Energy Baseline Study

For

Municipal Wastewater Treatment Plants

Prepared For: **Pacific Gas & Electric Company**
New Construction Energy Efficiency Program

Prepared By: **BASE Energy, Inc.**
5 Third Street, Suite 530
San Francisco, CA 94103
www.baseco.com
Phone: (415) 543-1600
Fax: (415) 543-1601

September 2006

Disclaimer

Legal Notice

Table of Contents

Acknowledgement

It has taken contributions from numerous individuals and organization to develop this report. We would like to Stephen Fok, PG&E senior program engineer for initiating and following-up the project, Angie Ong-Carrillo, PG&E program manager for approving and funding the project, all the plant managers/staff who took the time to fill the survey and PG&E account managers throughout PG&E service territory who helped distribute and administer the survey. We are also grateful to Professor Elahe Enssani of San Francisco State University (SFSU) who helped develop the survey, and Professors Christopher Wright and Pauline Velez, both of SFSU who helped to make the survey user-friendly and adapt it for Internet users.

Executive Summary

This report details the results of a detailed study of energy efficiency issues in wastewater treatment plants (WWTP). The report focuses on two distinct issues:

- Identification of energy efficiency issues in WWTP in PG&E service territory
- Determination of baselines for analysis of energy efficiency measures in WWTPs

The objectives have been achieved through:

- Surveying wastewater treatment facilitates in PG&E service territory
- Literature review
- Development of baselines for estimation of energy savings from application of specific technologies based on current status of the technologies and their use in WWTPs.
- Development of the analytical methodology for energy and demand savings estimation for energy efficiency measures (EEMs)

Overall, 11 technology areas were identified for the establishment of 16 energy efficiency baselines presented with 12 sample EEMs. The survey was distributed to about 480 PG&E's customers with a response rate of about 20% (99 respondents).

Table ES-1 summarizes major market-related results on the issues related to energy efficiency of WWTPs in PG&E service territory, while Table ES-2 summarizes the recommended advanced technologies and the proposed energy baselines. Table ES-3 summarizes major results of the survey related to adoption of energy efficient technologies in WWTPs in PG&E service territory, while Table ES-4 summarizes other major energy related findings from the survey. Figure ES-1 shows the distribution of energy intensity of the plants resulting from this survey.

Table ES-1 – Summary of the Market-Related Results Addressing Energy Efficiency*

	# of Plants	Percentage
Plants Engaged in Energy Efficiency Projects in Past Five Years	42	42%
Plants Received an Energy Audit in the Past Ten Years	32	32%
Audit Supported by PG&E	13	41%
Plants Greatly and Very Much Concerned About Energy Cost	67	68%
Plants Greatly and Very Much Concerned About Energy Efficiency Issues in New Design/Retrofit	36	36%
Plants which Used PG&E Rebates in their Projects	28	28%
Plants That Are Engaged in Controlling Peak Demand	33	33%

*Results are based on the responses from 99 filled-out questionnaires.

Table ES-2 Summary of Advanced Energy Efficient Technologies and Energy Baselines for WWTPs

Technology	Baseline	Sample Energy Efficiency Measure
Energy Efficient Measures (EEMs)		
Aerators (Blowers)	Coarse-Bubble Diffuser	Fine Pore Diffuser (Section 5.2 EEM 1)
	Inlet/Discharge Vane or No Control	Variable Frequency Drive Control (Section 5.2 EEM 6)
	Multi-stage centrifugal blowers	Singe-stage Centrifugal Blower with VFD Control (Section 5.2 EEM6)
	Fan System Assessment Tool (FSAT) Achievable Efficiency or Average Efficiency from Manufacturers' Data	High Efficiency Blower with Efficiency Better than Achievable/Average Efficiency (Section 5.2 EEM 6)
Aerators (Mechanical)	Constant Speed Motor	VFD Control Based on O_2 Content (Section 5.2 EEM 1)
Air Compressor	Air Compressor Modulating with Unloading	Rotary Screw Air Compressor with VFD Control (Section 5.2 EEM 10)
Dissolved Oxygen System	Manual Control	Automatic Control (Section 5.2 EEM 2)
Hydraulic-Driven Systems	Water or hydraulic-oil driven system	Electrical-Driven System (Section 5.2 EEM 4)
Motors	1992 EPAct Standard Efficiency Motors	Motor Efficiency is Higher than EPAct Efficiency (Section 5.2 EEM 7)
Pumps	Throttle, Bypass or No Control	Variable Frequency Drive Control (Section 5.2 EEM 5)
	Hydraulic Institute (HI) Achievable Efficiency	High Efficiency Pump with Efficiency Better than HI Achievable Efficiency (Section 5.2 EEM 5)
	Pneumatic	Electrical-Driven (Section 5.2 EEM 9)
Sludge Dewatering	Centrifuge	Screw Press (Section 5.2 EEM 11)
Sludge Thickening	Centrifuge Thickening System	Gravity Belt Thickening (Section 5.2 EEM 11)
Ultraviolet Radiation Disinfection	Medium-Pressure UV System	Low-Pressure UV System (Section 5.2 EEM 8)
Sludge Treatment Process	Aerobic Treatment System	Anaerobic Treatment System (Section 5.2 EEM 12)
Other Best Practices		
Aerator	Electrical Aeration Equipment	Solar-Powered Water Circulator (under review by PG&E)
Control System	Manual Control	Supervisory Control and Data Acquisition (SCADA) System
Lighting	CA Title 24 Standards	Lighting Power Intensity for an Area is Lower than CA Title 24

Table ES-3 – Summary of the Major Results on WWTP Energy Efficient Technologies*			
# of WWTP That Use Energy Efficient Technologies		*71 out of 99 (72%)*	
Energy Efficient Technologies Used		**# of Plants**	**Percentage of Total Responses**
Variable Frequency Drives (VFD)		60	61%
Application Where VFDs are Used	Pumps	55	56%
	Blowers	12	12%
	Compressors	3	3%
	Other	13	13%
Dissolved Oxygen (DO) Sensors		34	34%
Fine Pore Diffusers		29	29%
Advanced Instrumentation and Control / SCADA Systems		47	47%
High Efficiency Lighting		32	32%
Solar Aerators or Mixers		4	4%
High Efficiency Blowers		13	13%
Variable Intensity and/or Self-Cleaning Ultraviolet Lamps		4	4%
Pipe Internal Friction-Reducing Coating		9	9%
Screw Press for Sludge Dewatering		3	3%
Centrifuge for Sludge Dewatering		12	12%
Other Technologies		11	11%

*Results are based on the responses from 99 filled-out questionnaires.

Table ES-4 Summary of Other Major Findings From the Survey of WWTPs in PG&E Service Territory.			
		# of Plants	**Percentage**
Plants Producing Digester Gas		35	35%
Methods Digester Gas is Consumed	Flare	26	74%
	Continuous Flare	12	46%
	Power Production	18	51%
	Boiler	21	60%
	Other	2	6%
	Plants That Pre-Heat the Influent Sludge	23	77%
Plants Using Engine Driven Pumps		10	10%
Fuel for Engine Driven Pumps	Digester Gas	2	20%
	Natural Gas	4	40%
	Diesel	6	60%
	Other	1	10%
Plants Generating Electricity On Site		28	28%
Fuel for Electricity Generation	Digester Gas	18	28%
	Natural Gas	12	43%
	Other	9	32%

*Results are based on the responses from 99 filled-out questionnaires.

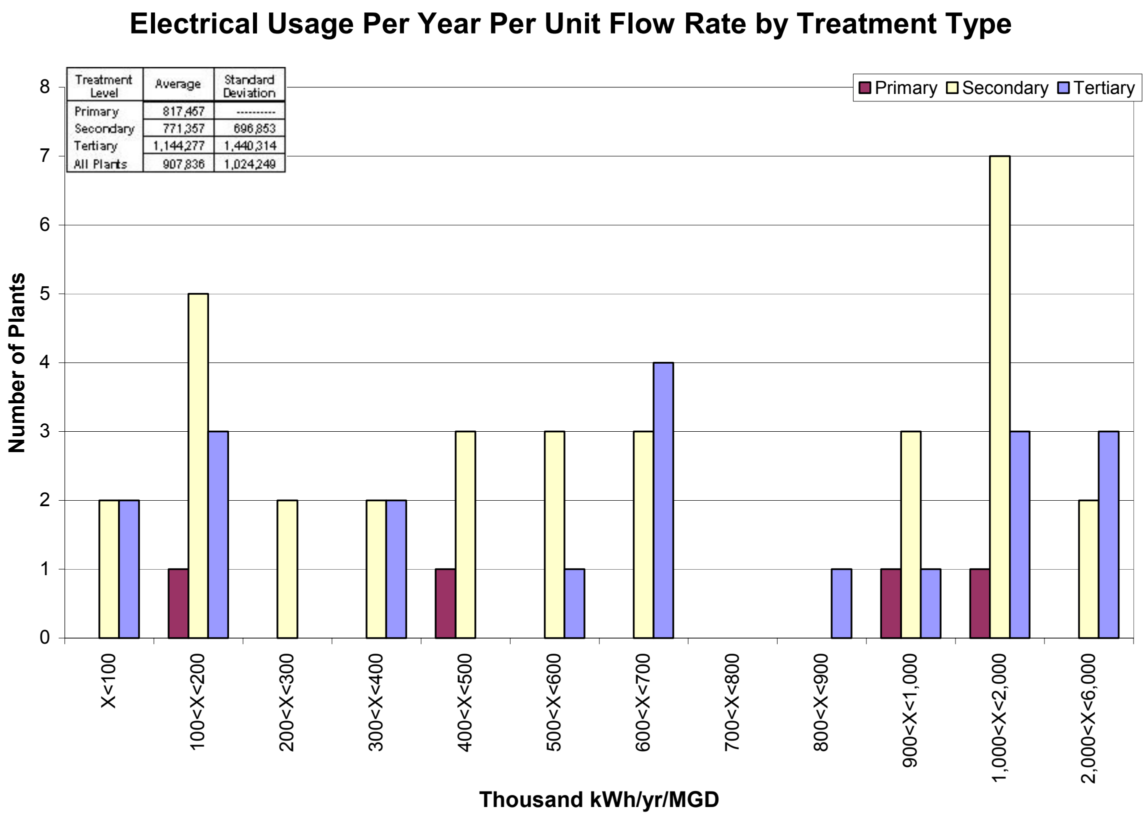


Figure ES-1 – Distribution of Energy Intensity of All Wastewater Treatment Plants Surveyed

1 - Introduction

1.1 - Project objective

The specific objectives of the project were defined as follows:

- Collecting statistics on the municipal WWT facilities in PG&E service territory.
- Review of up to ten selected energy efficient technologies or process optimization techniques and identification of baselines as applied in wastewater treatment facilities
- Proposing methods for calculation of energy savings based on identified baselines.

1.2 - Why the project was developed

Based on a survey conducted in this project, there are approximately 480 wastewater treatment (WWT) facilities in PG&E service territory. According to a 1993 study (Burton Environmental Engineering, et. al., 1993) these plants consume close to 1% of PG&E's electric power. A more recent study (M/J Industrial Solutions, 2003) quotes a higher percentage of total energy usage (1.5% across the US). WWT plants are one of the more energy intensive facilities managed by the public sector, with potential for being greatly influenced by energy efficiency at the design as well as retrofit stages (Burton Environmental Engineering, et. al., 1993). Several publications have addressed the issue of energy efficiency retrofits in WWT facilities, which are outlined in Section 4 and listed in the reference section of this report.

Since WWT plants are a major consumer of electrical energy in PG&E service territory, a detailed understanding of advanced state-of-the-art technologies, their energy consumption and how to estimate their energy saving potential become an important factor in providing incentives in application of the new technology in retrofit as well as new construction projects.

1.3 - Activities in Energy Efficiency and Demand Response of WWT Plants in PG&E Service Territory

PG&E currently is engaged in several activities to promote energy efficiency in wastewater treatment facilities, including:

- Integrated energy audit of WWT plants – This is done as a part of Customer Energy Efficiency Program. The results of energy audits are used as a reference for providing rebates for implementation of energy efficiency as well as demand response measures in the audited facilities.
- Non-Residential New Construction (NRNC) design assistance – This is the Savings by Design Program in which PG&E tries to influence the design of plants or any new construction by identifying energy efficiency measures to be included at the design stage. The analysis of the design that is performed by third party consultants is used to provide incentives for the implementing energy efficient technologies in the new construction.
- Non-Residential Retrofit (NRR) – This is the Standard Performance Contract Program, in which PG&E provides incentive for using energy efficient equipment in retrofit projects.
- PG&E has been funding some third party programs that specifically target energy efficiency of wastewater treatment facilities.

