Energy Research and Development Division
FINAL PROJECT REPORT

BROWN GREASE RECOVERY AND BIOFUEL DEMONSTRATION PROJECT

Oceanside Water Pollution Control Plant

Prepared for: California Energy Commission
Prepared by: San Francisco Public Utilities Commission
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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

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Brown Grease Recovery and Biofuel Demonstration: Oceanside Water Pollution Control Plant Final Report is the final report for the Brown Grease Recovery and Biofuel technology demonstration project (Contract Number PIR-06-001) conducted by the San Francisco Public Utilities Commission and URS Corporation. The information from this project contributes to Energy Research and Development Division's Renewable Energy Technologies Program.

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ABSTRACT

This report outlines the results for the Brown Grease to Biodiesel Demonstration Project conducted by the San Francisco Public Utility Commission at the Oceanside Water Pollution Control Plant. Brown grease, also known as "trap grease," is an energy-rich resource abundant in waste streams from restaurants. If left in wastewater, this grease collects inside the wastewater collection system and results in anaerobic conditions (the absence of oxygen), increased corrosion, and pipe blockages that can lead to wastewater overflows. Restaurants are required to install grease traps in their drains to prevent fats and oils from entering sewer pipes. The grease can then be collected to make biodiesel. This study provided valuable input regarding the operational complexities and costs of a brown grease recovery facility.

The demonstration facility was designed and built by the San Francisco Public Utilities Commission (SFPUC) to receive about 10,000 gallons per day of raw trap waste from private waste-hauling companies. Evaluated were the overall effects on the wastewater treatment process, the performance of recovery technology, and the potential for converting the brown grease to feedstock for biodiesel fuel production.

Based on the economic analysis, researchers conclude that collecting trap waste for inclusion in the existing wastewater treatment anaerobic process can result in a positive cash flow. Following up on this demonstration project, additional research in to how much biogas is produced by codigesting the whitewater and interface portions of trap waste appears warranted.

Keywords: Brown grease, restaurant trap waste, anaerobic codigestion, wastewater treatment, biodiesel, feedstock

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EXECUTIVE SUMMARY

The traditional role of municipal wastewater treatment facilities has been limited to accepting the incoming wastewater flow from the wastewater collection system, providing the required level of treatment, and disposing the residuals in a manner that is both economical and in compliance with regulations. A new view is emerging that includes wastewater treatment facilities as a key element in regional resource recovery in response to factors including more stringent regulations, concerns over energy use, carbon footprint, and worldwide depletion of fossil fuel resources. Resources in wastewater include chemical and thermal energy, nutrients, and water. Some energy-rich waste streams, such as waste fats, oils and grease, are concentrated in the drainage from restaurants and are amenable to enhanced recovery at the source.

Issues With Grease Management

There are numerous issues with conventional strategies for managing waste grease. If left in wastewater, grease collects inside the wastewater collection system and results in anaerobic conditions (the absence of oxygen), increased corrosion, and pipe blockages that can lead to wastewater overflows. Grease in wastewater that arrives at the wastewater treatment facility can impair the operation of preliminary treatment equipment and is only partly removed in the primary clarification process. Due to its high organic content, residual grease increases aeration demand and associated energy consumption in the secondary treatment process. Grease is usually separated from the bulk flow using on-site grease traps, which operate by providing sufficient retention time to allow grease to accumulate in a floating layer. Vacuum trucks are used to periodically remove the contents of grease traps for hauling to a waste management agency like a landfill, wastewater facility, or rendering company. When disposed of in landfills, grease is likely to undergo anaerobic decay prior to landfill capping, resulting in the atmospheric release of methane, a greenhouse gas (GHG).

Technology Demonstration

An alternative grease management system was designed and built by the San Francisco Public Utilities Commission (SFPUC), which included the installation of demonstration-scale grease receiving and processing facilities at the Oceanside Water Pollution Control Plant.

The demonstration facility was designed to receive about 10,000 gallons per day of raw trap waste from private trap waste hauling companies. Raw trap waste is the waste stream captured by restaurant grease traps located in kitchen drain lines. It is a complex and variable mixture of grease, residual food, other solids, and water. The raw trap waste was first subjected to a sequential heating, settling, and dewatering process to extract the brown grease from the trap waste. The brown grease was subsequently evaluated as a feedstock for conversion to biodiesel fuel in an on-site biodiesel production facility. Secondary impacts on the wastewater treatment process were measured by comparison with a set of baseline data. Bench and full-scale anaerobic digestion testing was conducted to demonstrate potential toxicity and/or changes in biogas production. Anaerobic digestion is a process in which microorganisms break down biodegradable material in the absence of oxygen.

The demonstration project is a component of an overarching research program designed to (1) validate technology performance; (2) determine the costs and benefits associated with co-locating this type of operation at a municipal wastewater treatment plant (including economic, socioeconomic, and GHG emissions reduction); and (3) develop a business case or model to facilitate replication of the application of the technologies and the SFPUC's overall fats, oils, and grease (FOG) control program by other municipal agencies. The evaluation considered the development of additional brown grease processing facilities at wastewater treatment plants that could support a centralized commercial scale biodiesel production operation (for example, in lieu of producing biodiesel at a WWTP).

Baseline Study

To evaluate and quantify the outcomes of the demonstration project on FOG management in San Francisco and wastewater treatment plant processes, a baseline study was first conducted to characterize the performance of the Oceanside plant systems that could be affected, including the plant's anaerobic digesters and energy systems. Selected findings from the baseline study, which was documented in a separate report include:

- *Waste FOG Production and Management in San Francisco*. Waste grease generation in San Francisco was estimated using the results of a study conducted by the National Renewable Energy Laboratory (NREL) in 1998, which found grease production rates in large U.S. cities of 8.87 pounds per person per year yellow grease and 13.4 pounds per person per year brown grease. The total amount of grease within the city of San Francisco that currently could be recovered is estimated to be 1.2 million gallons per year (Mgal/yr) for yellow grease and 1.8 Mgal/yr for brown grease. However, the SFPUC estimates that about half of sewer blockages result from grease discharges, an indication that the existing grease traps and existing clean-out practices are not effective.

- *Wastewater Collection and Treatment Systems at OSP*. OSP serves the western half of San Francisco, with an average flow of about 18.8 million gallons per day (Mgal/d). Treatment consists of preliminary treatment (screening, grit removal), primary clarification, pure oxygen-activated sludge with secondary clarification followed by discharge to the ocean. Limited data were available to estimate influent (inflowing) grease concentrations; however, it is recognized that reducing influent grease concentration using source control could reduce influent chemical oxygen demand concentrations and, therefore, aeration demand. Power consumption at the wastewater treatment facility was estimated to be 40,000 kilowatt hours per day (kWh/d). Plantwide natural gas consumption was estimated to be 150 therms per day (therm/d).

- *Biosolids and Digester Gas Management at OSP*. Residual solids and scum from the primary clarifiers are combined with residuals from the aeration process (i.e., waste activated sludge) and secondary scum, and subsequently thickened and digested under anaerobic conditions. Digested biosolids are then dewatered using a belt filter press before final offsite hauling. Biogas from the digester is used for on-site hot water generation with boilers, and for electricity and hot water generation with internal combustion engine-generator sets. During periods of cogeneration system maintenance or when the biogas supply exceeds capacity, excess biogas is flared. Due to deferred maintenance of biogas flow meters, accurate historical gas production data are not available.

- *Gaseous Emissions From Stationary and Mobile Sources Associated With FOG Management*. A life cycle analysis was performed on FOG to estimate GHG emissions associated with current grease management operations. It was found that the largest contribution to GHG emissions was the placement of trap waste in landfills, resulting in the production and release of methane gas to the atmosphere. The total of GHG emissions calculated for the baseline grease management practices is 154 tonnes carbon dioxide equivalent per year (CO_2e/yr). The mobile sources of CO_2e are insignificant compared to emissions from landfilled grease.

Brown Grease Recovery

The goal of the brown grease recovery feature of the demonstration project was to evaluate the performance of technology designed to process up to 10,000 gallons per day of restaurant trap waste to recover and produce a brown grease feedstock containing less than 2 percent moisture, insolubles, and unsaponifiables (organic oil constituents other than fatty acids or related triglycerids, which would not transform into biodiesel) that is suitable for the production of biodiesel. Pacific Biodiesel Technologies of Maui, Hawaii, supplied the grease receiving and processing equipment. Considerations for the management of the side streams and the best ultimate use of the brown grease were included in this evaluation.

From a wastewater management agency perspective, any activities that compromise the effluent water quality or disrupt routine operations are unacceptable. Therefore, assessing the impacts on the wastewater treatment plant operations and the benefits of co-location of a brown grease recovery unit were also important for this portion of the demonstration project. A number of potential impacts on the wastewater treatment facility and related operations were identified during project development:

- *Trap Waste Quantity and Quality.* A significant issue observed during the study was the difficulty in obtaining representative samples. As delivered in the trucks, trap waste is already stratified. Attempts to sample the incoming trap waste from a mixed-batch holding tank were also found to be unsatisfactory due to insufficient mixing and the concern that increased mixing could be counterproductive to grease separation. In addition, the high level of variability in the analytical data from the oil and grease method further eroded confidence in the sampling results. An average of 6,000 gallons per day of trap waste was delivered to the brown grease recovery process, with an average grease content of 4.7 percent. This equates to an oil and grease amount of approximately 470 gallons or 2,000 pounds per day that was diverted from landfilling.

- *Brown Grease Recovery.* The recovery of brown grease was evaluated over a six-month period. The overall monthly grease recovery was found to range from about 21 percent to 54 percent, with the balance of the influent grease content split between the interface layer and whitewater streams. The recovery was lower than the recovery needed to produce 300 gallons per day of brown grease. The low recovery was related to failure of certain component of the facility (i.e., automatic interface sensors) to accurately detect the transition between oil and water layers during decanting, and insufficient heat availability to efficiently free the brown grease from the trap waste.

- *Operational Experience.*One of the main operational problems associated with the facility was noxious, persistent odors that affected plant personnel. Odors were found to be an issue at the receiving sump, through faulty tank gaskets, at pressure release valves, and during truck unloading; however, solutions were developed for odor control at each location. An example of one of the solutions was the installation of a custom-designed receiving station that was both pressurized and heated, instead of the initial open screen box. The implementation of the demonstration project resulted in increased truck traffic at the facility that interfered with other operations at the site. Spillage during tank unloading resulted in asphalt staining, tracking of wheel marks, and a potential slip hazard.
- *Effects on Wastewater Treatment Operations.* Digester foaming was observed during the study period when whitewater and other products were being injected to the digesters. However, because of other operational changes that were also made during this time, the contribution of whitewater injection to digester foaming cannot be determined. Noted improvements in biogas production as a result of grease injection support the concept of direct trap waste injection as a digester feedstock instead of conversion to biodiesel fuel.

Biodiesel Production

The goal of the biodiesel production element of the demonstration project was to evaluate the performance of technology designed to process up to 300 gallons per day of brown grease feedstock and produce up to 240 gallons per day of American Society for Testing and Materials (ASTM) grade biodiesel. BlackGold Biofuels (BGB) supplied the equipment. The impacts on WWTP operations and the benefits of co-location of a biodiesel production facility were also important components of this portion of the demonstration project.

- *Brown Grease to Biodiesel Conversion.* The biodiesel production process consisted of the following process steps: (a) conversion of brown grease free fatty acids to fatty acid methyl esters using methanol and a catalyst (transesterification); (b) removing residual methanol through reduced-pressure evaporation (i.e., flashing)and removing glycerin and catalyst through decanting; (c) neutralization and removal of unreacted free fatty acids; and (d) distillation of biodiesel fuel. Methanol that was removed in Step (b) is recovered by distillation and reused. Biodiesel was transferred to a storage tank. The biodiesel process was subject to numerous operational issues and ancillary equipment part failures during the demonstration period. However, the chemical conversion process appeared to be sound, which was anticipated since it used a well-known organic chemistry reaction mechanism. Over the demonstration period, the facility produced fewer than 50 gallons of biodiesel. There was insufficient operational data made available to evaluate individual system components performances or develop a business case based on this technology.

- *Practical Considerations.* The biodiesel production facility experienced a variety of start-up issues resulting from components that were improperly sized, that could not withstand the corrosive salty atmosphere near the Pacific Ocean, that exhibited fouling of heated surfaces and tight internal clearances, and that were difficult to maintain in the extremely tight skid layout. Several major facility components were replaced following redesign. In addition there were a number of issues related to the quality of utilities and raw materials provided to run the facility. The plant's final effluent was about 10°F warmer than the potable water supply, and at times particulates fouled the biodiesel production facility's cooling system. The brown grease supplied to the facility was contaminated periodically with debris that needed to be moved from the day tank upstream of the core process reactor.
- *Impacts on Wastewater Treatment Operations.* While methanol is commonly used to promote nitrogen removal in wastewater treatment facilities that have effluent nitrogen limitations, the Oceanside plant does not perform nitrogen removal, and, therefore, OSP staff was not experienced in working with this chemical. Due to the hazardous nature of methanol, special handling and safety precautions were necessary. A spill prevention control and countermeasure plan was needed because of the storage of brown grease and biodiesel on site. Several of the byproduct and waste streams from the biodiesel production process, including methanol, glycerin, and catalyst, may be considered hazardous if they were to be hauled offsite. However, due to the co-location at OSP and their biodegradability, these materials were used as digester feedstocks.

Biogas Production at Pilot and Full Scale

Another objective of this study was to measure the methane gas formation and assess the performance and toxicity effect on anaerobic digesters when introduced with biodiesel production-generated by-products. This part of the research began in February 2010 with a pilot test to determine the effects on gas production during codigestion of brown grease and sludge. Attempts to replicate pilot findings at full scale were conducted between August and December 2011.

The pilot study reportedly did yield data indicating the potential for a relatively large increase in methane production when switching from regular digestion to co-digestion. Other findings reportedly included higher than usual solids and volatile solids destruction ratios, as well as limited to no toxicity from codigestion of typical biodiesel production byproducts.

Attempts were made to assess the performance of full-scale injection of trap waste, brown grease recovery waste streams, and dewatered brown grease into a single digester. The remaining two operating digesters were intended to be used as experimental controls. Key findings of the full-scale study include:

- The biogas collection system, in combination with the installed gas flow meters, produced ambiguous data during the test period.
- Within 20 minutes of injection of grease-containing fluids, a sharp incline was observed in the signal of the gas flow meters. This response was much faster than the response times reported in literature, which could indicate that the observed digester behavior was due to physical rather than biological effects
- The biogas production baseline was on the order of 10.3 standard cubic feet (scf) per pound volatile solids destroyed. August through December 2011 data showed an increase in biogas production (due to side stream injection) to a rate of roughly 16 scf per pound of volatile solids destroyed, which is in line with what operations staff noted during rounds.

Feasibility

After collection of demonstration-scale project data, a business case was identified for the feasibility of project replication at full scale in California. Important considerations in assessing the feasibility of a business case for co-locating a brown grease-based biodiesel refinery at a municipal WWTP include:

- *Technical Feasibility.* The decanting technology demonstrated by Pacific Biodiesel Technologies appears relatively mature and ready for replication at a similar or larger scale. To minimize trucking of trap waste, the construction of a network of brown grease recovery units similar in size to the demonstration unit should be considered.

  The chemistry of the Black Gold Biofuels conversion process appears to be working as claimed; however, several problems encountered during the demonstration period prevented the unit from producing biodiesel on a consistent basis. A number of these problems may have been related to nonstandard equipment sizes and small pipe diameters. Therefore, those issues require further improvement prior to potential successful implementation of this technology at a demonstration scale larger than the unit tested during this project. Regarding reproduction at a larger scale, it is the investigators' opinion that this technology still has not demonstrated sufficient robustness at a pilot scale. Additional development is recommended at a true demonstration scale prior to full-scale implementation.
- *Low Carbon Fuel Source Evaluation.* Waste grease-based biodiesel has a considerable advantage over virgin oil-derived biodiesel because waste grease, being a waste material, has no carbon footprint. Biodiesel produced from waste grease has a carbon intensity of 11.76 grams carbon dioxide equivalent megajoule (gCO_2e/MJ), which is 88 percent lower than petroleum-based ultra-low-sulfur diesel (94.71 gCO_2e/MJ; see 17 CCR95480-95490).
- *Economic Feasibility.* A business case analysis based on literature data for per capita waste grease production, has indicated that California is capable of producing 29 Mgal/yr of recoverable waste grease from trap waste recovered in major urban areas. Relative to

California's reported 92 million gallons of biodiesel production volume in 2010, this is a significant amount of biodiesel feedstock (California Energy Commission 2010). However, it will only be sufficient to produce about 1 percent of the current total diesel demand of the State.

The Brown Grease to Biodiesel Demonstration Project provided valuable input regarding the operational complexities and costs of a brown grease recovery facility. It made a strong case for not co-locating a biodiesel production facility at a publicly owned wastewater treatment plant due to process complexity and the hazardous chemicals involved.

Based on the economic analysis performed under the business case task of this project, it appears that collecting trap waste for anaerobic co-digestion is an activity that results in a positive cash flow. The GHG benefits of production of 20 Mgal/yr of biodiesel from waste grease were quantified at approximately 279,000 tonnes CO2e. This reduction in GHG emissions is equivalent to the GHG emissions related to the electricity use of approximately 145,000 households.

The green job creation potential of construction and operation of facilities to support production of 20 Mgal/yr of biodiesel from waste grease is estimated at 393 to 466 direct job years and 277 to 312 indirect job years during the construction of the facilities and 61 direct jobs over the lifetime of the facilities.

Publicly owned treatment works (POTWs) on average account for 3% of the total electricity consumed annually in the United States. This project has demonstrated that co-locating a FOG recovery facility at a publicly owned treatment works (POTW) can enable the POTW to reduce its overall reliance on fossil fuels and lessen its demand on the already overburdened power grid through generation of biogas and through a reduction of wastewater treatment efforts, respectively. There are more than 300 POTWs throughout California and widespread acceptance of this technology could not only lead to lower fees for electrical and sewer ratepayers, but also provide a network of decentralized biofuel feedstock production facilities that can supply a central biodiesel refinery. Replacing conventional diesel with biodiesel reduces statewide GHG emissions, currently regulated under the California Global Warming Solutions Act (i.e., AB32), and as such contributes to attaining the mandated GHG emission reductions.

Recommendations

Based on this demonstration project, it appears warranted to perform additional research as to concerning how much biogas is actually produced by codigesting the whitewater and interface portions of trap waste, since both fractions contain significant amounts of digestible food waste.

The project has also demonstrated that the biodiesel production facility, which employed a transesterification process as the means for chemically converting the brown grease into biodiesel, was unable to produce biodiesel on a consistent basis. Several modifications were made to the installation during the project, which eventually did not result in a working installation. More research and testing at a larger scale are needed to determine whether this technology holds promise.

Additional information is needed on the brown grease to biodiesel conversion capabilities of the recently developed heterogeneous catalytic processes. Those technologies appear promising, however at this time, insufficient scientific data are publicly available to fully assess their conversion capabilities and sensitivities to impurities commonly present in brown grease.

CHAPTER 1: Introduction

The demonstration project provides an outlet for trap waste grease that is removed from food service establishments (FSE) and is a trial of two innovative technologies that may transform the way that grease trap waste is managed in the future. These technologies are aimed at conversion of the lipid component of grease trap waste known as brown grease into ASTM D 6751 S15 biodiesel fuel. The idea of using brown grease as a source of renewable energy is not new, but there are hurdles in the way of wide-spread implementation of this concept. Historically, the implementation of new technologies at WWTPs has been slow, due to the need of providing an essential service and the fact that they rely on public funds. Although some agencies have begun to experiment with energy recovery programs, limited, reliable, verified data are available. Additionally, smaller wastewater agencies may not have the funds to conduct experiments on their own. A public model is needed that can be used to demonstrate the feasibility of brown grease recovery programs and that can provide wastewater agencies with the information needed to establish alternative energy programs.

The SFPUC conducted a Brown Grease to Biodiesel technology demonstration project with the support of grant funding from the U.S. Department of Energy, the California Energy Commission (Energy Commission), and the United States Environmental Protection Agency's (U.S. EPA's) *West Coast Collaborative*. The technology demonstration project was developed to assess the feasibility of beneficially reusing restaurant waste grease.

Demonstration project objectives include:

- Demonstrate technology that can be used to recover brown grease from grease trap waste, which can then be used as a feedstock for biodiesel production.
- Demonstrate the feasibility of co-locating a brown grease recovery and biodiesel production facility at a WWTP.
- Form the basis of a business model, based on findings and lessons learned, that would allow replication of the program or similar program at other agencies throughout California and the United States.

The demonstration project was designed to assess the performance of technologies designed to process restaurant grease trap waste and produce biodiesel. Demonstration project goals include:

- Recovery of brown grease from restaurant interceptor or grease trap waste as a viable biofuel feedstock containing less than 2 percent MIU.
- Processing of the brown grease feedstock into ASTM D 6751 quality biodiesel that also meets ultra-low sulfur requirements.

- Beneficial reuse or recovery of energy from all waste streams and byproducts associated with the demonstration technologies.

Based on those goals, the following scope was developed for this project:

- Demonstrate that up to 10,000 gallons per day of waste collected from grease traps and/or interceptors can be processed and converted to up to 300 gallons per day of brown grease product.
- Demonstrate that up to 300 gallons per day of brown grease product can be converted to up to up to 240 gallons per day of biodiesel product.
- Design and construct a 10,000gallon per day brown grease recovery and conversion facility at the SFPUC's OSP.
- Design and construct a facility that will convert up to 300 gallons per day of brown grease feedstock containing less than 2 percent MIU into a biodiesel product.
- Demonstrate multiple uses for the brown grease product including as an additive fuel to OSP anaerobic digesters to boost digester gas production.
- Establish the relative percent increase in digester gas production resulting from the discharge of brown grease and/or select demonstration facility waste streams to pilot-scale anaerobic digester(s) – target: 5 to 15 percent net increase in digester gas production.
- Establish the optimum operating range for co-digestion of brown grease and/or select demonstration facility waste streams at the pilot-scale digesters (in terms of anaerobic digester loading rate and hydraulic retention time).
- Make available technical data that may be used by other municipal agencies interested in developing their own program.

The project further had to meet the following economic objectives:

- Demonstrate a viable pathway for the conversion of brown grease to biodiesel that can be replicated on a commercial scale.
- Produce biodiesel from a brown grease feedstock at a demonstration plant level at a cost of about $5.00 per gallon (includes cost of brown grease and methanol). The target production cost at a commercial scale is $1.74 per gallon.
- Increase digester gas production at OSP by about 5 percent, potentially decreasing the amount of natural gas that the plant would need to purchase (target natural gas use reduction in the OSP's boilers and cogeneration facilities by approximately 3 percent).
- Achieve production of up to 240 gallons per day of biodiesel, equivalent to fueling 25 to 40 SFPUC trucks that were previously run on diesel.

- Demonstrate a business model for municipal agencies that are interested in developing their own renewable energy programs, but unaccustomed to dealing with the financial and environmental aspects of such a program.
- Demonstrate the production of biodiesel from an alternative feedstock that could allow California to reduce its dependence on palm and coconut oils imported from abroad.
- Develop a Pro Forma and cost/benefit analysis based on demonstration program data.

1.1 Report Organization

This report documents and discusses the execution and findings of the demonstration project. It is organized as follows:

- Brown grease recovery demonstration
- Biodiesel production demonstration
- Effects on wastewater plant performance

Subsequent sections then discuss potential economic aspects of FOG to biodiesel projects, as well as outreach activities undertaken to promote replication of the project. Those sections are laid out as follows:

- Economic Analysis and Business Case
- Benefits for the State of California
- Technology Transfer

The report is ended with a conclusions and recommendations section.

CHAPTER 2:
Project Execution – Brown Grease Recovery

This section documents and discusses the project implementation of the Brown Grease Recovery Facility constructed and tested at SFPUC's Oceanside Water Pollution Control Plant (OSP). This section also documents and discusses data collected during the project demonstration period, which ran from December 2010 through May 2011 and was subsequently extended through December 2011.

2.1 Project Implementation

The goal of the Brown Grease Recovery Facility portion of the demonstration project was to evaluate the performance of technology designed to process up to 10,000 of restaurant trap waste to recover and produce a brown grease feedstock containing less than 2 percent MIU that can be used to produce biodiesel. Consideration of the disposition of the side streams and the best ultimate use of the brown grease are included in this evaluation. Assessment of the impacts on the WWTP operations and the benefits of colocation of a brown grease recovery facility at the WWTP are also an important component of this portion of the demonstration project and are discussed in subsequent Section 4 of this report.

2.1.1 Project Schedule

A project construction schedule was prepared that would meet the various grant deadlines:

- April 2009: Technology research, vendor interview, and selection
- April-May 2009: Purchase order document preparation
- May-August 2009: SFPUC internal approvals and purchase order advertisement
- August 2009: Purchase order award
- August-November 2009: Equipment design, procurement and fabrication, and site modifications design and construction
- November 2009: Brown Grease Recovery Facility equipment delivery and installation

2.1.2 Design Requirements

Based on the project demonstration goals for the Brown Grease Recovery Facility, design criteria were developed both for the prospective grease recovery technology and for the co-location site These criteria were based on estimates of trap waste generation in San Francisco, literature data on trap waste composition, and site-specific conditions related to co-locating such a facility at a WWTP in San Francisco.. These criteria are listed below.

2.1.2.1 Technology-Related Design Criteria

- Demonstration facility shall be capable of processing up to 10,000 gallons per day of grease trap waste and produce up to 300 gallons per day of brown grease (assuming the trap waste contains at least 5 percent brown grease);

- Brown grease product shall contain ≤ 2 percent MIU;
- Factory-tested, modular equipment, to facilitate construction, start-up and expansion;
- Demonstration facility shall meet all local codes, including design for Seismic Zone 4;
- The grease trap waste hauler unloading and transfer shall be fully automated;
- The separation of grease trap waste to brown grease shall be fully automated;
- No additional personnel shall be required to operate the facility;
- Demonstration facility shall meet the project specifications based on using available site utilities for heating;
- Equipment shall be delivered by November 2009 (within 3 months of RFP publication); and
- Requiring minimal site modifications.

2.1.2.2 Co-location Siting Criteria

- Sufficient space for installation of the facility's equipment;
- Sufficient space for trap waste hauler tankers to unload and park;
- Close proximity to existing utilities;
- Close proximity to Brown Grease-to-Biodiesel Facility for brown grease transfer;
- Close proximity to head works for Brown Grease Recovery Facility discharges;
- Close proximity to anaerobic digesters for Brown Grease Recovery Facility discharges;
- Minimal site modifications;
- Sufficient clearance for access, equipment cleaning, maintenance, and so forth;
- Sufficient clearance from existing major utilities; and
- Sufficient clearance from existing traffic.

The criteria listed above formed the basis of design for the Brown Grease Recovery Facility, and were used to solicit bids from identified technology providers.

2.1.3 Facility Design

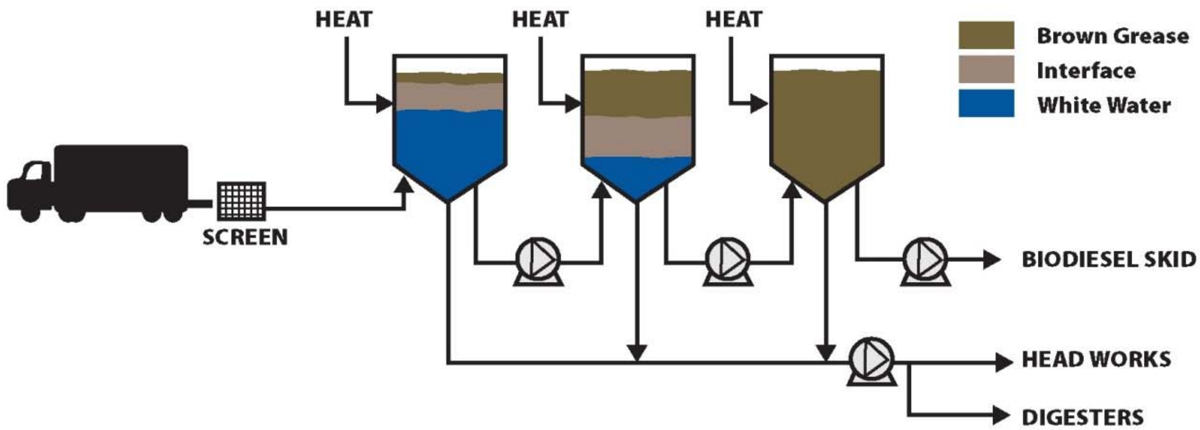
PBTech was selected to provide a brown grease recovery facility. Their approach utilized a refurbished, pre-owned yellow-grease receiving installation to fit the needs of the project. The main refurbishments consisted of installation of additional piping and an adaptation of the control panel. The unit was disassembled at its prior location in Oregon and shipped to the project site.

In its initial configuration, the Brown Grease Recovery Facility at OSP had the nameplate capacity to receive and process up to 10,000 gallons per day of grease trap waste. The Brown Grease recovery process can be divided into three simplified steps:

A simplified process flow diagram for the Brown Grease Recovery Facility is presented in figure 1. An artist's rendering of the installation is presented in Figure 2.

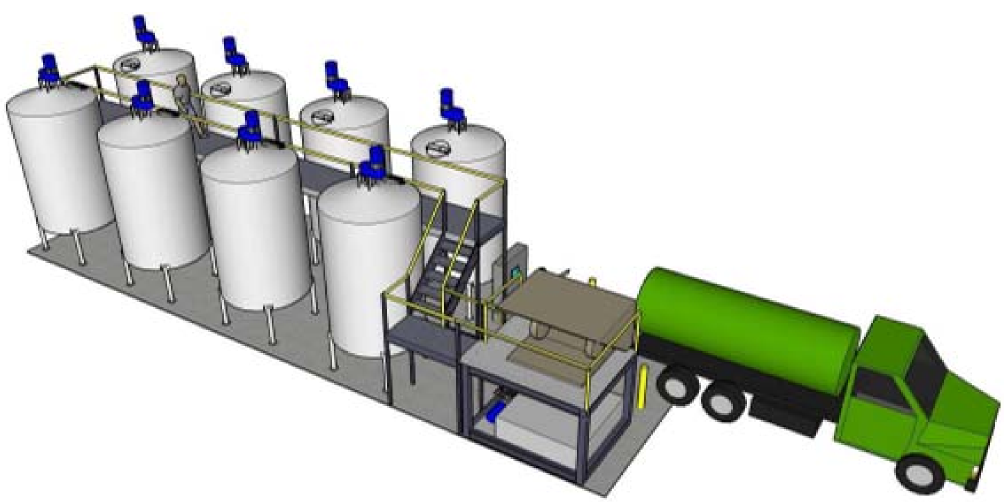
Table 1 summarizes the specifications and utility consumptions for the Brown Grease Recovery Facility. Improvements made to the installation during startup and trouble-shooting are described in Section 2.3.

Figure 1 : Simplified Brown Grease Recovery Facility Flow Diagram



Source: PBTech

Figure 2 : PBTech's Brown Grease Recovery Facility



Source: PBTech

Table 1 : Brown Grease Recovery Facility Space and Utility Requirements

System Dimensions	
Length	70 ft
Width	22 ft
Overall Height	21 ft
Pad Pressure	35 psi
Power Requirements	
Voltage	480V 3 phase @ 60 hz
Connected Load	60 kVA
Recommended Disconnect Size	100 A
Estimated Consumption, Maximum	220 kWH/day
Hot Water Supply	
Temperature	180 - 200°F
Flow	200 gpm
Pressure Range	30 - 40 psig
Estimated Consumption, Maximum	500,000 BTU/hr
Cooling Water Supply	
Pressure, Minimum	40 psig
Flow, Minimum	20 gpm
Compressed Air	
Flow	5 CFM
Pressure	125 psig
Dew Point	38°F

1. Unloading of trap waste by haulers and coarse solids separation by filtration.
2. Heating and gravity separation of the trap waste into brown grease, whitewater, and interface layer.
3. Polishing of the brown grease quality for solids and moisture reduction.

Each of those three steps is described in more detail in the following subsections.

