuming that the digester volume will be increased from the current 130,700 cubic feet per tank to 213,600 cubic feet per tank by the conversion from fixed to floating cover digesters.

Primary sludge and WAS will continue to be fed to the digesters through the existing feed piping. The new mixing facilities (pumps and piping) would likely be constructed in separate vaults adjacent to each digester. It may be possible to locate the pumps in the room currently occupied the existing gas mixing equipment, however, this space is small and may not be able to accommodate the large pumps and piping.

5.2.2 Digester Cover

In combination with improving the digester mixing system it is recommended that the existing floating covers be replaced with fixed steel covers or membrane gas covers. The primary reasons for this recommendation are to increase available digester volume and avoid potential difficulties that could arise with using floating covers. Some the potential difficulties with floating covers include guide mechanism failure and resulting seal failure, and reduced efficiency of pumped mixing due to friction losses caused by blockage by the floating cover skirt.

Fixed steel covers consist of radial steel supports converging on a central compression ring. At the tank wall, a skirt plate is provided for a gas seal, and a thrust ring carries all radial loads and prevents radial load transmittal to the tank wall. The radial steel supports, typically tube steel, are welded to the exterior side of the cover plates. The cover is anchored to the top of the digester wall using between 20 and 30 steel outriggers and is self supporting, requiring no interior columns. The outriggers are designed to allow differential movement, including thermal expansion and contraction, between the steel cover and the concrete wall. Fixed steel covers are most commonly applied to digesters where little variation in liquid level or sludge volume is expected.

The steel cover can be installed using two different methods. The first method would involve lowering the pieces of the cover into the base of the digester, assembling the pieces, and hoisting the assembled cover into place with some type of jacking system (see Figure 14). The second method would involve assembling the cover outside of the digester and hoisting into place with a crane.
Since the support system is located on the exterior surface of the cover, the interior surface is smooth. The result of this smooth surface is reduced effort involved in coating the underside of the cover. Coatings can be spray or brush applied in less time due to the absence of multiple welded joints and reinforcing members, as shown in Figure 15.

Alternatively membrane covers could be used to provide even more volume for gas storage and utilization. The covers are similar to the covers used at EBMUD. Typically these covers cost in the range of 30 to 40% less than steel fixed covers and have 20 to 30% more gas storage volume.

The features and concept of membrane covers are shown in Figure 17.

A detailed analysis of cost and benefits of cover systems should be undertaken prior to detailed design.
**DuoSphere™ Digester Covers**

Tank-mounted digester covers provide an innovative and cost-effective solution for new and replacement covers:

- Less capital and installation cost
- Absolute odor containment
- New or existing digesters
- Variable liquid level

<table>
<thead>
<tr>
<th>DuoSphere Cover</th>
<th>Installed Weight (lbs)</th>
<th>Gas Storage (cubic feet)</th>
<th>Installation Duration (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duosphere</td>
<td>75,000</td>
<td>150,000 (above wall)</td>
<td>~3</td>
</tr>
<tr>
<td>Steel Drum</td>
<td>305,000</td>
<td>33,000</td>
<td>~8-10</td>
</tr>
</tbody>
</table>

---

DuoSphere Digester Cover

- Digester cover for tank mount
- PVC coated polyester fabric membranes, stainless steel anchors
- Radio frequency welds form a very strong seam. Support cables are not necessary
- Custom fabricated to fit tank
- 25 ft to 100 ft diameter plus
- AMCA spark resistant construction, two fans for safe duty/standby operation
- 13 weeks for a digester cover

*FROM WESTECH ENGINEERING INC.*

**BULLETIN 2008 DUOSPHERE GAS HOLDER**

**SALT LAKE CITY, UTAH**

---

Kennedy/Jenks Consultants

**CITY OF SAN RAFAEL/CMSA**

**METHANE CAPTURE FEASIBILITY STUDY**

**MEMBRANE GAS HOLDER COVER**

**K/J 0868015**

**DECEMBER, 2008**

**FIGURE 16**
5.2.2.1 Digester Structural Analysis

A structural analysis of the existing digester should be performed to confirm the adequacy of the existing tank to handle hydraulic and seismic forces from the increased liquid volume and to support a fixed steel or membrane gas cover. This typically would include observations of the conditions of the digester structure and review of record drawing information.