- As a part of its Public Interest Energy Research (PIER) program, California Energy Commission has funded research projects in developing technologies that are applicable to energy efficiency of wastewater treatment facilities.
- California Energy Commission has sponsored preparation of energy audit manuals (in late 1990s) as well as case studies on energy efficiency of WWT plants.

1.4 - Main Activities of the Project

The following have been the main activities in this project:

- Development of a comprehensive survey for WWT facilities in PG&E service territory
- Administering the survey through the Internet, email and regular mail
- Literature search on energy efficiency of wastewater treatment facilities
- Development of baselines for estimation of energy savings from application of specific technologies.
- Development of the analytical methodology for energy, demand savings estimation for efficiency measures (EEMs)
- Estimation of the energy intensity of WWT facilities in PG&E service territory

1.5 - Presentation of the Project Results

A brief background on the technologies for WWT plants is presented in Section 2. Section 3 includes the statistics on WWT plants in PG&E service territory. The advanced technologies used in WWT, and the analyses of energy usage of these technologies are the subject of Section 4. Section 5 includes the proposed baselines for analysis of energy efficiency measures for new construction. Survey instruments and details of the results of the survey are included in Appendixes A and B respectively. Detailed analytical methods for calculation of energy and demand savings are presented in Appendix C of the report. Appendix D presents some detailed results on energy intensity of a sample of the surveyed facilities.

2 - Background of the Industry

2.1 - Methods for WWT and the Applicable Technologies

The common methods for WWT are:

- Aerobic activated sludge systems
- Trickling filter (fixed media or fixed film reactor) systems
- Oxidation pond systems

2.1.1 - Activated Sludge

Aerobic activated sludge is the most commonly used wastewater treatment process consisting of primary treatment, secondary treatment, optional tertiary treatment, disinfection and sludge processing. Details of the processes for activated sludge WWT could be found in Hammer and Hammer (2004) and Metcalf and Eddy (2003).

Primary Treatment

Primary treatment involves screening, grinding and sedimentation/clarification to remove the floating and settleable solids found in raw wastewater. When raw wastewater enters the treatment plant it is typically coarse screened to remove large objects, ground to reduce the size of the remaining solids and then flows to primary sedimentation tanks. The sedimentation tanks provide sufficient capacity to establish quiescence in the wastewater, allowing solids with a higher specific gravity than water to settle and those with a lower specific gravity to float. Major users of energy in primary treatment include:

- Electric drives
- Various types of pumps
- Pre-aeration equipment (circumstantial)

Secondary Treatment

Conventional secondary treatment is accomplished by a biological process called aerobic, which includes suspended growth and activated sludge treatment. Activated sludge secondary treatment typically accounts for 30 to 60% of total plant energy consumption. Effluent from primary treatment is treated in large reactors or basins. In these reactors, an aerobic bacterial culture (the activated sludge) is maintained, suspended in the liquid contents. The secondary process removes organic material that is either colloidal in size or dissolved.

Secondary treatment typically removes 70 to 85% of the Biological Oxygen Demand (BOD) entering with the primary effluent. Aerobic conditions are produced by injection of dispersed air, or by injection of pure oxygen dispersed by mechanical agitation. The bacteria metabolize the organic carbon in the wastewater, producing carbon dioxide, nitrogen compounds and a biological sludge. Treated effluent from the aeration basins flows to secondary clarification. A portion of the sludge from the clarifier is recycled to the aeration basins/reactors and the rest is withdrawn, or "wasted". The waste sludge is dewatered and disposed of by various methods. In some WWT systems the clarified effluent from secondary treatment is disinfected and discharged. Major users of energy in secondary treatment include:

- Electric drives
- Mixers/Mechanical aerators
- Various types of pumps
- Blowers

Tertiary Treatment

Tertiary treatment (also known as "advanced wastewater treatment) is becoming more common as discharge permits increasingly call for the removal of specific contaminants not normally removed during conventional secondary treatment. Removal of nutrients (particularly nitrogen) prior to discharge requires additional treatment.

The air activated sludge secondary treatment process can be combined with anoxic processing for removing nitrogen from the wastewater. The anoxic zone is a section of the aeration basin where no aeration is provided. The purpose of the anoxic zone is to provide an environment for nitrification-denitrification to occur.

Nitrification is the biological conversion of ammonia to nitrites and nitrates. Denitrification is the biological conversion of nitrate to nitrogen gas. When nitrogen gas is formed, it rises through the wastewater and is released into the atmosphere. The purpose for incorporating the nitrification-denitrification process is to reduce the amount of nitrates, which would otherwise remain in the plant effluent. Nitrogen removal during nitrification-denitrification requires additional oxygen over what would be required for BOD removal. Approximately 4.5 lb. of O_2 are consumed per lb. of ammonium nitrogen removed. Consequently if nutrient removal is required, substantial additional energy will be consumed in providing the additional oxygen needed. The biological nitrification-denitrification process may increase total plant energy consumption by 40 to 50 percent.

In addition to nutrient removal, tertiary treatment is also used to: remove suspended solids to very low levels usually accomplished by filtration, remove refractory toxic organic compounds using activated carbon, or remove dissolved inorganic solids using ion exchange or membrane processing.

Major consumers of energy in tertiary treatment include:

- Electric drives
- Mixers/Mechanical aerators
- Various types of pumps
- Blowers

Disinfection

Chlorine - Clarified effluent from secondary treatment is usually disinfected with chlorine before being discharged into receiving waters. Chlorine gas is fed into the water to kill pathogenic bacteria, and to reduce odor. Done properly, chlorination will kill more than 99 percent of the harmful bacteria in an effluent. Some municipalities have switched from chlorine gas to sodium hypochlorite disinfection to avoid the risk and liability of transporting and storing large amounts of chlorine gas.

Chlorine or hypochlorite in treated effluents may be harmful to fish and other aquatic life. Consequently, many states now require the removal of excess chlorine before discharge to surface waters by a process called dechlorination. Chloramine and chlorine dioxide are also used as chemical disinfectants. The energy use of chlorination is minimal, since it is mainly the requirements of the metering equipment and mixing at the point of chemical application. Chemical costs are the main factor in determining whether chlorination is cost effective.

Ultraviolet - Ultraviolet irradiation is gaining market share as an alternative to chlorine disinfection. It obviates the risk and cost of storing and handling chlorine gas or other toxic chlorine containing chemicals. In addition, it leaves no chemical residue in the effluent, which is important if the water is to be reused or discharged to a river or estuary with vulnerable aquatic life.

An Ultraviolet (UV) disinfection system transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material (DNA and RNA). When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce. The effectiveness of UV disinfection depends on the characteristics of the wastewater, the intensity of UV radiation, the amount of time the microorganisms are exposed to the radiation, and the UV reactor configuration.

The main components of a UV disinfection system are mercury arc lamps, a reactor, and ballasts. The source of UV radiation is either low pressure or medium pressure mercury arc lamps with low or high intensities. The optimum wavelength to effectively inactivate microorganisms is in the range of 250 to 270 nm. The intensity of the radiation emitted by the lamp dissipates as the distance from the lamp increases. Low-pressure lamps emit essentially monochromatic light at a wavelength of 253.7 nm. Medium-pressure lamps are often used in large facilities. They have approximately 15 to 20 times the germicidal UV intensity of low-pressure lamps. The medium-pressure lamp disinfects faster and has greater penetration capability because of its higher intensity. However, these lamps operate at higher temperatures with significantly higher energy consumption. Low-pressure UV systems are generally 40 to 50% more energy efficient than medium pressure systems, but the large number of low-pressure lamps required may result in higher maintenance and capital costs.

Ozone - Although historically ozone systems have primarily been used for disinfection of water, recent technological advances in ozone generation and destruction has made ozone economically more competitive for disinfection of wastewater. Based on Metcalf & Eddy (2003) ozone can also be used in wastewater treatment for odor control and removal of soluble refractory organics, in lieu of carbon adsorption process. However, since ozone is toxic and corrosive, it cannot be stored and must be produced on site.

The main components of an ozone disinfection system are ozone generator, ozone contact reactor, and off-gas destruction unit. The major requirement for power is in the ozone generator, and preparation of feed gas. Feed gas can be air, oxygen or air enriched with oxygen. The electrical requirements are approximately double the requirement of an ultraviolet system (Pakenas, 1995). It is important to note that escaping ozone gas is an air pollutant and need to be destructed before entering the atmosphere.

Major consumers of energy in disinfection processes include:

- UV lamps
- Ozone generators

- Pumps

Sludge Processing
Sludge processing is complex and can consist of a variety of operations, including: sludge thickening, sludge stabilization by lime addition or digestion (either aerobic or anaerobic), sludge de-watering, and ultimately disposal by landfill, composting, land application, or incineration. In most plants, primary and secondary sludge are combined, thickened by sedimentation or flotation, stabilized, and dewatered by use of a belt filter press or centrifuge.

Thickening - Thickening is used to reduce the volume of sludge prior to further treatment. Combined primary and secondary waste activated sludge typically contains less than 1% total solids. Thickening can achieve an increase in total solids to 4% to 6% and thus greatly reduce sludge volume that must be handled in subsequent processing. There are two principal sludge-thickening methods: gravity thickening (GT) and dissolved air flotation (DAF).
GT is similar to primary sedimentation. Dilute sludge is fed into a circular tank through a center feed well. The sludge settles, compacts, and is withdrawn from the bottom of the tank. In DAF, air is introduced into the liquid sludge held under pressure. The sludge and air mixture is introduced into a flotation tank where the dissolved air comes out of solution as tiny bubbles, carrying the sludge to the surface of the tank for removal by skimmers.

Stabilization - Sludge is stabilized to reduce pathogens and eliminate odor. Lime stabilization involves mixing the sludge with lime to achieve a pH of 12 or higher.

Aerobic stabilization is similar to activated sludge secondary treatment. It is carried out in open tanks with air introduced from the bottom of the tank. The aerobic digestion not only stabilizes the sludge, but also reduces the sludge volume as organic material is biodegraded. Digested sludge is decanted from the tank and dewatered.

Anaerobic digestion is carried out in large sealed tanks or digesters in the absence of air or oxygen. Anaerobic conditions promote the development of bacteria that biodegrade the sludge producing methane and carbon dioxide gas. The digesters are heated and mixed both by re-circulated gas and with mechanical mixers. The digester gas produced has a heating value of about 600 BTU/cubic foot, and is used for digester heating, producing steam or for generation of electricity. Sludge is removed from the digester and dewatered.

De-watering - Sludge de-watering is usually accomplished by either a belt filter press (BFP), a centrifuge (CF) or a screw-type (SC) de-watering system.

A BFP is a continuous feed de-watering device that involves gravity drainage and mechanical pressure to de-water sludge. Conditioned sludge is fed to a gravity drainage section of the filter press where free water drains from the sludge. Following gravity drainage, pressure is applied by squeezing the sludge between opposing cloth belts forcing additional water from the sludge. The dewatered sludge is removed from the belts by scraper blades. Belt filter presses can produce a de-watered sludge of 15 to 30% total solids.

In CF de-watering, sludge is fed at a constant flow rate into the rotating bowl of the centrifuge, where it separates into a dense cake and a concentrate containing low-density solids. The concentrate is returned to the plant headworks. The cake is typically 20 to 30% solids and is discharged from the centrifuge by a screw feeder onto a conveyor belt.

Sludge Drying
To further reduce the sludge moisture it can be air-dried of dried through steam heating.

Major energy consuming equipment in sludge processing include:

- Electric drives
- Various types of pumps
- Blowers
- Various types of presses

2.1.2 - Fixed-Growth Biological Systems

Fixed growth biological systems are systems that cause contact of wastewater with microbial growth attached to the surface of supporting media. In these systems wastewater is distributed over a bed of rock, slag or synthetic media. Alternatively the media can move through the wastewater. Based on Hammer and Hammer (2004) these systems are categorized as:

- Tricking filter, where water is distributed over a bed of crushed rock or slag
- Biological tower, where synthetic media is used in place of rock with a greater depth
- Biological tower, where a series of circular plates on a common shaft are slowly rotated while partly submerged in wastewater.

Although the physical structures may be different, the biological process is essentially the same in all these fixed-growth systems. Municipal wastewater sprinkled over the fixed media, which causes a slow flow over the media produces biological slimes that coat the surface. As the wastewater flow over the slime layer, organic matter and dissolved oxygen are extracted and metabolic end products such as carbon dioxide are released. Dissolved oxygen is replenished from the air. No aeration is needed in fixed growth biological systems.

The major energy consuming devices include:

- Pumps for transport of wastewater
- Electrical drives for rotating the rotary wastewater distributors
- Hydraulic (water) drives for rotating the rotary wastewater distributors

2.1.3 - Oxidation Ponds

Oxidation ponds, also called stabilization ponds or lagoons are utilized for smaller communities. According to Hammer and Hammer (2004), oxidation ponds are classified as facultative, tertiary, aerated and anaerobic according to the type of biological activity that takes place in them.