2.1.3.1 Unloading and Screening

Upon arrival at the OSP, trap waste haulers unload grease trap waste by pumping the contents of their truck through a screening device and into one of the receiving tanks for heating and gravity separation. A booster pump provides additional pressure to overcome the static head due to the height of the receiving tanks.

2.1.3.2 Heating and Gravity Separation

Following unloading and screening, the trap waste is heated in jacketed vessels and separated by gravity. Gravity separation results in the following fractions: fine debris, whitewater, interface layer between oil and water, and brown grease. Within 24 hours of receiving the trap waste, the fine debris and whitewater are decanted for discharge to the anaerobic digesters. The interface layer, which contains a significant fraction of the brown grease, is allowed to separate further for at least another 24 hours, thus improving the oil recovery efficiency. The collected raw brown grease remains stored in a heated tank for several days, where further moisture and solids reduction occurs. Heat to facilitate the separation is provided by a closed-loop water circuit, which is heated by plant hot water in a heat exchanger.

2.1.3.3 Polishing

Depending on the quality of the brown grease produced in the heating and separating process step (see above), there is the option for that grease to undergo a solids and/or moisture reduction step. During that step, further solids reduction is obtained through filtration and moisture reduction using vacuum treatment. The finished brown grease is then stored in a heated tank awaiting transfer to the biodiesel production facility.

During the design phase, the variability and impact of grease trap waste unsaponifiables on the final product quality was discussed with PBTech. They stated that the unsaponifiables content of grease trap waste tends to be variable and appears to be related to solvents, cleaners, and mineral oils originating from kitchen cleaning practices. The Brown Grease Recovery Facility does not have the ability to treat or remove unsaponifiables. For this project it was assumed that, because several loads would be commingled daily, PBTech expected that the average unsaponifiables concentration in the final product would be below 1 percent, and no additional post treatment for unsaponifiables would be required to produce brown grease with less than 2 percent MIU.

2.1.4 Site Modifications and System Integration

Once a suitable location within OSP was identified for the Brown Grease Recovery Facility, the following major site modifications were designed and constructed to integrate the Brown Grease recovery process with the wastewater treatment processes at OSP:

- Structural foundations and equipment pads;
- Traffic controls for trap waste hauler tankers within OSP;
- Electrical power supply for pumps, instrumentation and controls;

- Supply and return of hot utility water for tank heating, area wash down, and so forth;
- Supply of cold utility water for wash down, and so forth;
- Supply of potable water for safety shower and eyewash station;
- Supply of plant air for instrumentation and controls and piping blow down;
- Whitewater discharge pipelines to tie-in to anaerobic digester and headworks feed lines; and
- Brown grease transfer line between the Brown Grease Recovery and Biodiesel Production Facilities.

To further integrate the facility with the regular OSP operations, the following policies and procedures were developed and implemented, regulating operations at the Brown Grease Recovery Facility:

- Procedures for permitting and managing grease trap waste haulers;
- Standard operations and maintenance procedures;
- Health and safety procedures for minor and major spillage;
- Spill Prevention Control and Countermeasures Plan (SPCC);
- Staffing plan;
- Digester Transfer procedures; and
- Testing and sampling plan.

The intent of the Brown Grease Recovery Facility design was to include remote access and controls that would be integrated into the OSP Operation Central Control (Central). This integration would have had the added advantage of allowing the manufacturer to remotely view, operate, and calibrate the Brown Grease Recovery Facility. However, this integration plan was abandoned due to security concerns related to potential access of critical OSP operations by unauthorized outside contractors. Therefore, the final design included only localized access and control at the Brown Grease Recovery Facility.

2.1.5 Construction

A general construction contract was issued for the site modifications prior to installation of the Brown Grease Recovery Facility. That contract was subsequently extended to also include Brown Grease Recovery Facility installation, testing, and startup. Originally, the Brown Grease Recovery Facility was intended to be erected adjacent to the biodiesel production facility. However, SFPUC staff indicated that locating the Brown Grease Recovery and Biodiesel Production facilities too close to one another would create a negative visual impact. Therefore, the final location of the Brown Grease Recovery Facility was moved approximately 250 feet to the West, which required re-design of the site modifications and interconnecting piping. Part of these site modifications still had to be implemented after on-site arrival of the equipment, which delayed the installation of the facility by several months.

During the second half of 2009, the selected Brown Grease Recovery Facility was dismantled into major components at its original location, shipped to San Francisco on open-rig tractor-trailers, and received on site in November 2009. Once on site, the Brown Grease Recovery Facility was unloaded, installed, and connected to the site facilities. Installation was complete by mid December 2009 and the unit was prepared for startup testing, while awaiting finalization of the site modifications.

2.2 Facility Permitting

The primary goal of the permitting efforts for the Brown Grease Recovery Facility was to ensure that the operation of these new facilities would fit within the existing regulatory framework and not impact plant operations from a public nuisance standpoint. Nuisance could be generally described as spills, odor emissions, and excess traffic. The secondary goal was to identify a fair and open process for permitting grease trap waste haulers that also protects the city's WWTP facilities, which is considered a key outcome for this project.

2.2.1 Permitting Considerations

One of the key advantages of co-locating grease recovery facilities with a WWTP is that WWTPs are heavily regulated and have permits, policies, and procedures in place to address most of the additional regulatory issues associated with new grease recovery facilities. The brown grease recovery facilities represent a physical treatment process, very similar to other processes typically employed at WWTPs. For example, OSP's primary treatment facilities employ settling and decanting processes that parallel the core function of the brown grease recovery facilities installed. As such, additional permitting requirements for the recovery facilities themselves were fairly minimal, and the main compliance effort consisted of preparation of a site-specific SPCC. Instead, the permitting focus at this facility was on the grease trap waste haulers entering the facility.

2.2.2 Environmental Permitting

Following the federal passage of the National Environmental Policy Act in 1969, the California legislature passed the California Environmental Quality Act (CEQA) (Public Resources Code 21000-21177 Statutes of 1970) to supplement NEPA through state law. CEQA applies when state or public agencies undertake a project that may cause a direct or foreseeable indirect change in the environment. The basic purpose of CEQA is to inform government decision makers and the public about potential environmental impacts of a proposed project and to identify ways that such impacts can be avoided or reduced. Thus, an agency must, at a minimum, provide an initial review of the project and its potential environmental effects. The analysis of a project required by CEQA usually takes the form of an Environmental Impact Report, Environmental Impact Statement, or Initial Study, which then results in a (Mitigated) Negative Declaration, Categorical Exemption (CatEx) or Environmental Assessment.

This demonstration project involved installation and operation of a temporary processing facility to investigate the feasibility of reducing energy consumption at the OSP while determining beneficial uses for grease removed from grease traps and interceptors. The temporary nature of this project, along with the location within an existing treatment plant, led SFPUC staff to pursue a CatEx under CEQA. Categorical exemptions are descriptions of types of projects which the Secretary of the Resources Agency has determined do not usually have a significant effect on the environment, per Article 19 of the CEQA Guidelines (Section 15300.2).

The OSP is located on Assessor's Block 7281, Lot 007 within a Public Use zoning district and an Open Space height and bulk district. The demonstration project does not expand the wastewater treatment capacity of the OSP. The skid-mounted demonstration facility measures approximately 60 feet long by 8 feet wide and has been placed inside the OSP on a paved area near the existing anaerobic digesters. The project did not involve excavation, demolition or removal of any trees. The demonstration plant includes both a Brown Grease Recovery Facility and a Biodiesel Production Facility.

The Brown Grease Recovery Facility includes: eight 4,500gallon receiving and settling tanks, two trap waste receiving screens, one hot water circulation system, a moisture content polishing system, and ancillary pumps, piping, controls, instrumentation, electrical, structural, and access elements.

CEQA State Guidelines Section *15306,* or Class 6, provides an exemption from environmental review for basic data collection, research, experimental management, and resource evaluation activities which do not result in a serious or major disturbance to an environmental resource. This project was determined to be exempt from environmental review under Class 6, because the project purpose was considered information collection.

If the results of this investigation confirm the desirability of construction of a permanent facility, a permanent facility could be subject to a subsequent full environmental evaluation process. This full process can take anywhere from several months to several years to complete, depending upon the determined environmental impacts.

2.2.3 Spill Prevention, Control, and Countermeasure (SPCC) Plan

Part 112 of 40 CFR outlines the requirements for both the prevention of and the response to oil spills. The prevention aspect of the rule requires preparation and implementation of SPCC Plans. These regulations establish spill prevention procedures, methods, and equipment requirements for non-transportation-related onshore and offshore facilities with combined aboveground oil storage capacity greater than 1,320 gallons (or greater than 660 gallons in a single container), or completely buried oil storage capacity greater than 42,000 gallons. Regulated facilities are limited to those that, because of their location, could reasonably be expected to discharge oil in harmful quantities into the navigable waters of the United States or adjoining shorelines. As such this rule applies to the brown grease recovery process, even though core wastewater operations are exempt from 40 CFR 112.

The SFPUC was notified of the need for an SPCC plan by its consultant in Fall 2010. A SPCC plan for the OSP location was completed by March 2011 and certified by a California-licensed engineer. That plan covered all oil storage at the OSP, including the brown grease recovery unit. The necessary secondary containment for the stored oil is being provided by sub-surface stormwater collection basins, in combination with the grading and pavement of the areas surrounding the brown grease recovery skid. Calculations showed that a catastrophic spill following the worst 24hour 25year storm event would still be fully contained within the OSP. Several of the additional spill prevention measures detailed in the Plan were implemented prior to plan finalization, in an effort to proactively reduce the risks and consequences of a potential oil spill. SPCC Plans are not part of the public domain. Therefore, reference is made to a SPCC Plan template (U.S. EPA 2010) available through U.S. EPA's web site (http://www.epa.gov/oem/content/spcc/tier1temp.htm).

2.2.4 Permitting Haulers

To regulate the haulers bringing trap waste into OSP, the SFPUC created a process modeled after an existing program – the trucked waste program. This program is managed by the Collection System Division, who issues permits to haulers and sets fees based on water quality criteria. The new permitting process sought to ensure that all haulers entering OSP abided by specific best management practices and set fees that could cover known costs.

For the initial startup and testing of the brown grease recovery system, the SFPUC made arrangements with two private haulers to deliver grease, free of charge, to the OSP. This was considered a preliminary phase for grease receiving, as the research team debugged the system and made operational improvements. Through successive changes to the grease receiving station and the recovery system, the team was able to improve the unloading time from an average of two hours to approximately twenty minutes. Once routine procedures had been established and operation of the system became routine, the team made the decision to open up a permitting process that would allow a wider variety of waste haulers into the OSP and would charge a tip fee for the waste received.

Permit conditions were established based upon the SFPUC's existing trucked waste program, as well as other best management practices, such as those imposed on the SFPUC's biosolids hauler. These conditions included the following: possession of appropriate licenses for grease hauling with the California Department of Food and Agriculture (CDFA); possession of proper DOT tank endorsements for each driver; ability to provide manifests demonstrating that the trap waste came from the nine-county Bay Area; adequate health and safety training for all drivers (including spill control); a minimum tank capacity of 800 gallons (established to minimize truck traffic to the OSP); proof that the firm was not in violation of local, state or federal laws; and possession/maintenance of pollution liability insurance. The intent was that grease haulers entering the OSP would comply with all regulations, allow for appropriate truck sampling, be liable for any spills or other accidents and generally be a good partner to the SFPUC during the course of this project. In addition to the permit conditions, a tipping fee of $0.05 per gallon was established, based upon the best available cost recovery data. Finally, the decision was made to issue the permits on a first come, first serve basis. The facility at OSP had, at the time, a daily processing capacity of approximately 10,000 gallons and was receiving waste grease from two haulers, each delivering a 5,000- to 6,000gallon load per day. The team became aware, however, that several smaller grease haulers might be interested in the program. To create discharge opportunities for as many grease haulers as possible, haulers would be permitted in the order in which their completed packages were received; the first hauler permitted would be given the right of first refusal to discharge on any given day, followed by the second hauler permitted and so on.

A packet of information, including an introductory letter, an application, and required permit conditions was developed and mailed out by SFPUC to all waste grease haulers listed on the CalFOG website (www.calfog.org) as operating in San Francisco County. Three waste haulers submitted complete packages within the first two weeks following solicitation. A protocol was established whereby trap waste deliveries for the following week would be scheduled every Friday.

An additional complicating factor in permitting trap waste receiving stations is that the CDFA oversees activities involved in hauling and rendering FOG, since waste FOG has historically been sent by renderers to farms and dairies as feed. WWTPs and the CDFA are currently (2012) in discussion to avoid duplicate oversight on this front. Specifically, the approach that WWTPs should not be considered renderers if they receive FOG or food waste because they keep and process FOG on site through their digesters, as opposed to rendering the material and selling it to farms. That reasoning does not apply to WWTPs who would embark on a FOG to Biodiesel project, since portions of the FOG would not be kept on site but instead would either be converted to Brown Grease and sold to biodiesel manufacturers (also regulated by the CDFA) or converted to biodiesel and used in fleets. In both cases, the material does not stay on site and associated activities therefore would not be regulated under the WWTP's NPDES permit. Therefore it appears likely that the CDFA would want to permit and oversee activities associated in developing and selling biodiesel feedstock as well as biodiesel production. (SFPUC 2012)

2.3 Encountered Implementation Issues

In this subsection, issues are documented which were encountered during the brown grease recovery implementation phase of the demonstration project. Those issues were related to trap waste solids, odors, and whitewater handling.

2.3.1 Screenings Management

The original design of the Brown Grease Recovery Facility included a screening hopper located on one of the skid's elevated platforms. The initial plan was to accumulate the screenings in that hopper awaiting periodical transfers into an on-site dumpster for off-site disposal. This solution was found to be challenging because a single truck load of trap waste would contain enough solids to block the screen in the hopper.

During the initial phases of the demonstration project, this issue was addressed by manually clearing the screens during the unloading, utilizing shovels. A chute was installed adjacent to the hopper platform to guide the separated solids into two 96gallon containers at ground level. The screenings were subsequently collected and disposed of by the local waste management company.

This process was inconvenient for skid operators, while direct contact with trap waste posed an avoidable health risk. In addition, this screen removed a significant portion of the trucks loads' grease content, often present as a solid. Therefore, the screening process was re-designed to be a pressurized, heated process.

2.3.2 Odor Issues

Odors generated by the Brown Grease Recovery Facility have been a major concern during the start-up. A discussion of odor sources and mitigation is presented below.

2.3.2.1 Whitewater Receiving Sump

Since OSP is a fully contained facility, the initial plan was to discharge hot whitewater (~150°F) into a nearby storm drain, which drains into a sub-surface sump. From that sump, the whitewater would be pumped to the plant headworks. This strategy was selected because it would provide equalization and avoid potential unknown, negative effects of whitewater discharges on the performance of the site's anaerobic digesters. However, that particular drain and sump are located in the immediate vicinity of the OSP maintenance shop. During the first whitewater transfer, vapor rising from the sump generated an unbearable odor in the maintenance shop and the plant canyon.

Therefore, the project team investigated the possibility of sealing the sump, which proved impractical. Alternatively, adding an oxidant such as sodium hypochlorite to the whitewater was considered, but rejected for safety reasons. Finally, the team decided to assess a different whitewater disposal route, consisting of injection into the anaerobic sludge digesters via the digester feed tank. . To that effect, pilot tests were performed to determine that grease trap waste and whitewater discharges to the anaerobic digesters would have no adverse effects on the digestion process. Additionally, this solution utilized already installed piping intended for disposal of more concentrated wastes from the Brown Grease Recovery Facility.

This alternate disposal route proved to be a much better solution because it eliminated the odor issue at the shop and it provided the plant with the potential to generate additional biogas. Additionally, inspection of that unheated, unmixed sump following the first transfers of whitewater and surface cleaning wash water to the headworks, revealed that grease and solids did separate out in that sump and would have eventually filled-up the sump or clogged its drain lines, which was for the most part eliminated by the alternate disposal route.

After implementation of this process change, the digester feed tank was found to have a less than perfect seal, resulting in increased odor levels in the vicinity of its manhole. A temporary solution was implemented, awaiting replacement of that lid with a hermetically sealing type lid.

2.3.2.2 Process Tanks Lids

Pungent vapors were noted to be seeping out of the process tank lids during truck unloading and during internal tank-to-tank liquid transfers. This issue was addressed by replacing missing or incompatible neoprene lid gaskets with nitrile ones and by interconnecting the tank head spaces.

2.3.2.3 Process Tanks Automatic Pressure Release Valves

Each tank is equipped with a pressure release valve set to vent off at a pressure of 1 psi. Pungent vapors were intermittently emitted during liquid transfers. This type of vapor was primarily generated in the interface tank where the hot whitewater accumulated before being pumped to the digester feed tank. This odor issue was addressed by interconnecting the head spaces of the tanks, and venting any excess vapors through an activated carbon filter (Carbtrol-brand, 60gallon canister). To date, vessel interconnection in combination with the carbon unit has provided sufficient odor abatement. The stand time of the carbon drum exceeded 4 months during the demonstration project.

2.3.2.4 Truck Unloading

Besides the issues mentioned above, odors were emitted during trap waste screening. As described in earlier, the trap waste discharged by the hauling trucks used to be screened in a process open to the atmosphere. This issue has been addressed by installing a different screening process, which is not open to the atmosphere. However, odors continue to be an issue during servicing/cleaning of the screens.

2.3.3 Impact of Whitewater Injection on Digester Foaming

The OSP has been experiencing seasonal anaerobic digester foaming since plant start-up in 1993. Although digester foaming has significantly decreased since the addition and the optimization of an anaerobic selection process in the secondary treatment system, seasonal foaming events persisted. OSP Digester foaming is directly related to the amount of Gordonia spp (filamentous bacteria) present in the system. Because of an unusually high number of plant shut downs during the summer of 2010, sludge retention times increased, allowing for higher filamentous growth rates, resulting in Gordonia spp concentrations in the mixed-liquor volatile suspended solids to exceed 10^6 intersections per milligram. That concentration has been determined the threshold for anaerobic digester foaming.

Whitewater was first injected in the digesters starting on November 3, 2010, at an initial daily dose of approximately 9,000 gallons, injected within one hour (from Monday to Friday). Shortly thereafter, Operations staff began raising some concerns about the potential impact of the additional whitewater load on the digester process for reasons of a perceived increase in foaming since the inception of whitewater introductions.

Although plant personnel initially concluded that the Brown Grease Recovery Facility waste streams exacerbated digester foaming, this was not borne out during the initial demonstration period December 2010 – May 2011 nor in the months when the filtered trap waste was delivered directly to the digesters. Process control to prevent the accumulation of Gordonia spp, early detection of foam recycle, and experimentation with digester mixing modes has minimized nuisance foaming events. This demonstration project has documented that the Brown Grease Recovery Facility streams did not enhance or sustain digester foaming at OSP.

2.3.4 Sampling

Obtaining representative samples is a critical operation to ensure that the data collected during the study can be used to assess the process performance. A brief discussion on sampling from various locations is presented below.

2.3.4.1 Sampling of Trap Waste

The common industry practice for sampling trap waste consists of collecting a composite sample directly from the truck. This sample is composited of three equal volumes originating from the bottom, the middle and the top of the trap waste column, in an attempt to correct for stratification. The SFPUC Health and Safety Program staff did not recommend this practice because it involves staff accessing the tops of tanker trucks. Furthermore, because truck trailers are generally compartmentalized and stratification takes place in the trailers, it is unlikely that a sample collected from one such compartment be representative of the entire load. In addition, it was impossible to determine the depth of each layer, thereby making it difficult to assign a weight factor to each of the three grab samples.

To satisfy the need for representative trap waste sampling, another methodology was investigated: sampling the trap waste receiving tanks following a mixing period. This subsection provides details on and results from this investigation.

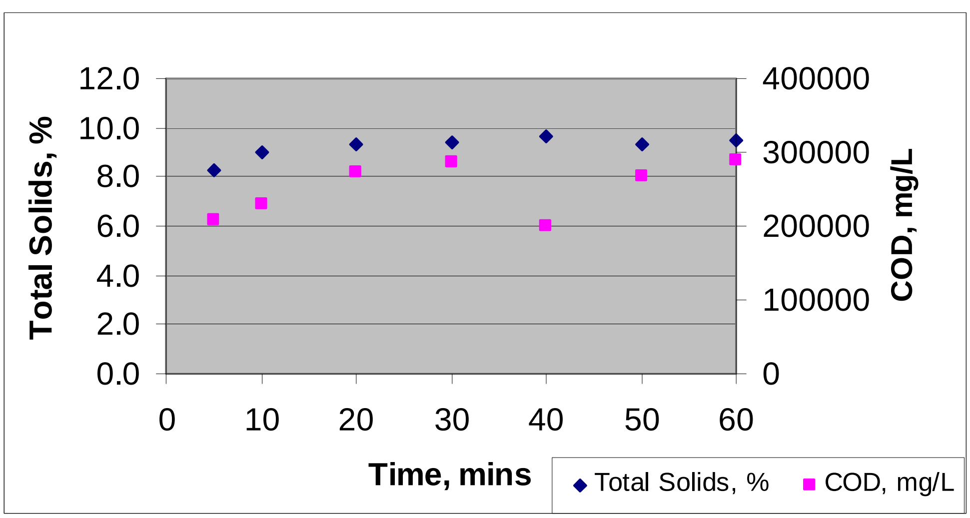
Each process tank in the Brown Grease Recovery Facility, including the three trap waste receiving tanks, is equipped with a pitched-blade mixer capable of running at a speed of 24 rpm (Figure 3). Utilizing those mixers, a receiving tank full of trap waste was mixed for up to an hour, while samples were collected from a sampling spigot near the lower tank tangent line at 5 and 10 minutes from start of the mixing, and each 10 minutes thereafter. Those samples were analyzed for their solids and COD content. The results are shown in Figure 4 which shows that after 10 minutes of mixing, measured values for solids and COD content began to stabilize.

Given that mixing is the opposite of what the facility intends to accomplish (such as, separation and decanting), and because prolonged mixing times have the potential to emulsify the grease content of the trap waste, it was imperative to identify the shortest mixing time possible. Based on the test results, and the previously stated need to minimize mixing duration, it was determined that for the purpose of preparing a mass balance, a 5-minute mixing time would suffice. Therefore, the grease content of incoming trap waste was determined from a composite of three samples, equal in volume, each one collected from one of the receiving tanks following a 5-minute mixing period.

Utilizing the results from this sampling method, mass balance calculations were performed for the complete brown grease recovery process. Those calculations then indicated that the sum of the grease mass flows in whitewater, interface, and brown grease streams leaving the facility exceeded the incoming grease mass flow by approximately 10 percent. Based on those results, an alternative sampling method was attempted, consisting of compositing grab samples collected from the incoming trap waste at 400 gallon intervals. Unfortunately, the composite sampling method yielded grease mass results that were even lower than those based on the mixed tank samples (80 to 90 percent lower). Therefore, the project team decided going forward to use mixed-tank trap waste sampling with a 10 percent correction.

Figure 3 : View of Mixers Used in Process Tanks

Figure 4 : Trap Waste Consistency after 1 Hour of Mixing



2.3.5 Sampling of Whitewater and Interface Layer

Following decanting, both the whitewater and interface layers are transferred to a common buffer tank before being discharged to the digesters. That buffer tank is filled with the whitewater and interface layer from one specific process tank at a time, while being mixed continuously. This provides the option to collect a sample from each specific process tank. At this stage, the grease content of this mixture is significantly less than from the unprocessed trap waste batches. Furthermore, the mixture temperatures are elevated (>150°F), resulting in a greatly reduced grease viscosity. Both factors have a positive effect on the homogenizability of the mixture and representative samples were obtained after only 5 minutes of mixing.

Sampling of whitewater and interface layer provided insight regarding the decanting process efficiency. The samples originating from the three receiving tanks were combined into a single composite sample, which was then blended before being analyzed.

2.3.6 Summary of Start-up Issues

Significant modifications had to be made to the Brown Grease Recovery Facility during the initial stages of the demonstration period to address a series of issues related to high odor emission, labor-intensive screening process, time intensive fluid transfers, high volumes of wet screenings, frequent clogging of tank discharge piping, difficulties to pump the entire volume of the trailer and non-representative sampling methods. Various implemented modifications and their benefit to the overall process are presented in Table 2. The modifications resulted in a significant reduction of odor nuisance, a significant reduction in labor required to operate the facility, and a higher grease recovery.

Table 2 : Modifications Made to the Brown Grease Recovery System

Issue	Process Modification	Benefits
High level of odor coming out of the process tank during transfers	Built a manifold connecting all tank vents to a gas scrubber	No serious odor complaints from plant operations since the implementation
Labor-intensive screening process	Abandoned original screening process and built an enclosed filter equipped with heated jacket.	Reduced unloading time from 1 to 2 hours to 20 to 40 minutes. Significantly reduce operator's exposure to trap waste and odor.
High volume of wet screenings	Abandoned original screening process and built an enclosed filter equipped with a heated jacket.	Reduced screening volume from about 100 gallons per day to less than 100 gallons per week. Increased grease

		recovery.
Frequent clogging of tank discharge piping and time consuming trouble- shooting	Installed hot water injection points (~150◎F/80 psi) in the transfer pipes. Use water to flush the pipes and unclog the lines.	Reduced time needed to unclog the lines to about 5 minutes.
Difficulties to pump the entire volume of trap waste out of the trailer during unloads	Implemented a piping system to pump hot whitewater (~150◎F) back into the trailer.	Increased overall grease recovery.
Non-representative trap waste sampling method	Conducted a comparative study with a more robust and time consuming sampling method and determined a correction factor for the routine sampling method.	Improved Mass Balance.

2.4 Demonstration Test Program

This section reviews and discusses the performance of the Brown Grease Recovery Facility demonstration period from the start up on December 1, 2010 through May 31, 2011. To evaluate said performance, data on operation and maintenance of the brown grease recovery system were collected. Those data were also used in the determination of overall process efficiency (such as, brown grease recovery), calibration of life cycle cost analysis/energy balance models, and can be used in development of a scaled-up design. The data collection was conducted based on the requirement set forth in the performance certification test plan.

2.4.1 Issues Observed During the Test Program

The intent of the brown grease recovery demonstration period was to operate and evaluate the facility for a 6month period. The demonstration test program was extended by an additional 6 to better determine project impacts on the production of digester gas.

The facility was monitored to verify the manufacturer's claims of being able to produce 300 gallons brown grease daily with an MIU content of less than 2 percent. The skid was also monitored for reliability and robustness of the equipment. During this same period the facility was also evaluated for general operational issues. Those issues that seemed to be of high importance and/or were threatening the project as a whole were corrected, which included severe odor emissions as well those causing labor-intensive and non-ergonomical operation. These corrections resulted in a greatly improved Brown Grease Recovery Facility. An overview of the encountered and resolved issues is presented below.

2.4.1.1 Logistical Issues

Largely because of the inconvenience of the location of the OSP relative to major freeways, lack of automatic receiving, and the limited hours of manned receiving, the program was initially not successful in securing the 10,000 gallons of daily trap waste supply needed for operation at full capacity.

Hours of availability is an important criterion to consider when operating a trap waste receiving station, because the haulers service restaurants during the night and prefer to drop off their load(s) in the early morning hours. Initially, the earliest available drop-off time was 8 AM, which was unacceptable for the majority of the local haulers. However, due to a highly unionized OSP work environment, it was not possible to modify that time during the 6-month demonstration period. Later in 2011, SFPUC was successful in shifting the OSP operator work hours. This resulted in an earliest drop-off time of 6 AM, which yielded greater success in terms of total trap waste volume received. This earlier drop-off time still proved to be a competitive disadvantage relative to competing installations across the San Francisco Bay, which tend to have 24-hrs per day receiving capacity. To offset this disadvantage, OSP had to lower its tipping fee.

Receiving 6,000 gallons of trap waste at the demonstration facility required between 20 and 60 minutes, between connecting the hoses, unloading and disconnecting the hoses, independent of OSP operator efficiency. Just fluid transfer required on the order of 20 minutes because of the limitations of the pumping speed, pipeline configuration, and filter screen size. However, screening and transfer of solids-rich trap waste could take as long as 60 minutes per 6,000-gallon truck. If a truck did not unload after 60 minutes of pumping, the trap waste hauler was turned away because 1) the majority of the volume of trap waste had been unloaded; or 2) the remaining trap waste quality and/or consistence were incompatible with the system.

2.4.1.2 Automation

The lack of automatic operation resulted in time consuming manual controls for receiving and processing.

Transferring approximately 6,000 gallons between tanks for processing and to the digester day tank for disposal required the operator to monitor the levels and control the sequences of tanks, valving and pumps for two to four hours. This time depended on operator efficiency and absence of additional complications (for example grease and debris clogs, mechanical failures, and so forth). A typical grease clog would require an additional 20 to 40 minutes on average to locate the source of the clog and to unclog the system.

The lack of automation in general made operation of the system time consuming and required specially trained and dedicated operators and well written, easy to follow standard operating procedure (SOPs). Almost a complete 8hour operator shift was required to process and transfer the fluids in the Brown Grease Recovery Facility, receive up to three 6,000gallon trap waste loads, perform general site cleanup after receiving, and complete daily paperwork. Some efficiency and time saving could be achieved by simultaneously performing process transfers and receiving. However due to the relative complex nature of the piping systems, multi-tasking bears a potential risk of error, which could result in contamination of a significant amount of finished brown grease product or digester upset. Therefore it was determined that during the test period, each procedure was to be completed in its entirety before moving on to the next procedure. Even with these procedures in place, at some point the brown grease finished product tank was found to be almost half full of whitewater. An increased level of automation would most likely have avoided this contamination and in general have accelerated the operations.

2.4.1.3 System Heating

Heat was provided to the Brown Grease Recovery Facility through a closed heating loop, which received its heat from a branch of the OSP heating ventilation and air conditioning (HVAC) closed heating loop. Heat between those two systems is transferred in a plate heat exchanger located adjacent to the test facility. Although there are some system heat losses, the temperature available for heating at the skid is close to the temperature of the HVAC loop temperature. However, the HVAC system temperature can vary significantly during the day, depending on plant management's preference for controlling the on-site boilers both in automatic or manual control modes, and their preferred ranges of operating temperatures. The temperature provided at the facility averaged approximately 150◎F during the test period, with a high of 190◎F and a low of 90◎F. Without proper heat supply, the brown grease recovery could not be optimized.

Two attempts were made to provide more heat at the required temperature to optimize facility performance. The first attempt consisted of an increase of the temperature setting at the boiler, which would have resulted in a subsequent temperature increase in the HVAC loop. This showed improvements in the brown grease recovery. However, operations did not maintain the boiler temperature setting at this elevated level for fear it would disrupt control of their HVAC systems or compromise the conditions of the aging boiler.

A second attempt to increase the system's heat input targeted an increase of the hot water flow rate in the HVAC loop available for heating of the Brown Grease Recovery Facility. Reviews of OSP facility plans, equipment specifications and field inspections indicated that the HVAC heating loop should be capable of providing sufficient volumes of hot water to the Facility, Unfortunately, field observations of hot water volumes did not match the design capacity. The reason for lack of flow could not be verified due to limited access to that system. On the days where adequate temperatures were achieved, brown grease recovery was between 20 to 50 percent of the available FOG content. By contrast, the brown grease recovery was approximately 4 percent when the temperatures were not maintained at the required levels. Therefore, availability of heat at the proper temperature is a critical factor for the design and operation of a full-scale or replication facility.

Phase Detection Sensors

PBTech developed a proprietary combination of sensors, which were designed to detect interfaces between the grit, the whitewater, the interface and the oil layers. The signal of this sensor combination was then compared to values provided by PBTech to discriminate between the different layers.

The sensor output was evaluated by comparison to visual observation of the color and consistency of the stream going through an inline sight glass located upstream of the transfer pump. During the demonstration period, the visual observations of the stream indicate that the sensors were providing relatively reliable information on the transition between whitewater and interface layers and the transition between interface and free oil.

During the demonstration period, the sensors required no maintenance or calibration. Operation at elevated temperatures appears to contribute to keeping the sensors from fouling

2.4.1.4 Guided Wave Radar Level Sensors

Guided wave radar level instruments use reflections of a radar signal on a liquid surface to detect the position of that surface relative to the sensor. This technology includes a wave guide cable installed inside the process vessel, parallel to the vertical vessel wall.