It is likely that the existing digester walls will need to be reinforced at mixing pipe penetrations and along the lower portion of the digester wall. Reinforcement of the digester walls at pipe penetrations typically consists of concrete jackets on the interior and exterior of the digester wall. The purpose of the jackets is to provide additional hoop reinforcing around the pipe penetration where the existing hoop steel is cut. The lower part of the digester wall is typically reinforced using an interior concrete skirt. This skirt provides additional wall strength for the elevated stresses caused by the deeper liquid level.
Section 6: Preliminary Project Costs

6.1 Cost of Separation and Processing Facilities

Conceptual capital costs were determined for the food waste separation and processing facilities on the basis of the preliminary layouts of the facilities, vendor quotations, and bid prices from recent similar projects.

The estimate includes a 4% allowance for bonds and insurance, 15% allowance for contractor overhead and profit, and 12% allowance for engineering design. A 25% contingency was added to the estimate on the basis of the guidelines from the Association for the Advancement of Cost Engineering for a Class 4 conceptual estimate.

The estimated costs of separation and processing facilities are summarized in Table 6. A detailed estimate of the costs is presented in Appendix F. The digester mixing costs and the cost of cover rehabilitation or replacement with a new fixed or membrane cover were not included in the food waste separation and processing costs, because these costs have been budgeted under plant maintenance to provide additional digestion and gas holding energy recovery.

Table 6: Cost Estimate Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Separation Facility</th>
<th>CMSA Processing Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yard Piping &amp; Site Work at CMSA</td>
<td>$225,000</td>
<td>$1,396,000</td>
</tr>
<tr>
<td>Separation Facility(1)</td>
<td>$580,000</td>
<td></td>
</tr>
<tr>
<td>CMSA Processing Facility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digester Mixing Improvements(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digester Cover Improvements(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtotal:</td>
<td>$580,000</td>
<td>$1,621,000</td>
</tr>
<tr>
<td>Bonds and Insurance @ 4%</td>
<td>$23,000</td>
<td>$65,000</td>
</tr>
<tr>
<td>Contractor OH &amp;P @ 15%</td>
<td>$87,000</td>
<td>$243,000</td>
</tr>
<tr>
<td>Subtotal:</td>
<td>$690,000</td>
<td>$1,929,000</td>
</tr>
<tr>
<td>Estimate Contingency @ 25%</td>
<td>$173,000</td>
<td>$482,000</td>
</tr>
<tr>
<td>Subtotal:</td>
<td>$863,000</td>
<td>$2,411,000</td>
</tr>
<tr>
<td>Engineering(3) @ 12%</td>
<td>$103,000</td>
<td>$289,000</td>
</tr>
<tr>
<td><strong>Total Conceptual Project Cost:</strong></td>
<td><strong>$1,030,000</strong></td>
<td><strong>$2,700,000</strong></td>
</tr>
</tbody>
</table>

Notes:

(1) Costs based on location of food waste separation equipment at MSS transfer station in San Rafael or other waste transfer facility in the San Rafael area of Marin County, CA.

(2) Digester mixing and cover improvements budgeted by CMSA under a separate digester rehabilitation project.

(3) Construction management and inspection costs not included in this estimate as these services could be provided by MSS and CMSA at no additional cost.
6.2 Annual Operating Costs

Annual costs for the separation and processing facilities, including labor, power, and equipment maintenance, were determined in Section 4. The total annual operating costs were estimated to be $72,900 for the separation facility and $58,000 for the CMSA processing facility.

6.3 Cost Savings and Payback

Cost savings for the food waste separation facility proposed at MSS or other solid waste transfer facility come from savings in food waste landfill disposal tipping fees and transportation costs. The landfill tipping fees were calculated based on 15 tons/day of food waste, a 260-day operation, and a $57/ton Redwood Landfill tipping fee. There is an additional transportation cost of $11/ton for each roundtrip to the landfill. The landfill disposal and transportation costs are based on 2009 rates that have been escalated at 4% per year to 2010. It is expected that the transportation costs would be considerably reduced if the separation facility is located at MSS, which is less than a mile from CMSA. This is in contrast to the 30-mile roundtrip distance to the Redwood Landfill, yielding an estimated net savings of $9/ton in transportation costs.

Cost savings for the proposed food waste processing facility at the CMSA WWTP derive from the natural gas that would not be required to operate the cogen engine for about 12 hours per day. The methane generated from food waste and FOG will provide enough biogas fuel to run the cogen engine nearly 24 hours/day, seven days/week. CMSA’s cost of natural gas for fiscal year 2008-2009 to supplement the running of the cogen engine is approximately $360,000. Escalating the cost of natural gas at 5% per year to the projected start of food waste and FOG processing in mid-2010 results in an annual cost savings of $396,900.