Facultative ponds are the most common type of ponds employed for municipal wastewater treatment. The bacterial reactions include both aerobic and anaerobic decomposition. Waste organic are decomposed by bacteria releasing carbon dioxide, nitrogen and phosphorous. Algae use these compounds, along with energy from sunlight for growth, releasing oxygen to the solution, which is in turn used by bacteria. These are shallow pools with 2-5 feet of depth.

Tertiary ponds also referred to as maturation ponds serve as third-stage processing of effluent from activated sludge or trickling filter secondary treatment. Stabilization by retention and surface aeration reduces suspended solids, BOD, microorganisms and ammonia. The water depth is generally limited to 2-3 feet for mixing and sunlight penetration.

Aerated ponds are completely mixed units, usually followed by facultative ponds are used for first stage treatment of high-strength municipal wastewaters and for pretreatment of industrial wastewater. The basins are 10-12 feet deep and are aerated with pier-mounted floating mechanical units. The biological process does not include algae. BOD removal is a function of aeration period, temperature and nature of wastewater.

The major energy consuming devices in oxidation ponds include:

- Pumps for transport of wastewater
- Electrical drives for surface aeration

2.2 - Advanced Technologies Applicable to WWT Plants

With increasing energy costs, wastewater treatment plants are turning to advanced technology to operate their plant more efficiently and reduce operating costs. Some of the energy efficient measures that wastewater treatment plants have incorporated into their operations include but are not limited to the following. More details regarding these measures are presented in Section 5 – Baselines.

- Variable frequency drives for applications with variable loads (aeration system, various wastewater pumps, etc.)
- Automatic continuous dissolved oxygen (DO) control
- Fine bubble diffusers for aeration systems
- Retrofitting hydraulic-driven systems with electrical drives
- High efficiency pumps and blowers
- Premium efficiency motors
- Low-pressure ultraviolet (UV) disinfection system
- Retrofitting pneumatic pumps with electrical pumps
- Air compressor with variable frequency drive
- Gravity belt thickening of sludge
- Rotary and screw-type sludge dewatering
- Use of anaerobic digestion in place of aerobic digestion of sludge

Some of the other best practices for wastewater treatment plants that have not been included in this report include, but are not limited to the following:

- Solar-powered water circulators (under review by PG&E)
- Supervisory control and data acquisition (SCADA) system for monitoring and controlling the demand and energy usage of the plant
- High efficiency lighting

- Recovering biogas from anaerobic digesters for use in cogeneration engine-generators to produce electricity and heating for the plant.
- Flow equalization for demand and energy cost control

3 - Statistics of the WWT Plants in PG&E Service Territory

There are about 480 wastewater treatment facilities in PG&E service territory. This figure was extracted from the listing maintained by California Department of Water Resources as matched to the PG&E service territory obtained from CEC website. In cases that there was any doubts whether the plant is in PG&E service territory, the issue was clarified by contacting the respective plant. The extracted list has been the basis of the survey for this report.

PG&E serves a wide variety of WWT plants in size and processes. Figure 3-1 shows the distribution of plant sizes based on design million gallons per day (MGD), while Figure 3-2 shows the type of processes that these plants use for wastewater treatment.

Overall, 11 technology areas were identified for the establishment of 16 energy efficiency baselines presented with 12 sample EEMs. The survey was distributed to about 480 PG&E's customers with a response rate of about 20% (99 respondents).

Details of the survey results are presented in Appendix B of this report.

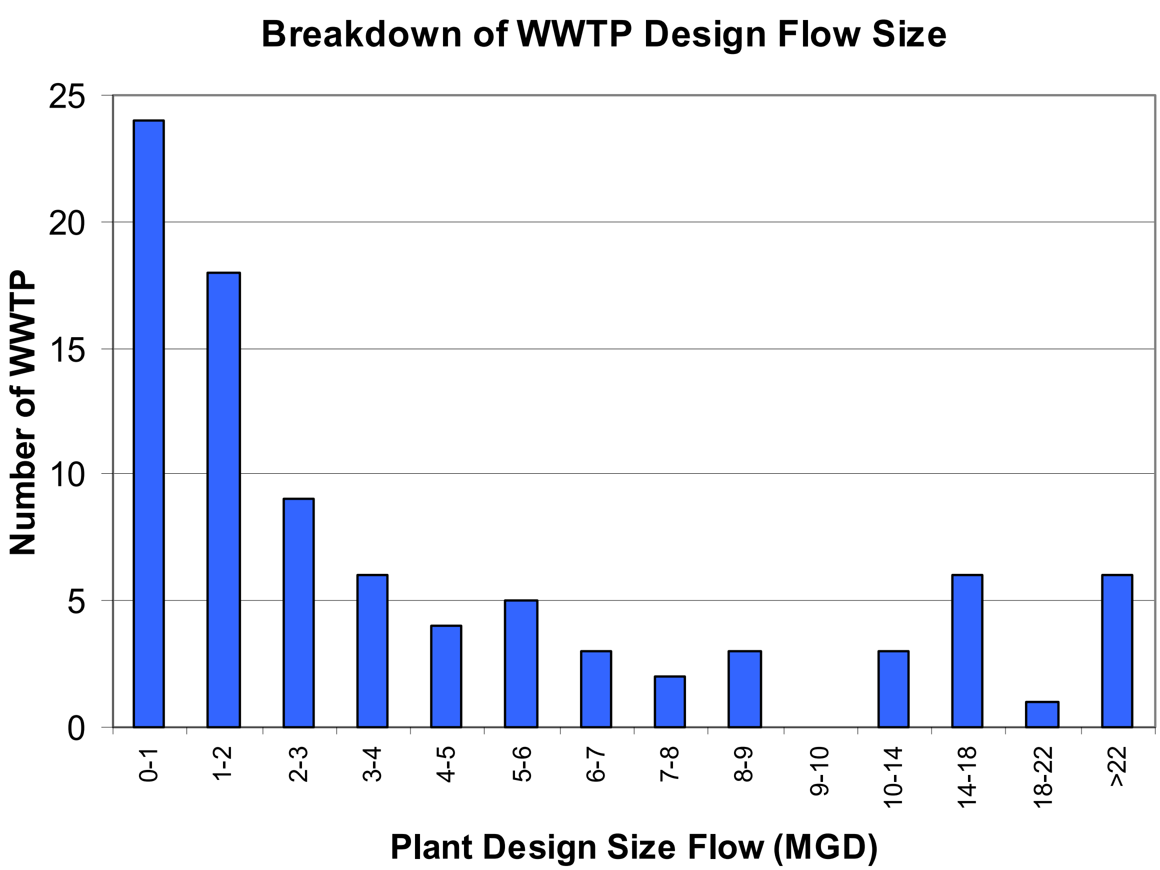


Figure 3-1 – Plant sizes in PG&E service territory based on 99 survey responses.

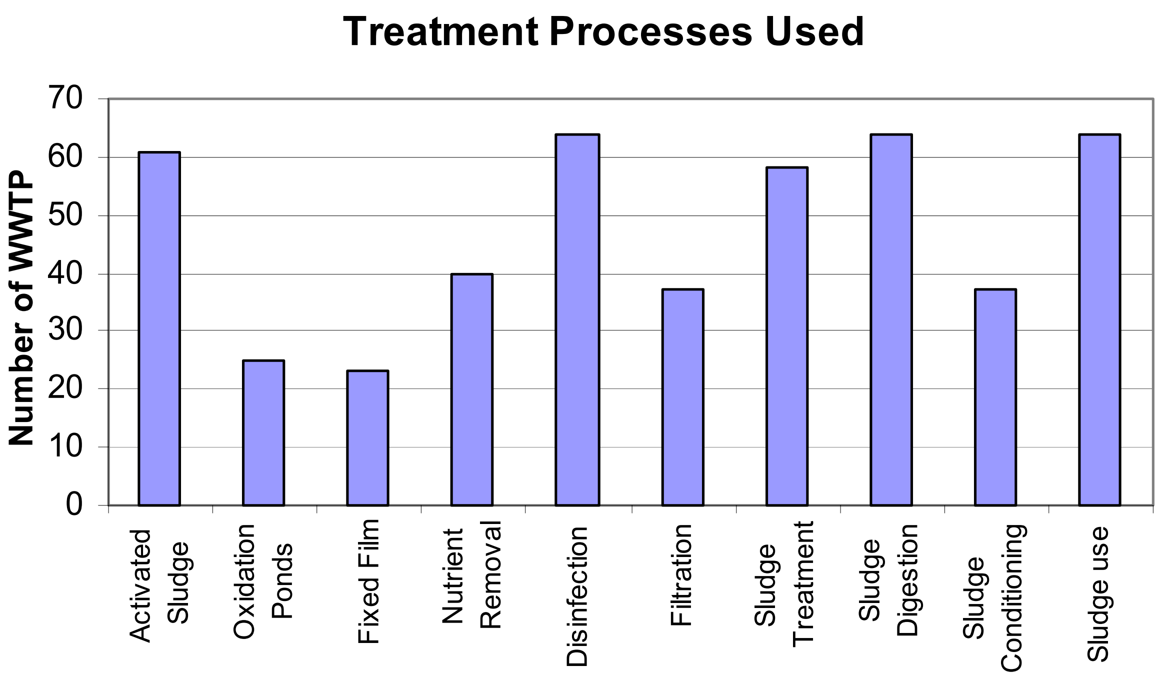


Figure 3-2 – Processes used in WWT plants in PG&E service territory.

3.1 - Market Considerations

The survey asked various questions about the energy efficiency issues in these facilities. Main questions include whether:

- The plant has been engaged in any energy efficiency projects in the past five years
- The plant has received any energy audit in the past ten years
- The plant is concerned about the cost of energy
- The plant has considered energy efficiency in its expansion/retrofit projects
- The resources the plant has used to ensure energy efficiency in its expansion/retrofit projects
- The plant has used PG&E rebates in its projects
- The plant controls peak demand
- The methods the plant uses to control peak demand

Table 3.1-1 summarizes the responses to these market-related questions. The results are also presented graphically in Appendix B.

Table 3.1-1 – Summary of the Survey Results Addressing Energy Efficiency Market Demands		
	# of Plants	**Percentage**
Plants Engaged in Energy Efficiency Projects in Past Five Years	42	42%
Plants Received an Energy Audit in the Past Ten Years	32	32%
Audit Supported by PG&E	13	41%
Plants Greatly and Very Much Concerned About Energy Cost	67	68%
Plants Greatly and Very Much Concerned About Energy Efficiency Issues in New Design/Retrofit	36	36%
Plants Which Used PG&E Rebates in its Projects	28	28%
Plants That Are Engaged in Controlling Peak Demand	33	33%

3.2 - Technology Considerations

Several questions in the survey explored the adoption of energy efficient technologies in PG&E service territory. The main questions concerning the adoption of energy efficient technologies include whether:

- Plant uses variable frequency drives
- Plant uses dissolved oxygen sensors for control of aeration
- Plant uses fine pore diffusers its aeration system
- Plant uses SCADA system
- Plant uses high efficiency lifting
- Plant uses solar aerators or mixers
- Plant uses high efficiency blowers
- Plant uses variable intensity or self cleaning UV lamps
- Plant uses pipe internal friction-reducing coating
- Plant uses screw press for dewatering
- Plant uses centrifuge for sludge dewatering

Table 3.2-1 summarizes the responses to questions about energy efficient technologies.

Table 3.2-1 – Summary of the Survey Results Addressing Application of Energy Efficient Technologies.

# of WWTP That Use Energy Efficient Technologies		***71 out of 99 (72%)***	
Energy Efficient Technologies Used		**# of Plants**	**Percentage of Total Responses**
Variable Frequency Drives (VFD)		60	61%
Application Where VFDs are Used	Pumps	55	56%
	Blowers	12	12%
	Compressors	3	3%
	Other	13	13%
Dissolved Oxygen (DO) Sensors		34	34%
Fine Pore Diffusers		29	29%
Advanced Instrumentation and Control / SCADA Systems		47	47%
High Efficiency Lighting		32	32%
Solar Aerators or Mixers		4	4%
High Efficiency Blowers		13	13%
Variable Intensity and/or Self-Cleaning Ultraviolet Lamps		4	4%
Pipe Internal Friction-Reducing Coating		9	9%
Screw Press for Sludge Dewatering		3	3%
Centrifuge for Sludge Dewatering		12	12%
Other Technologies		11	11%

3.3 - Other Energy Related Issues

Other energy related issues that were addressed in the survey include whether:

- The plant produces digester gas, and if it does, how the gas is utilized
- The plant uses engine driven pumps
- The plant generates electricity on site and the fuel source

Table 3.3-1 summarizes the results of the survey in this category. The results are also presented in graphical form in Appendix B.