PBTech had selected guided-wave radar level sensors for the vessels because this technology is a non-contact, direct level measurement based on the distance between the sensor and the liquid surface, and would therefore be unaffected by fluid properties such as density and viscosity. This technology is also relatively insensitive to changes in temperature, pressure and composition of the vapor phase above the liquid.

During the demonstration period, the functioning of the installed sensors was periodically evaluated by visually comparing the liquid levels in the tanks to the instrument readings, and by cross-comparing measured volume drops in one tank to measured volume gains in the other tank during liquid transfers. Based on those observations, the guided wave radar level sensors appear to be are an accurate method of in-tank level measurement of clean fluids.

However, two issues were noted during the demonstration period, which were both related to the wave guide cable. First, since the cable is mounted parallel to the vertical portion of the tank wall. Therefore, the sensor cannot measure the volume present in the conical tank bottom. Consequently, the sensor setups each had a blind volume of 230 gallons before registering any volume. This created difficulties towards the end of a decanting step in the primary separation tank, when attempting to measure remaining interface and/or oil volumes, which are often less than 230 gallons. Second, level readings were affected by the frequent accumulation of rags and strings on the cable. Removal of these accumulations using a water jet or other mechanical action was not very successful. As a result, the operator was instructed to confirm tank levels visually in an attempt to make sense of the data shown on the control panel.

Based on the issues identified above, it was determined that the selected level detection technology was unreliable, and made fully automated operation difficult. A different in-tank level measurement technique, such as ultrasonic sensing should be selected for this application.

2.4.1.5 Reliability of the Transfer Pumps

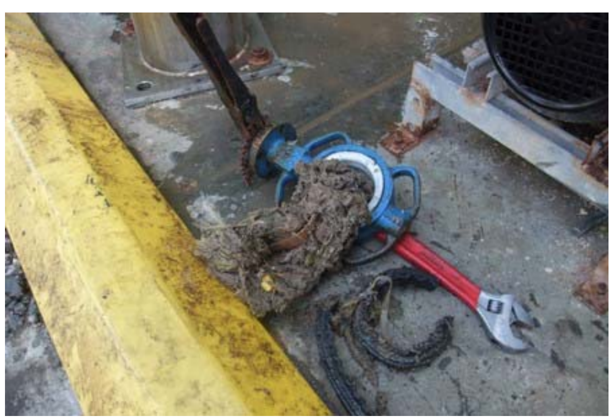
PBTech installed trash pumps of the model AMT 394A-95 CI to transfer fluids between the different process tanks and AMT 393A-95 CI for transfers from the brown grease recovery installation to the digester feed tank. Although the pumps have a reputation to be inexpensive, robust, and forgiving, a considerable amount of rocks and rags passing through the screens caused several pump failures during the demonstration period. The rocks tended to damage the pump seals, impellers and volute. The rags had a tendency to wrap around the impeller and create resistance to rotation, which caused the pumps' motor controllers to trip. As a result, each of the skid's pumps had to be rebuilt at least twice between December 2010 and May 2011 (Figure 5). When designing a full-scale or replication facility, selection of a different pump type is recommended.

Figure 5 : Material Removed During Rebuilding of Transfer Pump

2.4.1.6 Inappropriate Use of Butterfly Valve

All valves on the facility were butterfly valves. As shown in Figure 6, the valve disc had a tendency to get clogged with rags and other debris from trap waste. Operation had to be interrupted twice during the demonstration period to remove material wrapped around the valve discs. SOPs to prevent grease clogs were prepared but did not fully prevent periodic clogging. System clogging due to tangled strings or other debris required time to resolve, sometimes resulting in delivery cancellation calls to haulers.

Figure 6 : Clogging of Butterfly Valves with Rags



2.4.1.7 Nuisance to Plant Operations and Personnel

The OSP's original layout was not designed to accommodate the installation of a brown grease recovery facility. Its layout specifically includes a canyon between the semi in-ground process installations and operations building and therefore, some issues related to operation of such a grease recovery facility are more obvious in this configuration than for a facility with ample space and a more open layout. However, through this demonstration project, valuable lessons were learned that would benefit any replication project aimed at collocation of a brown grease recovery facility in a WWTP. The major nuisance issues are as follows:

- Odor - One major nuisance to plant operations was the initial emission of odorous vapors from the demonstration unit. Installation of vent lines interconnecting the vessels' head spaces and a carbon vessel to treat excess vapors did reduce the majority of the odor nuisance. The remaining odors are mainly generated during truck unloading events, when vapors are released from the truck's tank.
- Increases in truck traffic - Arrival of about 3 trucks daily was perceived by some staff as a nuisance.
- Staining of pavement - Staining of the asphalt pavement from leaked truck's hydraulic fluids as well as by tank volume spillage has been observed, which may cause a slip hazard over time. Addition of a sloped concrete pad with drain should solve these issues.
- Spills – When disconnecting truck unloading hoses, a certain amount of spillage is unavoidable. Trap waste unloading areas should therefore be designed to include gutters and be washed down with a pressure washer periodically.

2.4.1.8 Automatic Operation

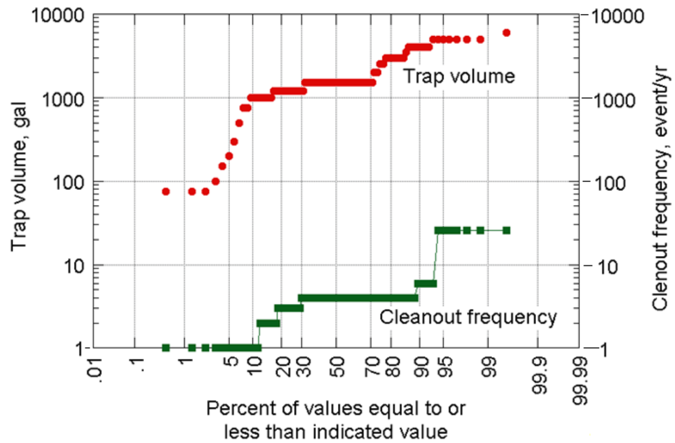
As discussed above, Operations did not allow installation of a fully automated system for security reasons. However, having an automated system is the key to improve monitoring and control of the unit. To mitigate the security concerns while facilitating remote control, the vendor's remote access to the current PLC was disabled and replaced with a connection to the OSP SCADA system.

2.4.2 Trap Waste Assessment

2.4.2.1 Trap Waste Generation and Hauling

Trap waste was delivered to the Brown Grease Recovery Facility on a regular basis during the test program. Data were collected from trap waste haulers to determine the source of the trap waste, the size of the tank, and the cleanout frequency. A summary of the restaurants' on-site grease trap volumes and cleanout frequencies is shown in Figure 7. As shown, serviced grease trap volumes ranged from 75 to 6,000 gallons; however, 60 percent of grease traps ranged in volume from 1,000 to 1,500 gallons. It should also be noted that the serviced grease traps were typically cleaned 2 to 4 times annually.

Figure 7 : Summary of Grease Trap Volume and Cleanout Frequency



2.4.2.2 Trap Waste Loading

The daily delivery volumes of trap waste over the demonstration project timeframe, as well as the oil and grease and COD content are summarized in Figure 8. The average delivery volume was on the order of 5,800 gallons daily, while the average loading of oil and grease and COD were 1,700 and 5,900 lbs/day, respectively. Trap waste deliveries have proven to depend on tipping fees and regional market mechanisms. After the demonstration project timeframe, deliveries as high as 26,000 gallons daily have occurred. Figure 9 shows a summary of the grease content in the incoming trap waste.

2.4.2.3 Trap Waste Characteristics

The trap waste was found to have a grease content that ranged from about 1 percent to 25 percent, with a weighted mean of 4.67 percent. However, numerous issues were identified with the analytical methods used for oil and grease determination.

Figure 8 : Summary of Trap Waste, COD, and Oil and Grease Input to the Brown Grease Recovery Process

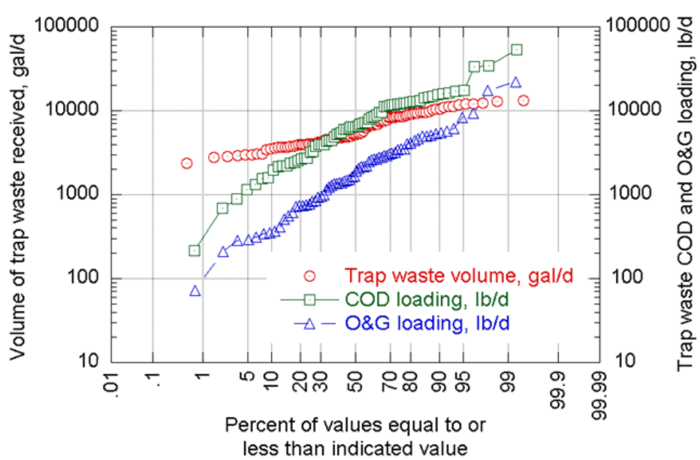
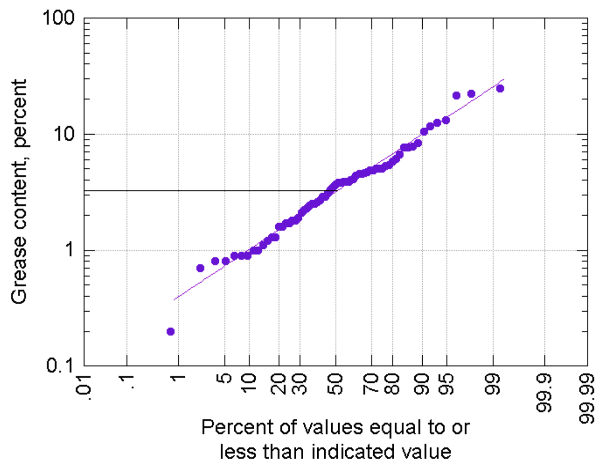


Figure 9 : Summary of Incoming Trap Waste Percent Grease Content



As described previously, trap waste was received on a regular basis. However, because of factors related to conflicts with operational hours and hauler preference, the design loading of 10,000 gallons per day was not achieved. A monthly summary of the operational characteristics and constituents in the first six months of received trap waste are presented in Table3**.**

Table 3 : Summary of Trap Waste as Received Data

Parameter	Unit	Month					
		Jan	Feb	Mar	Apr	May	Jun
Operational time	d	18	11	20	12	13	16
Trap waste volume	1,000 gal	135.4	74.5	121	49.2	54.5	71.6
Screenings volume	gal	ND	80	80	80	80	80
Number of samples		12	8	14	10	12	13
Trap waste oil and grease concentration							
Average	percent	6.64	4.15	5.79	5.05	4.38	3.89
Minimum	percent	2.14	1.76	1.34	0.99	0.99	0.22
Maximum	percent	22. 5	8.3	21.2	11.6	9.9	24. 7
Trap waste total solid concentration							
Average	percent	8.7	5.15	6.88	7.35	6.75	5.68
Minimum	percent	4.01	2.24	1.02	1.45	1.5	0.37

Maximum	percent	22.4	9.71	26.4	16.8	16.9	35.3
Trap waste COD concentration							
Average	g/L	277.9	159.3	162.5	190.8	120.6	77.6
Minimum	g/L	115.3	58.5	38.8	32.8	44.5	6.5
Maximum	g/L	679.5	313.0	524.8	369.0	228.0	151.5

2.4.3 Brown Grease Recovery Process Assessment

The performance of the brown grease recovery process was assessed using a mass balance approach. The total input grease was compared to the grease that was discharge with the whitewater, interface, and brown grease product streams. Similarly, a monthly summary of interface characteristics is presented in Table 4. As shown in Figure 10 and Table 4, a significant amount of grease and COD was contained in both the whitewater and interface streams. High grease concentrations in these waste streams are problematic because it is indicative of low recovery. The causes of the low recovery include sensor interference, mechanical failures, and operational issues.

As shown in Table45, the total brown grease recovery during the first six months of operation varied between 21 and 54 percent. Studies are ongoing to determine if the recovery could be improved.

Table 4 : Summary of Whitewater Data from Brown Grease Recovery Process

Parameter	Unit	Month					
		Jan	Feb	Mar	Apr	May	Jun
Whitewater vol.	1000 gal	115.2	58.6	99.6	38.0	42.7	71.6
Number of samples		18	8	11	0	5	14
Whitewater oil and grease concentration							
Average	percent	2.29	1.39	2.25	ND	1.88	1.46
Minimum	percent	0.59	0.92	0.89	ND	0.25	0.22
Maximum	percent	11.67	2.9	3.88	ND	4.88	4.64
Whitewater total solid concentration							
Average	percent	3.23	3.62	2.26	ND	2.93	2.23
Minimum	percent	1.06	1.43	0.45	ND	0.43	0.38

Maximum	percent	12.9	8.74	4.38	ND	7.45	7.02
Whitewater COD concentration							
Average	g/L	98.2	94.9	77.9	ND	76.2	36.6
Minimum	g/L	24.0	42.1	23.3	ND	24.3	6.5
Maximum	g/L	301.8	248.1	222.3	ND	169.6	130.1

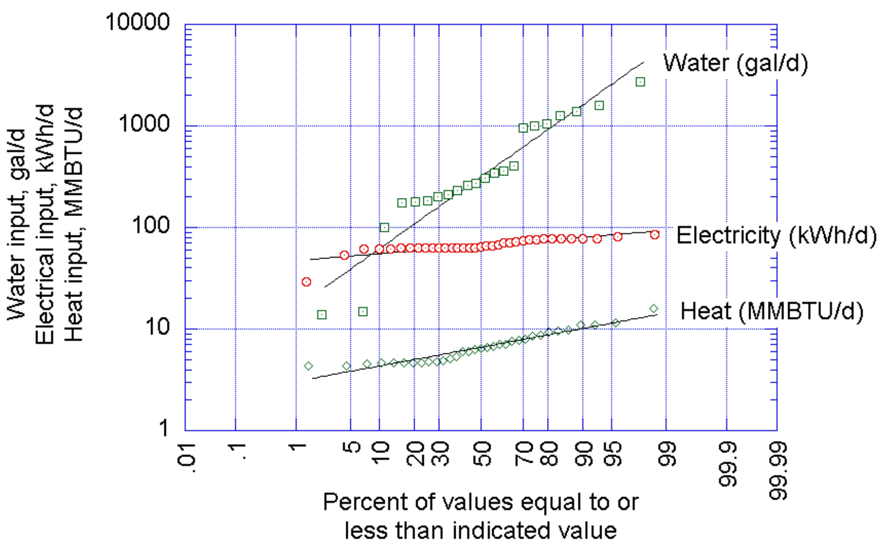
Energy use was tracked in terms of water consumption, electricity usage, and hot water usage (heat input) for the month of July 2011.. All data were determined to be geometrically distributed, with mean values for water, electricity, and heat of 320 gallons per day, 67 kWh/d, and 6.6 MMBTU/d. Converting electricity to heat energy results in a total energy consumption of 6.9 MMBTU/d. For the one month period, 74,000 gallons of trap waste with a grease content of 5.6 percent was processed. Of the 23,527 lb of influent grease, 7,681 lb of brown grease was recovered, for a total recovery rate of 33 percent.

Table 5 : Summary of Interface Data from Brown Grease Recovery Process

Parameter	Unit	Month					
		Jan	Feb	Mar	Apr	May	Jun
Interface produced	1,000 gal	14.3	15.2	20.5	6.8	8.7	7.8
Number of samples		11	4	8	0	4	6
Interface oil and grease concentration							
Average	percent	21.41	22.91	17.03	ND	8.16	11.32
Minimum	percent	8.79	16.69	0.64	ND	1.88	0.33
Maximum	percent	30.55	33.1	27.46	ND	13.72	26.72
Interface total solid concentration							
Average	percent	32.19	30.56	21.07	ND	12.37	18.8
Minimum	percent	15.5	19	0.86	ND	3.01	0.48
Maximum	percent	65.4	43.1	34	ND	21.78	53.67
Interface COD concentration							
Average	g/L	754.0	870.3	510.2	ND	227.2	181.4

Minimum	g/L	124.0	737.0	25.2	ND	97.0	12.2
Maximum	g/L	1,548.5	1,041.0	970.5	ND	486.3	474.0
Operational Data							
Brown grease loading	gal	8,991	3,092	7,006	2,485	2,387	2,785
Oil and grease in whitewater	gal	2,638	815	2,241	ND	803	1,045
Oil and grease in interface layer	gal	3,062	3,482	3,491	ND	710	883
Brown grease recovery	gal	1,900	ND	1,600	946	526	1,515
	percent vol.	21.1	ND	22.8	38.1	22.0	54.4

Figure 10: Summary of Energy Use for Month of July 2011



CHAPTER 3: Project Execution – Brown Grease To Biodiesel

This section documents and discusses the project implementation as it pertains to the Brown Grease Recovery Facility which was constructed and tested at SFPUC's OSP. It also presents a summary of data collected during the project demonstration period, which ran from December 2010 through May 2011 and was subsequently extended through December 2011.

3.1 Project Implementation

The goal of the Biodiesel Production Facility portion of the demonstration project was to evaluate the performance of technology designed to process up to 300 gallons per day of brown grease feedstock containing less than 2 percent MIU and produce up to 240 gallons per day of ASTM D6751-S15 grade biodiesel. The impacts on WWTP operations and the benefits of co-location of a Biodiesel Production Facility are also an important component of this portion of the demonstration project.

3.1.1 Design Requirements

Design requirements for selection of the Biodiesel Production Facility technology were developed based on the demonstration project goal. Those criteria were further based on estimates of trap waste generation in San Francisco, literature data biodiesel production processes, and site-specific conditions related to co-locating such a facility at a WWTP in San Francisco. These requirements were as follows:

- Demonstration facility shall be capable of processing up to 300 gallons per day of brown grease feedstock (containing <2 percent MIU) and produce up to 240 gallons per day of biodiesel;
- Biodiesel product shall meet ASTM D6751-S15 requirements;
- Factory-tested, modular equipment, for easy construction, start-up and expansion;
- Meet all local codes, including design for Seismic Zone 4;
- The conversion of the brown grease into biodiesel shall be fully automated;
- No additional personnel required to operate the facility;
- Capable of meeting the specifications while using available site utilities for heating;
- Equipment delivery by November 2009 (within 3 months of RFP publication); and
- Requiring minimal site modifications.

The siting criteria were as follows:

- Sufficient space for installation of the facility's equipment;
- Sufficient space for diesel tankers to load and park;

- Close proximity to existing utilities;
- Close proximity to Brown Grease Recovery Facility for brown grease transfer;
- Close proximate to anaerobic digesters for byproduct discharges;
- Minimal site modifications;
- Sufficient clearance for access, cleaning, maintenance, and so forth;
- Sufficient clearance from existing major utilities; and
- Sufficient clearance from existing traffic

Lastly, the following project construction schedule was prepared, to meet the various grant deadlines:

- August – October 2008: Technology research, vendor interview, and selection
- October 2008: Purchase order document preparation
- October 2008 - January 2009: SFPUC internal approvals and purchase order advertisement
- January 2009: Purchase order award
- January-November 2009: Equipment design, procurement and fabrication, and site modifications design and construction
- November 2009: Biodiesel Production Facility equipment delivery and installation

These requirements together formed the basis of design for the demonstration project, and were used to solicit bids from identified technology providers.

3.1.2 Facility Design

Upon selection as technology provider for the Demonstration Project, BlackGold Biofuels (BGB) had a skid-mounted biodiesel production plant designed to meet the needs of the project. The design of various components was prepared by a subconsultant design firm. Due to the inclusion of proprietary conversion process elements, BGB designed the skid layout to have storage tanks and control panels located on the front (driveway)-side and unit operations on the rear side. Larger auxiliary equipment that could not be placed on the rear side was placed inside a front-side enclosure. During the design process, it was agreed that all chemicals and by-product storage would be located off-skid and become part of the site design.

The components of the unit were assembled at the skid construction company and the skid was subsequently shipped to OSP on a regular flat-bed truck.

The Biodiesel Production Facility has a nameplate capacity to process up to 300 gallons per day of brown grease feedstock. The biodiesel production process is as follows:

The Reactor #1 system recovered brown grease, methanol and catalyst are fed to the reactor system, where the majority of the free fatty acids (FFAs) and glycerides within the grease are converted to fatty acid methyl esters (FAMEs). FAMEs, non-reacted FFAs, methanol, water, glycerin and catalyst exit the reactor and go in the demethylation system. The demethylation system removes methanol and water from the mixture by flashing. Then the glycerin and catalyst are continuously decanted from the system. After decanting, the FAMEs and non-reacted FFAs continue to Reactor #2. The Reactor#2 system adds chemicals to the FAMEs/FFAs stream to remove any remaining FFAs. Then, the chemicals and FFAs are separated from the FAMEs and the FAME stream continues on to the biodiesel distillation. In the biodiesel distillation system, the FAME stream is fed into a continuous distillation system which separates the FAME into a high quality ASTM grade biodiesel stream, which is the desired main product of the process, and a biobunker fuel stream, which contains the heavier compounds. In the methanol distillation system, the methanol and water mixture removed in the demethylation section of the process is fed to a methanol distillation column which dries the methanol and separates it into a 99 percent methanol stream to be reused in processing and a dilute methanol reject stream to be disposed of. In storage and transfer system, the biodiesel product is stored in an on-site tank and removed periodically for blending and use.

A simplified process flow diagram for the Biodiesel Production Facility is presented on **31**. Improvements made to the installation during startup and trouble-shooting are described in later sections.

3.1.3 Site Modifications and System Integration

Once a suitable location within OSP was identified for the Biodiesel Production Facility, the following major site modifications were designed and constructed to integrate with the brown grease recovery process and the wastewater treatment processes at OSP:

- Structural foundations and containment basin;
- Electrical power supply for pumps, instrumentation and controls;
- Supply and return of hot utility water;
- Supply of chlorinated effluent water for cooling;
- Supply of potable water for safety shower and eyewash station;
- Supply of plant air for instrumentation and controls and piping blow down;
- Brown grease transfer line between the Brown Grease Recovery and Biodiesel Production Facilities; and
- Design of chemicals, biodiesel, and byproducts storage facilities.

Figure 11 : Simplified Biodiesel Production Facility Flow Diagram

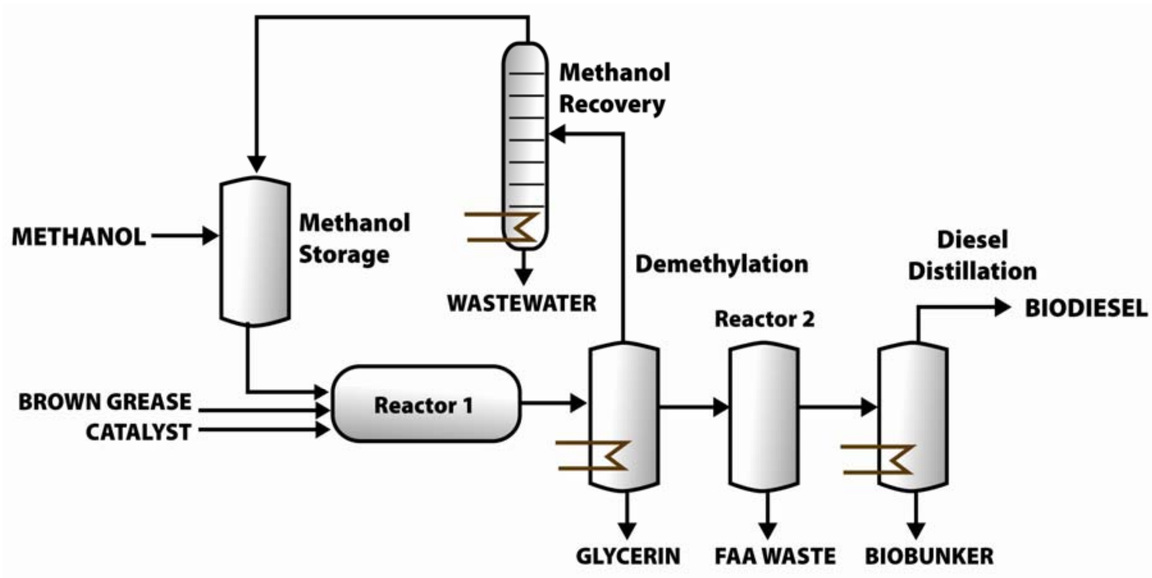
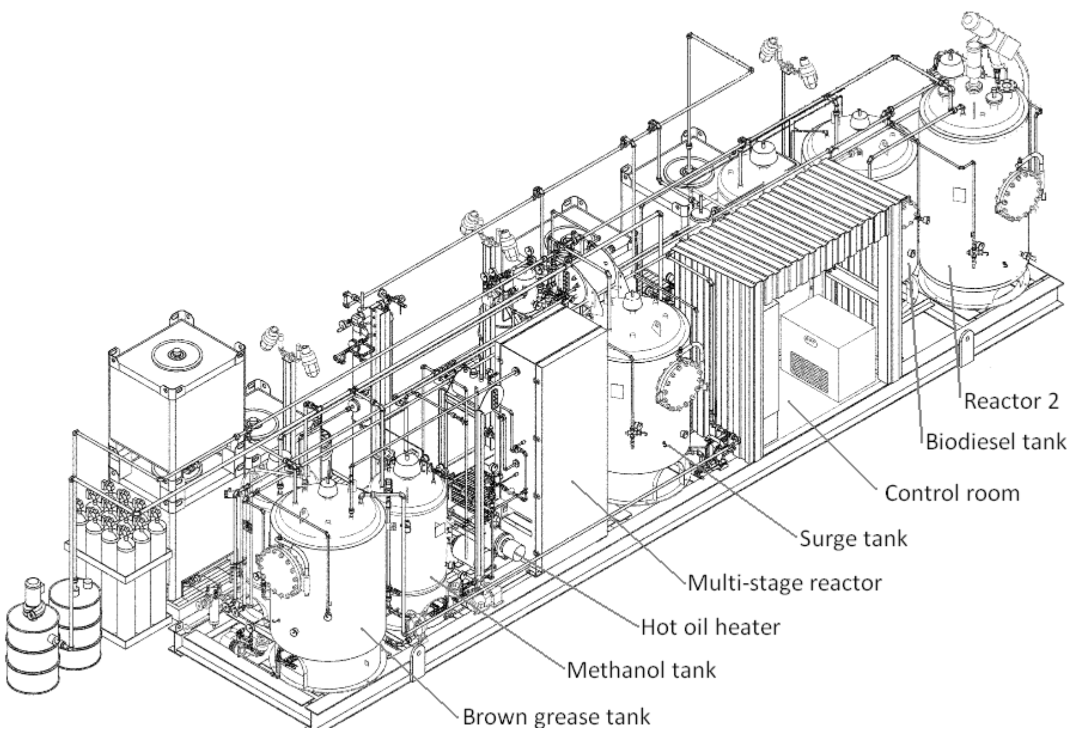


Figure 12 : BGB's Biodiesel Production Facility



Source: BGB

Table 6 : Biodiesel Production Facility Space and Utility Requirements

System Dimensions	
Length	38 ft 8 in
Width	6 ft 8 in
Overall Height	12 ft 4.5 in
Pad Pressure	35 psi
Power Requirements	
Voltage	480V 3 phase @ 60 hz
Connected Load	60 kVA
Recommended Disconnect Size	100 A
Hot Water Supply	
Temperature	190®F
Pressure Range	30 - 65 psig
Cooling Water Supply	
Temperature, Maximum	60®F
Pressure, Minimum	80 psig
Flow, Minimum	18 gpm
Compressed Air	
Flow	85 CFM
Pressure	100 psig

In theory, the byproducts of the biodiesel process (glycerin, waste methanol, and biobunker) do have a market value and could serve as feedstock for alternative uses. However, due the relatively small quantities being generated, without specified chemical quality, it was decided that these waste streams would be discharged to the OSP anaerobic digesters.

To further integrate the facility with the regular OSP operations, the following policies and procedures were developed and implemented, regulating operations at the Brown Grease Recovery Facility.

- Standard operations and maintenance procedures;

- Health and safety procedures for minor and major spillage, catastrophic tank failures, and so forth;
- SPCC;
- Staffing plan;
- Digester Transfer procedures; and
- Testing and sampling plan.

The toxicity tests with by-products formed during the biodiesel production process such as methanol, bio-bunker, and glycerin were performed in SFPUC's pilot digester test facility located at the Southeast Wastewater Pollution Control Plant. Test results indicated small adverse effects on digester performance. Additional details of that test facility are provided in Section 4.2.

Chemicals storage, containment, and safety were design considerations. However, the extent of the health and safety requirements, in particular as they relate to storage and use of methanol, was not realized until the time of installation. To meet the regulations, SFPUC required all electrically powered equipment and instruments within the skid area to be of a type suitable for use in areas with explosive atmospheres, implemented both a fixed and personal detection and alarm system for methanol vapors, and added vapor control (for example, carbon adsorption) to all methanol exhaust piping.

The Biodiesel Production Facility design originally included remote access and controls, intended for integration into the OSP Central. Integration would have had the added advantage of allowing the manufacturer to remotely view, operate, and calibrate the Biodiesel Production Facility. However, this integration plan was abandoned due to security concerns related to potential access of critical OSP operations by unauthorized outside contractors. Therefore, the final design included only localized access and control at the Biodiesel Production Facility.

3.1.4 Construction

A general construction contract was issued for the site modifications.

The OSP site modification contract was extended to include Biodiesel Production Facility installation, testing, and startup. The prefabricated skid was manufactured off-site and received by November 2009. Once on site, the Facility was unloaded from the open rig tractor trailer, positioned, erected, bolted, and connected to the site utilities. Auxiliary equipment was delivered separately and installed adjacent to the Brown Grease-to-Biodiesel Facility. Major installation was completed by mid-December 2009.

3.2 Biodiesel Production Facility Permitting

Unlike the Brown Grease Recovery Facility, the Biodiesel Production Facility represents a chemical process unit, which is entirely new to the WWTP. At OSP, this posed certain challenges, especially in the area of health and safety. Managing new chemicals and waste streams would be a challenge for any WWTP. The SFPUC's procedure for meeting this challenge is described in this section. Also new to the SFPUC were the permitting and regulatory requirements associated with the production of biodiesel. When introducing a new process into an existing treatment plant, it is critical to ensure both regulatory compliance and staff education on any new health and safety issues.

3.2.1 Permitting Considerations

In the early stages of the project, the main goal of the permitting effort was to address health and safety issues. Many of these issues stem from the use of methanol on site. While methanol is sometimes used in wastewater treatment (in plants that are required to achieve nutrient removal), it is not used in any Bay Area WWTPs and the risks associated with its presence at OSP had to be assessed and addressed. Once the facility was up and running, the permitting goals focused on ensuring that the road-ready biodiesel produced at the facility could be used in SFPUC fleet vehicles and that all appropriate procedures were in place to track, account, and manage its use.

3.2.2 Health and Safety

Although several different chemicals are in use on the biodiesel skid, methanol was the most foreign to the WWTP staff. An initial hazard assessment by SFPUC Health and Safety Program staff found that methanol posed a particular problem in that its presence on site had the potential to trigger regulatory requirements with which the plant staff were not familiar. Thus, to achieve a positive outcome, the SFPUC hired two independent consultants to review the specific regulatory requirements related to methanol and to provide methanol health and safety training to plant staff.

Extensive safety evaluations, focused on methanol, were performed by both SFPUC Health and Safety Program staff and independent consultants TetraTech and Nancy Crane of Golden Gate Environmental, to assure compliance with applicable occupational and safety regulations. A memorandum and related letters prepared by TetraTech in early 2010 are summarized in the following subsections. Plant staff training materials were developed by Nancy Crane but cannot be disclosed for trade secret reasons.

The information presented in this section is not intended to be an all-inclusive report of the determinations made by SFPUC consultants, but rather a highlight of those issues that were the most challenging for the agency and/or caused the most concern.