In addition, a range of tipping fees for processing solid food waste at the CMSA WWTP and the corresponding payback on the capital cost of the processing facility are presented in Table 7.

The digester cover and mixing improvements are not included in the payback analysis. Although these improvements are beneficial to food waste digestion, they also benefit to municipal sludge digestion and future programs such as FOG digestion. CMSA has budgeting for the digester cover and mixing improvements under future plant O&M infrastructure replacement.

The cost saving and payback for the separation and processing facilities are shown in Table 7.
Table 7:  Cost Savings and Facilities Payback

Food Waste Separation Facility\(^{(1)}\)

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Capital Cost Estimate</td>
<td>$1,030,000</td>
</tr>
<tr>
<td>b. Annual Operating Costs</td>
<td>$72,900</td>
</tr>
<tr>
<td>c. Annual Cost Savings</td>
<td></td>
</tr>
<tr>
<td>Transport to Landfill ($9/ton)(^{(2)})</td>
<td>$35,100</td>
</tr>
<tr>
<td>Landfill Tipping Fees ($57/ton)(^{(2)})</td>
<td>$220,300</td>
</tr>
<tr>
<td>d. Net Annual Savings (c-b)</td>
<td>$184,500</td>
</tr>
<tr>
<td>e. Payback on Capital Cost (a/d)</td>
<td>5.6 years</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Food waste separation facilities would be located at MSS or another nearby solid waste transfer facility

\(^{(2)}\) Based on 2009 transport and disposal costs (escalated at 4% per year to 2010) x 15 tons/day x 260 days/year

Food Waste Processing Facility\(^{(1)}\)

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Capital Cost Estimate</td>
<td>$2,700,000</td>
</tr>
<tr>
<td>b. Annual Operating Costs</td>
<td>$58,000</td>
</tr>
<tr>
<td>c. Annual Cost Savings</td>
<td></td>
</tr>
<tr>
<td>Natural Gas – Cogen(^{(2)})</td>
<td>$396,900</td>
</tr>
<tr>
<td>d. Net Annual Savings (c-b)</td>
<td>$333,900</td>
</tr>
<tr>
<td>e. Payback on Capital Cost (a/d)</td>
<td>8.0 years</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Food waste processing facilities would be located at CMSA

\(^{(2)}\) Projected natural gas cost of $360,000 for fiscal 2008-2009 escalated at 5% per year for 2 years to 2010-2011

The following are reduced payback periods for the food waste processing facility proposed at CMSA considering a range of tipping fees to be paid to CMSA by food waste haulers:

<table>
<thead>
<tr>
<th>Tipping Fee ($/ton)</th>
<th>Annual Revenue</th>
<th>Net Annual Savings</th>
<th>Processing Facility Net Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10/ton</td>
<td>$39,000</td>
<td>$377,900</td>
<td>7.1 years</td>
</tr>
<tr>
<td>$20/ton</td>
<td>$78,000</td>
<td>$416,900</td>
<td>6.5 years</td>
</tr>
<tr>
<td>$30/ton</td>
<td>$117,000</td>
<td>$455,900</td>
<td>5.9 years</td>
</tr>
<tr>
<td>$40/ton</td>
<td>$156,000</td>
<td>$494,900</td>
<td>5.5 years</td>
</tr>
<tr>
<td>$50/ton</td>
<td>$195,000</td>
<td>$533,900</td>
<td>5.1 years</td>
</tr>
</tbody>
</table>

As Table 7 shows, the estimates of capital cost, annual operating cost, and annual savings for the food waste separation and processing facilities yield payback periods of 5.6 years and 8.0 years, respectively. This result assumes no tipping fee at the processing facility that would be constructed and operated at CMSA WWTP. Considering a CMSA tipping fee ranging from
$10/ton to $50/ton, the payback period for the food waste processing facility would range from 7 to 5 years, respectively.

The payback period could be further reduced if funding from incentives, grants or carbon credits can be obtained (described in Section 7), or if future electricity and/or natural gas costs increase.
Section 7: Project Incentives, Loans, and Permitting

7.1 Incentives and Loans

Several options are available for obtaining incentive payments to reduce capital and/or operating costs. Loans also are available to help reduce the cost of and need for capital.