Table 3.3-1 – Summary of Survey Results Addressing Other Energy Related Issues

			# of Plants		**Percentage**	
Plants Producing Digester Gas			35		35%	
Methods Digester Gas is Consumed	Flare			26		74%
		Continuous Flare		12		46%
	Power Production			18		51%
	Boiler			21		60%
	Other			2		6%
	Plants That Pre-Heat the Influent Sludge		23		77%	
Plants Using Engine Driven Pumps			10		10%	
Fuel for Engine Driven Pumps	Digester Gas			2		20%
	Natural Gas			4		40%
	Diesel			6		60%
	Other			1		10%
Plants Generating Electricity On Site			28		28%	
Fuel for Electricity Generation	Digester Gas			18		28%
	Natural Gas			12		43%
	Other			9		32%

4 - Methodology for Determination of Baselines

The basis for development of the baseline for WWT plants include:

- Survey of WWT plants in PG&E service territory
- Literature survey

These methods will be briefly described below.

4.1 - Survey of WWT Plants

A comprehensive survey instrument was developed with two main objectives:

- To identify the technologies that have traditionally been used in WWT plants in PG&E service territory
- To identify energy efficiency issues in WWT plants in PG&E service territory

The survey was first tested by asking the managers in two wastewater treatment facilities in San Francisco Bay Area to fill and critique it. The two facilities have the general characteristics shown in Table 4.1.

Table 4.1-1 – General Characteristics of Plants Chosen for Testing the Survey

Plant	Plant No. 1	Plant No. 2
Design Influent (MGD)	29.5	29
Level of Treatment	Tertiary	Tertiary
Technology	Oxidation Ponds	Activated Sludge and Trickling Filter

The test plants did not find any major deficiencies or issues with the survey. The survey was then distributed to WWT plants through PGE account managers, as well as direct mailing. The plants could respond through the Internet, email, fax or regular mail. A total of ninety nine responses were received.

4.2 - Literature Survey, Identification of Energy Efficient Technologies in WWT

An extensive literature search was done and the current practices as well as the advanced technology for WWT were identified. A listing of literature and references are provided in the reference section of the report.

Since wastewater treatment is a major consumer of electrical power in municipalities as well as utility territories, various organizations have sponsored studies and R&D projects addressing the issue of energy efficiency of wastewater treatment facilities. Additionally various case studies on energy efficiency of equipment, processes and operations of wastewater treatment plants have been published. Table 4.2-1 lists some of the major studies and R&D projects/reports that deal with energy efficiency of wastewater treatment facilities, while Table 4.2-2 lists some typical case studies detailing energy efficiency opportunities in specific wastewater treatment facilities. Application of advanced technologies has proven to reduce the consumption and cost of energy in WWT facilities. Table 4.2-3 summarizes the results of some of the studies as related to various advanced technologies.

Table 4.2-1 – Listing of Some Major Studies on Energy Efficiency of Wastewater Facilities			
Report/Paper Title	**Author and Publication Year**	**Sponsor**	**Content**
Water and Wastewater Industries: Characteristics and DSM Opportunities	Burton Environmental Engineering, et. al. (1993)	EPRI	Description of water and WWT processes, DSM opportunities and statistics on energy consumption of processes as well as WWT plant in major utilities territories.
Report on the Development of Energy Consumption Guidelines for Water and Wastewater	Energenecs Inc., et. al. (2003)	Wisconsin Focus on Energy	Design guidelines for energy efficient design practices in water and wastewater plant based on several case studies
Modeling Wastewater Aeration Systems to Discover Energy Savings Opportunities	Bolles (2003)	Process Energy Services, LLC	Presents several aeration systems for municipal WWTP and evaluate the energy usage of the various systems.
Energy Efficiency in Municipal Wastewater Treatment Plants	Pakenas (1995)	NYSERDA	Discusses the energy efficiency opportunities in WWTP and compare the energy usage of various technologies.
Wastewater Treatment Systems Best Practices	Focus on Energy www.focusonenergy.com	Wisconsin Focus on Energy	Briefly describes eleven measures to save energy in WWTPs.
Energy Saving Opportunities for Wastewater Facilities	Elliot (2003)	Energy Center of Wisconsin and Wisconsin Focus on Energy	Outlines major energy saving opportunities based on treatment process
Wastewater Treatment and Sludge Management	Pakenas (1995)	NYSERDA	Discusses the details of energy usage and energy efficiency opportunities per process in WWTP and presents several case studies
Market Research, Pacific Northwest Water and Wastewater Market Assessment	Quantum Consulting, Inc. (2001)	Northwest Energy Efficiency Alliance	Assesses the water and wastewater industries with the objective to introduce energy efficient technologies
Energy Efficiency for Wastewater Operations	University of Louisville (2002)	Kentucky Pollution Prevention Center	Discusses some energy efficiency opportunities for municipal wastewater treatment facilities and presents a few case studies.

Table 4.2-2 – Some Case Studies of Energy Efficiency Opportunities in Specific Wastewater Treatment Facilities		
Case Study	**WWTP Location**	**Source**
Process Optimization and Automation Improves Reliability and Cost Efficiency of Oxnard WWTP	Oxnard, CA	Moise and Norris (2005)
Various case studies	Various locations, mostly in Europe	www.caddet.org
Various case studies	Various plants in California	www.energy.ca.gov
On-Line Process Monitoring and Electric Submetering at Six Municipal Wastewater Treatment Plants	Various locations in NY State	Ferguson, et. al. (1998)
Aeration Control Using Continuous Dissolve O_2 Monitoring in an Activated Sludge Wastewater Treatment Process	UC Davis, CA	Phillips and Fan (2005)
Report on the Development of Energy Consumption Guidelines for Water and Wastewater	Several plants in Wisconsin	Energenecs Inc., et. al. (2003)
Wastewater Treatment and Sludge Management	Various locations in NY State	Pakenas (1995)
Energy Conservation in Wastewater Treatment Operation, A Case Study at Himmerfijarden WWTP	Himmerfijarden, Sweden	Anderson (2006)
Energy Efficiency Alternatives for Fortuna Wastewater Treatment Facility	Fortuna, CA	Fuller (2003)

Table 4.2-3 – Effect of Application of Energy Efficient Technologies on Energy Savings From Selected References		
Advanced Technology	**Energy Savings**	**Source**
Application of fine pore systems	40-50% of aeration energy	Pakenas (1995)
Monitoring and control of dissolved oxygen	20 - 30% of aeration energy 15-30% of aeration energy 23% of total plant energy 15% of Aeration energy	Pakenas (1995) Moise and Norris (2005) Phillips and Fan (2005) Anderson (2006)
SCADA System	23% of plant's energy	California Energy Commission "Water/Wastewater Guide 1"
Rotary Press	82% of dewatering energy	Earle (2005)
High Efficiency Pumps	10% of total plant energy	Flex Your Power Case Study: Inland Empire Utilities Agency
Variable Frequency Drives	2.81 million kWh/yr 498,600 kWh/yr	U.S. Department of Energy Case Study: Onondaga County Flex Your Power Case Study: South Tahoe Public Utility District
High Efficiency Blower	35.6% of aeration energy	Schwarz (2006)

5 - Baselines

This section presents a more detailed summary of the energy efficient practices presently used in the wastewater treatment industry as mentioned in Section 2.2 – Advanced Technology Applicable to WWT Plants. The details on the methods for analysis of these measures are presented in Appendix C.

5.1 - Summary of Energy Efficiency Measures

These measures have been selected based on the following criteria:

- Have proven and mature technology
- Have a proven record of energy savings
- Have been utilized in PG&E service territory or at least California

Each energy efficient technology has been presented as a measure. Table 5-1 presents the baseline and sample energy efficiency measures for various wastewater treatment technologies.

Table 5-1 Summary of Baseline and Energy Efficiency Measures for Various WWT Technologies

Technology	Baseline	Sample Energy Efficiency Measure
Energy Efficient Measures (EEMs)		
Aerators (Blowers)	Coarse-Bubble Diffuser	Fine Pore Diffuser (Section 5.2 EEM 1)
	Inlet/Discharge Vane or No Control	Variable Frequency Drive Control (Section 5.2 EEM 6)
	Multi-stage centrifugal blowers	Singe-stage Centrifugal Blower with VFD Control (Section 5.2 EEM6)
	Fan System Assessment Tool (FSAT) Achievable Efficiency or Average Efficiency from Manufacturers' Data	High Efficiency Blower with Efficiency Better than Achievable/Average Efficiency (Section 5.2 EEM 6)
Aerators (Mechanical)	Constant Speed Motor	VFD Control Based on O_2 Content (Section 5.2 EEM 1)
Air Compressor	Rotary Screw Compressor with Load/Unload Control	Air Compressor with VFD Control (Section 5.2 EEM 10)
Dissolved Oxygen System	Manual Control	Automatic Control (Section 5.2 EEM 2)
Hydraulic-Driven Systems	Water or hydraulic-oil driven system	Electrical-Driven System (Section 5.2 EEM 4)
Motors	1992 EPAct Standard Efficiency Motors	Motor Efficiency is Higher than EPAct Efficiency (Section 5.2 EEM 7)
Pumps	Throttle, Bypass or No Control	Variable Frequency Drive Control (Section 5.2 EEM 5)
	Hydraulic Institute (HI) Achievable Efficiency	High Efficiency Pump with Efficiency Better than HI Achievable Efficiency (Section 5.2 EEM 5)
	Pneumatic	Electrical-Driven (Section 5.2 EEM 9)
Sludge Dewatering	Centrifuge	Screw Press (Section 5.2 EEM 11)
Sludge Thickening	Centrifuge Thickening System	Gravity Belt Thickening (Section 5.2 EEM 11)
Ultraviolet Radiation Disinfection	Medium-Pressure UV System	Low-Pressure UV System (Section 5.2 EEM 8)
Sludge Treatment Process	Aerobic Treatment System	Anaerobic Treatment System (Section 5.2 EEM 12)

5.2 - Details of Energy Efficiency Measures

Each energy efficient technology has been presented as a measure. Included in this section are the details of the individual energy efficiency measures.

The details on the methods for analysis of these measures are presented in Appendix C.

Measure #1 – Application of Variable Frequency Drives

A variable frequency drive (VFD, also known as adjustable speed drive) is an electronic controller that reduces electrical energy consumption by matching the motor's speed to the load, allowing the motor to be continually adjusted relative to the power needed. Variable frequency drives allow operators to fine tune processes based on the process demands while reducing costs for energy and equipment maintenance.

In the wastewater treatment industry, two applications that benefit greatly due to the use of variable frequency drives are pumping and aeration.

(a) Pumps
Flow requirements in wastewater treatment plants often vary, which in turn requires the wastewater pumps to in most cases throttle or use bypass valves to accommodate the fluctuating demand. Variable frequency drives are more energy efficient means of controlling the speed of the pump based on flow demands than throttling or valving. VFDs allow pumps to accommodate fluctuating wastewater demands by running the pumps at various speeds to meet pump flow demands while consuming less energy. VFDs offer more precise control of the process needs and can maintain the desired conditions with closer tolerances. Additionally, VFDs provide a "soft start" capability, which gradually ramps up a motor to the desired operating speed. This reduces the wear and tear on a motor, thus reducing the maintenance required for the pump and also extends the motor's life.

Centrifugal and positive displacement pumps are the more common types of pumps used in wastewater treatment plants. Centrifugal pumps (variable torque) are well suited for VFD applications, but care should be taken when selecting variable frequency drives for positive displacement pumps, since they need to produce a constant torque. Unlike the centrifugal pump power which varies with the cube of speed, constant torque applications vary power in direct proportion to speed. This results in lower savings for a given reduction in speed but there are still significant savings available in some applications.

Energy savings due to using VFDs to control a pump can be determined by comparing the energy usage of a pump with either throttle, bypass or no control with the energy usage of the pump with VFD control.

Baseline Considered:
The baseline may vary based on the different equipment using various control technologies. If the VFD is installed for energy efficiency (and not because it is required for control), the baseline would be either throttling, on/off, or by-pass control.

(b) Aeration System

The two basic methods of aerating wastewater are:

(1) using blowers to introduce air or pure oxygen into the wastewater with submerged diffusers or other aeration devices, or
(2) mechanical agitation of the wastewater to promote solution of air from the atmosphere.

Aeration Blowers

The most commonly used blowers for aeration systems are positive displacement type blowers and centrifugal blowers (single stage and multi-stage). Blowers are required to meet a wide range of airflows and pressures at a wastewater treatment plant, therefore methods of regulating the flow must be considered in the blower system design. Typical methods of regulating blower flows are bypassing, inlet throttling, adjustable discharge diffuser, parallel operation of multiple units, timed on/off operation and variable frequency drives. Inlet/discharge throttling and adjustable discharge diffusers are applicable only to centrifugal blowers. Positive displacement blowers are constant capacity with variable flow and thus cannot be throttled, but their capacity can be controlled through the use of multiple units operating in parallel, timed on/off operation or variable speed drive control.