3.2.2.1 General Handling and Safety Precautions for Methanol

The presence of methanol on site can pose a health and fire/explosion hazard. Therefore, SFPUC Health and Safety Program staff, in collaboration with TetraTech, developed several recommendations for the handling of methanol (TetraTech 2010a, b). In addition to recommending methanol-specific personal protective equipment for staff, the SFPUC Health and Safety Program staff also required the purchase of personal methanol meters and two stationary methanol meters, placed at either end of the skid. Chemical fire extinguishers and tepid eyewash stations were also installed on either end of the skid. Additional countermeasures put in place, in accordance with the National Fire Protection Safety Association (NFPA) standards NFPA 30 (NFPA 2008a) and NFPA 497 (NFPA 2008b), were:

- Control of potential ignition sources: site access control (K-Rails) and signage were installed in a 10foot perimeter around the biodiesel skid forbidding ignition sources inside the controlled area. Ignition sources were considered to include commonly present items such as vehicles, radios, and cell phones. Intrinsically safe (for example, non-sparking) accessories and tools were required for operation and maintenance of the skid.
- The installation was isolated by a more than 30linearfoot set-back from property lines.
- Storage of methanol was kept below trigger value of 4,400 gallons.
- Containment and spill response established (see SPCC section below).
- Venting: In accordance with the National Electrical Code (NEC Sections 500 et al.), the biodiesel installation was classified as a Class 1, Division 1, Group D installation. Consequently, a spherical hazardous area with a three-foot radius, centered at the vent of any equipment with the potential to vent methanol vapors to the atmosphere, was established. This equipment included the waste methanol drum, the process reactor, and the transfer point for the waste methanol to OSP.
- Leakage: Points of potential leakage were considered to be Class I, Division 2, Group D installations. The NEC requires a semi-spherical hazardous area with a three foot radius from the potential source. This was considered to be applicable to the methanol storage area, pumps used to transfer methanol, and valves in the methanol piping system.

3.2.2.2 Process Safety Management Determination

Federal and state Process Safety Management (PSM) standards are set by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) and the State of California, respectively, with the intent of preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals. If a process is subject to these standards, the operator must develop a written plan of action (Process Safety Management Plan) and communicate that plan to all relevant employees. TetraTech reviewed the PSM standards with respect to the biodiesel production at OSP and concluded that the PSM regulations as applied by OSHA (29CFR1910.119) and/or the State of California (8CCR 5189) do not apply for this specific situation (TetraTech 2010c). The main reason for this conclusion was that methanol is not a specifically listed chemical in either the state or the federal regulations; however, if the inventory of methanol and methanol waste on site were to exceed 10,000 pounds (approximately 1,500 gallons), federal and state requirements for flammable liquids would have been applicable. TetraTech's interpretation of the state and federal regulations was that the methanol *as stored on the OSP site* did not exceed threshold quantities for flammable liquid requirements.

The methanol storage facilities on site were designed to ensure that the quantity of methanol and methanol waste on site would not exceed the 10,000 pound threshold, along with other storage limitations.

Notable methanol handling recommendations made in the PSM evaluation letter include:

- Monitor the methanol inventory to ensure that on site quantities remain below 10,000 pounds at all times;
- Schedule shipments of fresh methanol such that most of the on-site quantities have been expended before new methanol is delivered to the site;
- Be diligent with the handling of mobile storage containers (for example, the 300-gallon totes which were later replaced by a 500gallon, double-walled UL 142 tank).

The PSM determination for the OSP biodiesel skid (TetraTech 2010c) is considered to be site and chemical specific; entities wishing to install biodiesel manufacturing facilities at their premises should undertake a site and situation specific determination rather than rely on this determination prepared for SFPUC.

3.2.2.3 Hazardous Materials Business Plan

The SFPUC, like many wastewater agencies, is required by its Local Enforcement Agency (LEA) to maintain a current hazardous materials business plan, accompanied by a site plan showing chemical storage locations. In San Francisco, the LEA is the San Francisco Hazardous Materials Unified Program Agency. Prior to this demonstration project, OSP already had a Hazardous Materials Business Plan on file. This plan was modified in 2010 to include the new chemical storage facilities and related stored quantities.

3.2.2.4 Hazardous Waste Treatment Facility Designation

The biodiesel skid generates several waste streams, including waste methanol, waste glycerin, and waste catalyst. All of these wastes have the potential to be considered a hazardous waste. However, if they are treated within a closed loop system, they are not subject to hazardous waste regulations. This was seen as a key advantage of co-location – biodiesel wastes could be piped to the digesters for treatment. Confirmation of this interpretation was done by contacting California Environmental Protection Agency, Department of Toxic Substances Control and speaking with Quinn Johnston through their hazardous waste hotline (Johnston 2010).

3.2.2.5 Spill Prevention Control and Countermeasures Plan

A site-specific SPCC Plan was prepared by URS Corporation in Fall 2010. The SPCC Plan contains the proper preventative actions that should be taken to minimize the risk of harm to waters of the United States in the event of release of petroleum from OSP per the requirements of 40 CFR 112.7. The SPCC Plan includes the following:

- Sitemap that shows the approximate locations of all aboveground oil storage tanks with a capacity of over 55 gallons;
- Location of secondary containment areas that will hold oil spills;
- Procedures for required notification and emergency response in the event of a spill or accidental release;
- Calculations showing that the plant’s secondary containment will contain the worst case release (which is defined as the release of the contents of the largest oil storage tank) following a 25year, 24hour storm event.

Given that all containment and drainage areas will be diverted to OSP headworks and treated; there is minimal risk of harm to waters of the United States.

Since it is not considered an oil, the storage of methanol on site did not require preparation of a SPCC. The storage of brown grease and biodiesel did require having a SPCC detailing brown grease and biodiesel storage.

Chemical spill training with a particular focus on methanol was provided to OSP Operations and Maintenance staff, as well as any Engineering or Laboratory staff involved in the project.

3.2.3 Environmental Permitting

The demonstration project involved installation and operation of a temporary, skid-mounted biodiesel production facility to investigate the feasibility of reducing energy consumption at the OSP while determining beneficial uses for grease removed from grease traps and interceptors. The temporary nature of this project, along with the location of this skid within our existing treatment plant, led SFPUC staff to pursue a Categorical Exemption under the California Environmental Quality Act, a policy established by the California Legislature to review proposed projects to determine possible environmental impacts.

SFPUC also consulted with Bay Area Air Quality Management District staff to assess whether the biodiesel process would require additional air permitting and with Regional Water Quality Control Board staff regarding potential changes in the plant's Waste Discharge Requirements under its NPDES Permit. Lastly, the operation of a biofuels facility and related storage of biodiesel is subject to a considerable number of local, State, and Federal environmental codes and regulations, which were identified with help of independent consultants.

The project was determined to be exempt from CEQA review under Class 6, because the project purpose was considered information collection.

3.2.4 Registration

In developing the accounting methodologies for the registrations and filings of biodiesel use and production, the SFPUC contracted with a third party consultant from the biodiesel industry, Ben Jordan of Biofuel Recycling Cooperative, to compile necessary registration and reporting requirements relating to production, sale, and ultimate use of the various outputs associated with this demonstration. As with the health and safety issues, third party contracting was deemed necessary when addressing areas outside the SFPUC's typical expertise.

3.2.4.1 United States Environmental Protection Agency

When fuel is produced for sale to the public, the seller is required to be registered with the U.S. EPA as a supplier of road fuel along with submitting the appropriate sales tax and alternative fuel tax credits. For this purpose, U.S. EPA maintains three different registering programs: 1) road fuel registration requiring batch-sampling, 2) Renewable Fuel Standard (RFS) for the creation of Renewable Identification Numbers (RINs) and 3) the Fuel and Fuel Additive Registration Program. Additional details on those programs are provided below.

When the seller employs a certified meter or scale, this fuel can then be sold to other agencies within the City, to the open market (called the rack), or to private biodiesel fleets, such as several small and mid-size fuel distribution companies.

3.2.4.2 EPA Road Fuel Registration

To produce and/or use any fuel as a highway road fuel, several different steps must be taken to both initially register as a fuel producer and then to pay taxes and maintain filings throughout the fuel production period. Essentially, this entails registering with the U.S. EPA as a producer and submitting payment to both the state and federal tax collection agencies while collecting data on the usage of the experimental fuel.

There is an important threshold dividing the extent of accounting effort required – whether or not the fuel is sold in any way. If a sale (transfer of ownership) occurs, obligation of additional taxes arises in addition to the need to meet U.S. EPA's fuel registration requirements (40 CFR 80.140). If the fuel is solely used as a research demonstration project for data collection, then the project would be exempt as outlined in 40 CFR 79.4A.3.

If transfer of ownership occurs (as opposed to sole use by a producer's fleet) or there are fiscal impacts from the production, then this definition of research demonstration project may not apply and taxes would be imposed. One element of selling fuel that is most notable is the federal tax credit available for biodiesel, which currently has a value of $1.00/gallon of B100 used.

3.2.4.3 EPA Renewable Fuel Standard and Renewable Identification Number

The RFS is part of the Clean Air Act (42 U.S.C. §7401 et seq.), as amended by the Energy Policy Act of 2005 (42 USC §13201 et seq.), and the Energy Independence and Security Act of 2007 (Public Law 110-140). The RFS requires that an environmental quantification mechanism be used and applied to each gallon of fuel used. Due to biodiesel's low carbon intensity, biodiesel earns 1.5 credits per gallon, as opposed to ethanol with a higher carbon intensity, which earns one credit per gallon. Therefore, biodiesel producers are incentivized to assign a RIN for each gallon produced, which can be held on to or sold to obligated parties such as petroleum refineries. This RIN then accompanies the fuel from the point of sale through to the point of use. According to the February 2011 issue of Biofuels Digest (Lane 2011), there is a developing market involving the purchase and sale of these numbers; while the emerging nature of this market has resulted in values ranging from less than $0.01 to close to $2.00 per gallon (Biodiesel News.Com 2011). At a minimum, the recording and accounting of the RINs needs to be accomplished for potential use in carbon reduction programs and/or public sale.

3.2.4.4 EPA Fuel and Fuel Additive Registration Program

In accordance with the regulations of 40 CFR 79, all diesel vehicle fuels need to be registered. This program's objective is to gather health and safety information through the use of medical studies that analyze impacts to human and environmental exposure to a given road fuel. Registration of a fuel producer is granted through an application process that includes specific fuel related data. Data are obtained within two registration sections or tiers. Tier I testing is required as part of a fuel producer's application and generally costs several million dollars to perform. This information can also be obtained through a National Biodiesel Board (NBB) Membership (see below), which is fairly common practice among small to mid-sized biodiesel production facilities. Tier II testing requirements are applicable only to producers generating in excess of $10 million in revenue. Once the registration process is completed, there are no initial or annual fees to the U.S. EPA. Quarterly reports are to be submitted which contain volume and fuel use information. Based on the anticipated maximum throughput of the demonstration facility, only Tier I test data were required, which SFPUC obtained through NBB (see below).

3.2.4.5 National Biodiesel Board

The NBB is an organization that was formed by the Soy Bean Association to perform Tier I health effects testing on biodiesel. This information is available to NBB membership only and allows for completion of the U.S. EPA Fuel and Fuel Additive Registration. These Tier I health data will enter the public domain after a period of 15 years, which would be 2012 for the oldest data on file. Until then, small producers wishing to access the Tier I data must become Producer Members of the NBB. This process is fairly rapid and the associated fees are $2,500 annually plus a $0.01 charge per gallon of biodiesel produced.

BGB currently maintains a membership with the NBB as a biodiesel producer and has access to the Tier I and Tier II Health Effects Data. For the purposes of this demonstration, an agreement was reached between the SFPUC and BGB to utilize this annual membership and submit the annual charge on the B100 volume produced through BGB.

3.2.4.6 Internal Revenue Service Registration

Between 2008 and 2011, biodiesel producers were eligible for available alternative fuel blending credits, to take advantage of these tax credits, public agencies needed to register their facilities as petroleum blending facilities (IRS 2011). With this blender's license, diesel could be mixed in small quantities, 0.01 percent to make B99.9. This credit was worth $1.00 per gallon of tax credit on existing tax liabilities for each gallon of fuel sold. This limited the retail price of biodiesel to roughly $0.50 to $1.00 per gallon more than ultra-low sulfur diesel. This credit also applied to the biodiesel produced and used as B20, such as within the City of San Francisco's Master Fueling Contract.

3.2.4.7 Internal Revenue Service Reporting and Tax Submission

The IRS collects the federal excise or road tax, which is currently $0.244 per gallon. This is calculated on Form 720 and is submitted quarterly.

3.2.4.8 California State Board of Equalization Excise Tax Submission

The SFPUC registered with the State Board of Equalization's Fuel Tax Division under two categories, as a Fuel Producer and as a Fuel Reseller (BOE 2007).

The Fuel Producer Permit requires payment of a $0.18 California Excise Tax, or road tax. This tax is required for payment when the fuel is produced or imported into California. The tax filings are to be submitted on Form BOE 501 DD, which has schedules for detailing volumes of fuel transferred to a fuel distributer. These schedules provide the input for the calculation of the excise tax obligation.

Public agencies within California can register with the State Board of Equalization as a Fuel Reseller so that they may calculate the sales tax obligation over the fuel that was sold. The Board of Equalization assesses an initial pre-paid sales tax of $0.103 per gallon that an agency must pay prior to releasing the fuel into the fuel distribution network. The remaining sales tax calculated at the point of sale is also submitted by the producer to the Board of Equalization. The Fuel Schedule, G form (DOE 401 GS) is the appropriate schedule to accompany a reseller's monthly sales tax forms.

3.2.4.9 California Department of Food and Agriculture, Division of Measurements and Standards

The laws and regulations governing the activities of CDFA can be found in the California Business and Profession Code Division 5, Chapters 1 to 17, the California Code of Regulation (CCR) Title 4, Division 9 Chapter 1 to Chapter 12, and the National Institute of Standards and Technology Handbook 44. All fuel producers are required to dispense fuel using only meters approved by CDFA. There are a limited number of meters that are approved for the use of biodiesel sales at retail dispensers, however there is a wider range of approved meters for bulk sales. For this demonstration project, no meter was selected because of lack of diesel production.

3.2.4.10 California Air Resource Board Low Carbon Fuel Standard Biofuel Registration

The California Air Resources Board (CARB) is registering facilities that produce ethanol or biomass-based diesel for use in California. CARB has posted the Low Carbon Fuel Standard (LCFS) Biofuel Producer Registration Form on the LCFS website (CARB 2010). The LCFS Biofuel Producer Registration Form is to be used by biofuel producers to provide data on the carbon intensity of the fuel produced at each facility and a documentation of physical pathway (route of the fuel transported to California). On that same website, CARB directs applicants to use their GREET software to determine carbon intensity values for each facility and each fuel. .

CARB is also developing a reporting tool for regulated parties to report their fuel volumes quarterly and annually. The SFPUC expects that the facility ID, carbon intensity and physical pathway information from the Biofuel Producers Registration Form will be available for use by regulated parties for that reporting tool. All production information and contract information will be maintained as business confidential and will not be released to the public.

3.2.5 Required Reporting Summary

The following subsections summarize the reporting requirements for biodiesel production at SFPUC.

3.2.6 EPA - Fuel and Fuel Additive Registration Program

- RIN Registration – Office of Transportation & Air Quality Regulations: Fuels Programs Registration and Central Data Exchange
- Form 3520-12 – Initial Form for Fuel Additives Manufacture Notification
- Form 3520-12Q – Quarterly reports submitted within 45 days after close of each calendar quarter – Fuel Production and Fuel Volume Reporting

- Form 3520-12A – Submitted on or before March 31st for the preceding year or part thereof – Fuel Properties, Notification and Certification
- Verify Renewable Fuels Standard 2 (RFS2) Registered Renewable Fuel Producer List and Verify Facility ID Number
- Update and Record RIN Database with additional renewable fuel produced for the previous volumes within updated files

3.2.6.1 National Biodiesel Board

- Initial Application - NBB Member packet NBB cover letter
- Annual membership registration requirements

3.2.6.2 CA Board of Equalization

- Form BOE-400-FCO - Motor Fuel Suppliers and Ultimate Vendors – Initial filing form for refiner as atypical fuel - biodiesel
- BOE-501-DD – Supplier of Diesel Fuel Tax Return – Monthly – Off Road Tax, Excise Tax, Prepaid Sales Tax and Point of Sale Tax

3.2.6.3 IRS Registration

- Form 637 – Initial application for registration for certain excise tax activities – contact info, type of activity (Type M), product volume for blending, annual blended taxable fuel produced
- Form 720 - Federal Excise Tax Filing – Includes Blenders Credit
- Form 4136 – Credit for Federal Tax Paid on Fuels Used for Off-Road if needed

3.2.6.4 CA Air Resource Board

- CARB LCFS Biofuel Registration
- Verify CARB LCFS Biofuel Facility ID Number and Address List - and check for additional upcoming reporting activities

3.3 Encountered Implementation Issues

On February 5, 2009, BGB toured the site, discussed the layout, and met the project team. The engineering phase was well underway at that time, and the subcontracted fabrication firm was in the process of converting BGB's design P&IDs to a customized facility for the OSP. The Biodiesel Production Facility arrived at OSP on November 8, 2009 and was installed on November 9, 2009.

Between initial installation in April 2010 through December 2011, the Biodiesel Production Facility has been plagued with a variety of start-up issues resulting from components that were improperly sized, that could not withstand the corrosive salty atmosphere near the Pacific Ocean, that exhibited fouling of heated surfaces and tight internal clearances, and that were difficult to maintain in the extremely tight skid layout. Several major components were replaced following re-design, including the original demethylation section, and the methanol distillation column.

In addition there were several problems associated with integration at the OSP and the shared responsibilities between contractor and SFPUC staff. The plant's chlorinated plant process water was about 10°F warmer than the potable water supply and at times particulates caused fouling of the facility's cooling system. The brown grease supplied to the facility, at times was contaminated with debris that needed to be moved from the day tank upstream of the core process reactor. There were several quality issues regarding the SFPUC-supplied chemicals and consumables.

3.3.1 Hot Oil System

- The initially installed hot oil system was not properly designed for outdoor use, as it allowed atmospheric humidity to enter the system through its air purge routine. The hot oil system manufacturer, Mokon, took the unit off-site for implementation of retrofits. The hot oil system was re-installed in 2010, and a dry compressed air system was added to the skid.

3.3.2 Catalyst Feed Pump

- In [Information deleted per direction of SFPUC and BlackGold Biodiesel] 2010, BGB determined that the catalyst feed pump was oversized. The pump was retrofitted with a gear reducer by the manufacturer, PRI.

3.3.3 Pressure Sensors

- Seven pressure sensors were removed from the skid in 2010 after two of those sensors had failed. A more 'rugged' type was selected and installed to better withstand the site's corrosive atmospheric conditions.

3.3.4 FAME Distillation System

- In [Information deleted per direction of SFPUC and BlackGold Biodiesel] 2010, BGB studied, troubleshot and modified the FDS vacuum system to protect the vacuum pump from fouling due to mist.

- Ultimately [*Information deleted per direction of SFPUC and BlackGold Biodiesel*], a coalescing filter was installed in the FDS to protect the FDS vacuum pump.

3.3.5 Demethylation Section

- Starting in 2010, BGB troubleshot a number of different pumping and mixing methods to allow for continuous flash removal of methanol and water before ultimately identifying and installing new equipment in [*Information deleted per direction of SFPUC and BlackGold Biodiesel*] 2011.

3.3.6 Methanol Distillation Section

After months of intensive study by BGB it was discovered that the subcontractor responsible for the system's design had made a significant mistake in the system sizing, requiring complete replacement of the column. Distillation trouble-shooting included:

- August 2010 - A couple of retrofits were made to the methanol distillation column. The configuration of the condenser was rearranged to optimize the flow and a temperature probe was added to the reflux line to aid in better control of the column's temperature gradient.
- November 2010 - A different valve positioner was installed on the hot oil control valve to optimize the heat supply to the column's reboiler.
- December 2010 – After addition of a number of additional flow meters, BGB was able to run the column at the design flow rate, and noticed that this caused column flooding. Column flooding is caused by excessive vapor flow velocities. Flow calculations for the installed structured packing learned that the installed column had approximately half the diameter required for proper distillation at the design vapor flow rate.
- January 2011 - BGB had a new methanol distillation column designed and fabricated, scheduled for delivery in February 2011. Awaiting column replacement, BGB ran the methanol distillation section at approximately 20 percent of the design capacity to limit disposal of spent methanol.
- February 2011 - The new, larger diameter methanol distillation column was installed. The column was started-up following a leak test and has produced consistent quality since, per initial BGB specification.
- April 2011 - BGB replaced the reboiler heating element, which had experienced mechanical failure. Following replacement, the column was tested and calibrated with this new element.

3.3.7 Brown Grease Day Tank

- May 2011 – Particulates were found in various portions of the installation that caused line blockages resulting in a shut-down of the unit. The particulates were later identified as plastic fragments originating from the Brown Grease Recovery Facility. BGB reinstalled baskets in the inline strainers before and after the brown grease day tank, to avoid future plugging.

3.3.8 Cooling Water Source

- June 2010 – A reduction in cold water flow was attributed to contaminants in the chlorinated effluent water (inorganic and organic solids), which clogged the flow meter. An inline strainer was installed to remove the contaminants. In order to maintain the required cooling water flow, that strainer required daily inspection and cleaning. SFPUC arranged a temporary supply of utility water to avoid the problems.

3.3.9 Waste Disposal

Initially, glycerin, waste methanol, and waste catalyst were produced and stored in separate 55gallon steel drums and biobunker was produced and stored in a 330gallon stainless steel international bulk container tote. Expended organic heating oil and chiller antifreeze were stored in 55gallon steel drums. When the containers became full, containers were moved by forklift to the digester feed tank manhole in the Canyon. Then wearing appropriate personnel protective equipment, the container content was siphoned into the digester feed tank through the opened digester feed tank manhole. For health and safety and tracking in the event of adverse digester effects, there was a worksheet to be completed with operator name, date, chemical to be disposed, quantity being disposed, beginning and ending disposal times, and checklist of required person protective equipment.

This manual disposal method was conducted safely numerous times but the chance of spillage, exposure, and accidents still exist. Therefore, a separate disposal line was installed to convey the chemicals to the digester day tank from the biodiesel facility. The biobunker, glycerin, waste methanol, and waste catalyst effluent lines from the biodiesel facility were disconnected from the containers and connected to the disposal line manifold. The disposal line utilized a side stream of the biodiesel facility return cooling water as carrier water for the chemical disposal. The expended heating oil and chiller antifreeze continued to be stored in 55gallon drums for manual disposal as aforementioned because of the infrequency of their disposal. Off-specs biodiesel and even biodiesel could be rerouted through valving to utilize the dedicated disposal line for disposal.

3.4 Demonstration Test Program

The goal of this chapter is to review and discuss the performance of the process from the start up to the end of the testing period. To do that, detailed data on operation and maintenance of the biodiesel production system were to be collected. This data was also intended to be used in determination of overall process efficiency in terms of brown grease conversion, calibration of Life Cycle Assessment /energy balance models, and development of the scaled-up design documents. Thus, a data collection plan was laid out in the performance certification test plan.

However, during the demonstration period from December 2010 through May 2011 and in the extension period from June to December 2011, BGB was not able to run the unit for any prolonged time period, and only an insignificant amount of biodiesel was produced. Therefore, the intended evaluation of biodiesel production and lifecycle costs for such a unit could not be determined.

SFPUC and BGB plan to run the system for an additional year, through Fall 2012, and anticipate that significant data will be collected over this period for supplementary analysis.

3.4.1 Issues Observed During the Test Program

Most of the issues observed during the test program were related to either equipment failure, equipment fouling, or flawed system design. This resulted in a unit being plagued by repeated shutdowns. A good amount of the equipment fouling and failure problems can be blamed on three factors: miniaturization of unit operations, unavailability of steam, and insufficient space in the skid.

Regarding the first factor, miniaturization led BGB to incorporate non-industrial grade equipment, which was constructed with narrow internal clearances and reduced wall thicknesses, and was likely not intended for continuous use in an outdoor environment. The narrow clearances led to repeated plugging of heat exchangers during the demonstration test. Additionally, equipment cleaning was near to impossible because of the same narrow clearances. The reduced wall thickness made equipment less rugged, which resulted in a number of failures of oil-filled heaters.

The unavailability of steam for equipment heating forced the design to include either direct electrical heating or a hot oil system. BGB installed the latter, which resulted in heating medium temperatures significantly above those of a steam system. Since elevated temperatures are capable of degrading organic compounds, it is not unlikely that this choice for hot oil may have contributed to the observed equipment fouling.

It has been a challenge to fit an automated biodiesel process including several unique purification systems required to handle the brown grease, in a skid with the dimensions of a standard shipping container. The limited height and width of that skid have resulted in an installation with insufficient access for maintenance. In addition, it resulted in problematic pumping conditions, which the industry typically solves by providing additional height. While the decision to construct the unit in a single skid was completely BGB's, budget constraints have played a role in this decision. A modular approach for convenient expansion was the only requirement imposed from the start. This left room for skid-mounted installations requiring the space of two or more shipping containers.

As mentioned, the project had budget constraints, which drove a number of design decisions. Despite encountering the system issues presented above, BGB was fully accountable for all design and fabrication issues and made corrections as well as hired the required labor to do so at its sole cost.

Lastly, the intent of the project was to create a new commercialization pathway. As with most beta commercialization projects, encountering start-up issues is not entirely surprising. Beta projects inherently come with their own challenges, and the issues observed and addressed in this project will help inform, enable and mitigate risk for future commercialization.

3.4.2 Biodiesel Product Assessment

The limited amounts of diesel produced during the test period were close to meeting the biodiesel ASTM standard. Sample analytical test results from the biodiesel sample derived on June 1st 2011 are summarized in table 7. As shown in the table, the majority parameters from the biodiesel produced in demonstration facility met the ASTM standard except S 15 grade sulfur and free glycerin, which were 60 and 130 percent higher than the standard values, respectively. It should be noted that, however, the results were reported on B-100 scenario and the results were not off too much from the standard, which mean the biodiesel generated from the demonstration facility can meet the ASTM standard by blending with regular diesel with low or none sulfur and glycerin contents. Those results could be an indication of the potential of this technology when implemented at a (semi-) industrial scale.

Table 7 : Sample Analytical Test Results from the Biodiesel Produced During the Test Period

Analyte	Procedure	Standard		Results 6/1/11	Pass as B100
Calcium & Magnesium, combined	EN 14538	5 maximum	ppm (µg/g)	2.5	Y
Flash Point (closed cup)	D 93	93 minimum	°C	NM	
Alcohol Control					
1. Methanol Content	EN14110	0.2 maximum	mass %	NM	
2. Flash Point	D93	130 minimum	°C	132	Y
Water & Sediment	D2709	0.05 maximum	% vol.	0.01	Y
Kinematic Viscosity, 40 C	D 445	1.9 – 6.0	mm2/sec.	4.3	Y
Sulfated Ash	D 874	0.02 maximum	% mass	<0.005	Y
Sulfur					
S 15 Grade	D 5453	0.0015 max. (15)	% mass (ppm)	0.0024	N
S 500 Grade	D 5453	0.05 max. (500)	% mass (ppm)		
Copper Strip Corrosion	D 130	No. 3 maximum		1a	Y
Cetane	D 613	47 minimum		56.3	Y
Cloud Point	D 2500	report	°C	7	Y
Carbon Residue 100% sample	D 4530*	0.05 maximum	% mass	0.01	Y
Acid Number	D 664	0.5 maximum	mg KOH/g	0.25	Y
Free Glycerin	D 6584	0.020 maximum	% mass	0.046	N
Total Glycerin	D 6584	0.240 maximum	% mass	0.081	Y

Phosphorus Content	D 4951	0.001 maximum	% mass	<0.0001	Y
Distillation	D 1160	360 maximum	°C	356	Y
Sodium/Potassium, combined	EN14538	5 maximum	ppm (µg/g)	2.4	Y
Oxidation Stability	EN15751	3 minimum	hours	8.6	Y
Cold Soak Filtration	D7501	360 maximum	seconds	30	Y
For use in temperatures below -12 °C	D7501	200 maximum	seconds		

CHAPTER 4:
Effects On Wastewater Treatment Plant Performance

4.1 Introduction

One component of the demonstration program was focused on assessing the impacts of co-locating a brown grease recovery or trap waste processing facility at a municipal WWTP employing anaerobic digestion and cogeneration. While part of the demonstration project included a separate biodiesel production operation, co-location of this type of facility was never deemed advantageous to the WWTP owner/operator or private industry. However, in theory, a regional biodiesel production plant could be supported by a number of WWTP brown grease recovery operations that would supply the recovered grease as feedstock for the regional facility.

Based on data collected during the demonstration period and a smaller pilot digester study, it was determined that there is significant value in municipal WWTP receiving and processing trap waste. Measured benefits include (may be site dependent):

- Waste heat from the treatment plant operations can be used to aid in recovery of the brown grease
- On-site processing of the Brown Grease Recovery Facility side-streams enabled lower energy recovery of stream resources instead of processing these side streams through the headworks as part of the raw plant influent wastewater stream
- Brown Grease Recovery Facility side-streams are high in COD and volatile solids content and when added to the treatment plant's anaerobic digester(s), a measurable increase in biogas production is observed
- WWTP facilities operate 24 hours per day, 7 days per week and have the ability to accept trap waste at all hours
- WWTP operations personnel have the required training and aptitude needed to run or operate a receiving and/or processing facility and manage impacts to the treatment plant unit operations

In addition, it was determined that a number of measures would need to be implemented at the treatment plant to support a long-term trap waste receiving and processing operation including:

- Odor control when unloading trucks (for example,, vacuum connection to facility)
- Local hot water connection for daily cleanup
- Pre-mixing of side-streams in digester return line

As for discharging biodiesel production facility still bottoms, by-products and waste side-streams to the digesters, further research to measure impacts on overall treatment plant operation is recommended. Pilot-scale work did not revealed significant negative impacts to digester performance.

Given that the waste streams from the demonstration facilities were fed directly to the WWTP's anaerobic digesters, this section specifically focuses on the impacts seen at the digesters. Further, in an effort to measure the potential range of impacts of feeding the digesters different volumes of waste streams and grease, a pilot digester study on a smaller scale was performed separately.

4.2 Effects of Brown Grease Recovery Facility on Anaerobic Digesters

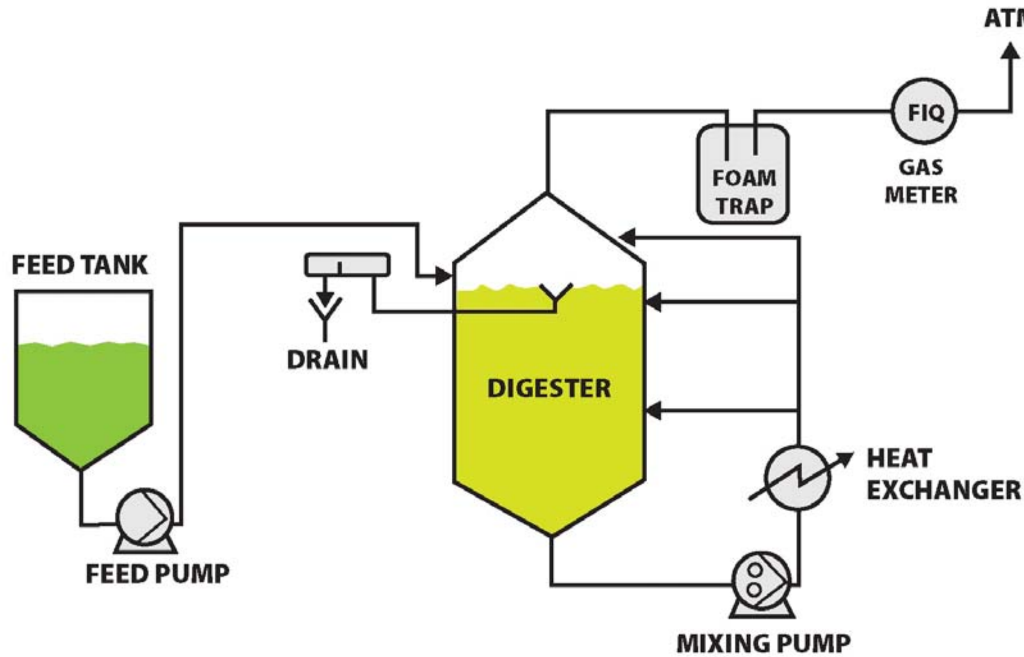
A pilot-scale study using 30-gallon digesters was first conducted to assess any biological or performance impacts to digestion and gas production that could result from demonstration facility waste streams (such as, biodiesel facility still bottoms, glycerol waste, and low-grade methanol; and brown grease facility white water and concentrated brown grease streams). An overview of the pilot study work and results follows.