7.1.1 PG&E

PG&E offers a Wastewater Treatment Program designed to assist WWTPs in becoming energy-efficient and using digester gas to generate electricity. Details can be found at: http://www.pge.com/mybusiness/energysavingsrebates/incentivesbyindustry/wastewater/.

7.1.1.1 Energy Analysis, Rebates & Incentives, and Design Assistance

PG&E offers an integrated energy audit and analysis program that is geared toward a total energy management solution. The integrated audit takes a comprehensive view of all energy management options, including energy-efficiency opportunities, time-of-use management, demand response opportunities, and self-generation and renewable energy information.

PG&E has a customized energy-efficiency program that offers technical assistance and cash incentives for new energy-efficient equipment installed in existing facilities and new construction projects. Incentives are available for energy-efficiency measures (EEMs) such as dissolved oxygen control, variable-frequency drives, premium efficiency motors and pumps, aeration blowers, UV disinfection, screw presses, air compressors, HVAC equipment, boilers, and lighting.

PG&E also offers design assistance to encourage the design and construction of high-performance energy-efficient facilities. This offering includes technical assistance to analyze and design more energy-efficient buildings and process systems, incentives for new construction project owners to offset energy-efficiency investment costs, cash incentives that reward design teams for meeting ambitious efficiency targets, and education to facilitate the design of high-performance facility process systems.

7.1.1.2 Net Metering

PG&E’s Net Energy Metering Service for Biogas Customer-Generators (NEMBIO) rate schedule is an optional rate schedule for customers with an eligible biogas digester operated in parallel with PG&E to supply some or all of the customer’s energy needs. A biogas digester is defined as a generating facility used to produce electricity as a byproduct of the anaerobic digestion of biosolids. The new generation project must be used onsite, be less than 1 MW, use Best Available Control Technology (BACT), and begin operation by December 31, 2009 to be eligible for the program. (The statute caps availability of NEMBIO to 50 megawatts. Once this limit is reached, the NEMBIO rate will be closed to new customers unless extended by law.) The program credits the entity’s monthly bill, at its existing rate tariff, for the electricity generated and allows a carry-forward of Net Excess Generation (NEG) on a monthly basis, but at the end of each 12-month period any remaining NEG is granted to PG&E.
7.1.1.3 Self-Generation Incentive Program (for Fuel Cells)

If fuel cells are used in the future for additional cogeneration, then the project would be eligible for the Self-Generation Incentive Program (SGIP). As of January 1, 2008, IC engines, microturbines, and small and large gas turbines will no longer be offered incentives through this program. PG&E offers $4,500/kW for fuel cells using digester gas for onsite electrical use, up to 5 MW in size; however, the incentive begins to decline for fuel cells between 1 MW and 3 MW. For a 400-kW fuel cell, the incentive payment would be substantial at $1.8 million, and it would cover a majority of the capital costs. To be eligible, the project must become operational by the end of 2011.

7.1.1.4 Demand Reduction

PG&E also has incentives for customers to reduce electric power use when the California Independent System Operator (CAISO) determines that the state's energy supplies are low. There are numerous demand reduction programs with different rules and different reimbursement rates. Wastewater treatment facilities can be great candidates for these Demand Response programs, and it would be prudent to further explore the benefit of this program.

7.1.1.5 Power Purchase Agreement for Small Renewable Generation

PG&E will purchase the kWh output from eligible renewable resources up to 1.5 MW in size. Generation using digester gas is an eligible project. Since this program is designed to help electric utilities meet their renewable portfolio standard (RPS), all the energy, renewable energy credits (RECs), and green attributes would be sold to PG&E. If the project’s energy output is sold under this program to PG&E, the customer cannot participate in any other California state incentive program. The price would be based on the RPS program market price referent (MPR) table. Contracts can be for 10, 15, or 20 years. For a 20-year contract, the starting price in 2009 is 9.7 cents/kWh and ends in 2020 with a sale price of about 12 cents/kWh, plus or minus a factor for time-of-use. It is also allowable to keep the energy for onsite use and for that portion retain all the green attributes and RECs, and sell to PG&E only the NEG.