The inlet vanes "throttle" the airflow into a centrifugal blower, which reduces the amount of airflow through the blower and slightly reduces the power draw of the blower motor. In the past, discharge throttling had been used as a method to control the blower airflow. Inlet vane throttling is less energy-intensive than discharge throttling but is not the most efficient method of controlling the capacity of the blower. A variable frequency drive (VFD) can be installed to control the speed of the blower motor, which will reduce the airflow through the blower and significantly reduce the power draw of the blower motor. Energy savings can be obtained due to the fact that it is more efficient to control the airflow through a blower by controlling the speed of the blower with a VFD than it is to control the airflow with inlet vanes. Also, VFDs provide a "soft start" capability by gradually ramping up a motor to the desired operating speed. This lessens the mechanical and electrical stress on the motor and reduces maintenances costs and extends the life of the motor. Table 1(b)-2 presented in Appendix C shows the comparative energy consumption of three control strategies: Inlet, Outlet, and VFD control. Energy consumption is presented in the table as the percentage of energy consumed relative to 100 % load with no control.

The energy savings will be calculated by determining the energy usage of a blower currently controlling airflow with inlet/discharge vanes and subtracting the energy usage of the blower controlling airflow with a VFD.

Baseline Considered:

The baseline is inlet/discharge vane control of the aeration blower flow.

<u>*Mechanical Aerators*</u>
Mechanical aerators are commonly divided into the following two groups based on the design and operating features:

1) Surface aerators (vertical axis or horizontal axis), or
2) Submerged aerators (vertical axis or horizontal axis)

Turbulence is generated mechanically to mix all the effluent in the pond/basin and oxygen is introduced to the effluent through the mechanical aeration equipment. This is commonly achieved by either introducing air under the pond surface so that the air bubbles through the effluent (submerged aerators) or by spraying effluent into the air or agitating the effluent (surface aerators). The figures below show two typical mechanical aerators.

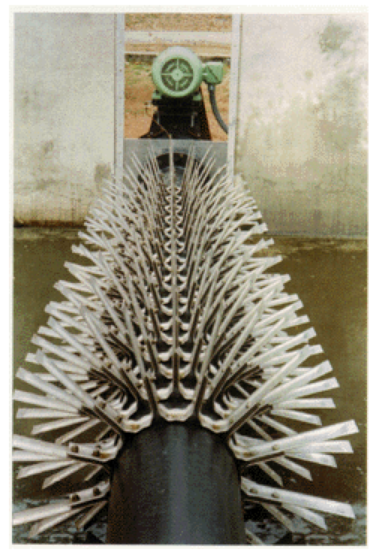


Figure 1(b)-1 – (*Left*) Typical submerged aerator (*Right*) Rotary brush surface aerator (*Photos courtesy of Pumpability Pty Ltd & Lakeside Equipment Corporation*)

Mechanical aerators are typically operating at a constant speed regardless of whether they are needed or not. Energy savings can be realized by installing two-speed or more preferable variable speed drive control on the aerators to control their operation based on the dissolved oxygen level of the wastewater.

Baseline Considered:
The baseline is mechanical aerators with no speed control, just on/off control.

(c) Positive Displacement Pumps/Blowers

Positive displacement pumps or blowers are constant torque systems. They will produce the same flow at a given speed regardless of the discharge pressure. Their flows cannot be throttled, but their capacity can be controlled through the use of either one of the following methods:

- operating multiple units in parallel,
- timed on/off operation, or
- variable frequency control

Baseline Considered:

The baseline is positive displacement pumps/blowers with on/off control.

Measure #2 – Dissolved Oxygen (DO) Sensors

Dissolved oxygen is required for the respiration of aerobic microorganisms as well as all other aerobic life form. Since the rate of biochemical reactions that use oxygen increase with increasing temperatures, dissolved oxygen levels tend to be more critical during the summer months. Due to large daily variation in wastewater flows, stable dissolved oxygen levels are hard to maintain. As a result, typically too much oxygen is provided to handle peak flow conditions. An automatic dissolved oxygen (DO) system can be installed to measure the level of dissolved oxygen in the wastewater using DO sensors and provide a variable signal to adjust the blower air flow or mechanical aerators speed.

Aeration systems operate to try to maintain a DO concentration that matches the demand of the biological activity, which is typically around 2.0 mg/l. In manual systems, wastewater treatment plant operators manually measure the dissolved oxygen level with portable oxygen analyzers and then manually adjust the aeration system to operate at the desired level. However, as wastewater flow and strength fluctuate constantly, it’s impossible to continuously manually adjust the aeration system to match the DO level. Thus, plant operators tend to provide excess oxygen into the ponds/basins to avoid violating the standards, but in turn results in excess electrical energy usage by the aeration system.

By optimizing the DO concentration of the wastewater, the blowers or mechanical aerators will not need to continuously operate at or near full load. Aerator power input is continuously monitored and adjusted to match the actual process oxygen demand, reducing excessive energy use. According to the U.S. Environment Protection Agency (EPA) Design Manual on Fine Pore Aeration Systems, the energy savings achievable by automatic aeration on DO control is typically 25% to 40%, but can be as high as 50%.

Baseline Considered:
The baseline is a manually controlled DO measurement system.

Measure #3 – Fine Pore Diffusers

The equipment used to deliver oxygen to the aeration system is commonly provided by surface mechanical aerators or submerged diffused aeration systems. A mechanical system agitates the wastewater to introduce air from the atmosphere into the wastewater. In a submerged system, air is introduced by diffusers (or other devices) submerged in the wastewater. The main components in a diffused air system include a blower(s), air piping system and diffusers that break the air into bubbles as they are dispersed through the aeration tank. The efficiency of oxygen transfer to the wastewater depends on several variables; one of the more critical is the type of aerator used. Table 3-1 presents some of the more common aeration systems and their typical oxygen transfer efficiencies (OTE).

TABLE 3-1 OXYGEN TRANSFER EFFICIENCIES FOR COMMON WASTEWATER AERATION SYSTEMS[1]

Aeration System		Use or Application	Oxygen Transfer Efficiency (lb O_2/hp-hr)
Submerged Diffused Aeration Systems			
Coarse-bubble (nonporous) system		All types of activated-sludge processes, channel and grit chamber aeration and aerobic digestions	2.0 to 3.0
Fine-bubble (fine-pore) system	Disk/Dome	All types of activated-sludge processes	5 to 7
	Membrane	All types of activated-sludge processes	Up to 12
Flexible Membrane Disk / Tube Grid		All types of activated-sludge processes	4 to 7
Surface Mechanical Aeration Systems			
Rotors (brush aerators)		Oxidation ditch, channel aeration and aerated lagoons	2.5 to 3.5
Low Speed Turbine Aerator		Conventional activated-sludge processes, aerated lagoons and aerobic digestion	3.0 to 3.5
High Speed Floating Aerator		Aerated lagoons and aerobic digestions	2.5 to 3.25
Induced Surface Aeration		Aerated lagoons	1.0 to 1.5

Mechanical aerators or coarse-bubble systems are often used in wastewater treatment facilities due to lower implementation costs, less maintenance and absence of air-purity requirements (for coarse-bubble systems). However the benefits of a higher oxygen transfer efficiency (less energy consumption to deliver more oxygen to the wastewater) and the ability to cover a large area which facilitates mixing and oxygen transfer, makes fine bubble aeration systems a more energy efficient aeration alternative. Studies on retrofits from coarse-bubble systems to fine-bubble systems have produced an average energy savings of approximately 30%, and in some cases up to 50% energy savings using ultra-fine bubble systems.

Baseline Considered:
The baseline design would be a coarse-bubble (nonporous) system.

[1] Environmental Dynamics Inc. Tech Bulletin 127 "Energy Consumption and Typical Performance of Various Types of Aeration Equipment", 2003.

Measure #4 – Replace Hydraulic Drives with Electrical Drives

Electric motors are recommended in place of any application that uses hydraulic systems (water or hydraulic-oil driven equipment). Hydraulic drives are less energy efficient than electric drives because in a hydraulic system energy is converted three times (electric to mechanical, mechanical to hydraulic and hydraulic to mechanical) while an electric drive converts energy once (electric to mechanical). Because energy is lost during each conversion, a hydraulic system is much less efficient than an electrically driven system. Because electric motor drives use less power than the hydraulic drives, energy savings and demand savings are possible.

The improved performance of electrical drives gives better motor control and easier set-ups. Electrical drive systems are also easier to adjust and calibrate. Since there are no valves to open or close, operations are quicker, more direct and more controllable in the operating environment. This can lead to significant cycle time reductions thus reducing the energy used for the operating the motor at the desired speed. Electrical systems can be optimally controlled with variable frequency drives (VFD) to vary the speed of the motor to match the desired operational requirements.

Another major benefit of electrical drives compared to hydraulic systems (water or hydraulic-oil driven equipment) is the reduced maintenance load due to the elimination of the need for cleaning and servicing, potential leaks in the hydraulic system, etc. Thus replacing hydraulic systems (water or hydraulic-oil driven equipment) with direct drive (electric drive) systems result in energy and maintenance cost savings. Hydraulic drives are also more expensive than AC drives to purchase, install and maintain

Energy savings can be estimated based on the energy consumption of a hydraulic-powered system (water or hydraulic-oil driven equipment) and comparing it with the anticipated energy consumption of electric motors. Information from motor manufacturers has shown that replacing hydraulic drives with electric drives resulted in energy savings of over 20%.

Baseline Considered:
The baseline design would be a hydraulic-driven system (water or hydraulic-oil driven equipment) in areas where hydraulic drives are typically used.

Measure #5 – High Efficiency Pumps

The most commonly used pumps in the wastewater treatment industry are centrifugal, progressive cavity and positive displacement pumps. The typical applications that these pumps are used in are presented in the Table 5-1 below:

TABLE 5-1 TYPICAL WASTEWATER PUMP TYPES AND THEIR APPLICATIONS

Types of Pumps	Typical Applications
Centrifugal Pump	Raw Wastewater, Primary Sludge, Secondary Sludge, Effluent Wastewater, Flush Water, Spray Water, Seal Water
Progressive Cavity Pump	Primary Sludge, Thickened Sludge, Digested Sludge, Slurries, Chemical Feed Applications
Positive Displacement Pump	All types of sludge and slurries

To establish a baseline for centrifugal pumps, a method outlined in Report No. 920.2-04.45 "Pump Efficiency Baseline Study" prepared by PG&E Savings by Design Program has been utilized. The method is based on Hydraulic Institute's ANSI/HI 1.3-2000 Standard "American National Standard for Centrifugal Pumps". The baseline pump efficiency is based on the 'high efficiency' pump performance calculated by the PSAT program. The efficiency at the expected operating point of the proposed pump is compared to the typical 'high efficiency' pump performance. The difference is used to determine the energy savings.

Using the Pumping System Assessment Tool (PSAT), which has been developed under the Department of Energy (DOE) sponsorship, to look-up the "Hydraulic Institute Achievable Efficiency Estimate Curves" for the selected pump type, the achievable efficiency at optimum specific speed are obtained as well as correction factors for the specific speeds. The achievable pump efficiencies are taken as the baseline efficiencies.

In cases where the pump type is not available with PSAT (such as for positive displacement pumps), the efficiencies of several pumps (from various manufacturers) operating under the same condition will be compared and the average of these is taken as the baseline case

Baseline Considered:
The baseline is achievable pump efficiencies based on "Hydraulic Institute Achievable Efficiency Estimate Curves" or the average efficiencies from several pump manufacturers.

Measure #6 – High Efficiency Blowers

The most commonly used blowers for this purpose are positive displacement type blowers and centrifugal blowers (single stage and multi-stage). Blowers are required to meet a wide range of airflows and pressures at a wastewater treatment plant, therefore methods of regulating the flow must be considered in the blower system design. Centrifugal blowers are widely used when capacities greater than 15,000 cfm are required. Positive displacement blowers are commonly used for applications where a high discharge pressure is required and for capacities smaller than 15,000 cfm.

High Efficiency Blowers
To establish a baseline for centrifugal blowers, the Fan System Assessment Tool (FSAT), which has been developed under the Department of Energy (DOE) sponsorship, will be utilized (if applicable) to determine the achievable and optimum efficiencies for the selected blower type at the specified operating conditions. In cases where the blower type is not available with FSAT, the efficiencies of several blowers (from various manufacturers) operating under the same condition will be compared and the average of these is taken as the baseline case.

Energy savings will be calculated based on the difference between the anticipated energy consumption of a high efficiency blower and the baseline energy usage.

Baseline Considered:
The baseline is achievable fan efficiencies based on the "Fan System Assessment Tool" or the average efficiencies from several blower manufacturers.