4.2.1 Pilot-Scale Digester Evaluation

The pilot digester set up was comprised of two parallel process trains, each of which was equipped with a 30-gallon stainless steel egg-shaped digester, positive displacement (PD) pumps for recirculation and heating of the sludge, a water bath with jacket heaters, and Moyno pumps to feed sludge to the digesters. The pilot digester tanks were equipped with a number of nozzles to facilitate feeding, withdrawal, and recirculation of sludge.

The digesters were maintained under completely mixed, mesophilic (95^{o}F) conditions. Mixing and heating of the sludge to mesophilic temperature was achieved by PD pumps that would withdraw the sludge from the bottom of the tank, circulate it through a heat exchanger coil immersed in a hot water bath and then discharge it back into the top of the digester tank. A 55-gallon drum was used as a water bath for each process train. The temperature in the water baths was maintained by means of jacket heaters wrapped around the drums. The jacket heaters were furnished with a thermostat to achieve the desired temperature. The temperatures in the digester tanks and water baths were monitored using resistance temperature devices (RTDs), installed in each water bath and digester tank. The amount of gas formed during the anaerobic process was measured using thermal-dispersion-type mass flow meters. The digester tanks, interconnecting piping, and water baths were wrapped in fiberglass insulation to reduce heat loss. Raw combined primary and activated sludge (CPAS) collected at the treatment plant was stored in a 55-gallon feed tank and fed to the digester tanks using Moyno pumps. The CPAS was strained before transporting it to the 55-gallon feed tank using a 1/16 inch screen to remove large particles. The feed tank was equipped with a stainless steel stirrer to keep the CPAS solids in suspension. The temperatures of the digester tanks and gas formation were logged on a continuous basis. The pilot set up is shown in Figure 13.

Figure 13 : Schematic of Pilot Digester Setup



Co-digestion of brown grease with primary and activated sludge proved to be advantageous in producing increased methane yields. Based on the pilot study, co-digestion of brown grease appeared to yield a significant increase in methane gas production, which can be used to generate part of the electricity needed to run the treatment plant. The studies also indicated achievable total solids (TS) and total volatile solids (TVS) destruction above 60 percent and chemical oxygen demand (COD) reduction above 80 percent during brown grease co-digestion. The results obtained are significantly higher than values reported in the literature. This could be due to the well-controlled conditions of the pilot digesters and their superior mixing regimes or to a flawed gas metering setup. The toxicity tests with by-products formed during the biodiesel production process such as methanol, bio-bunker fuel, and glycerin showed small adverse effects on digester performance. A slight impairment was observed in TS and TVS destruction, and COD reduction when compared to the control digester. Overall, the pilot digesters performed well in terms of COD removal and TS, and TVS destruction. During the study period, the average TS concentrations exceeded 3 percent and the average COD concentrations were greater than 7,000 mg/L.

4.2.2 Full-Scale Digester Evaluation

This section describes the effects of the demonstration project on WWTP operations, with a focus on the anaerobic digester performance.

4.2.2.1 Digester Gas Production

Three anaerobic digesters are operated in parallel at the OSP to digest primary solids and waste activated sludge generated as part of the treatment process. As part of the demonstration study, the Brown Grease Recovery Facility waste streams (whitewater and interface layer) were pumped primarily to Digester No.2 on a regular basis. Biogas production data from co-digesting side streams were measured with thermal gas meters and recorded in the plant's process control system during the demonstration period. The methane content of the produced biogas for this period was calculated from the measured carbon dioxide (CO_2) concentration in the biogas through subtraction from total gas volume, assuming no other constituents were present in substantial quantities.

Three sets of biogas production data were reviewed as part of the study: 1) 12 months of data for 2006 were used to establish a performance baseline; 2) January 2011 through July 2011;, and 3) August 2011 through December 2011. The January through July 2011 data were determined questionable and discarded.

The baseline digester gas production was established at 10.3 scf per pound of VS destroyed for a total of 65 percent VS reduction across the digester. The baseline gas production volume is within the standard range of typical municipal wastewater digester performance (for example, 10 to 15 scf biogas per pound VS destroyed), as well as the total VS reduction across the digesters. August through December 2011 data showed an increase in biogas production (due to side stream injection) to a rate of roughly 16 scf per pound of VS destroyed, which is in line with what operations staff noted during rounds.

4.2.2.2 Digester Gas Generation Patterns

The WWTP's control system recorded significant spikes in gas production during injection of brown grease facility waste streams. Approximately 20 minutes following injection of whitewater into the digesters, the gas production showed a spike that lasted for about one hour (Figure 14). The research team was unable to identify any literature on co-digestion of waste grease that reports a similar gas production pattern. Since available literature in general reports relatively slow responses to grease addition, it is uncertain whether this observed phenomenon was caused by a biological or a physical process.

Figure 14 : Digester Gas Production Screenshot

4.2.2.3 Evaluation

The data indicate that during the demonstration period, and the months thereafter, the digester monitoring protocols at OSP were not accurate enough to fully characterize the variations in process conditions caused by whitewater injections into the digesters.

4.2.2.4 Digester Biosolids Quality

Because whitewater and off-spec brown grease were periodically added to the digesters for treatment, several samples of brown grease and whitewater were analyzed for metals and/or pesticides. The results, summarized below, will be reported separately at a national wastewater conference in 2012 (for example, Water Environment Federation (WEF) Residuals and Biosolids Conference; Sierra 2012).

Laboratory analyses indicated that of the 40 CFR 503-regulated metals, only copper, lead, nickel, and zinc were present in the sampled whitewater and brown grease streams in detectable quantities. However, the concentrations of all detected metals in the bulk wastewater and grease were well below the regulatory levels for Class A EQ. Based on the reportedly relatively low levels of metals in the OSP biosolids prior to the addition of brown grease and brown grease facility waste streams (2008-2010 data), it would be unlikely that the importation of trap waste would have an adverse impact on final biosolids quality.

In addition, a number of volatile organic compounds were detected in whitewater samples. The majority of those compounds were typical chlorination byproducts or chlorinated solvents detected in the micrograms per liter concentration range. The compound detected at the highest concentrations was 2-butanone (at approximately 300-600 micrograms per liter). None of those compounds would pose a threat to the biosolids quality at the observed concentrations.

Concerns about reduced detention time that could impact 40CFR503 compliance are a site-specific issue. An analysis of excess digestion capacity should therefore be conducted prior to the acceptance of significant quantities of trap waste for discharge in a site's digesters.

CHAPTER 5: Economic Analysis – Business Case

The purpose of this section is to present a business case study for co-locating a brown grease-based biodiesel refinery at a municipal WWTP. The business case includes analysis of the California biodiesel market including the regulatory drivers, analysis of potential site locations based on available brown and yellow grease, selection of business case scenario, and study of economic feasibility for a selected business case.

5.1 Introduction

Biodiesel, being a biogenic fuel, provides the following benefits relative to petroleum diesel: reduction in foreign oil dependence; lower GHG emissions; lower overall air pollutant emissions; decrease in public health effects; ability to be produced locally; and sustainability. Therefore, federal and state regulatory policies are mandating the gradual substitution of petroleum diesel with biodiesel. Competition of food and fuel crop production for arable land as well as relatively low fuel prices during the past several years rendered the mandated production quota hard to meet. Consequently, to date only a small fraction of the annual national diesel consumption has been replaced by biogenic fuel.

Brown grease, which is high in energy content, is generated through the preparation of food in residential homes and FSEs. From there, brown grease makes its way into wastewater systems, causing line blockages that result in sanitary sewer overflows (SSOs) which pose a risk to public health and the environment and cause costly maintenance issues in both the wastewater collection system and the WWTP.

Municipal wastewater agencies are facing new challenges due to pressure from both regulatory actions and energy needs while reducing GHG and preparing for future carbon footprint requirements. The issues present a unique opportunity for lowering GHG emissions, producing clean and sustainable energy, and lowering the risk of exposure to compounds/substances that could have harmful public health effects.

5.2 California Biodiesel Market Drivers

The California biodiesel market is a subsidized and regulatory driven market. Subsidies essentially make up the difference in production costs between biodiesel and petroleum diesel. Recent federal (RFS2) and state legislation (LCFS) established compliance schedules to meet biodiesel production targets. This section summarizes drivers for the local biodiesel market related to production regulations, health risks, sewer overflows, as well as current infrastructural impediments to a biodiesel market expansion.

5.2.1 Biodiesel Production Regulations

Development of domestic biodiesel production capacity is an integral component of both Federal and California energy policy. Given the objectives of this study, diesel and biodiesel substitutes are the focus of the regulatory discussion presented below.

5.2.1.1 Federal Regulations – EISA and RFS2

At the federal level, The Energy Independence and Security Act (EISA) of 2007 mandates that 36 billion gallons (ethanol equivalent volume) of advanced biofuels be used by 2022, which includes no less than 1.0 billion gallons (ethanol equivalent volume) of biodiesel. EISA forms the basis for the RFS2 which establishes a compliance schedule and fuel volume requirements to be incorporated into U.S. transportation fuel. To qualify as renewable, a fuel must provide a minimum GHG emission reduction, relative to the 2005 GHG emission for the fuel being substituted (either gasoline or diesel). RFS2 defines five categories of renewable fuels with corresponding minimum GHG emission reduction thresholds:

1. Conventional biofuel (ethanol) – minimum of 20 percent GHG reduction
2. Advanced biofuels (corn starch-derived non-ethanol fuel) – 50 percent GHG reduction
3. Cellulosic biofuel (derived from cellulose, hemicellulose or lignin based on renewable biomass) – 60 percent GHG reduction
4. Biomass-based diesel, including both biodiesel (virgin oil and waste grease feed stocks) and non-ester renewable diesel – 50 percent GHG reduction
5. A fifth category titled other advanced biofuel is used in the RFS2 analysis for additional biofuels needed to achieve the 2022 target of 36 billion gallons per year. Fuels of this category consist of other biodiesel and imported ethanol.

Subsequently, each state determined its fair share of the RFS2 obligation, based on historical fuel usage data. Table 8 shows California's fair share of their RFS2 obligation, by renewable fuel classification (CARB 2009).

At a federal level, Renewable Identification Numbers (RINs) are used to track each gallon of renewable fuel produced and to determine compliance with the national renewable fuel production obligation. Within this system, each type of renewable fuel has a different assigned RIN value. Due to biodiesel's low carbon intensity, biodiesel earns 1.5 credits per gallon, as opposed to ethanol with a higher carbon intensity, which earns one credit per gallon.

RINs also have a monetary value and can be traded between fuel producers and consumers, much like carbon credits. RIN values have substantially increased from less than $0.20 in 2009 (LaSalle Group 2010), to an average of $1.24 (USDA 2011), and has peaked close to $2.00 (Biodiesel News.Com, 2011). While some of this price increase is most likely due to transaction costs and speculators; the RIN credit appears as it may be a substantial windfall for biofuel producers.

Table 8 : California Fair Share of RFS2 Obligation

Year	Conventional Biodiesel Corn Ethanol (billion gallons/yr)	Advanced Biofuel (billion gallons/yr)	Cellulosic Biofuel (billion gallons/yr)	Biomass-Based Diesel (billion gallons/yr)	Other Advanced Biofuel - Biodiesel (billion gallons/yr)	Other Advanced Biofuel-Imported Ethanol (billion gallons/yr)
2010	1.34	0.11	0.01	0.07	0.00	0.00
2011	1.41	0.15	0.03	0.09	0.00	0.00
2012	1.49	0.23	0.06	0.11	0.00	0.00
2013	1.56	0.31	0.11	0.11	0.02	0.01
2014	1.63	0.42	0.20	0.11	0.04	0.02
2015	1.70	0.62	0.34	0.11	0.06	0.05
2016	1.70	0.82	0.48	0.11	0.08	0.09
2017	1.70	1.02	0.62	0.11	0.08	0.15
2018	1.70	1.24	0.79	0.11	0.08	0.20
2019	1.70	1.47	0.96	0.11	0.09	0.25
2020	1.70	1.70	1.19	0.11	0.09	0.25
2021	1.70	2.03	1.53	0.11	0.10	0.24
2022	1.70	2.37	1.81	0.11	0.11	0.29

5.2.1.2 State Regulations – AB 32 and LCFS

The State of California has passed a series of laws and promulgated executive orders directing state agencies to oversee the reduction in GHG emissions and the increase of in-state biofuel production (summarized in). The California Global Warming Solutions Act of 2006, known as AB 32, is the main driver, and requires CARB to develop regulations and market mechanisms to reduce California's GHG emissions to 1990 levels by 2020.

AB 32 also establishes the basis for the California LCFS, which mandates a reduction of at least 10 percent in GHG emissions by 2020, based on the carbon intensity[1,2] of the state transportation fuel portfolio.

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[1] Carbon intensity provides a life cycle "well to wheels" accounting of carbon released per energy produced which accounts for energy usage associated with producing, transporting, distributing, and using the energy.

[2] Carbon intensity values based on final LCFS published in June 2011.

Table 9 : Overview of Key California GHG-related Regulations

Name	Regulation	Description
California Global Warming Solutions Act of 2006	AB 32	Reduce GHG emissions within California to 20% below 1990 levels by 2020
Alternative and Renewable Fuel and Vehicle Technology Program.	AB 118	Authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help meet the state's goals for reducing greenhouse gas emissions and petroleum dependence in the transportation sector
State Alternative Fuels Plan	AB 1007	A Plan to increase the use of alternative fuels in California
GHG Reduction	Executive Order S-03-05	Reduce GHG emissions within California to 20% below 1990 levels by 2020 and to 80% below 1990 emission levels in 2050
Biofuels and bioenergy from renewable resources	Executive Order S-06-06	The state shall produce a minimum of 20% of its biofuels consumption, including ethanol and biodiesel fuels made from renewable resources, within California by 2010, 40% by 2020, and 75% by 2050
LCFS	Executive Order S-01-07	Calls for a reduction of at least 10% in the carbon intensity of California's transportation fuels by 2020

This reduction in carbon intensity contrasts with the federal RFS2, which establishes a timeline for absolute fuel volume reductions to achieve the stated goal. Within LCFS, separate reduction schedules are established for gasoline and diesel-related carbon intensity. The carbon intensity compliance schedule for petroleum-based diesel and diesel substitutes (17 CCR, Sections 95480 – 95490) is listed in**.** The 2010 value in the table corresponds to the carbon intensity of petroleum diesel. Subsequent average carbon intensity values reflect a projected fuel consumption portfolio with increasing biodiesel content, gradually lowering the statewide average carbon intensity related to diesel fuel.

Table 10 : LCFS Compliance Schedule for Diesel and Diesel Substitutes

Year	Average Carbon Intensity (gCO2E/MJ)	Percent Reduction 1)
2010	94.71	0%
2011	94.47	0.25%
2012	94.24	0.50%
2013	93.76	1.00%
2014	93.29	1.50%
2015	92.34	2.50%
2016	91.40	3.50%
2017	89.97	5.00%
2018	88.55	6.50%
2019	87.13	8.00%
2020	85.24	10.00%

1) Relative to 100% petroleum diesel intensity in 2010

The carbon intensities of the individual diesel fuel types recognized under the LCFS (17 CCR, Sections 95480 – 95490) are summarized in**.** Comparison of soy and waste grease-based biodiesel with petroleum diesel shows that:

- Biodiesel produced from soybean virgin oil (83.25 gCO_2e/MJ) has a carbon intensity 12 percent lower than biodiesel produced from petroleum-based ultra-low-sulfur diesel (ULSD) (94.71 gCO_2e/MJ); and

Biodiesel produced from waste grease (11.76 gCO_2e/MJ - low temperature process) has a carbon intensity 88 percent lower than petroleum-based ULSD (94.71 gCO_2e/MJ).

From those values, it is apparent that biodiesel produced from waste grease has a considerable advantage over virgin oil-derived biodiesel, and that it can contribute significantly towards LCFS compliance. To indicate how compliance may be achieved through the year 2020, CARB presented a scenario of diesel consumption, including gradual substitution of petroleum diesel with conventional (soy-based) or advanced renewable (including waste grease-based) biodiesel (Scenario 5; CARB 2009). summarizes that scenario. However, the actual diesel substitution fuel types used to achieve the reduction goal will be driven by availability and other market factors. It is expected that system enforcement will employ a market-based credit system, rewarding biofuel producers that exceed their obligation (for example, have more fuel credits than fuel deficits) with a credit that can either be sold or banked for future use.

Table 11 : Carbon Intensity Values for Diesel and Biodiesel

Fuel	Pathway Description	Carbon Intensity Values (gCO2e/MJ)		
		Direct Emissions	Land Use or Other Effects	Total
Diesel	ULSD – based on the average crude oil delivered to California refineries and average California refinery efficiencies	94.71	0	94.71
Biodiesel	Conversion of waste oils (Used Cooking Oil) to biodiesel (fatty acid methyl esters -FAME) where cooking is required	15.84	0	15.84
	Conversion of waste oils (Used Cooking Oil) to biodiesel (fatty acid methyl esters -FAME) where cooking is not required	11.76	0	11.76
	Conversion of Midwest soybeans to biodiesel (fatty acid methyl esters -FAME)	21.25	62	83.25
Renew-able Diesel	Conversion of tallow to renewable diesel using higher energy use for rendering	39.33	0	39.33
	Conversion of tallow to renewable diesel using lower energy use for rendering	19.65	0	19.65
	Conversion of Midwest soybeans to renewable diesel	20.16	62	82.16

Table 12 : LCFS Compliance Schedule under Diesel Substitution Scenario 5

Year	Total Diesel (M gal/yr)	Conventional Biodiesel 1) (M gal/yr)	Advanced Renewable Diesel 2) (M gal/yr)	Total Diesel Substitution (M gal/yr)	Percent Carbon Intensity Reduction
2010	4,393	0	0	0	0%
2011	4,484	6	11	17	0.25%
2012	4,577	12	23	35	0.5%
2013	4,672	25	47	72	1.0%
2014	4,768	36	72	108	1.5%
2015	4,866	64	126	190	2.5%
2016	4,977	90	177	267	3.5%
2017	5,091	133	262	395	5.0%

2018	5,207	175	344	519	6.5%
2019	5,325	218	433	651	8.0%
2020	5,445	281	557	838	10.0%

1) Soy-based biodiesel with a carbon intensity of 83 gCO2e/MJ

2) Advanced renewable diesel with a carbon intensity of 15 gCO2e/MJ

Source: CARB, 2009 v2

5.2.1.3 Evaluation of Regulatory Impacts on California's Biodiesel Substitution Obligation

California's biodiesel substitution obligations for RFS2 and LCSF, as discussed above, are summarized in. The data show that up to 2014, the RFS2 biodiesel substitution volume obligation dictates, and LCFS for the period thereafter. However, given the differences in GHG reduction accounting approach between the two regulations, a substitution volume inventory alone is not adequate to ensure compliance. The key difference between the two rules is that LCFS takes into account the carbon intensity of the various biodiesel production processes.

These accounting differences translate into an increased overall biodiesel substitution volume requirement and more diverse feedstock portfolio to achieve LCFS goals, as compared to achieving RFS2 goals. Table 13 plots these LCFS and RFS2 goals on a total volume basis, together with the projected total diesel demand for California. The green line in this figure represents the sum of the biodiesel substitutions projected for CARB's Scenario 5. The figure reveals that even in the year 2020, the mandated biodiesel substitution (838 million/yr) is only 15 percent of the projected total diesel demand (5.444 million/yr). It is also apparent from this figure that the RFS2 volume requirements dictate through 2014, and the LCFS volumes from 2015 onward.

Table 13 : LCFS and RFS2 Biodiesel Substitution Volume Obligations for California

Year	LCFS Total Biodiesel Substitution 1) (million gallons/yr)	RFS2 Biomass-based Biodiesel plus Other Biodiesel Substitution (million gallons/yr)
2010	0	70
2011	17	90
2012	35	110

2013	72	128
2014	108	150
2015	190	173
2016	267	190
2017	395	193
2018	519	193
2019	651	198
2020	838	204

1) Based on CARB Scenario 5 (CARB, 2009).

Table 14 : Diesel GHG Emission Reduction Comparison LCFS and RFS2

GHG Emission Reduction	Unit	LCFS	RFS2
Reduction by 2020	percent	10[1)]	3 [1)]
Reduction virgin oil derived diesel	percent	12[1)]	50
Waste grease-derived diesel	percent	88[1)]	50

1. Based on CARB Scenario 5 (CARB 2009b)

Figure 15 shows the details for the RFS2 and LCFS regulatory target volume requirements over the time period of 2010 to 2020, including CARB's projections for both conventional (soy-based high carbon intensity) and advanced renewable biodiesel (low carbon intensity feedstock-based). The figure also shows the state's existing biodiesel production capacity as of the beginning of 2010, which will have to be expanded rapidly to meet the regulatory goals.

For an appreciation of the importance of low carbon intensity feed stock biodiesel to achieve the LCFS goals, Figure 16 was developed. This figure shows the influence of the low carbon intensity component in the Scenario 5 substitution portfolio. Without that component, the volume of biodiesel needed to meet LCFS requirements increases by a factor 5, because one gallon of low carbon intensity feed stock (15.00 gCO_2e/MJ) is equivalent to 5.55 gallons of high carbon intensity feed stock (83.25 gCO_2e/MJ).

Figure 15: California Diesel Demand and Regulatory Biodiesel Substitution Requirements

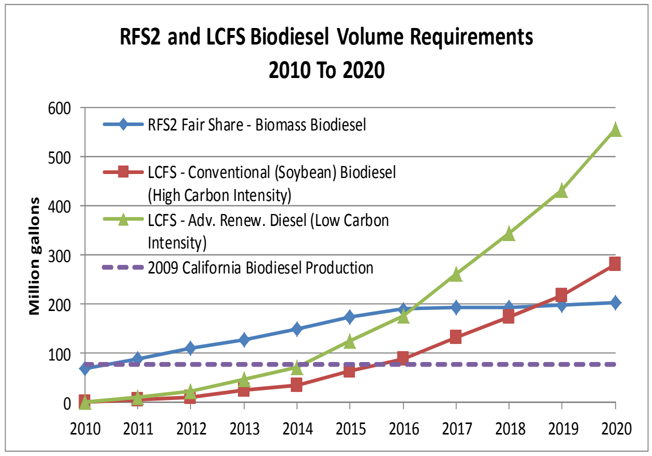


Figure 16: RFS2 and LCFS Regulatory Target Volume Requirements, 2010 to 2015

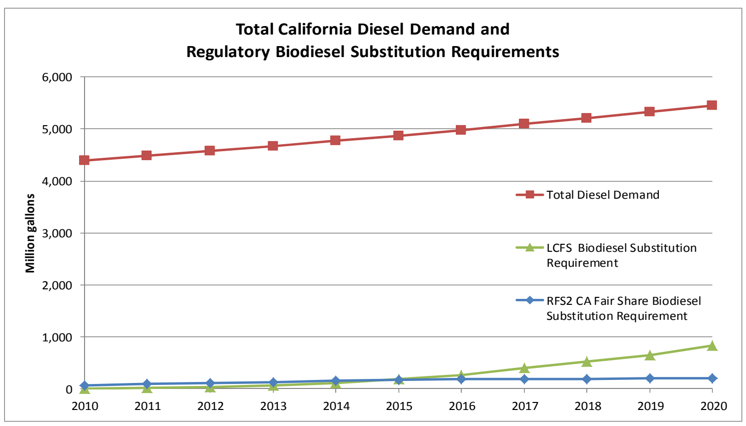
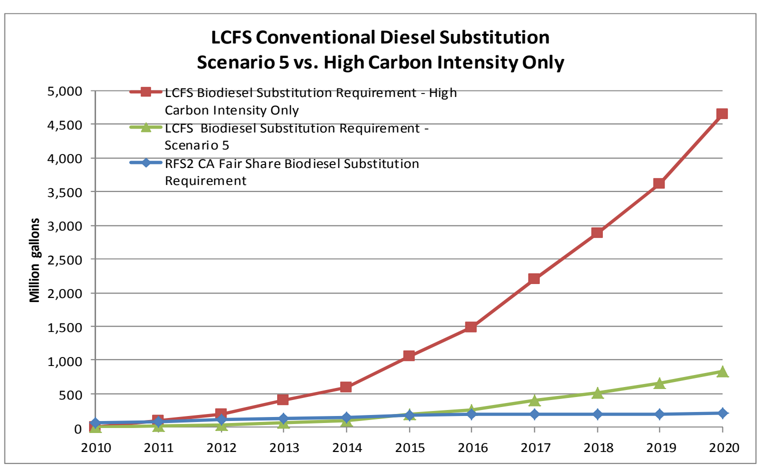


Figure 17: LCFS Conventional Diesel Substitution – CARB Scenario 5 versus High Carbon Intensity Biodiesel Only



5.2.1.4 LCFS Credit Market

One final aspect of the LCFS regulations is its credit market system. That system is envisioned to act like an emissions reduction credit program. Obligated parties that achieve more emission reduction than required will receive credits; obligated parties that do not meet their emission reduction target will receive debts. At the end of the year, those parties with credits may choose to either sell them or bank them for future use. Obligated parties who are in a deficit at the end to the year will be required to purchase credits from the market. Although the details of how this market will function are still being determined, this credit market will provide economic incentives for generating low carbon intensity feedstock biodiesel like waste grease feedstock biodiesel.

The above indicates that the California Biodiesel Market will likely become a "regulatory-pull" market with the federal biodiesel tax credit subsidizing market prices and the LCFS Credit Market providing additional financial incentives. Low carbon intensity feedstock biodiesel, like waste grease feedstock biodiesel, will most likely play an important role in achieving the LCFS goal of 10 percent GHG reduction.

5.2.2 Biodiesel Air Pollutant Emissions and Health Risks

Diesel exhaust is a complex mixture of constituents that includes carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), and particulate matter (PM), all regulated under the 1990 Clean air act. Health risks associated with petroleum diesel emissions are well documented (U.S. EPA 2007). Health effects attributed to diesel fuel include eye irritation, asthma, lung cancer, and even premature death. Organizations like The National Toxicology Program (NTP), the National Institute for Occupational Safety and Health (NIOSH), and the U.S. EPA, all classify diesel fuel as a likely carcinogen (NTP 2000, NIOSH 1988, and U.S. EPA 2004a). As part of their 2011 National Air Toxics Assessment (NATA), the U.S. EPA states that, EPA has concluded that diesel exhaust is among substances that may pose the greatest risk to the U.S. population (U.S. EPA 2011). CARB has also listed diesel PM as an air toxin (CARB 2005). This subsection summarizes the regulations related to reductions in health risks due to emissions of diesel-related air pollutants.

5.2.2.1 Current Situation

PM is an aggregate of organic and inorganic matter including chemicals like polycyclic aromatic hydrocarbons (PAH). PM has been linked to increased rates of lung-related illnesses, due to the ability of the PM to make its way into human lungs. Current regulations divide PM into two categories: PM_{10} for particles of 10 micrometers or less and $PM_{2.5}$ for particles of 2.5 micrometers or less. Figure 18 depicts the increase in California PM_{10} as reflected in the change in PM_{10} concentrations in ambient air from the three year period average of 2001 to 2003 to the 3year period average of 2006-2008 (U.S. EPA 2009). Examination of the 2002 data for annual average $PM_{2.5}$ concentration reveals over 100,000,000 person-days of air quality standard exceedances, with Los Angeles County alone having almost 90,000,000 person-days of exceedances.

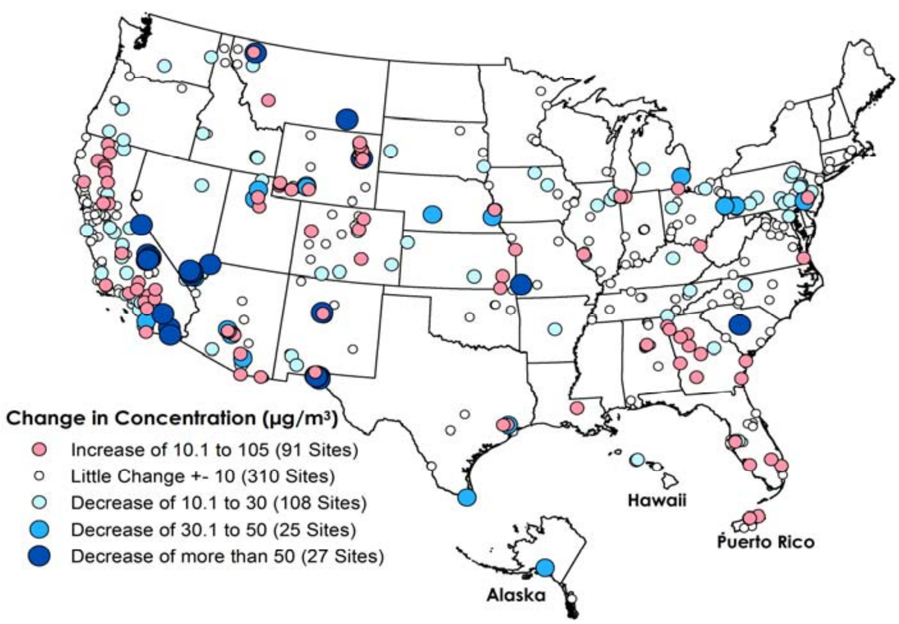
The Multiple Air Toxics Exposure Study (MATES III) report (SCAQMD 2008) concluded that 80 percent of the air basin's 1,200 per million risk of cancer due to air toxins are attributable to diesel exhaust. The area with the highest risk for air toxin exposure was determined to be the vicinity of the port of Los Angles.

Because of the increasing evidence of the health effects of diesel exhaust, President Obama recently signed into law the Diesel Emissions Reduction Act of 2010 (S. 3973/H.R. 6482), which authorizes $500 million in diesel clean-up funds over the next five years. The U.S. EPA estimates that over the life of the program, every $1 spent on emissions reduction will have a savings of approximately $20 in PM-related health care cost (U.S. EPA 2010).

5.2.2.2 Effects of Biodiesel Substitution

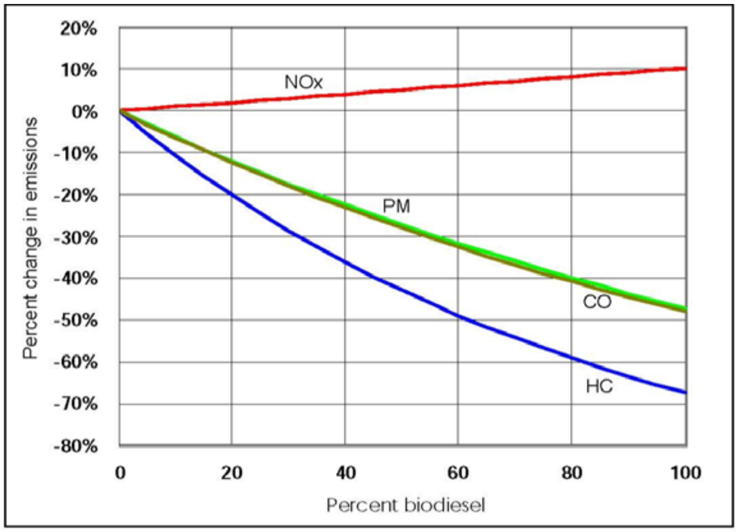
Figure 19 shows a baseline comparison of regulated air toxins for biodiesel emission relative to petroleum diesel (ULSD) emission, based on U.S. EPA study data presented in the 2002 NATA (U.S. EPA 2009).