7.1.2 Carbon Reduction Project and Renewable Energy Credits

AB 32, the Global Warming Solutions Act, set in motion the development of regulations, a market for carbon reduction projects (offsets), and a cap-and-trade system. Capturing and using methane to displace fossil-based electricity on the grid are generally considered GHG reduction projects. If the project is developed correctly using appropriate protocols and is certified and registered, it may become eligible to be used to meet either the City’s or CMSA’s GHG reduction goals, or, it may become eligible to be sold into the marketplace to another entity that needs to reduce its carbon footprint. To establish the credit, the actual reduction in metric tons of GHGs must be determined. Currently, offset projects are being sold in the range of $10 to $15 per metric ton.

Renewable Energy Credits (RECs) are derived from the generation of electricity from renewable resources, such as generation from digester gas. One REC is equivalent to 1 MWh of electricity and is currently being sold at about $20 to $30 per MWh.

Page 7-2 City of San Rafael/CMSA Methane Capture Feasibility Study
KJ 0868015

p/sw-group/admin/jobs/080868015_sr-cmsa_food_waste/09-reports/sr_cmsa_meth_capture_feasibility_study-updated-01-08-09.doc
7.1.3  Third-Party Lease Option

Since governmental entities cannot take advantage of tax credits that are available for renewable energy generation, it may make sense in the future to explore allowing a third-party to own the equipment, take the tax advantage, and return some of that value back to the governmental entity in the form of lower lease payment or lower cost of sold-back energy. There are is a Renewable Energy Production Tax Credit, accelerated depreciation, and other tax incentives currently available for projects using digester gas.

A tax-exempt entity could take advantage of these incentives through a lease arrangement with UTC Power or Chevron Energy Solutions. For example, UTC Power has a financing division that would calculate the installed cost of the a fuel cell or microturbine project, including the cost of a service contract, would apply the tax incentives, and would provide the system to the City/CMSA through a lease based on these costs. UTC’s lease, or Energy Services Agreement, term is typically 10 years. Leasing the equipment through UTC allows the City/CMSA to gain some of the advantage of the tax incentives. UTC would be responsible for service and maintenance of the equipment during the term of the agreement. UTC would monitor the system through their 24/7 call center, and the City/CMSA would not have to use their limited capital.

7.1.4  California Energy Commission Loan

The California Energy Commission (CEC) offers loans at a current interest rate of 3.95 percent for energy saving projects. The maximum loan amount per application is $3 million. To be eligible for the loan, the project must demonstrate energy savings and technical and economic feasibility, and the loan must be repayable within 15 years.

7.1.5  State Revolving Fund

The State Revolving Fund (SRF) is administered by the State Water Resource Control Board (SWRCB). The fund is a low-interest loan program intended for the construction of publicly owned wastewater treatment and water reclamation facilities, as well as for other activities to correct non-point source pollution and enhance estuaries. The interest rate for the loan is one-half the rate of the most recent sale of the State General Obligation Bonds, and the loans must be repaid within 20 years.

The project must address water-quality objectives, protection or enhancement of beneficial uses, or the anti-degradation policy. Eligible projects are placed on a statewide SRF Project Priority List. The application process includes completion of an application form, demonstration of evidence of compliance with the California Environmental Quality Act by submission of an Environmental Impact Report, Negative Declaration or Categorical Exemption, and submission of a Planning Study.

7.1.6  Marin Municipal Water District

Additional electric energy developed by this project could be provided to MMWD for operation of its proposed desalination project or other municipal facilities.
7.2 **Permitting**

The permits described below may be required for this project.

7.2.1 **City**

The City of San Rafael requires that a separate permit be obtained for each building or structure to be constructed. A building permit from the City of San Rafael would be required for construction by MSS or the owner of the separation and transfer facility, and a zoning permit would be required by both this entity and CMSA.

7.2.2 **Environmental**

An environmental assessment and CEQA process would be necessary for this project.

7.2.3 **Air Quality**

CMSA has an existing air-quality permit for the engine generator, but it may need one for the additional food waste preparation facility odor scrubber. MSS or a comparable facility owner may not need an additional permit for the separation facility located within an existing building at the transfer station.

7.2.4 **California Integrated Waste Management Board**

A permit from the Integrated Waste Management Board (CIWMB) would be required if the solid waste separation is done at CMSA. If solid waste separation is done at a solid waste transfer facility such as MSS, it is likely that the separation operations would be included under the existing CIWMB permit.
References

Sections 1 and 2


Section 3


Section 4


2. EBMUD (2008), Information from Paul Suto, Senior Engineer, obtained during August 27, 2008 tour of Food Waste Processing Facility.


Section 5


Section 6