Centrifugal Blowers
There are two types of centrifugal blowers: single stage and multiple stage (multistage). Multistage blowers are generally used in older plants for aeration to produce variable flows at a constant pressure. However, multistage blowers have limited turndown capacity (typically 70%), which causes it to produce excess air that is wasted into the atmosphere. Single stage blowers are more efficient than multistage blowers and are capable of maintaining a high level of efficiency at various loads (from full load to 40% load). Single stage blowers with variable inlet vanes and variable discharge diffusers allow flow adjustments while maintaining constant impeller speed. Variable frequency drives are a more efficient method to control the flow of a centrifugal blower while maintaining a constant pressure. The disadvantages of single stage blowers are the higher capital costs and noise levels.

Baseline Considered:
The baseline is multiple stage blowers.

Measure #7 – Premium Efficiency Motors

High efficiency and premium efficiency motor baselines are based on the 1992 EPAct (Energy Policy Act) and NEMA (National Electrical Manufacturers Association), respectively. While the EPAct baseline covers up to 200 hp motors and the NEMA baseline covers up to 500 hp motors, both baselines were developed to include two, four, and six pole, open drip proof or totally enclosed fan cooled induction motors.

The U.S. Department of Energy offers an energy-efficient motor selection and management tool, MotorMaster software, which is distributed by Motor Challenge Clearinghouse. The software includes a catalog of over 20,000 AC motors and features motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting, and environmental reporting capabilities. We recommend obtaining this software package, at no cost, by calling (800) 862-2086 or it can be downloaded at the Department of Energy (DOE) web site (http://www1.eere.energy.gov/industry/bestpractices/software.html). The software can help you identify premium efficiency motors that will save energy compared to your existing standard efficiency motors.

Baseline Considered:
The baseline is motor efficiencies are based on the 1992 EPAct threshold.

Measure #8 – Low-Pressure Ultraviolet (UV) Radiation Disinfection

Ultraviolet (UV) radiation is a common method used for disinfection in the wastewater treatment industry due to its effectiveness at inactivating most viruses, spores and cysts. Another advantage in using UV disinfection is that it eliminates the need to generate, handle, transport or store toxic/hazardous or corrosive chemicals. To produce UV radiation, lamps containing mercury vapor are charged by striking an electric arc. The energy generated by the excitation of the mercury vapor contained in the lamps results in emission of UV light. Generally, UV disinfection systems fall into three categories: low-pressure low-intensity, low-pressure high-intensity, and medium-pressure high-intensity systems. A comparison of these systems is presented in the Table 8-1 below.

TABLE 8-1 TYPICAL CHARACTERISTICS OF COMMON UV DISINFECTION SYSTEMS[2]

	Low-Pressure Low-Intensity Lamps	Low-Pressure High-Intensity Lamps	Medium Pressure High-Intensity Lamps
Input Power (Watts)	15-75	150-400	1,000-20,000
UV-C Efficiency* (%)	**32-38**	**30-36**	**12-16**
Pressure (atm)	0.01	0.01	1-2
Lifetime (Hours)	8,000-12,000	8,000-15,000	3,000-9,000
Operation	Long warm-up time	Long warm-up time	Short warm-up time
Performance – Effect of Water Temperature on Output	Efficiency very dependent on water temperature	Efficiency somewhat dependent on water temperature	Efficiency independent of water temperature
Maintenance - Cleaning	Low fouling rate Manual, offsite cleaning required	Automatic lamp cleaning available	Automatic lamp cleaning available
Maintenance - Lamp Replacement	Long lamp life but high number of lamps to replace	Long lamp life and average number of lamps to replace	Average lamp life but low number of lamps to replace

* UV-C efficiency is the amount of electrical power (in Watts) converted into Watts of UV light emitted in the effective germicidal range of 240-290 nm.

Low-pressure low-intensity lamps are the most energy efficient lamps of the three systems considered. However, the efficiency of these lamps is highly dependent on the water temperature and the required offsite cleaning makes them unsuitable for many wastewater treatment applications.

Low-pressure high-intensity lamps are similar to low-pressure low-intensity lamps with the exception that a mercury-indium amalgam is used in place of mercury, which allows them to provide greater stability over a broad temperature range and have a greater lamp life. They are more energy efficient (use over 50% less energy than medium pressure lamps) and are typically used for low to medium wastewater flows (up to 38 MGD).

[2] Dussert, Bertrand W., "Essential Criteria for Selecting an Ultraviolet Disinfection System", Journal AWWA (American Water Works Association), July 2005.

Medium pressure high-intensity lamps use considerably more energy than its low-pressure counterparts. However, due to its higher intensity, fewer lamps (though more costly than low-pressure lamps) are required to provide adequate disinfection thereby reducing initial installation costs. Medium pressure high-intensity lamps are typically used for higher wastewater flows or on sites where space is limited.

Baseline Considered:
The baseline design for UV disinfection systems would be a medium pressure UV system.

Note: We recommend that customers get information regarding self-cleaning UV systems from vendors.

Measure #9 – Replace Pneumatic Pumps with Electrical Pumps

Compressed air is expensive to generate. Since the compressed air used to drive air pumps (a.k.a. pneumatic pump) are expensive to produce, it is recommended that any application where air pumps are used be replaced with a comparable motor driven centrifugal (or another appropriate electrically driven) pump. Centrifugal (or other suitable electrically driven) pumps can achieve the same pumping capacity as an air pump while consuming significantly less energy. The anticipated savings is the difference between the energy needed to produce the air used by the air operated pump and the energy used to run a motor driven centrifugal pump.

Another benefit of using electric pumps is a reduction in the occurrence of air leaks, which is quite common when using air equipment. Air leaks represent lost compressor horsepower, which translates directly into increased energy usage for plant operation.

Baseline Considered:
The baseline design would be a pneumatic (air) pump if that is what typically used for the application.

Measure #10 – Air Compressor with Variable Frequency Drive

It is recommended that a rotary screw air compressor with variable frequency drive (VFD) control be installed to produce compressed air at the plant. An air compressor with VFD control will reduce your annual electrical energy costs

For operating conditions where the compressed air demand of the plant varies, a VFD controlled rotary screw compressor can produce compressed air more energy efficiently, especially in part-load operations. Rotary screw-type air compressors typically operate in an "inlet modulation with unloading" mode. In this control scheme, the compressor will produce compressed air until the desired set point pressure is reached. At the desired set point pressure, the air compressor starts to modulate and then "unloads" (stop compressing air but continue rotating) when the maximum setpoint pressure is reached. Based on manufacturer's data, a rotary screw compressor will still consume approximately 20% of its full electrical load even when it is in the "unload" mode, based on AirMaster+. A VFD controlled rotary screw air compressor can produce the compressed air more efficiently than the "inlet modulation with unload" control sequence, especially in part-load operation resulting in electrical energy savings.

Electrical energy savings can be determined by comparing the current energy usage of the air compressor with inlet modulation with unloading control with the anticipated energy consumption of the air compressor with VFD control.

Baseline Considered:
The baseline is a rotary screw compressor with inlet modulation with unloading control.

Measure #11 – Sludge Thickening and Dewatering

Sludge Thickening

Thickening is used to increase the solids content of sludge by removing a portion of the liquid fraction. Thickening is used prior to subsequent dewatering processes to increase the efficiency of the dewatering equipment. Some of the common types of methods used for thickening sludge are presented in Table 11-1 below. The method used for sludge thickening depends on site specific needs and the type of sludge to be thickened.

TABLE 11-1 COMMON SLUDGE THICKENING METHODS*

Method	Description	Solids Concentration
Gravity Thickening	Feed sludge fed into a tank and allowed to settle and compact. Thickened sludge is withdrawn. Can be odorous.	Varies greatly
Dissolved Air Flotation Thickening	Air is introduced into liquid sludge that's held at an elevated pressure. When sludge is depressurized, dissolved air is released as finely divided bubbles carrying solids to the top, where they're removed. High operating costs.	2% to 3%
Centrifuge Thickening	Water is forced out of the sludge placed in a spinning drum	4% to 6%
Gravity Belt Thickening	Sludge is conditioned with a polymer and fed into a feed box. Sludge distributes evenly on moving belt as water drains through, then sludge is discharged.	3% to 6+%
Rotary Drum Thickening	Polymer mixed with dilute sludge. Conditioned sludge passed through rotating screen drums, which separate solids from water. Thickened sludge rolls out ends of drums and water empties out through screens.	4% to 6+%

* Extracted from Metcalf & Eddy "Wastewater Engineering Treatment and Reuse", 2003.

Centrifuge thickening is typically the most energy intensive option. Dissolved air thickening is very energy intensive also because it requires a significant amount of energy for air pressurization. Gravity thickening and gravity belt thickening are the more energy efficient options. Gravity thickening is one of the most common thickening methods used and is the most effective method for primary sludge, but requires a significant amount of space and high initial costs to install the settling tank.

Gravity belt thickening consists of a gravity belt driven by a drive motor, which should be controlled by a variable frequency drive. Dilute sludge is introduced at the feed end of a horizontal filter belt. As the sludge makes its way down the moving belt, water drains through the porous belt. The solids are continuously turned, encouraging the drainage of more water. Sludge is discharged at the end of the horizontal filter belt. A schematic of a gravity belt thickener is shown in Figure 11-1. Advantages of a gravity belt thickener include the following:

- Low energy consumption
- Small space requirement
- Reduction of sludge volume by up to 90%
- Ease of automation & control
- Less retention time
- No flotation troubles
- Optional cover to prevent odors
- Clear filtrate

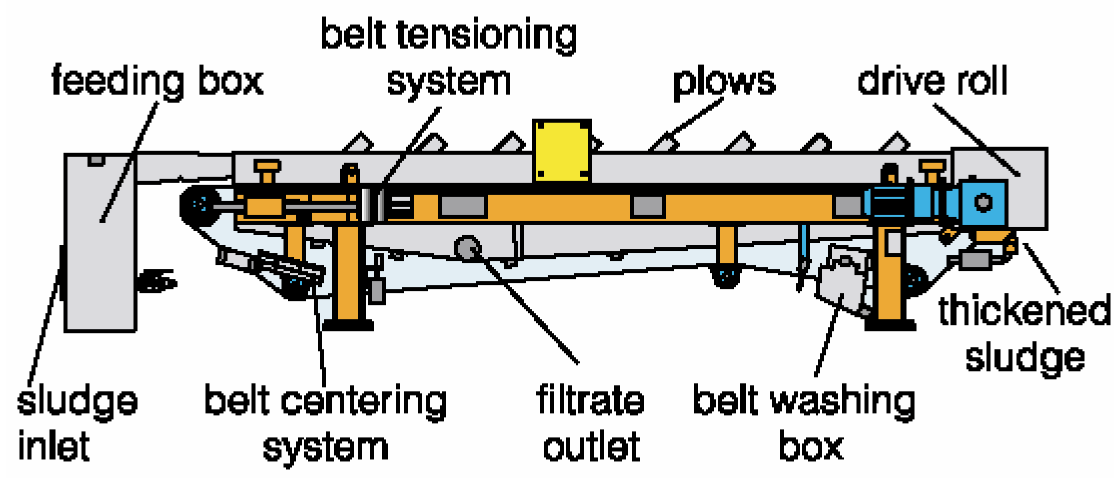


Figure 11-1 Schematic of Gravity Belt Thickening System (*Courtesy of USFilter)*

Baseline Considered:
The baseline is using a centrifuge thickening system.

Sludge Dewatering

Dewatering is a mechanical process to reduce the moisture content of the sludge, with the goal to reduce disposal costs of the sludge. Dewatering reduces the volume of sludge and biosolids to be disposed, which can be costly. Dewatering is required prior to incineration of the sludge, composting or landfill. The common techniques used for dewatering are presented in Table 11-2 below. The dewatering method to use depends on a variety of factors including plant size and location, electrical costs, chemical costs, disposal costs and plant personnel experience.