Figure 18 :Change in Average Ambient Air PM10 Concentrations From Three Year Period Average of 2001 to 2003 to the Three-Year Period Average of 2006-2008



Source; U.S. EPA 2010

Figure 19 : Baseline Comparison of Exhaust Constituents from Biodiesel Relative to Petroleum Diesel



Source: U.S. EPA 2009

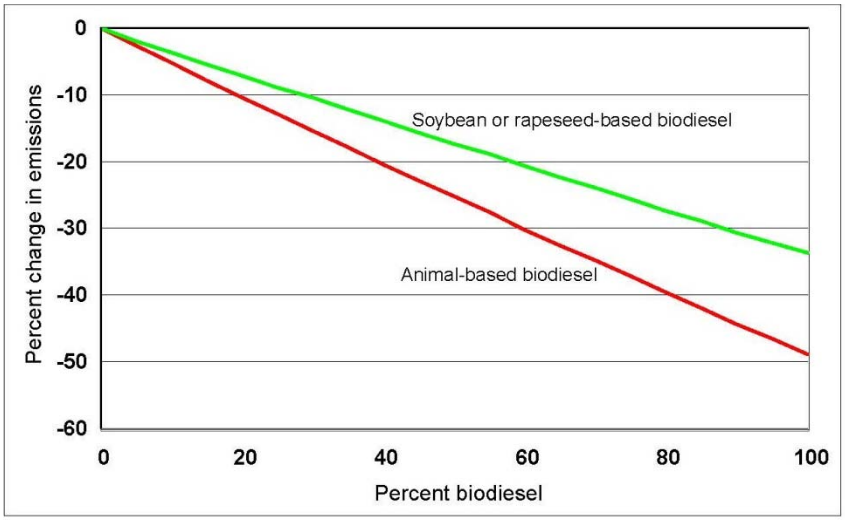
Referring to Figure 19, it is evident that for a popular 20 percent biodiesel-petroleum diesel blend (B20), the change in air emissions are as follows:

- NOx: increased 2 percent
- PM: decreased 10 percent
- HC (hydrocarbons): decreased 21 percent
- CO: decreased 11 percent

Except for NOx, there is a significant decrease in air emissions for the listed constituents related to the added biodiesel. Therefore CARB is currently investigating means to help mitigate and/or offset the NOx increase (Energy Commission 2010).

Further, U.S. EPA has performed analyses investigating the difference in biodiesel PM emission as a function of the biodiesel source stock (U.S. EPA 2009). In this study, the animal grease plot shown in Figure 20 below included waste grease. From that same figure, it may be inferred that waste grease-based biodiesel may have a lower PM emission profile than a virgin oil-based biodiesel like either soy or rapeseed.

Figure 20 :Difference in PM Emission as a Function of Biodiesel Feed Stock (U.S. EPA 2002)



The NREL performed an air toxics modeling study to project the risk of premature death due to toxins emitted by B20 and petroleum diesel in the California South Coast Air Basin (SoCAB). SoCAB is home to the ports of Los Angeles, Long Beach and the San Pedro Bay Port Complex. These ports handle two-thirds of all the containers arriving in the U.S. from Asia and the corresponding traffic from the heavy duty diesel vehicle (HDDV) fleet that transports these goods. The study results indicate that a market penetration of 50 percent and 100 percent of B20 into the HDDV fleet could result in a decrease in risk of premature death of 2 percent and 5 percent, respectively (NREL 2003).

In summary, the referenced studies indicate that using biodiesel as a substitute for petroleum-based diesel can improve overall air quality and lower health risks associated with diesel exhaust emissions. Biodiesel is also the only fuel to successfully meet the health testing requirements of the 1990 Clean Air Act (NBB 2009).

5.2.3 FOG and Sanitary Sewer Blockages – An Additional Driver

In urban areas, waste fats, oils and grease (FOG) is produced from the preparation of food in residential homes and FSEs. Waste cooking FOG can be categorized according to its relative purity as yellow grease or brown grease. Yellow grease is deteriorated oil from the deep frying process. It is also known as waste vegetable oil or used fryer oil. Brown grease is waste kitchen FOG that has been commingled with kitchen wastewater, or grey water, in dishwashing sinks and drainage systems. Brown grease sources include oily residue washed from cookware and dishware; grease rendered from the heating of fat, such as from frying bacon or roasting chicken; waste dairy fats; and grease collected in overhead kitchen ventilation systems. In many locations, FSEs are required to install and maintain grease traps in their kitchen drains to reduce disadvantages of FOG. Brown grease not captured in the FSEs grease trap winds up in the wastewater collection system.

FOG creates significant problems in wastewater collection systems that affect operation and maintenance (O&M) costs of collection and treatment systems, and potentially the public health. FOG can accumulate and restrict flow in wastewater collection systems and other pipelines causing pipe blockages that could result in SSOs or backups. **57** shows the results of an U.S. EPA study on the causes of SSOs (U.S. EPA 2004b).

Nationwide approximately 35 percent of the blockages resulting in SSOs are attributed to grease (FOG). Sanitary sewer costs associated with FOG-related SSOs and backups are difficult to quantify and are site specific. An interview with SFPUC staff, who maintains the approximately 1,000 miles of combined sewer system in San Francisco, revealed that they spend $3.45M per year on servicing grease-related blockages (Larson 2010) or $3,450 per mile per year of sewer to stay in compliance with the National CSO Policy. This is at the low end of the sewer maintenance cost spectrum of $3,100 to $12,500 per mile of sewer which were reported in a national survey (U.S. EPA 2004b).

Exposure to wastewater from sewer backups or SSOs, either directly or through a contaminated drinking water source, can result in illness due to microbial pathogens and toxic chemicals. summarizes annual illnesses attributed to exposures to sewer overflows published by U.S. EPA (2004b). Federal (40 CFR 403), state, and local ordinances are in place to reduce the likelihood of an SSO occurring, and to help keep FOG out of the wastewater collection system.

Figure 21: Nationwide SSO Causes with a Breakdown of Specific Blockage-Related Causes (U.S. EPA 2004b)

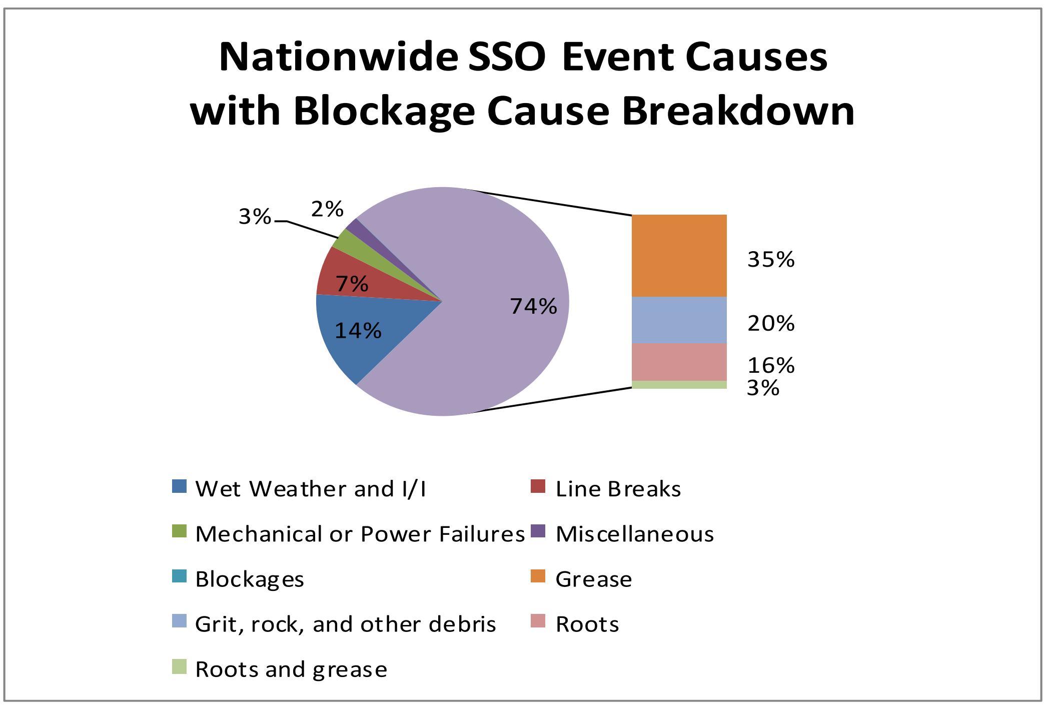


Table 15: Annual Illnesses Attributable to Exposure to Sewer Overflows

Overflow Type	Lower Estimate	Higher Estimate
SSOs	2,269	3,669
CSOs	845	1,367
CSO/SSOs	334	540

Source: U.S. EPA 2004b

The State of has defined Category 1 SSOs as meeting one or more of the following criteria:

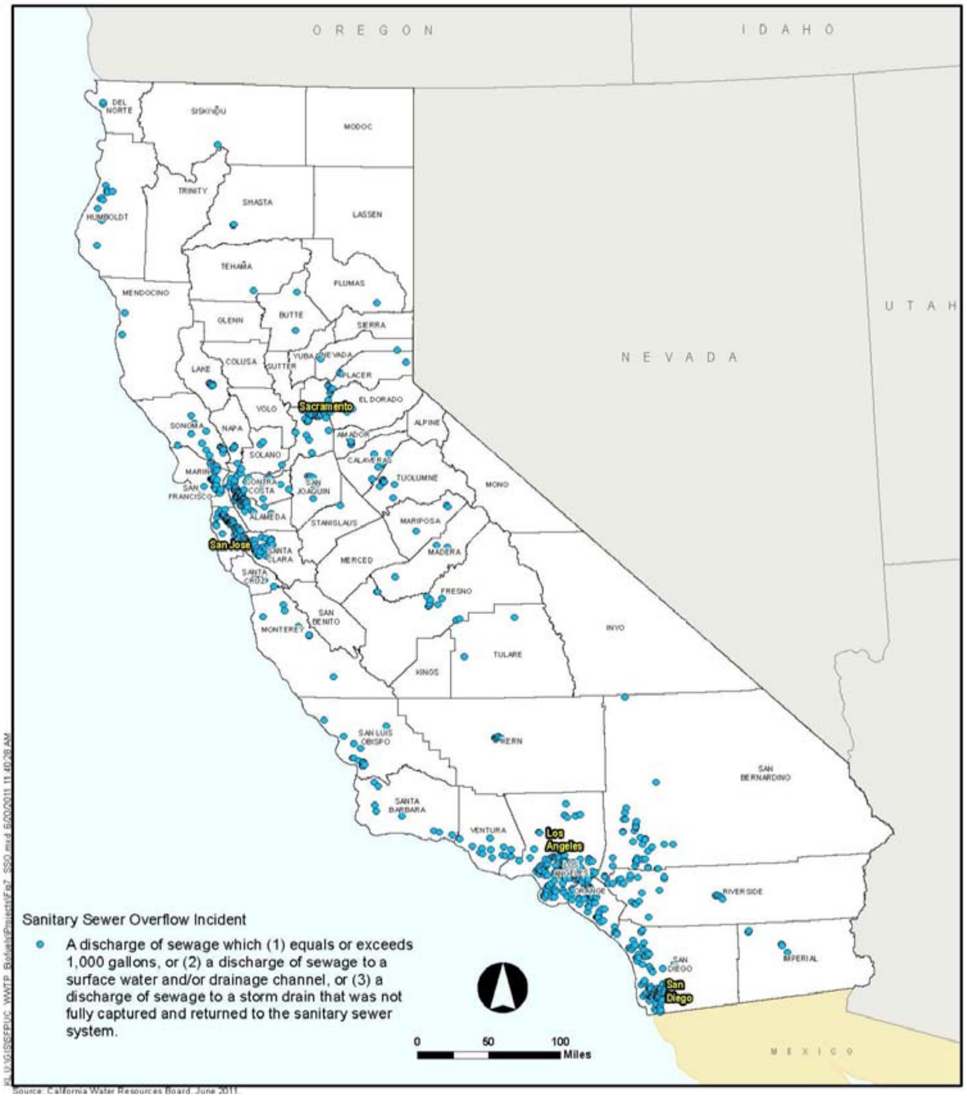
- Discharge of sewage from an event which equals or exceeds 1,000 gallons
- Discharge of sewage to a surface water and/or drainage channel
- Discharge of sewage to a storm drainpipe which was not fully captured and returned to the sanitary sewer system

California State Water Resources Control Board (SWRCB) requires all utilities to report any Category 1 SSOs that occurred between October 2010 and May 2011 (SWRCB 2006). Over this time frame, there were 5,684 reported category 1 spills of which, 1,119 were attributed to FOG. Figure 22 shows the distribution of Category 1 SSOs occurring from October 2010 to May 2011. This data indicates that improved grease management has the potential to significantly reduce the SSO frequency.

5.2.4 Biodiesel Subsidies and Historical Market Demand

The American Jobs Creation Act of 2004 included a tax credit for every gallon of biodiesel blended with petroleum diesel. A credit of $1 was established for first use biodiesel or biodiesel made from virgin oils, like soybean oil. The tax credit for second use or biodiesel made from recycled oils was established at $0.50. The difference in tax credit was intended to make up for the higher feedstock cost for first use biodiesel, relative to second use biodiesel. Since its inception, the biodiesel tax credit has been extended three times, with the exception of a lapse during 2010. The biodiesel tax credit was re-instated as part of H.R. 4853, the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010, signed into law by President Obama in December 2010. The current tax credit is $1.00 per gallon tax credit and applies to both first use and second use feedstock diesel. An economic analysis of the biodiesel tax subsidy opined that a discontinuation of the $1.00 per gallon biodiesel tax credit could have a detrimental effect on this market and potentially lead to a continuing decline in the industry (Urbanchuk 2007). The general consensus in the industry is that the $1 per gallon biodiesel tax credit will help enable the industry to meet the ambitious goals of the RFS2 and LCFS (NBB 2011). In June 2011, the House and Senate introduced the Biodiesel Tax Incentive Reform and Extension Act which extends the $1.00 per gallon tax credit from 2012 through 2014 and will reform the biodiesel tax incentive from a blenders excise tax credit to a production excise tax credit. However, this credit is not expected to remain available for any significant time beyond 2014.

Figure 22: Category 1 SSOs Occurring between October 2010 and May 2011



Source: SWRCB's website

Annual U.S. biodiesel production from 2001 through 2011 is presented on Figure 23 (U.S. Energy Information Administration (EIA) 2012). The growth shown between 2004 and 2005 correlates directly with the introduction of the biodiesel tax credit in 2004. Factors that may have contributed to the drop in U.S. biodiesel production in 2009-2010 were the lapse in the biodiesel tax credit, the drop in crude oil prices and the continuing effects of the Great Recession of 2008-2009. This drop coincides with a drop in retail diesel prices (Figure 24). When the tax credit was resumed, the biodiesel production in 2011 jumped back to the same high level as in 2008 from 2010's low point.

A further analysis of diesel retail pricing shows a comparison of U.S. west coast pump prices for biodiesel blends and petroleum diesel from 2006 through 2010. As would be expected, fuel price trends track with the crude oil price trend. During the report period, the B20 and B100 prices are on average 5 percent and 10 percent higher than diesel price, respectively.

Figure 23: U.S. Biodiesel Production, 2001-2010

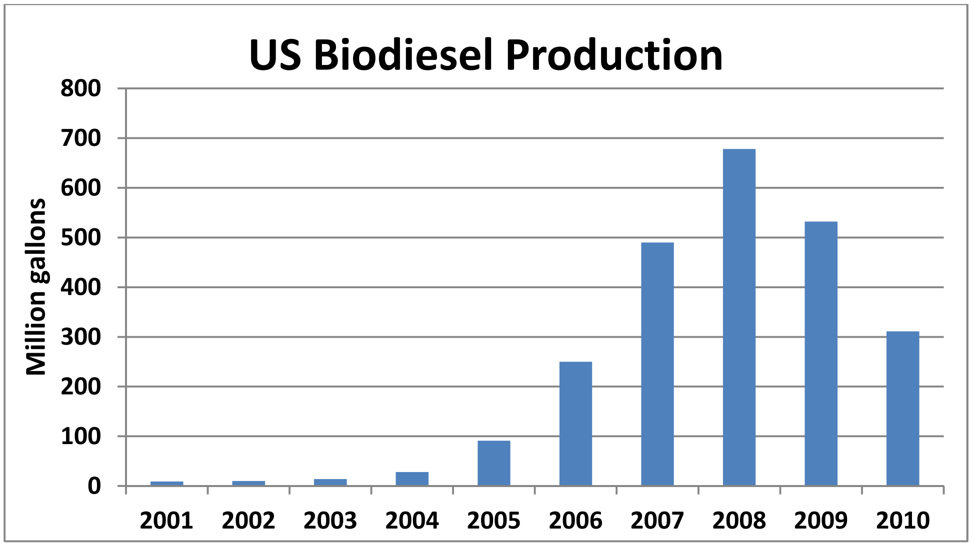
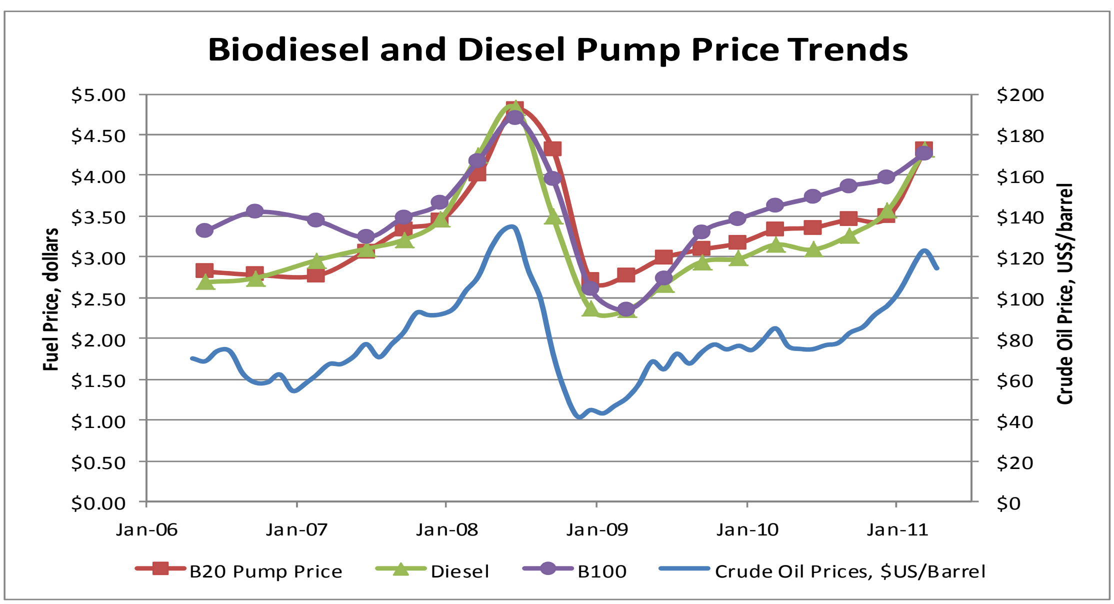


Figure 24 : West Coast Pump Prices for Biodiesel and Diesel



Source: EIA 2012

Data trends of interest include:

- First half of 2008 when biodiesel prices were lower than diesel prices which may be explained by the high price of crude oil;
- End of 2008 through mid-2009 when biodiesel prices varied from 10 percent to 20 percent higher than diesel prices; and
- End of 2009 through most of 2010 when biodiesel prices varied from 12 percent to 20 percent, higher than diesel prices, which likely corresponded with the lapse of the biodiesel tax credit in 2010 and with continued low crude oil prices.
- The first 10 months of 2011, which showed a sharp rebound in biodiesel production, mainly fuelled by increasing crude oil prices.

Volatility of biodiesel pump prices is a concern. High prices could curtail consumption; low prices could impact a facility's bottom line.

5.3 Site Selection

The purpose of this section is to analyze the availability of brown grease in California and select locations suitable for large-scale biodiesel production based on the outcome. Since the predominant factor for availability of brown grease is related to population density, this section utilizes population data for areas in proximity to major WWTPs. The analysis results in a list of candidate WWTP sites for locating biodiesel refineries.

5.3.1 Site Selection Criteria

The U.S. EPA 2008 Clean Watershed Needs Survey (CWNS) database identified over 600 WWTPs in the state of California ranging in size from 0.002 MGD to 460 MGD (U.S. EPA 2004b).

Ultimately, site selection is driven by locations that generate enough biodiesel to be economically viable, and can handle biodiesel refinery waste streams. These objectives were translated into the following site selection criteria:

- An urban location with proximity to enough trap waste to produce at least 300,000 gallons of collectible brown grease per year, which corresponded to selecting WWTP sites in metro areas larger than 1.4 million people and with total municipal treatment flows greater than 40 MGD. Note that these flows may come from more than one plant in the area.
- A 25mile radius sphere of influence to help achieve a balance between feedstock collection and feedstock competition with adjacent municipalities.
- An anaerobic digester(s) to convert whitewater waste streams into energy and to process raw trap waste in the event of a system malfunction. Note that many plants with anaerobic digestion still operate without cogeneration.

5.3.2 Site Analysis and Selection

A total of 17 WWTPs managed by 11 municipal facility owners were identified, for which the CWNS database indicates they meet the site selection criteria.

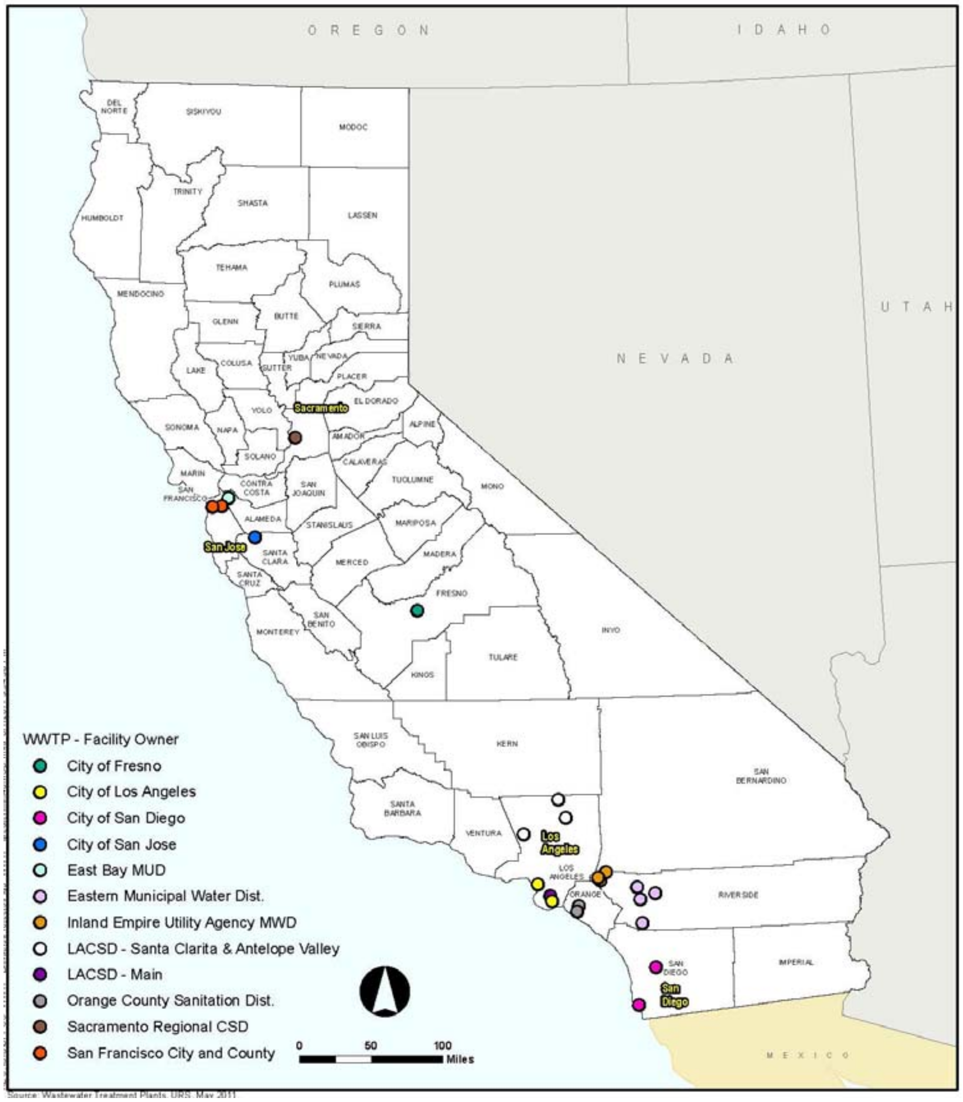
Table 16 lists the WWTPs by treated flow rate and facility owner and Figure 25 shows their locations. The identified plants are located in some of the top-13 most populated counties in the state. It should be noted that Los Angeles County Sanitation District (LACSD) is broken out into two entities: LACSD-Main, which is the location of the Joint Water Pollution Control Plant, and LACSD – Santa Clarita & Antelope Valley, which is the location of three remote WWTPs.

Table 16 : WWTP Candidate Sites with Treated Plant Flows Greater than 10 MGD and Operating Anaerobic Digestion

Facility	Facility Owner	Treated Flow (MGD)
Chino Basin RP 1	Inland Empire Utility Agency	37
Fresno WTF	City of Fresno	65
Terminal Island Treatment Plant	City of Los Angeles	30
Hyperion TP	City of Los Angeles	437
San Diego Point Loma	City of San Diego	172
San Jose/Santa Clara WPCP	City of San Jose	167
EBMUD Main WWTP	East Bay Municipal Utility District	78
EMWD - Moreno Valley RWRF	Eastern Municipal Water District	16
EMWD - Perris Valley RWRF	Eastern Municipal Water District	11
EMWD: Hemet/San Jacinto RWRF	Eastern Municipal Water District	11
LACSD-JWPCP	Los Angeles County Sanitation District (LACSD)	331
Valencia WRP	LACSD - Santa Clarita & Antelope Valley	10
OCSD Plant No. 2	Orange County Sanitation District	155
OCSD Plant No. 1	Orange County Sanitation District	89
Sacramento Regional WTP	Sacramento Regional County Sanitation District	181
San Francisco SE WPCP	San Francisco Public Utilities Commission	62
San Francisco Oceanside WPCP	San Francisco Public Utilities Commission	23

Source: U.S. EPA 2004b

Figure 25 : WWTPs with Treated Plant Flows Greater than 10 MGD

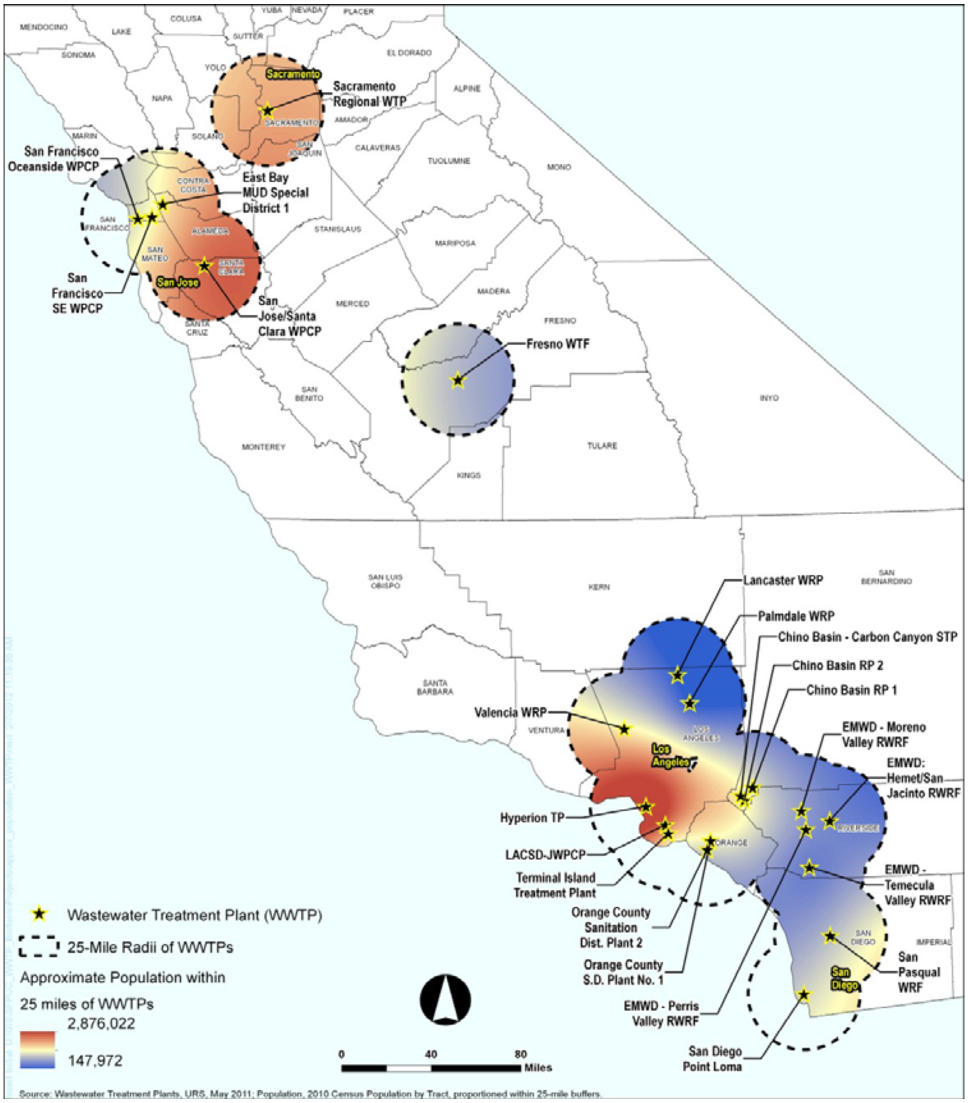


Based on the NREL data discussed in Section 3 for per capita grease waste generation (NREL 1999), 2010 U.S. Census population data (U.S. Census 2010) and the volume conversion efficiencies of brown and yellow grease to biodiesel of 80 and 100 percent, respectively, the recoverable brown grease, yellow grease and total biodiesel production potential per year were calculated with 25-mile radius (Figure 24). Moreover, Figure 26 shows the potential biodiesel production site locations with the 25mile radius area located based on the centroid of the WWTPs. Note that where census tracts are located in overlapping 25mile radii, the population and corresponding quantities are equally distributed among the respective facilities, as seen in Figure 24 and Figure 26. The identified candidate WWTPs located in North and South California have the potential for generating enough waste grease to produce approximately 19.79 and 9.27, MGAL/YR biodiesel, respectively.

Table 17: Summary of Waste Grease Collection and Biodiesel Production Potential by Municipal Facility Owner

Facility Owner	Brown Grease Collection (Mgal/yr)	Yellow Grease Collection (Mgal/yr)	Biodiesel Production (Mgal/yr)
Inland Empire Utility Agency MWD	1.78	4.26	4.96
City of Los Angeles	0.80	1.91	2.22
LACSD - Main	1.02	2.43	2.83
City of San Diego	1.20	2.87	3.33
City of San Jose	1.01	2.42	2.81
Orange County Sanitation District	1.05	2.51	2.91
East Bay MUD	0.66	1.57	1.82
Sacramento Regional CSD	0.78	1.85	2.16
San Francisco City and County	0.89	2.13	2.48
Eastern Municipal Water District	0.89	2.13	2.48
City of Fresno	0.38	0.92	1.07
LACSD - SC&A	0.63	1.49	1.74
Totals	10.47	24.99	29.06

Figure 26: Annual Biodiesel Production Potential with a 25-mile Radius for Selected WWTPs.



Based on the data presented, the identified locations account for 29 million gallons per year of biodiesel production potential. This is about 63 percent of California's total potential for grease-based biodiesel production, which is on the order of 46 Mgal/yr (calculated with the above-referenced per-capita. To put these values into context, a biodiesel production of 29 Mgal/yr corresponds to 23 percent of the 2015 and 5.5 percent of the 2020 LCFS low carbon intensity feedstock biodiesel target. The importance of low carbon intensity feedstock biodiesel is achieving the LCFS goals necessitates an approach that maximizes development of waste grease-based feedstock biodiesel production.