TABLE 11-2 COMMON DEWATERING METHODS*

Method	Advantages	Disadvantages
Centrifuge	• Good odor containment • Produces relatively dry sludge cake • Low capital cost	• High power consumption and noisy • Potentially high maintenance • Moderately high suspended solids content in concentration
Vacuum Filtration	• Relatively clean filtrates • Easy access to sludge cake • Less sensitive to sludge variability	• Energy intensive • Higher residual moisture in sludge cake • Difficult to clean
Belt Filter Press	• Low energy requirements • Relatively low capital and operating costs • Easier to maintain • Capable of producing very dry sludge cake	• High odor potential • Requires sludge grinder • Very sensitive to sludge variability • Automatic operation not advised
Recessed-Plate Filter Press	• Highest cake solids concentration • Low suspended solids in filtrate	• Batch operation • High equipment & labor cost • Special support structure required • Additional solids due to chemical addition require disposal
Rotary Press	• Low energy consumption and very quiet • Low operation & maintenance costs • Fast startup and shutdown • Smaller installation space • Much lower wash water requirements • Effective containment of odor	• Operating at higher throughput than design may reduce cake solids
Screw Press	• Low energy consumption • Low operation & maintenance requirements • Simple, unattended operation • Low wash water requirements • Can be modified (by adding heat) to produce Class A biosolids	• Potential for odor problems • Low suspended solids recovery • Large installation space
Sludge Drying Beds	• Lowest capital cost method • Minimal operator attention and skill • Low energy consumption • Low to no chemical consumption • Higher solids content • Less sensitive to sludge variability	• Requires large area of land • Requires stabilized sludge • Susceptible to climatic effects • Labor-intensive to remove sludge
Sludge Lagoons	• Low energy consumption • No chemical consumption • Low capital cost • Minimal skills required for operation	• Potential for odor problems • Potential for groundwater pollution • More land intensive • Unappealing sight • Susceptible to climatic effects

* Extracted from Metcalf & Eddy "Wastewater Engineering Treatment and Reuse", 2003.

Vacuum filtration is the most energy intensive method, but has largely been replaced by alternative methods in recent years. Centrifuge is also a very energy intensive method, but because they often achieve a higher solids content the disposal costs will be reduced that may offset the additional energy requirement. Sludge drying beds are the least energy intensive, typically requiring only a sludge pumping system. Belt filter presses and centrifuges are two of the more prevalent dewatering technologies in the wastewater industry, but two alternatives – screw presses and rotary presses – are increasingly gaining recognition.

A screw press is a simple, slow-moving mechanical dewatering device that also has low power consumption. Dewatering is continuous and accomplished by gravity drainage at the inlet end of the screw and then by reducing the volume as the material being dewatered is conveyed from the inlet to the discharge end of the screw press. A schematic of a screw press is shown in Figure11-2 below.

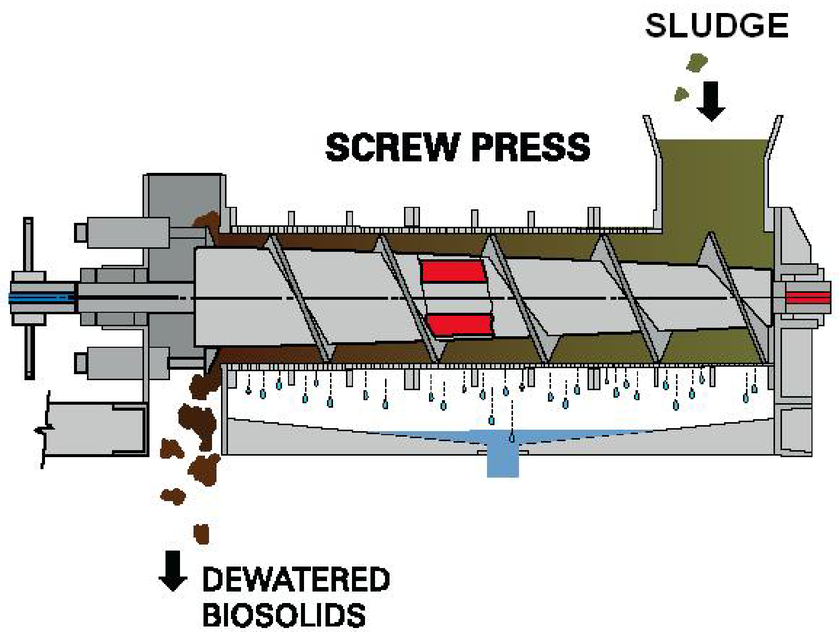


Figure 11-2 Schematic of Screw Press (*Courtesy of FKC Co.*)

The operation of a rotary press is relatively simple. Sludge is fed into a rectangular channel, and rotated between two parallel revolving stainless steel chrome plated screens. The filtrate passes through the screens as the flocculated sludge advances within the channel. The sludge continues to dewater as it travels around the channel, eventually forming a cake near the outlet side of the press. The frictional force of the slow moving screens, coupled with the controlled outlet restriction, results in the extrusion of a very dry cake. A schematic of a rotary press is shown in Figure11-3 on the following page.

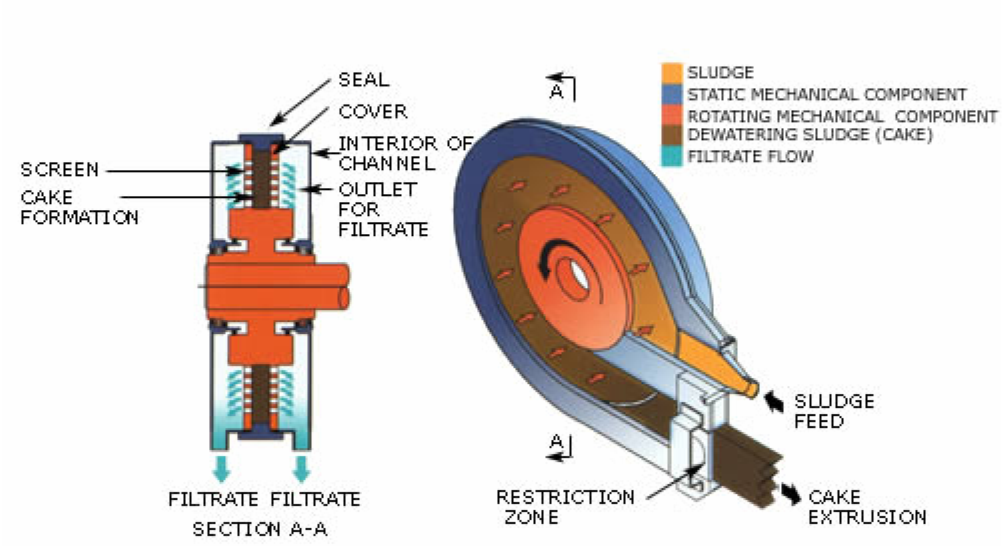


Figure 11-3 Schematic of Rotary Press (*Courtesy of Fournier Industries Inc.*)

Baseline Considered:
The baseline is using centrifuge for dewatering sludge.

Measure #12 – Anaerobic Sludge Treatment System

Wastewater treatment plants have the option of either utilizing aerobic treatment or anaerobic treatment. Most conventional wastewater treatment processes utilize 'aerobic' treatment, meaning that oxygen is taken in to break down the waste products. This results in a high energy consumption since oxygen has to be supplied by aeration equipment, which is probably the one of most energy intensive process in a wastewater treatment facility. Also the sludge production is higher for aerobic processes, requiring more equipment to thicken and dewater the sludge prior to disposal.

'Anaerobic' treatment processes do not use oxygen. The energy requirements and sludge production is much less than for aerobic processes, thus making the process less costly and simpler. However, one of the main disadvantages of anaerobic processes is that they are much slower than aerobic processes and are only good at removing organic waste and not any other sort of pollution – such as nutrients or pathogens. Anaerobic processes generally like 'steady' effluents – they are not good at coping with variations in flow or composition. The principal advantages and disadvantages of anaerobic treatment are presented in Table 12-1 below.

TABLE 12-1 ADVANTAGES & DISADVANTAGES OF ANAEROBIC TREATMENT

Advantages	Disadvantages
• Less energy required • Less biological sludge production • Fewer nutrients required • Methane production (potential energy source) • Smaller reactor volume required • Most organic compounds can be transformed with acclimation • Rapid response to substrate addition after long periods without feeding	• Longer start-up time to develop necessary biomass inventory • May require alkalinity and/or specific ion addition • May require further treatment with an aerobic treatment process to meet discharge requirements • Biological nitrogen and phosphorus removal is not possible • Much more sensitive to the adverse effect of lower temperatures on reaction rates • May be more susceptible to upsets due to toxic substances • Potential for production of odors and corrosive gases

Baseline Considered:
The baseline is an aerobic treatment system.

5.3 - Other Best Practices in Wastewater Treatment Industry

Table 5.3-1 Summary of Other Best Practices for Wastewater Treatment Industry		
Technology	**Baseline**	**Sample Energy Efficiency Measure**
Other Best Practices		
Aerator	Electrical Aeration Equipment	Solar-Powered Water Circulator (under review by PG&E)
Control System	Manual Control	Supervisory Control and Data Acquisition (SCADA) System
Lighting	CA Title 24 Standards	Lighting Power Intensity for an Area is Lower than CA Title 24

Solar-Powered Water Circulators

In 2001, a solar-powered water circulator called the SolarBee was developed with a capability of moving over 10,000 gallons of wastewater per minute from any depth with a solar-powered pump. The SolarBee is used to reduce aeration operating time while maintaining or improving wastewater quality, resulting in significant energy savings for the aeration equipment. In addition to the energy cost savings, some other benefits include but are not limited to:

- More effective and consistent odor control
- Reduced biosolid volume at the bottom of the pond/basin, thus reducing costs to dredge and dispose biosolids
- Improved secondary and tertiary treatment
    - Reduction of BOD, TSS, algae, ammonia and phosphorus
- Improved dissolved oxygen and pH levels

The solar-powered mixers from SolarBee are specifically designed to produce mixing in the upper layers of a lagoon/basin without disturbing the anaerobic sludge layer at the bottom. This enhanced mixing and circulation also increases the amount of water in contact with the air and results in increased oxygen transfer to help keep the top layer of the lagoon/basin aerobic, providing consistent odor control. Data on Solar Bee mixers indicates the mixers produce a direct flow of 3,000 gpm and an induced flow of an additional 7,000 gpm for a total flow of 10,000 gpm. The solar-powered mixers also have battery packs included in the installation to store excess daytime power for nighttime operation. The battery pack allows for 24 hours operation as well as operation up to 7 days without significant sunlight. Figure 5.3-1 below shows a photograph of the SolarBee (*left*) and a schematic of the operation of the SolarBee (*right*).

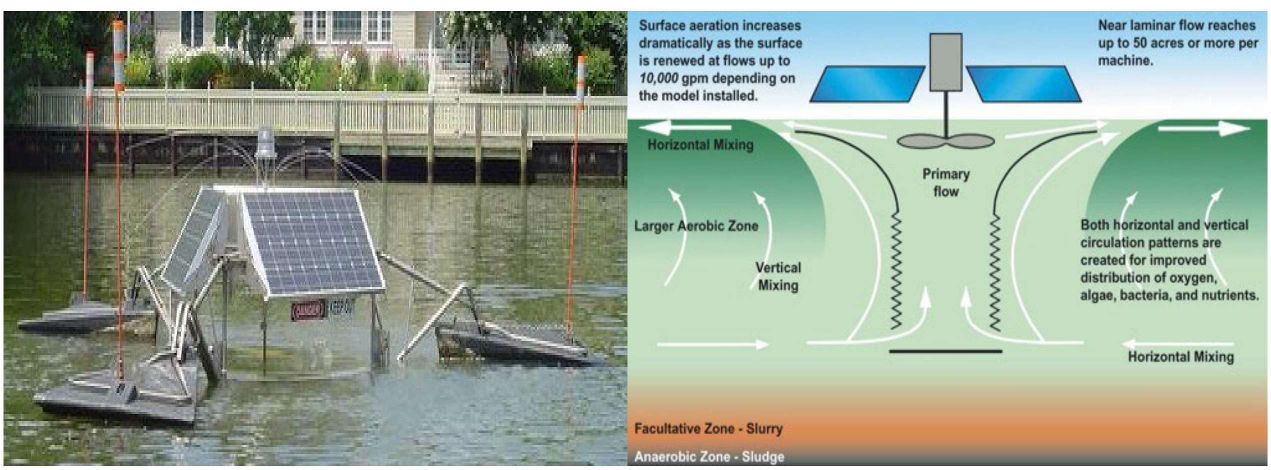


Figure 5.3-1 – (*Left*) Photo of SolarBee (*Right*) Schematic of SolarBee operation
(*Photos courtesy of SolarBee/Pump Systems, Inc.*)

The SolarBee will not only reduce the energy consumption and electrical demand of the aeration system in a wastewater treatment plant during peak period hours, it will also reduce the maintenance of the aerators, resulting in significant electrical and maintenance cost savings. Based on information provided on SolarBee's website (http://www.solarbee.com/) the SolarBee model SB10000v12, which is the model typically used in wastewater treatment plants, can replace 1000 hp-hrs per day of electric-powered aeration run time with its ½-hp motor and achieve better results in terms of overall water quality, BOD and TSS reduction, sludge reduction and odor control.

Baseline Considered:
The baseline is electrical aeration equipment. This equipment is not eligible for Non Residential New Construction (NRNC) or Non Residential Retrofit (NRR) incentives. It may be eligible under other solar programs for rebates (under review by PG&E).