Economy of scale, opportunity for regionalization, air quality improvements, and SSO reduction are all factors to consider when prioritizing facility importance. Inland Empire Utility Agency, the City of Los Angeles and LACSD facility owners each serves a population large enough to support a 5 Mgal/yr biodiesel facility, followed closely by the City of San Diego facility which could support a 4 million gallon per year facility. The clustering of facilities shown in Figure 26 reveals regionalization opportunities in both southern California and the San Francisco Bay area. Although promising from the economy of scale perspective, the hauling market could prove difficult to maintain, given the hauling distances and congestion-related concerns associated with southern California and the San Francisco Bay area. Referring back to Section 5.2.2, conventional diesel air emissions and associated health effects are most pronounced in Southern California in the vicinity of the ports. Weighting of the above factors results in a clear prioritization for Southern California facilities. Further examination of SSO data reported revealed significant spill volumes occurring in southern California counties, of which a considerable portion is attributable to FOG. In summary, it is recommended that southern California to be given priority to construct a network of waste grease feedstock biodiesel production facilities due to its economy of scale, opportunity for regionalization, potential air quality improvements, and SSO reduction.

5.4 Scenario Selection

5.4.1 Brown Grease Recovery Scenario

Based on the market analysis presented in the above subsections, it is evident that roughly one third of California's recoverable brown grease is available in the San Francisco Bay Area and two third in the greater Los Angeles/San Diego basin. As discussed earlier, one of the main issues with trap waste is its dilute nature. This has a direct negative impact on the transportation effort per unit of grease hauled. Therefore, it is important to reduce the water content of the trap waste as soon as possible following its collection. Driven by this need to reduce transportation, hauler past practices included in-vehicle decanting. This method enabled haulers to collect the contents of a grease trap, followed by returning the majority of the water fraction into the trap and retaining only the oily fraction in their trucks. However, in recent years this practice has been banned by California Assembly Bill 1333 passed in 2006 (AB 1333 2006) since it was perceived as a way of discharging unidentified solid waste into public sewer systems.

Another method of reducing the water content of trap waste is installation of automatic grease removal devices. Those devices periodically skim the collected grease off the liquid in the trap, thereby reducing the water content of the waste grease. However, this is not yet proven technology.

Therefore, the only legal and proven effective method to reduce the trap waste transportation effort is to set-up a network of local or regional brown grease recovery facility installations (URS 2012). Those installations apply physical separation methods only, without any chemical conversion, and are straight forward relatively easy to operate. Since such brown grease recovery facility installations produce a high-strength wastewater stream (whitewater), co-location with a wastewater plant appears to be a logical step. The recovery installation size should be determined based on the population in the WWTP's service area. A network of 30 installation units with a trap waste receiving capacity of 5.2 million gallons per year appears adequate to cover all of California the minimizing the required transportation effort reduction.

5.4.2 Biodiesel Refinery Scenario

Biodiesel refineries are complex installations that chemically convert grease into biodiesel, followed by various separation processes to recover the desired diesel product in pure form, to recover unreacted chemicals (mainly methanol), and to produce potentially useful byproducts like glycerin and bunker fuel. Those installations generally work with one or more toxic and/or flammable chemicals at elevated temperatures and pressures. Consequently, biodiesel refineries require close attention from trained operators. This type of chemical processing is foreign to the wastewater industry, but closely resembles many petro-chemical industries. Further, because of their complexity, biodiesel refineries benefit greatly from an economy of scale effect, since most controls and supervision requirements are capital-intensive but virtually size-independent.

A recent inventory of available biodiesel technology providers (URS 2011) indicates that heterogeneous catalysis is the basis for several recently constructed, large-scale (for example, >200 million gallons per year) biodiesel refineries, each of which is co-located at an oil refinery site. Additionally, those facilities' operations are increasingly independent of the FFAs content of the grease feedstock, which is important when processing brown grease, and use hydrogen to produce hydrocarbon diesel, rather than methanol esterification. This apparent trend may indicate a centralized future for biodiesel production.

Thus, setting up larger biodiesel refineries at oil refinery or similar industrial sites appears a logical scenario. To minimize the cost of transportation, while at the same time being mindful of the need for larger biodiesel refineries, it appears justifiable that brown grease produced in Northern California would be refined in a San Francisco Bay Area location, while Southern California material would be processed in one or two plants in that area. The recoverable grease volumes for northern and southern California are on the order of 10 million and 20 million gallons annually, respectively. Therefore, a total of two 20million gallon refineries is proposed in the following analysis.

5.5 Economic Analysis

5.5.1 Methodology and Assumptions

The economic analysis of brown grease recovery and biodiesel production is laid out as follows:

- A comparison between a brown grease recovery facility located at a WWTP that sells brown grease to the biodiesel refinery versus a facility that just collects all grease for digestion;
- A comparison between constructing and operating two 10 Mgal/yr biodiesel refineries (one located in Northern California close to Richmond and the other in Southern California near El Segundo) versus one 20 Mgal/yr biodiesel refinery in Southern California.

In analyzing financial feasibility, the benefit cost analysis (BCA) only includes the revenues, costs and savings for the owning entity whether that is a public utility (public ownership) or a private company (private ownership). It does not include other economic, social and environmental benefits and costs that would typically be monetized in a net social BCA.

The process of discounting enables the direct comparison of amounts of money that accrue or are spent over different time periods. Discounting gives greater weight to initial benefits and costs and less weight to those occurring in the future. The present value of a future sum is lower the higher the discount rate. Industry sources suggest discount rates in the range of 10 to 20 percent to capture market risk for the biodiesel refinery, depending on the extent to which the plant develops procurement contracts for both production inputs and outputs (Ginder and Paulson 2006). Given conservative assumptions for production and knowledge that all biodiesel production will be used by the vehicle fleet, a nominal discount rate of 10 percent has been used in this evaluation. The period of analysis is 30 years, which was based on the estimated useful life for the biodiesel refinery.

Analysis of the trap waste accepting facility at the WWTP (which will either recover the brown grease or else send it all to be digested) will use a lower discount rate of 5 percent; this value is that recommended for government projects (Office of Management and Budget 2011). The equipment is expected to have a lifespan of 20 years.

5.5.1.1 Inflation and Variable Cost Expenditures

The base year for the analysis is 2011, the first year of operation for both the brown grease recovery facility and the biodiesel refinery is expected to be 2016. All expenses and revenues are inflated/escalated over the life of the analysis and then discounted back into 2011 dollar terms. The inflation and default economic value assumptions used in the analysis are listed in Table 18 and Table 19**.**

Table 18 : Inflation Assumptions

Parameter	Value
General Inflation	2.44%
Natural Gas (industrial) Consumed	3.10%
Electricity (industrial) Consumed	1.40%
Whole Sale ASTM Biodiesel	3.80%
RIN	5.00%
Offspec Biodiesel/biobunker fuel	3.80%
LCFS	3.80%
Capital Costs	3.80%

Table 19: Default Economic Value Assumptions

Parameter	Value	
Capital Costs	100%	
Trap Waste Tipping Fee	$0.06	
Brown Grease	$0.19	
Ratio Yellow/Brown Grease Price	$1.78	
Yellow Grease Price (calculated)	$0.34	
Wholesale ASTM Biodiesel	$3.00	
RIN	$0.50	
LCFS	$0.10	
Trap Waste Processing	**Brown Grease Recovery**	**Digestion**
Debt	100%	100%
Grant	0%	0%
Equity	0%	0%
Nominal Interest Rate	5.0%	5.0%
Biodiesel Refinery	**Two 10 Mgal/yr**	**One 20 Mgal/yr**
Debt	50%	50%
Grant	0%	0%
Equity	50%	50%
Nominal Interest Rate	10.0%	10.0%

The project's construction cost is capitalized and depreciated using the straight line method over 20 years. No salvage value is been assumed for assets. The income tax rate used is 41 percent, which included a 35 percent rate for the Federal Government and a 9 percent rate for California. Three forms of financing were modeled, namely debt (long-term loan), grant contribution and equity. The default values used are listed in Table 19.

There are many additional cost data used in this analysis, which are related to market prices for raw materials, products, and utilities, and general business economics. Table 20 and Table 21 provide an overview of those data. These values are used throughout the entire economic sensitivity analysis.

Table 20: Raw Material, Product and Utility Price Information

Input	Unit	Value
Water w/ disposal at WWTP	$/100 cu ft	$0.00
Electricity (WWTP) Consumed	$/MWh	$105.32
Natural Gas (WWTP) Consumed	$/MMBTU	$9.33
Electricity (WWTP) Produced	$/MWh	$105.32
Natural Gas (WWTP) Produced	$/MMBTU	$9.33
Trucking Fee	$/hr	$80.00
Methanol	$/gal	$1.30
Sulfuric Acid	$/lb	$0.05
Calcium Oxide	$/lb	$0.09
Water (Refinery)	$/100 cu ft	$5.03
Wastewater disposal (Refinery)	$/100 cu ft	$6.55
Natural Gas (Refinery) Consumed	$/MMBTU	$5.84
Electricity (Refinery) Consumed	$/MWh	$105.32
Offspec Biodiesel/biobunker fuel	$/lb	$0.29
Glycerol	$/lb	$0.00

Table 21: Business Economical Input Parameters

Parameter	Unit	Value	
Trap Waste Processing		**Brown Grease Recovery**	**Digestion**
Permit+ Odor Control	$/yr	$6,100	$6,100
Payroll	$/yr	$187,500	$187,500
Annual Maintenance	% of Capital Cost	3.80%	3.80%

Property Tax	% of Capital Cost	0.00%	0.00%
Insurance	% of Capital Cost	0.30%	0.30%
Contingency	% of O&M, G&A	5.00%	5.00%
Life Span	Yrs	20	20
Loan Length	yrs	20	20
Discount Rate		5%	5%
Biodiesel Production Facility		**Two 10 Mgal/yr**	**One 20 Mgal/yr**
ASTM Testing	$/yr	$60,000	$30,000
Product Marketing Pricing	% of Revenue	0.00%	0.00%
Payroll & Benefits	$/yr	$2,5 Million	$3,8 Million
Fixed Operating Expenses	% of Revenue	0.50%	0.50%
Annual Maintenance	% of Capital Cost	3.80%	3.80%
Corporate Overhead	% of Revenue	1.00%	1.00%
Insurance	% of Capex	0.30%	0.30%
Property Tax	% of Capex	1.00%	1.00%
Management Fees	% of Revenue	0.00%	0.00%
IP Fees	% of Revenue	0.00%	0.00%
Contingency	% of O&M, G&A	5.00%	5.00%
Depreciation (Straight line, for 20 yrs)	%	5.00%	5.00%
Life Span	yrs	30	30
Loan Length	yrs	25	25
Discount Rate	%	10%	10%
Tax Rate	%	41%	41%

5.5.2 Capital Cost Expenditures

The capital costs used in this business case assessment include: (1) construction of the different alternative facilities (brown grease recovery vs. digestion, and two 10 Mgal/yr biodiesel production facilities versus one 20 Mgal/yr biodiesel production facility); and (2) working capital necessary for operation of the biodiesel production facility for the first 3 months. As presented in Table 22, the capital costs estimate for a 6 Mgal/yr brown grease recovery facility is $3.8 million, while the infrastructure for only a digesting facility would cost on the order of $2.3 million. The capital cost for two 10 Mgal/yr and one 20 Mgal/yr commercial biodiesel production facilities are estimated at $74.1 and $56.7 million, respectively.[3] There is assumed to be no working capital required at the trap waste receiving facilities; however, the biodiesel production facilities are expected to need 3 months of working capital. This amounts to $18.8 million and $9.8 million, respectively for the two 10 and one 20 Mgal/yr facilities.

Table 22: Capital Costs and Working Capital Estimates

Facility	Capital Costs ($1000s)	Working Capital ($1000s)
Brown Grease Facility	$3,783	$0
Digester Facility	$2,338	$0
Two 10 Mgal/yr Biodiesel Production Facilities	$64,832	$13,185
One 20 Mgal/yr Biodiesel Production Facility	$49,618	$12,646

Note: In 2011 dollars

The primary equipment included in the cost estimate is for brown grease at the WWTP, biodiesel processing, and the storage of all reactants and products. In addition, capital costs are included for facility land purchase at the current industrial real estate prices (on a per acre basis) in Richmond and El Segundo. Land purchase is assumed necessary for the co-location of the brown grease recovery facilities. The schedule of expenditures is shown in Table 23.

Table 23: Capital Cost Expenditure Profile for Biodiesel Production Facilities During Construction

Year	% Total Capital Cost	Working Capital
2012	10%	0%
2013	20%	0%
2014	40%	0%
2015	30%	0%
2016	0%	100%
Total	**100%**	**100%**

[3] All costs presented in this report are in 2011 dollars unless otherwise noted.

5.5.2.1 Measures of Financial Feasibility

Financial feasibility analysis of a business involves some measure of profitability. Common metrics include net profit and earnings (profit) before interest, depreciation, taxes, and amortization (EBIDTA).

Net profit refers to the difference between revenues from all sources and all costs (including income taxes). It includes both operating and non-operating measures, the former arising from the actual sale of the specific goods and services produced by the enterprise. Non-operating costs reflect the administrative and related expenses required in running any business, but which are not specific to the direct production process of goods and services being sold.

EBIDTA is a quantitative description of the operating profitability of a business. It is measured by subtracting from total operating revenues all costs, excluding interest, depreciation, taxes, and amortization. The four excluded expenses may vary significantly even among businesses of similar size within the same industry. Differences may arise because of variations in the following areas:

- Assets – current, for example cash and inventory, versus fixed, for example buildings and machinery
- Liabilities – debt, for example owed to lenders, versus equity capital, provided by business owners
- Interest expenses, which may differ because of the times that loans were obtained, amount of debt versus equity financing, length of loans, and guarantees and collateral required by lenders
- Depreciation, which may differ depending on the service lives of capital assets and when they are actually purchased
- Taxes, which vary depending on different rate structures both between and within states
- Amortization, which for a new business typically refers to the payment of a loan over a specified number of periods and which may differ among borrowers

Because EBIDTA excludes these expenses, which can vary widely among otherwise similar businesses, it is frequently considered a better measure of the actual operating finances of a business than net profit.

Internal rate of return (IRR) is the annualized effective compounded return rate that can be earned on the invested capital. It represents the interest (discount) rate which equates the cost of an asset with the present value of the expected cash flows from the investment over time. It is typically calculated using the formula:

$$\text{Cost of asset} = \text{Present value of anticipated cash flows}$$

The IRR calculation rests on a critical assumption that all net earnings from an investment are reinvested by the business through the end of the investment's service life.

5.5.3 Benefit Cost Analysis

The results of the BCA are presented as a net present value (NPV), IRR, payback period, benefit-cost ratio (BCR), and break- even prices. Considerations when performing BCA are:

- The important decision rule to be considered cost-effective is that the NPV (present value of revenues less the present value of costs) must be greater than zero.
- The PP is the period of time it takes for cumulative cash flow to become positive. For this study, the payback period is discounted and therefore captures the opportunity cost of capital.
- The break-even price is the price at which the NPV is zero.

5.5.4 Base Case Analysis

A discounted cash flow analysis is presented in Table 24 and Table 25.

The results of the BCA indicate that a brown grease recovery facility, co-located at a WWTP, financially breaks even in about 20 years with a tipping fee of $0.08 per gallon of trap waste using the default economic values described in Table 19.

The results of the BCA also show that a commercial 10 Mgal/yr biodiesel refinery financially breaks even in 30 years with the overall wholesale biodiesel price (which includes LCFS and RIN credits) of $3.67; this is unacceptably long for private industry projects. A more common 5year payback is achieved at a biodiesel price of $4.66. As transportation fuel prices are volatile, it indicates RINs and other credits are necessary to be competitive during times of depressed fuel pricing. For a 20 Mgal/yr biodiesel refinery, 30- and 5year payback times are achieved at biodiesel prices of $3.40 and $4.24, respectively.

5.5.5 Sensitivity Analysis

The analysis undertaken is conceptual in that several of the variables used in the analysis are not known with any certainty. Sensitivity analysis has been used to explore the impact on the results of assumptions for capital costs and the source of project funding.

5.5.5.1 Capital Cost

A sensitivity analysis was undertaken for capital costs where costs were reduced by 20 percent and increased by up to 40 percent of the current cost estimate. The results of the analysis are shown in Table 26.

The results show the NPV is sensitive to Cap costs for both the brown grease recovery facility and 10 Mgal/yr biorefineries; if it were to increase by 20 percent that the NPV falls below zero and hence, the investment would no longer be cost-effective.

Table 24: Discounted Cash Flow Analysis Trap Waste Accepting Facility, Assuming 0% Equity Funding

Parameter	Brown Grease Recovery	Trap Waste Digestion
Revenue*	20-yr NPV	20-yr NPV
Tipping Fee	$5.36 Million	$5.36 Million
Brown Grease Production	$2.80 Million	N.A.
Electricity Production	$2.25 Million	$4.70 Million
Biomethane Production	$0.90 Million	$1.88 Million
TOTAL	**$11.30 Million**	**$11.93 Million**
Costs		
Cost of Goods Sold [A]	$8.11 Million	$5.91 Million
Principle Payment	$2.77 Million	$1.71 Million
Interest	$1.98 Million	$1.23 Million
Income Taxes	$0	$0
TOTAL	**$12.86 Million**	**$8.85 Million**
PROFIT	**($1.56Million)**	**$3.08 Million**
INVESTMENT SUMMARY		
Capital Investment	$0	$0
TOTAL 20-yr NPV	($1.56 Million)	$3.08 Million
Breakeven Tipping Fee ($/gal)	$0.08	0.03
Breakeven for Brown Grease ($/gal)	$0.30	N.A.

Note A: This covers annual expenses, such as labor, maintenance, and overhead

Table 25: Discounted Cash Flow Analysis Trap Waste Accepting Facility, assuming 50% Equity Funding

Parameter	Two 10 Mgal/Yr Biodiesel refineries	One 20 Mgal/Yr Biodiesel refinery
Revenue	30-yr NPV	30-yr NPV
Biodiesel	$1.76 Million	$1.76 Million
Tax Credit	$0	$0
RIN	$0.44 Million	$0.44 Million
Biobunker Fuel	$61,966	$61,966
LCFS Credits	$58,575	$58,575
Glycerol Production	$0	$0
TOTAL	**$2.32 Million**	**$2.32 Million**
Costs		
Cost of Goods Sold [A]	$1.91 Million	$1.80 Million
Principle Payment	$27,097	$19,695
Interest	$66,910	$48,633
Income Taxes	$0.11 Million	$0.17 Million
TOTAL	**$2.12 Million**	**$2.04 Million**
PROFIT	**$0.20 Million**	**$0.28 Million**
INVESTMENT SUMMARY		
Capital Investment	$39.01 Million	$31.13 Million
TOTAL 30-yr NPV	$159,896	$245,822
Breakeven Biodiesel+LCFS+RIN ($/gal)	$3.67	$3.40
Breakeven for Brown Grease ($/gal)	$0.207	$0.233

Note A: This covers annual expenses, such as labor, maintenance, and overhead.

Table 26: Capital Cost Sensitivity

Brown Grease Recovery Facility– sensitivity of results to capital costs, assuming 0% equity funding.				
PARAMETER	**80% Cap Costs**	**100% Cap Costs**	**120% Cap Costs**	**140% Cap Costs**
Cap Cost	$3.03 Million	$3.78 Million	$4.54 Million	$5.30 Million
TOTAL 20-yr NPV	$0.06 Million	($1.28 Million)	($2.62 Million)	($3.96 Million)
Breakeven Trap Waste	$0.0592	$0.0774	$0.0957	$0.1139
Breakeven Brown Grease	$0.1850	$0.2956	$0.4061	$0.5167

Digestion Facility– sensitivity of results to capital costs, assuming 0% equity funding.				
PARAMETER	**80% Cap Costs**	**100% Cap Costs**	**120% Cap Costs**	**140% Cap Costs**
Cap Cost	$1.87 Million	$2.34 Million	$2.81 Million	$3.27 Million
TOTAL 20-yr NPV	$3.37 Million	$2.54 Million	$1.71 Million	$0,88 Million
Breakeven Trap Waste	$0.0142	$0.0255	$0.0367	$0.0480

Two 10 Mgal/yr Refineries– sensitivity of results to capital costs, assuming 50% equity funding				
PARAMETER	**80% Cap Costs**	**100% Cap Costs**	**120% Cap Costs**	**140% Cap Costs**
Cap Cost	$65.05 Million	$78.02 Million	$90.98 Million	$103.95 Million
TOTAL 30-yr NPV	$47.39 Million	$23.07 Million	($1.25 Million)	($25.56 Million)
Breakeven Brown Grease	$0.23	$0.21	$0.19	$0.17
Breakeven Biodiesel+LCFS+RIN	$3.48	$3.67	$3.86	$4.05
IRR	16.50%	10.90%	5.70%	10.00%
Payback Period	11	19	No Payback	No Payback

One 20 Mgal/yr Refinery– sensitivity of results to capital costs, assuming 50% equity funding

PARAMETER	80% Cap Costs	100% Cap Costs	120% Cap Costs	140% Cap Costs
Cap Cost	$52.34 Million	$62.26 Million	$72.19 Million	$82.11 Million
TOTAL 30-yr NPV	$76.52 Million	$57.89 Million	$39.25 Million	$20.62 Million
Breakeven Brown Grease	$0.25	$0.23	$0.22	$0.21
Breakeven Biodiesel+LCFS+RIN	$3.25	$3.40	$3.54	$3.69
IRR	24.5%	19.0%	14.4%	10.3%
Payback Period	6	9	13	20

Notes

1. Present values are calculated using a discount rate of 10% over 30 years with the base year in 2016.

5.5.5.2 Project Financing

The results were sensitivity tested under different financing conditions. Four scenarios for financing were evaluated, namely:

- 100 percent Equity contribution
- 100 percent Debt Financing
- 50 percent Grant Funding and 50 percent Equity Financing
- 50 percent Grant Funding, 25 percent Equity Funding and 25 percent Debt Funding

The results are shown in **Table 27 and Table 28**.

Table 27: Project Financing

Brown Grease Recovery				
Financing Method	A	B	C	D
Cap Investment	$3.78 Million	$3.78 Million	$3.78 Million	$3.78 Million
Debt	$0	$3.78 Million	$0	$0.94 Million
Grants	$0	$0	$1.89 Million	$1.89 Million
Equity	$3.78 Million	$0	$1.89 Million	$0.95 Million
NPV	$(2.15 Million)	$(1.02 Million)	$(0.07Million)	$0.21 Million

Breakeven Tipping Fee	$0.081	$0.077	$0.053	$0.051
Breakeven BG[1] Price	$0.317	$0.296	$0.145	$0.140
IRR	1.4%	2.3%	8.9%	13.6%
Payback Period (yrs)	N.A.	N.A.	N.A.	10
Trap Waste Digestion				
Financing Method	A	B	C	D
Cap Investment	$2.34 Million	$2.34 Million	$2.34 Million	$2.34 Million
Debt	$0	$2.34 Million	$0	$0.58 Million
Grants	$0	$0	$1.17 Million	$1.17 Million
Equity	$2.34 Million	$0	$1.17 Million	$0.58 Million
NPV	$1.21 Million	$1.91 Million	$2.50 Million	$2.68 Million
Breakeven Tipping Fee	$0.028	$0.026	$0.010	$0.010
IRR	10.3%	N.A.	25.4%	46.3%
Payback Period (yrs)	9	N.A.	5	3

Notes: 1. BG – Brown Grease
Legend
Method A: All equity
Method B: All debt
Method C: 50% grant, 50% equity
Method D: 50% grant, 25% debt, 25% equity

The results show that any grant funding of the project's capital costs will significantly improve the financial attractiveness of the commercial biodiesel refinery. With 50 percent of capital costs financed by debt and the remainder financed grant funded, the NPV is $30.3 million and the payback period is less than 4 years.

Table 28: Project Financing (Continued)

Two 10 Mgal/yr Biodiesel Refineries				
Financing Method	A	B	C	D
Cap Investment	$78.02 Million	$78.02 Million	$78.02 Million	$78.02 Million
Debt	$0	$78.02 Million	$0	$19.50 Million

Grants	$0	$0	$39.01 Million	$39.01 Million
Equity	$78.02 Million	$0	$39.01 Million	$19.50 Million
NPV	$(1,784,298)	$14.35 Million	$17.72 Million	$21.75 Million
Breakeven Biodiesel Price	$3.760	$3.580	$3.450	$3.410
Breakeven BG[1] Price	$0.199	$0.215	$0.228	$0.232
IRR	9.7%	N.A.	18.0%	25.7%
Payback Period (yrs)	N,A.	N.A.	10	6
One 20 Mgal/yr Biodiesel Refinery				
Financing Method	A	B	C	D
Cap Investment	$62.26 Million	$62.26 Million	$62.26 Million	$62.26 Million
Debt	$0	$62.26 Million	$0	$15.57 Million
Grants	$0	$0	$31.13 Million	$31.13 Million
Equity	$62.26 Million	$0	$31.13 Million	$15.57 Million
NPV	$29.40 Million	$54.93 Million	$60.53 Million	$66.92 Million
Breakeven Biodiesel Price	$3.460	$0.239	$3.220	$3.190
Breakeven BG[1] Price	$0.226	$0.226	$0.249	$0.253
IRR	15.1%	N.A.	25.4%	36.8%
Payback Period (yrs)	10	N.A.	6	4

Notes: 1. BG – Brown Grease
Legend
Method A: All equity
Method B: All debt
Method C: 50% grant, 50% equity
Method D: 50% grant, 25% debt, 25% equity

5.5.6 Pricing Assumptions

In undertaking a BCA, it was necessary to make assumptions with regards to project revenues and project expenses. Values reported in Table 19 and Table 20 were estimated based on averages of each item's prices over the last 5 years (after inflating the prices to 2011 dollars using CPI). Several inputs and products have costs that are expected to have a large sensitivity on the project as well as potentially having a large uncertainty component.

5.5.6.1 Trap Waste Tipping Fee

Tipping fees are commonly charged to grease trap waste haulers by utility operators to receive and treat grease trap waste.

Grease trap waste haulers choose which receiving facility to bring their collected trap waste based on tipping and hauling costs. Tipping fee costs can be based on a flat fee, volume of waste tipped, trap waste characteristics (percent water, grease, and solids) or some combination thereof. Hauling costs include the fuel, drivers' wages, tolls, and vehicle maintenance, all of which depend on distance traveled from where the trap waste is collected to where it is tipped. Consequently, it may be more cost effective for a hauler to tip at a nearby facility with higher tipping fees than to haul to a more distant location with lower tipping fees.

Trap waste tipping fees in California range from $0.03 to $0.15 per gallon. Recently the fees have begun to fall as facilities compete for this revenue source (SFPUC 2011). While flow control ordinances could be used to keep collected waste grease in the district where they are produced, it assumed downward pressure from competition will continue to lower tipping fees closer to a minimum breakeven point. The assumed tipping fee used in the BCA is $0.06 per gallon based on tipping and hauling costs and facility convenience (for example, operating hours, ease of unloading and so forth).

5.5.6.2 Yellow Grease and Brown Grease

Yellow grease has recently become an attractive feedstock for biodiesel production as on average it was traded at half the price of virgin soybean oil. This has driven up the price of yellow grease and made it much more volatile than if it were based on the price of biodiesel.

Brown grease has generally had a small market and is used to replace yellow grease (for example, as animal feed). The price ratio between the two has, in general, stayed relatively constant at around 1.78 (Table 29), although there was an increase in 2010 (to 2.14) and a decrease in 2011 (to 1.56). This swing was most likely caused by the biodiesel cost swing and producers scrambling for alternative feedstock. Brown grease has generally not been considered by commercial producers; however, that will likely change in the future with new technology.

Although brown grease prices have averaged below $0.15 per pound over the last 5 years, the limited availability and increase in demand from biodiesel producers is most likely going to increase the long term average price closer to the 2010-2011 average of $0.19 per pound. Yellow grease is expected to continue to trade at a 78 percent premium to brown grease.

5.5.6.3 Biodiesel

Biodiesel prices have fluctuated substantially in the last decade to large demand driven by the regulatory environment, a substantial increase in biodiesel production and fluctuating diesel prices driven by crude oil prices. Recently, biodiesel has maintained an average pump price of almost $4 per gallon. While it is unlikely to continue to have a $0.40 premium to diesel, $3 per gallon is considered to be conservative future biodiesel price. This compares to data from OPIS showing that as of January 2012, the wholesale rack price in the Los Angeles market for yellow grease produced biodiesel is $3.11 (Jacobsen Publishing Company 2012 and OPIS 2012).

Table 29: Historical Average Pricing of Brown and Yellow Grease and Biodiesel

Prices of Brown Grease, Yellow Grease and Biodiesel				
Year	Brown Grease	Yellow Grease	Yellow Grease/Brown Grease	Biodiesel
	cent/lb	cent/lb		cent/gal
2007	11.3	19.8	1.74	333.9
2008	15.9	27.2	1.71	466.4
2009	9.4	16.2	1.73	323.8
2010	11.2	23.9	2.14	371.9
2011	25.9	40.2	1.56	487.9
2007-2011	14.7	25.5	1.78	396.8

Source: Jacobsen Publishing Company 2012

Although the U.S. Federal Government has been providing a $1 per gallon tax credit for blending, this is not expected to continue. The RIN market (which has steadily increased from less than $0.20 per RIN in 2009 to $1.60 in mid-2011) is much more likely to impact biodiesel prices and producers in the coming decades (LaSalle Group 2010, USDA 2011). The model used $0.50 per RIN as a starting point. In addition, biodiesel refineries producing biodiesel for the California market will be able to receive LCFS credits. These credits may have a value up to $0.10 per gallon.

Due to the uncertainty of both the RIN and LCFS markets, the price for biodiesel was lumped together with that of the RIN and LCFS. If RIN and LCFS credits are available, they will put downward pressure on wholesale biodiesel prices over the long term. The business case has used $3.60 per gallon to include the wholesale value to the producer of biodiesel and any associated RINs and LCFS credits. This is a conservative assumptionTable30 demonstrates the potential returns with higher prices.

Table 30: Biodiesel Prices vs. NPV, Payback and BCR

Biodiesel Sensitivity Analysis		
	Two 10 Mgal/yr	20 Mgal.yr
Capital Cost	$106.7 Million	$85.8 Million
Debt	50%	50%
Grant	0%	0%
Equity	50%	50%
Interest Rate	10%	10%
Brown Grease	$/gal	$0.19
Yellow Grease/Brown Grease Ratio		1.78

Biodiesel price [A]	***Two 10 Mgal/yr NPV***	***20 Mgal/yr NPV***	***Two 10 Mgal/yr payback***	***20 Mgal/yr payback***	***Two 10 Mgal/yr BCR***	***20 Mgal/yr BCR***
	In Millions	In Millions				
$3.30	-$47	-$12	No Payback	No Payback	-0.21	0.61
$3.40	-$34	$1	No Payback	30	0.12	1.02
$3.50	-$22	$13	No Payback	23	0.45	1.43
$3.60	-$9	$26	No Payback	17	0.77	1.84
$3.70	$4	$39	28	13	1.10	2.25
$3.80	$17	$52	22	10	1.43	2.65
$3.90	$29	$64	16	8	1.75	3.06
$4.00	$42	$77	13	7	2.08	3.47
$4.10	$55	$90	11	6	2.41	3.88
$4.20	$68	$103	9	5	2.74	4.29

$4.30	$80	$115	8	5	3.06	4.70
$4.40	$93	$128	7	4	3.39	5.11
$4.50	$106	$141	6	4	3.72	5.52
$4.60	$119	$153	5	4	4.04	5.93
$4.70	$131	$166	5	3	4.37	6.34
$4.80	$144	$179	4	3	4.70	6.75
$4.90	$157	$192	4	3	5.02	7.16
$5.00	$1	$204	4	3	5.35	7.57

Note A: Includes RIN and LCFS credits

CHAPTER 6: Benefits Of Project To California

6.1 Introduction

In the preceding section (Section 5), a business case scenario was introduced where brown grease recovery facilities are to be integrated with the systems and operations at a municipal WWTP, and a biodiesel refinery(s) with the systems and operations at an oil refinery. Roll-out of the demonstrated technology according that business case scenario has the potential to result in a number of public benefits, including:

- Health effects from reduced air pollution
- Reduction of the climate change potential
- Benefits due to reduction in the number of sewer blockages
- Green jobs creation

6.2 Health Effects from Air Pollution

The biodiesel produced will displace an equivalent amount of conventional diesel on a BTU basis. This will reduce not only GHG emissions but will also reduce other air pollutants normally emitted with diesel engine exhaust.

As discussed in Section 5.2.2.2, for diesel blend B20, the changes in air emissions relative to petroleum diesel (ULSD) are as follows:

- PM: decreased 10 percent
- HC (hydrocarbons): decreased 21 percent
- CO: decreased 11 percent
- NOx: increased 2 percent

The benefits of reduced pollution may include fewer cases of asthma and other lung ailments, and in some severe cases, a reduction in mortality (Wong et al. 2009). The difficulty with assessing the economic value of any air quality benefits associated with a commercial biodiesel production in California is estimating the net change in air quality that will occur where diesel is replaced by biodiesel. Based on annual California conventional diesel sales of approximately 2.8 billion gallons (BOE 2010), a production of 20 Mgal/yr biodiesel has the capacity to replace approximately 4 percent of that amount by a B20 blend. The likely impact on the local air quality is relatively small. Therefore, no benefits have been assessed for improved health effects associated with reduced air pollution.

6.3 GHG Emissions Reduction

One of the specific objectives of this study is to estimate the net change in GHG emissions for implementation of the business case relative to a baseline scenario. Utilizing the GHG emissions models that were previously developed for this project's Greenhouse Gas Report task (Martis 2011), the effects of full implementation of a 20 Mgal/yr business case, as described in Section 5 above were estimated by comparing the following two scenarios:

- Scenario 1: Business as Usual - a base case representing California's existing wastewater management, assuming the situation in San Francisco is representative for the rest of the state. This includes a scenario where 75 percent of grease-containing wastewater discharges from FSEs is discharged directly to the local wastewater collection system, as would be the case if FSEs did not have grease traps in place, or if grease traps were not functioning or maintained properly. The remaining 25 percent of grease-containing wastewater discharges are captured in traps and/or interceptors. The traps and interceptors are routinely cleaned and the trap waste is hauled to a landfill for disposal. The trap waste volume considered in this case is approximately 154 Mgal/yr, which is identical to the volume considered in Scenario 2.
- Scenario 2: Business Case - collection of 154 Mgal/yr of trap waste (containing approximately 5 percent brown grease) from FSEs, and operation of a network of brown grease recovery facilities co-located at WWTPs. This network will have a collective brown grease production capacity of approximately 3.4 Mgal/yr. The model further assumes collection of 17.2 Mgal/yr yellow grease and operation of two biodiesel refineries with a total biodiesel production capacity of 20 Mgal/yr, co-located at oil refineries in Central and Southern California.

Emissions of GHGs were quantified in two primary categories: mobile and stationary sources. A mass balance model was developed to evaluate the two scenarios based on estimated waste grease characteristics and volumes that could be generated in the City of San Francisco by FSEs. Based on information contained in the National Renewable Energy Laboratory's 1998 report, *Urban Waste Grease Resource Assessment*, it was assumed that an average of 13.37 lbs/person/yr of brown grease and 8.87 lbs/person/year of yellow grease are produced in the City of San Francisco. Based on national averages, the brown grease content in FSE grease traps and interceptors is 3 to 7 percent by volume. Based on laboratory analyses of trap waste samples, performed during the demonstration project in San Francisco, an average grease concentration of 4.67 percent by volume was used for the calculations. The model was customized to utilize hauling distances typical for an urban setting.

Biodiesel fuel that is created to replace petroleum-derived diesel on an equivalent BTU basis will reduce net GHG emissions. Most of the carbon dioxide released in the creation and use of biodiesel is biogenic, while all of the carbon dioxide released in the creation and use of diesel is anthropogenic. Based on the model results, it is concluded that the collection of FSE trap waste and beneficial reuse of brown and yellow grease for the production of digester gas and 20 Mgal/yr biodiesel, will yield an overall net reduction in GHG emissions compared with baseline Scenario 1 (current practice). A summary of the model results is presented in Table 31 and Figure 27.

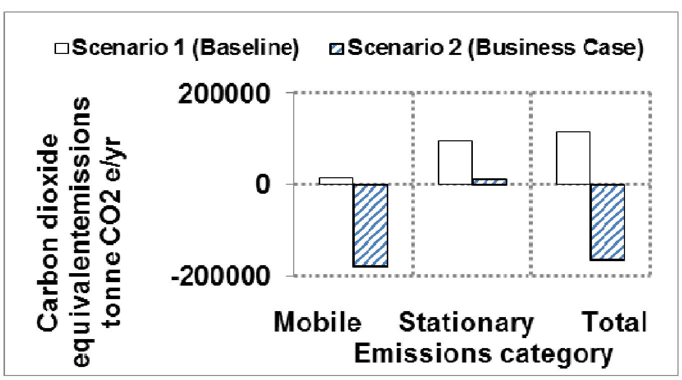
Table 31: Comparison of GHG Emissions for Different Grease Management Scenarios

		Emissions, tonne CO_2 e/yr			
Scenario	Description	Mobile	Stationary	Total	Changes from Baseline total
1	California Baseline	17,872	98,290	116,162	
2	California Business Case	-176,924	13,857	-163,066	-279,228

Source: URS Corporation staff calculations; Appendix G.

It should be noted that values reported for the business case scenario are relative to the baseline scenario; negative numbers indicate a relative reduction in emissions and positive number indicated a relative increase in emissions. The total GHG emissions calculated for Scenario 1 (the baseline), with GHG emissions reported in units of metric tons of carbon dioxide equivalent per year (tonne CO_2e/yr), are 116,162 tonne CO_2e/yr. It is estimated that the trap waste separation and brown and yellow grease to biodiesel business case (Scenario 2) will result in net emissions of about -163,066 tonne CO_2e/yr, for an estimated overall net GHG emissions reduction of about 279,228 tonne CO_2e/yr compared with the baseline Scenario 1. This net reduction is approximately equivalent to the GHG emissions related to the average annual electrical power usage of 145,000 San Francisco-area households. [4]

Figure 27: Summary of GHG Emissions Model Results: Comparison of Scenarios 1 and 2



Source: URS Corporation staff calculations.

[4] The average San Francisco area household has an annual electrical power use of 7350kWh (KEMA-XENERGY 2004). Pacific Gas and Electric Company lists a carbon footprint of 0.524 lbs CO2e per kWh (PG&E 2011).

6.4 Benefits Due to Reduced Sewer Blockages

The majority (75 percent) of California's brown grease is assumed to be disposed of in sanitary sewers. The brown grease tends to coat the inside of sewer lines, which can clog the pipes and reduce their capacity to collect and transport sewer flows to the WWTP. (Figure 28)

Figure 28: Pictures of (a) Clean Pipe with No FOG and (b) Pipe with Accumulated FOG

(a) (b)

Source: SFPUC, 2009

Clogged sewers result in SSOs, whereby untreated sewage is discharged to streets, and or sewers back-up into household residences, or restaurants. SSOs result in considerable clean-up costs, involve costly damage to sewer infrastructure, result in foul-smelling odors, can lead to loss of business income, and in extreme situations may cause severe health impacts.

Each year, the SFPUC spends an estimated $3.45 million responding to more than 2,500 grease-related blockages (Hurst 2009). Forty percent of the emergency work performed was undertaken on FSEs (Figure 29).

Although this project does not directly reduce disposal of grease into the sewer lines, it is likely to have a positive effect on grease collection through municipal enforcement of local ordinances once trap waste becomes a valuable commodity. The benefits to residences of reduced sewer blockages include reduced health impacts, improved amenities, and reduced odors.

6.5 Green Jobs Creation

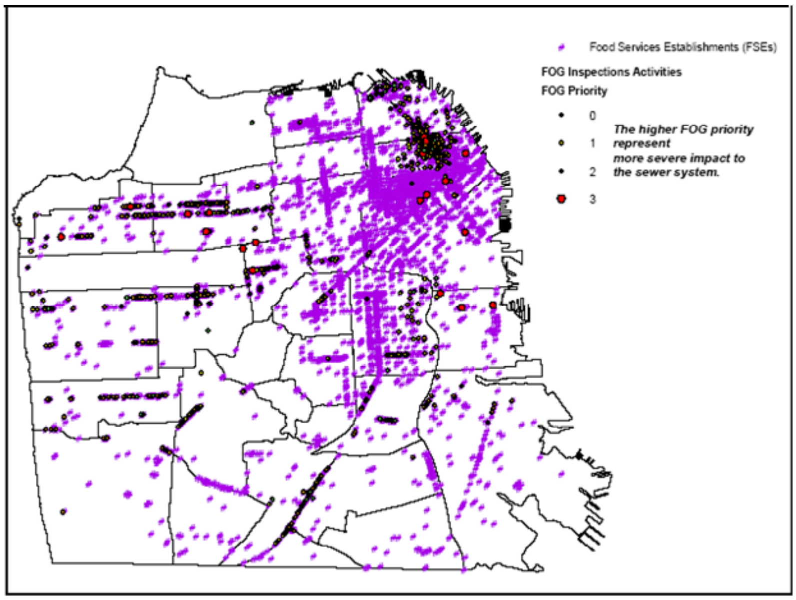
6.5.1 Introduction

Green collar jobs are defined as those that provide a sustainable solution to a waste management problem. The analysis adopts a broader view of green collar jobs, considering those working directly at the project sites as well as those additional indirect jobs created beyond the facilities' gates.

The jobs created will be classified into three categories:

- Direct (green collar jobs working to construct or operate the facilities and refineries),
- Indirect (green collar jobs working to provide inputs supporting the refinery), and
- Induced (non-green collar jobs working to provide services to direct and indirect workers who are spending their paychecks in the community).

Figure 29: Distribution of San Francisco's FSEs and FOG Inspection Activities (SFPUC 2006)



Note that induced jobs are not green collar jobs. These jobs are opportunities that arise within the community providing services in support of the new green collar workers. The primary focus in this analysis is on the direct and indirect green collar jobs as they have the greatest potential to positively impact the lives of local communities.

6.5.2 Total Job Creation Expected

The collection of trap waste, recovery of brown grease and operation of a commercial biodiesel refinery all have the potential to provide significant green-collar job creation both in the short-term during facility construction and in the long-term through facility operation. Employment resulting from the construction of Brown Grease Recovery Facilities and Biodiesel Production Facilities is not considered permanent and therefore a more relevant measure of this temporary job creation is job years rather than total number of jobs. For example, five people who work for two years are considered to have worked ten job years. The operation of a brown grease recovery facility and biodiesel production facility is ongoing and the employment created is considered permanent and is measured in the total number of jobs available annually. Given the uncertainties in continued operation surrounding any commercial facility like a biodiesel refinery, the job estimates in this analysis should be considered a first attempt to quantify and qualify the types of opportunities that could be created by the facilities. As the project proceeds and more facility specifics are developed, these estimates should be refined accordingly.

The number of green jobs was determined using two separate methodologies and the results were compared for consistency. The first methodology was created by the President's Council of Economic Advisors for determining job creation from capital spending under the American Recovery and Reinvestment Act (ARRA).[5] The second methodology was provided by the Political Economy Research Institute (PERI).[6] The results of those analyses are estimated green-collar job creation totals of 4.0 direct job years, 2.7 indirect job years per $1 million in capital spending. Note as stated above, induced jobs are not green collar jobs and are therefore not further examined in this analysis. For the business case of brown grease recovery in 11 facilities and refining in one 20 Mgal/yr or two 10 Mgal/yr refineries, construction has the potential to create somewhere between 393 to 466 direct job years and 277 to 312 indirect job years, respectively. If the industry selects to forego the production of biodiesel, but rather digests all trap waste, the estimated direct and indirect job years created are only at 22 to 25 percent of those values reported above. Table 32 shows projected job creation potential during the construction period.

Table 32: Projected Job Creation Potential during Construction Period

Facility	Cap Costs	Direct Jobs	Indirect Jobs
		(Job-Years)	(Job-Years)
Eleven Brown Grease Recovery Facilities	$41,613,000	166	112
Eleven Digester Facilities	$25,718,000	103	69
Two 10 Mgal/yr Biodiesel Production Facilities	$74,124,000	300	200
One 20 Mgal/yr Biodiesel Production Facility	$56,729,000	227	153

Although most of the jobs associated with equipment and material construction may not be created locally, almost all of the remaining positions must be staff locally.

5

Source: Council of Economic Advisors, 2009. This methodology suggested using 7 direct and indirect job years and 3.9 induced job years per million dollars of expenditures. This yields a total of 10.9 jobs per $1 million in spending.

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6 Source: PERI (2009). This methodology suggested using 7.4 direct and 5 indirect job years, and 5 induced job years per million dollars of expenditures. This yields a total of 17.4 per $1 million in spending

According to this scenario, once constructed, the facilities could potentially generate around 11 fulltime job equivalents annually in brown grease recovery and 50 fulltime job equivalents in biodiesel refining. A considerable number of these permanent green collar jobs would not require advanced degrees and could potentially be filled by residents.

CHAPTER 7:
Technology Transfer and Public Outreach

In the preceding Section 5, a business case scenario was introduced where brown grease recovery facilities are to be integrated with the systems and operations at a municipal WWTP, and a biodiesel refinery(s) with the systems and operations at an oil refinery. To successfully roll-out the demonstrated technology in California, and ultimately achieve that business case scenario, a significant technology transfer and outreach effort would be needed. This section describes the technology transfer and public outreach activities that SFPUC and URS undertook during the demonstration project.

7.1 Introduction

In 2009, SFPUC embarked on a demonstration Brown Grease to Biodiesel project. This project was partly funded by the U.S. EPA and the California Energy Commission. It was in the interests to both the U.S. EPA and the Energy Commission that SFPUC create a means of disseminating information about the project, including project performance, GHG emissions, and a business case showing the benefits of the technology. As a public agency, SFPUC prides itself on transparency and effective communication with its stakeholders. Staff from the SFPUC Communications Group were involved from the project's earliest days, and have worked with the Project Team to ensure effective communication.

Over its course, the demonstration project's focus for technology transfer has been to disseminate project information to municipalities and other interested parties in both formal and informal ways. In doing so, California ratepayers reap the maximum benefit from grant funding, as awareness of the technology deployed is raised among public agencies in California. The ancillary benefits also include raising public awareness of the project, as well as the potential for waste grease to be an energy resource. Long-term, the ability of public agencies to produce locally sourced fuel from waste grease can contribute to the renewable energy portfolio of local municipalities. SFPUC, BGB, PBTech, and URS all have participated in various technology transfer activities to achieve these goals. This section presents details on the performed activities.

7.2 Technology Transfer Activities Conducted

Technology transfer and public outreach activities are intertwined and generally fall into the following categories:

- Facility tours
- Interviews and articles in trade publications
- Media events
- Technical publications
- Conference and workshop participation

- Development and release of outreach materials such as brochures, FAQs, website information, and so forth
- Informal updates to industry and other interested parties through local and regional groups (such as California Association of Sanitation Agencies, California Water Environment Association, SFPUC's Citizens' Advisory Committee – Wastewater Subcommittee(WWCAC)
- Street fairs and other special public events
- General inquiries through the Communications Group

Prior to the project startup, outreach activities largely consisted of media interviews and technical presentations of project objectives to professional audiences. To coordinate those activities and maximize their effect, in June 2010, the Communications Group developed a Public Outreach Plan approximately 6 months in advance of the project startup. This plan included activities such as media events, media relations, maintaining a contact/issue database, participating in stakeholder meetings, creating communication materials, and providing outreach to other agencies. A primary public information officer from the Communications Group is designated as the responsible party for interacting with the Project Team and providing public relations support. Some of the outreach activities inevitably coincided with outreach activities for the existing SFGreasecycle program, which is a free yellow grease collection service offered to restaurants.

7.3 Implementation of the Public Outreach Plan

Communications efforts were limited in the first year of the project, as activities at the site were limited to construction, startup, and troubleshooting. The agency conducted a press event with San Francisco's Mayor in 2009, conducted interviews with the news media, issued a press release, and provided technical presentations at conferences. These efforts relayed the goals of the project and anticipated project outcomes.

The 2010 Public Outreach Plan has been implemented during a number of events. An overview of outreach categories is presented in the following paragraphs.

7.3.1 Contact/Issue Tracking Database

SFPUC maintains a database for media and public inquiries. This was used to track all inquiries related to this project. Largely, these were media calls, although periodically, other members of the public and industry representatives would contact the agency for information on the project. Interested parties were provided with requested materials (such as, fact sheets, presentations) in a timely manner.

7.3.2 SFPUC Citizens' Advisory Committee WWCAC Meetings and Stakeholder Groups

As a public agency that prides itself on transparency, SFPUC maintains a Citizens' Advisory Committee representing different stakeholders throughout the City of San Francisco. The WWCAC provides feedback on initiatives and programs within the Wastewater Enterprise.

Team members from the Brown Grease to Biodiesel project provided two updates to the WWCAC and will provide one final update when the project final report has been completed to disseminate the results of the research, GHG analysis, and business case model. In addition, team members presented information on the project to a group of community representatives on the Southeast Plant Digester Task Force as the kind of project that might be implemented at San Francisco's larger secondary WWTP. Future presentations to stakeholder groups will continue to be given upon request.

7.3.3 Street Fairs, Events, and Tours

SFPUC routinely participates in San Francisco's street fairs and public events to provide relevant and interesting information to San Francisco's diverse communities. By May 2011, a fact sheet was developed for this project for distribution at targeted street fairs and events. Information on tours is provided on the fact sheet and web site, and tours have been provided throughout the project by request. Towards the end of the demonstration period (May 2011), an official announcement went out through the California Association of Sanitation Agencies (CASA) eNews, offering tours to other public agencies.

7.3.4 Media Relations

SFPUC has a template for tracking media inquiries which was used for this project. In addition, the agency has a database tool, GoldMine™, which allows for the sending of e-mails with attachments to media outlets interested in a particular project. These tools were used to track interviews and general media inquiries and to assist in providing the appropriate information to those making inquiries. A press release will be held announcing the production of biodiesel at the site after a significant quantity of ASTM D6751 S15 biodiesel has been produced. Communications materials developed for the project are also provided to the media as requested.

7.3.5 Communications Materials

In order to make basic information on the project accessible, SFPUC developed a two-page fact sheet, available in printed form or via download from sfwater.org. This fact sheet outlines the process that is used, identifies the project goals, lists the technology partners, and presents the expected outcomes. Similarly, a poster was developed for the OSP with simple graphics and facts to give a basic project overview to the public. Basic project information and the fact sheet were made available on the SFPUC website – sfwater.org. Finally, for those attending tours or for other by-request presentations, the Project Team developed a standard Power Point presentation which walked through the goals of the project, the technologies deployed, and highlights of the project outcomes.

7.3.6 Agency Outreach

Upon completion of the six-month demonstration period (December 2010-May 2011), SFPUC posted a message to the CASA list serve. CASA represents over 90 percent of the sewered population in California, and as such, is able to provide a meaningful forum to reach out to other agencies. In addition, agency contacts were made through a consultant subcontracted to SFPUC. Three agencies were identified from this initial outreach effort – Napa Sanitation

District, Delta Diablo Sanitation District, and Eastern Municipal Water District. Additional agencies may request tours and information, and SFPUC made it clear that the project site is open to any interested parties. In addition, SFPUC have hosted tours for federal and state regulators, including the U.S. EPA, CalRecycle, and Energy Commission.

As the research portion of this project concludes, the Project Team will finalize a business case report, which, along with other reports (such as Socioeconomic report (Martis 2010), Greenhouse Gas report, and so forth) outreach materials developed, will form part of a toolkit for agencies interested in embarking on FOG recycling efforts. These final reports and outreach materials will be made available directly to the interested agencies listed above, as well as on the SFPUC website, sfwater.org. In addition, the Project Team staff will always be available to answer questions and assist other public agencies wishing to replicate any aspect of this project. It is thus anticipated that agency outreach will long outlast the demonstration/research period of this project.

7.4 Summary of Activities Conducted

Since inception of the project, a variety of outreach activities have been conducted. Table 33 provides a summary of those activities conducted through June 2011.

7.5 Conclusion

The Communications Group will continue to manage public interest in the project, providing tours, media interviews, and information to interested parties. SFPUC has made a good effort in public outreach, including reaching out to a number of municipalities. It is expected that the Brown Grease to Biodiesel project will continue to draw public attention for quite some time following the demonstration period, as more operational data become available. Therefore, SFPUC is committed to continue its outreach through facility tours and technical publications for a significant time period.

Table 33: Technology Transfer and Public Outreach Overview

Technology Transfer Category	Activities Completed
Facility Tours	• City of Orlando, 2/13/09 • U.S. EPA Region IX, 11/17/09 • California Water Environment Association (CWEA) - Young Professionals Group, 6/23/10, estimated 25 attendees • City of Dallas, 11/03/10 • City of Tempe, 11/4/10, 3 attendees • Bay Area Maintenance Managers Infoshare, 1/26/11, estimated 20 attendees

	• CleanTech, 3/14/11, 34 attendees • AECOM, Biosolids North American Practice Leader, 3/16/11, 1 attendee • NEWALTA, 3/22/11, 1 attendee • Energy Commission, French Consulate, German Consulate, Sacramento Municipal Utilities District, 4/28/11, 10 attendees • Eastern Municipal Water District, 6/17/2011 • BACWA - Quarterly Air Meeting, 7/20/2011, 18 attendees
Interviews and Articles in Trade Publications	• 2/4/09 Biodiesel Plant Project CBS 5 News • 2/4/09 San Francisco Receives Grant for Biodiesel Project *KCBS Radio* • 2/5/09 SF to Convert Guckiest Cooking Grease to Fuel *San Francisco Chronicle* • 2/5/09 SF Mayor Announces $1.2 Million Grant *San Francisco Examiner* • 2/5/09 S.F. Lands $1.2M in State and Federal Grants for New Brown Grease Biodiesel Plant *California Chronicle* • 2/5/09 Oil Gusher Discovered in San Francisco by Black Gold Biofuels *Market Watch (NPR)* • 2/6/09 San Francisco Receives Grant for Bio-Diesel Plant *Sacramento Bee* • 2/6/09 San Francisco to Convert 'Brown Grease' into Fuel *San Jose Mercury News* • 2/9/09 San Francisco to Convert 'Brown Grease' into Fuel *MSNBC* • 2/9/09 San Francisco Turns Potty Power Green *Greenbiz* • 2/11/09 Biodiesel's Leaps *San Francisco Bay Guardian*

Table 7-1 (continued): Technology Transfer and Public Outreach Overview

Technology Transfer Category	Activities Completed
Interviews and Articles in Trade Publications	• 2/11/09 San Francisco to Use BlackGold Biofuel's Technology*Biodiesel Magazine* • 2/13/09 SF Launches First City-Wide Brown Grease Program *Sustainable Business* • 2/27/10 Philly Co. Partners with San Francisco PUC to Produce

	Biofuel *Empowered Municipality* • 4/10 What to do with Brown Grease? *Plumbing Systems and Design* • 11/10 Tenderloin a Potential Gusher for Biodiesel *Central City Extra* • 10/1/10 Brown Grease Demo Biodiesel Plant Starts Up *Biodiesel Magazine* • 10/6/10 Plant to Create Biodiesel from Grease *Commercial Building Products* • First Quarter, 2011 Trap Grease Biodiesel - San Francisco Turns Brown Grease Into Renewable Fuel *Biofuels Journal* • 3/21/11, Water's Scarcity Spells Opportunity for Entrepreneurs *New York Times*
Media Events	• 2/4/09 – event with the Mayor (press release sent by the Mayor's Office)
Technical Publications	• Selected results will be reported at a national wastewater conference in 2012 (for example, WEF's Annual Technical Exhibition and Conference)

Table 7-1 (continued): Technology Transfer and Public Outreach Overview

Technology Transfer Category	Activities Completed
Conference and Workshop Participation	• CWEA San Francisco Bay Section, 4/15/08 • CWEA conference, 11/21/08 • Pacific Organics and Residuals conference, 10/2/08 • Sustainable Biodiesel Conference, 1/26/09 • National Biodiesel Board Annual Conference, Opening Plenary Session, 2/09 • P3S Conference, Monterey, 3/2/09 • CWEA Annual Conference, 3/31/09 • Greening Wastewater Infrastructure Workshop, sponsored by Maricopa Association of Governments, 2/1/10 • Innovative Energy Management (webcast), sponsored by U.S. EPA Region IX, 6/10 • CWEA Biosolids Specialty Workshop, 1/12 • WEF Residuals and Biosolids Conference, 3/12

Outreach Materials	• PowerPoint presentations (can be provided on CD by request) • 2-page graphic/summary of demonstration project
Informal Industry and Stakeholder Updates	• Update at Tri-TAC (Advisory Group consisting of members of League of Cities, CWEA, and CASA) Land Committee, 6/10
General Inquiries	• Conference call with Miami-Dade Utilities, 7/9/09 • E-mail exchange with Honolulu, 1/10/11 • Information exchange Central Marin Sanitation Agency 3/22/12
Other	• CWEA San Francisco Bay Section Research Award, 2011 • CWEA Statewide Research Award, 2011
Presentations	• Wastewater CAC, 7/16/2009 • Digester Task Force, 1/6/2010 • Wastewater CAC, 2/10/2011 • Carollo Engineers, 3/11/11, 22 people in attendance

CHAPTER 8: Conclusions and Recommendations

This project has demonstrated that brown grease of biofuels feedstock quality (less than 2 percent MIU) can effectively be recovered from trap waste. The demonstration project realized relatively low recovery rates, but those can most likely be increased by supply of sufficient heat (for example, steam) and more operator attention to the decanting process. Based on the findings of this demonstration project, the technology of the Brown Grease Recovery Facility is ready to be scaled-up. A distributed network of brown grease recovery facilities should be considered, given the GHG reduction potential associated with a reduced transportation effort.

The project has also demonstrated that the biodiesel production facility was unable to produce biodiesel on a consistent basis. Although several modifications were made to the installation during the project, a working installation was not achieved during the demonstration time frame. Additional research and testing at a larger scale are needed to determine whether this technology holds promise.

The Brown Grease Recovery and Biofuel Demonstration Project provided valuable input to quantifying the operational costs of a brown grease recovery facility. Project results also made a strong case for not co-locating a biodiesel production facility at a publicly owned wastewater treatment plant.

Recent industry trends indicate that heterogeneous catalysis is increasingly the basis for several large-scale (for example, greater than 200 million gallons per year) biodiesel refineries, co-located at oil refineries. This technology is independent of feedstock FFAs content. and use hydrogen to produce hydrocarbon diesel, rather than methanol esterification. This apparent trend may indicate a centralized future for biodiesel production.

Although literature indicates that co-digestion of grease waste increases biogas production in anaerobic digesters, the effects could not be quantified in terms of gas production per pound of grease VS destroyed within the scope of this project. Therefore, literature values were used in the preparation of the economic analysis.

The business case analysis has indicated that California should be capable of producing 29 Mgal/yr of recoverable waste grease. Relative to the State's reported 92 million gallons of biodiesel production volume in 2010, this is a significant amount of biodiesel feedstock (Energy Commission 2010). However, it will only be sufficient to replace about 1 percent of the current total diesel demand of the State.

The Brown Grease to Biodiesel Demonstration Project provided valuable input as to operational costs of a brown grease recovery facility. It further made a strong case for not co-locating a biodiesel production facility at a publicly owned WWTP.

Based on the economic analysis performed under the Business Case task of this project, it appears that collecting trap waste for anaerobic co-digestion is an activity that would results in a positive cash flow even with tipping fees on the order of $0.025 per gallon of trap waste.

Brown grease recovery, on the other hand, requires either a $0.31 per pound brown grease price at a standard tipping fee of $0.06 per gallon or a tipping fee of $0.08 per gallon at a standard brown grease price of $0.19 per pound . With the expected rising demand for trap waste, driven by mandates to reduce the energy intensity of wastewater treatment, digestion may remain the economically most viable route to process trap waste, unless a significant amount of grant funding is made available for brown grease recovery facilities (on the order of $1 million per 20,000 gallons per day facility).

The analysis of the biodiesel refinery economics indicates that at a brown grease price of $0.19 per pound, economic break-even for a 10 Mgal/yr refinery is reached at a biodiesel rack price of $3.58 to $3.76 per gallon. These prices are before taxes and without RIN and LCFS credit. Since biodiesel historically has sold for approximately $0.40 per gal above the petroleum diesel rack price, achieving break-even appears possible, albeit with a lengthy payback time or with a financial injection in the form of a government grant. Therefore, plans for construction of a 10 Mgal/yr biodiesel refinery would also require government match funding to become attractive to investors. Similar analysis of the economics for a 20 Mgal/yr refinery indicates that there is more room for profitability, since the calculated break-even diesel prices are approximately $0.30 per gallon lower than for a 10 Mgal/yr refinery and under standard conditions the payback time is on the order of 6 years.

The GHG benefits of production of 20 Mgal/yr of biodiesel from waste grease were quantified at approximately 279,000 tonnes CO2e. This reduction in GHG emissions is equivalent to the GHG emissions related to the electricity use of approximately 145,000 households.

The green job creation potential of construction and operation of facilities to support production of 20 Mgal/yr of biodiesel from waste grease is estimated at 393 to 466 direct job years and 277 to 312 indirect job years during construction and 61 direct jobs over the lifetime of the facilities.

8.1 Recommendations

Based on this demonstration project, it appears warranted to perform additional research to determine how much biogas is actually produced by co-digesting the whitewater and interface portions of trap waste, given that both fractions contain significant amounts of digestible food waste.

Furthermore, additional information is needed on the brown grease to biodiesel conversion capabilities of the recently developed heterogeneous catalytic processes. There is insufficient literature data to fully assess their conversion capabilities and sensitivities to impurities commonly present in brown grease.

LIST OF ACRONYMS AND ABBREVIATIONS

AB	Assembly Bill
ASTM	ASTM International (formally known as the American Society for Testing and Materials)
BCR	Benefit-Cost Ratio
BGB	BlackGold Biofuels
CARB	California Air Resources Board
CASA	California Association of Sanitation Agencies
CDFA	California Department of Food and Agriculture
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CPAS	Combined Primary and Activated Sludge
CWEA	California Water Environment Association
CWNS	Clean Watershed Needs Survey
D	Day
EBIDTA	Earnings Before Interest, Depreciation, Taxes, and Amortization
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
Energy	California Energy Commission
F	Fahrenheit
FAME	Fatty Acid Methyl Esters
FFA	Free Fatty Acid
FOG	Fats, Oils, and Grease
FSE	Food Service Establishment
GHG	Greenhouse Gas
gal/d	Gallons Per Day

HDDV	Heavy Duty Diesel Vehicle
Hr	Hour
IRR	Internal Rate Of Return
LACSD	Los Angeles County Sanitation District
lb	Pound
LCFS	Low Carbon Fuel Standard
LEA	Local Enforcement Agency
mg/L	Milligram(S) Per Liter
Mgal	Million Gallons
MGD	Million Gallons per Day
MIU	Moisture, Insoluble, Unsaponifiables
MMSCF	Million Standard Cubic Foot
MMBTU	Million British Thermal Units
NATA	National Air Toxics Assessment
NBB	National Biodiesel Board
NEC	National Electrical Code
NFPA	National Fire Protection Safety Association
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NTP	National Toxicology Program
O_2	Oxygen
O&M	Operation And Maintenance
OSHA	Occupational Safety and Health Administration
OSP	Oceanside Water Pollution Control Plant
PBTech	Pacific Biodiesel Technologies
PIER	Public Interest Energy Research

PM Particulate Matter

PSM Process Safety Management

RFS Renewable Fuel Standard

RFS2 Renewable Fuels Standard 2

RIN Renewable Identification Number

Scf Standard Cubic Feet (Foot)

SFPUC San Francisco Public Utilities Commission

SoCAB California South Coast Air Basin

SOP Standard Operating Procedure

SPCC Spill Prevention Control and Countermeasures Plan

SSO Sanitary Sewer Overflow

SWRCB State Water Resources Control Board

TS Total Solids

ULSD Ultra-Low-Sulfur Diesel

U.S. EPA United States Environmental Protection Agency

URS URS Corporation

VS Volatile Solids

WEF Water Environment Federation

WWCAC Wastewater Subcommittee

WWTP Wastewater Treatment Plant

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