Installing a Supervisory Control and Data Acquisition (SCADA) System

A Supervisory Control and Data Acquisition (SCADA) system is an effective tool for managing the energy usage in a wastewater treatment plant. SCADA is a system of sensors, transmitters, controls, communications and computer components used to monitor and control a wastewater system. A site operator can monitor and control processes that are distributed among various remote sites. Some of the benefits of a properly designed SCADA system includes but are not limited to the following:

- Energy cost savings (through continuous process monitoring)
- Reduced operating and maintenance costs
- More precise control of process parameters
    - Stabilizes and improves not only operation of controlled process parameter but also processes located downstream
- More accurate data collection (automatic data logging and archiving)
- Better overview of entire system

A SCADA system can be used for controlling many of the energy efficiency measures recommended in this report. For example, dissolved oxygen (DO) sensors can be used in combination with the SCADA system to allow operators to control the amount of aeration based on DO readings. Therefore, the aeration equipment will only need to run when necessary. If variable frequency drives (VFD) are installed on the aeration equipment, SCADA can control the speed of the VFD based on DO readings. Similarly, SCADA can control other process parameters such as pumps, motors, valves, etc and be able to monitor them from one location instead of having operators go to individual pieces of equipment. The more parameters that the SCADA is able to monitor and control, the more effective the system will be in operating the plant efficiently.

Many wastewater plants do have some type of SCADA system, although the capabilities of each system may vary widely. To see what the potential energy cost savings benefits of installing a SCADA, take the case study for Patterson Irrigation District[3]. It was estimated that installation of a SCADA system resulted in a reduction in energy consumption by 23%.

Baseline Considered:
The baseline is manual control of the wastewater treatment plant.

[3] Flex Your Power "Water/Wastewater Guide 1: Reduce Energy Use in Water and Wastewater Facilities Through Conservation and Efficiency Measures".

High Efficiency Lighting

The baseline for the lighting recommended in various areas in the facility is based on California's Title 24 nonresidential building code. The lighting standards were obtained from Title 24 according to the activity types to those areas. The lighting power density (LPD) is calculated based on the input wattage of the lamps illuminating the area divided by the total square footage of the area. Table 5.3-1 below lists the proposed lighting power densities of areas that may be applicable to wastewater treatment plants.

TABLE 5.3-1 TITLE 24 LIGHTING STANDARDS

Primary Function	Recommended Lighting Power Density ($Watt/ft^2$)
Corridors, Restrooms, Stairs and Support Areas	0.6
Electrical, Mechanical Rooms	0.7
General Industrial Work (High-Bay)	1.1
General Industrial Work (Low-Bay)	1.0
General Industrial Work (Precision)	1.3
Industrial Storage	0.6
Locker/Dressing Rooms	0.8
Conference Rooms	1.4
Office	1.2

Energy savings are calculated based on the energy consumptions under the baseline versus proposed conditions.

Baseline Considered:
The baseline is the lighting energy consumption based on Title 24 Standards (when applicable).

6 - References and Bibliography

Anderson, R., Holmberg, M. "Energy Conservation in Wastewater Treatment Operation. A Case Study of Himmerfjarden Waste Water Treatment Plant", Master Thesis from Department of Industrial Engineering and Automation, Lund University, Sweden, March 2006.

Balallo, Geronimo A. "Disinfection Performance and Applicable Process Design Parameters of State of the Art Open Channel Vertical Format Ultraviolet Disinfection System", Infilco Degremont, Richmond VA, 2003.

Bishop, Jim "Dewatering Technologies", Water Environment & Technology (WE&T), July 2006.

Bolles, S. A. "Modeling Wastewater Aeration Systems to Discover Energy Savings Opportunities", Process Energy Services, Londonderry NH, May 2003.

Burton Environmental Engineering, RCG/Hagler, Bailly, Inc. and Metcalf & Eddy, Inc. "Water and Wastewater Industries: Characteristics and DSM Opportunities", Electric Power Research Institute, Inc., EPRI TR-102015, Palo Alto CA, March 1993.

Carns, K. "Quality Energy Efficiency Retrofits for Wastewater Systems", Electric Power Research Institute, Palo Alto CA, Dec 1998.

Center for Sustainable Systems "U.S. Wastewater Treatment", Center for Sustainable Systems, University of Michigan, Ann Arbor MI, Aug 2005

Devisscher, M., Ciacci, G., Fe, L., Benedetti, L., Bixio, D., Thoeye, C., De Gueldre, G., Marsili-Libelli, S. and Vanrolleghem, P.A. "Estimating Costs and Benefits of Advanced Control for Wastewater Treatment Plants - The Magic Methodology", 2nd IWA Conference on Instrumentation, Control and Automation for Water and Waste Water Treatment and Transportation System, Busan Korea, May 2005.

Dussert, B. W. "Essential Criteria for Selecting an Ultraviolet Disinfection System", American Water Works Association Journal, Denver CO, July 2005.

Earle, John K. (Jake) "Wheels of Progress: Rotary Press Selection for Plum Island", Florida Water Resources Journal, April 2005.

Elliot, T. "Energy-Saving Opportunities for Wastewater Facilities", Energy Center of Wisconsin, Madison WI, 2003.

Energenecs Incorporated, McMahon Associates and WRC Group. "The Development of Energy Consumption Guidelines for Water/Wastewater", Focus on Energy, Wisconsin, May 2003.

Environmental Dynamics Inc. Tech Bulletin 127 "Energy Consumption and Typical Performance of Various Types of Aeration Equipment", 2003.

EPRI. “Energy Audit Manual for Water/Wastewater Facilities”, Electric Power Research Institute, Inc., CEC Report CR-104300, Palo Alto CA, July 1994.

Ferguson, L., Keenan, P. and Slosberg, R. “On-Line Process Monitoring and Electric Submetering at Six Municipal Wastewater Treatment Plants”, New York State Energy Research and Development Authority, Albany NY, July 1998.

Flex Your Power “Water/Wastewater Guide 1: Reduce Energy Use in Water and Wastewater Facilities Through Conservation and Efficiency Measures”.

Focus on Energy “Roadmap for the Wisconsin Municipal Water and Wastewater Industry”, State of Wisconsin-Division of Energy, Madison WI, Oct 2002.

Fuller, J. “Energy Efficient Alternatives for the Fortuna Wastewater Treatment Facility”, The Community Clean Water Institute Fortuna Water Quality Project, Fortuna CA, 2003.

Hammer, Mark J. and Hammer Mark J., Jr. Water and Wastewater Technology, 5th Edition. Prentice Hall 2004.

Kentucky Pollution Prevention Center. “Energy Efficiency for Wastewater Operations”, Kentucky Pollution Prevention Center & University of Louisville, Louisville KY, 2002.

Larson, L. E. “Water and Wastewater Technology Demonstration Projects”, California Energy Commission, Sacramento CA, Sept 1999.

Martin, C. P., Holtz, K. and Jensen, J. N. “Evaluation of Ultraviolet (UV) Radiation Disinfection Technologies for Wastewater Treatment Plant Effluent”, New York State Energy Research and Development Authority, Albany NY, Dec 2004.

McVay, R. “Guidelines for the Use of Variable Frequency Drive (VFDs)/Single Phase Generator Combinations For Short-Term Operation of Small Water and Wastewater Pumping Installations”, Florida Rural Water Association, Tallahassee FL, 2005.

Metcalf & Eddy, Inc. Wastewater Engineering: Treatment and Reuse, 4th Edition. McGraw-Hill 2003.

M/J Industrial Solutions “Municipal Wastewater Treatment Plant Energy Baseline Study”, Pacific Gas and Electric Company, San Francisco CA, June 2003.

Moise, M. and Norris, M. “Process Optimization and Automation Improves Reliability and Cost Efficiency of Oxnard WWTP”, Water Environment Federation (WEF) 2nd Joint Specialty Conference for Sustainable Management of Water Quality Systems for the 21st Century – Working to Protect Public Health, San Francisco CA, Aug 2005.

Office of Wastewater Management. “Primer for Municipal Wastewater Treatment Systems”, U.S. Environmental Protection Agency, Washington D.C., Sept 2004.

Pakenas, L. J. “Energy Efficiency in Municipal Wastewater Treatment Plants”, New York State Energy Research and Development Authority, Albany NY, 1995.

Phillips, David. L., Fan, M. M. “Aeration Control Using Continuous Dissolved Oxygen Monitoring in an Activated Sludge Wastewater Treatment Process”, University of California, Davis, Dec 2005.

Phillips, D.L., Fan, M. M. “Automated Channel Routing to Reduce Energy Use in Wastewater UV Disinfection Systems”, University of California, Davis, Dec 2005.

Quantum Consulting Inc. “Pacific Northwest Water and Wastewater Market Assessment”, Northwest Energy Efficiency Alliance, Portland OR, May 2001.

Risk Reduction Engineering Laboratory, Center for Environmental Research Information. “Design Manual: Fine Pore Aeration Systems”, U.S. Environmental Protection Agency, Cincinnati OH, Sept 1989.

Royce Technologies “Why Dissolved Oxygen Instruments Should be Considered for Wastewater Treatment Aeration Applications”, Technology Profile, Ontario Canada, Sept 1991.

SBW Consulting, Inc. “Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes at Various Municipal Wastewater Treatment Facilities”, Pacific Gas and Electric Company, Bellevue WA, Feb 2002.

Schwarz, James, J., Parker, Kim, Temofonte, Peter “Minimization of Required Aeration Power Utilizing a High Efficiency Single-Stage, Dual Vane Blower and System Automation Controls”, Presented at the Texas Water Conference April 4-7, 2006.

Singman, J. “Efficient Control of Wastewater Treatment Plants – a Benchmark Study”, Uppsala University School of Engineering, Uppsala NY, Nov 1999.

Smith, D. A., Clark, K. W. “Wastewater Treatment and Sludge Management”, New York State Energy Research and Development Authority, Albany NY, Oct 1995.

University of Louisville “Energy Efficiency for Wastewater Operations”, Kentucky Pollution Prevention Center, Louisville KY, 2002.

U.S. Department of Energy. “Best Practices: Performance Improvements at Wastewater Treatment Plants”, Office of Industrial Technologies, Washington, DC., Nov 2000.

Water Engineering Research Laboratory. “Fine Pore (Fine Bubble) Aeration Systems”, U.S. Environmental Protection Agency and Water Engineering Research Laboratory, Cincinnati OH, Oct 1985.

Appendix A – WWTP Survey Instrument

Wastewater Treatment Energy Efficiency Survey

This survey will ask a variety of questions on wastewater treatment and energy efficiency at your plant. You have been selected to participant in this survey because of your role at your plant. The information you will provide will assist PG&E in better meeting the needs of your plant. This survey should take no more than 20 minutes of your time.

There are three ways to complete the survey. Please choose whichever method is better for you.

1. You can complete it on your computer by using your mouse to click on the appropriate box or using your keyboard to complete the required fields (as highlighted in grey). Once you have completed the survey, you can email your responses to the email address on the last page.
2. Or, you can print out this survey, complete it with a pen, and fax your completed form to the fax number on the last page.
3. Complete the Internet version of this survey. To complete the internet version, please go to http://www.surveymonkey.com/s.asp?u=701591724658

The first set of questions will ask about energy efficiency issues at your plant.

1. Is your plant currently using any energy efficient technologies (some are outlined below)?
   - ☐ Yes
   - ☐ No (please skip to question 3)

2. Which of the following energy efficient technologies are being used at your plant? (Please check all that apply)
   - ☐ Variable Speed Drives (VSD)
     - 2a. If you are using VSDs, for what does your plant use the VSDs?
       - ☐ Pumps
       - ☐ Blowers
       - ☐ Compressors
       - ☐ Other (please specify)
     - 2a1. If you are using VSDs, has your plant experienced any problems with the application of VSDs ?
       - ☐ Yes
       - ☐ No
     - 2a2. What problems has your plant experienced with the application of Variable Speed Drives?
   - ☐ Dissolved Oxygen (DO) sensors to control blower operation for aeration
     - 2a3. Has your plant experienced any problems with the application of Dissolved Oxygen sensors?
       - ☐ Yes
       - ☐ No
     - 2a4. If you are using DO sensors, what problems has your plant experienced with the application of theses ?
   - ☐ Fine Pore Diffusers in your aeration system
     - 2a5. If your plant is using Fine Pore Diffusers, has your plant experienced any problems with these diffusers?
       - ☐ Yes
       - ☐ No
     - 2a6. If your plant is using Fine Pore Diffusers, what problems has your plant experienced with the application of these diffusers?
   - ☐ Advanced instrumentation and control/SCADA systems
     - 2a7. If any, what brand is your advanced instrumentation and control/SCADA system?
   - ☐ High efficiency lighting
     - 2a8. If any, what type of inside, high efficiency lights does your plant use?
     - 2a9. If any, what type of outside, high efficiency lights does your plant use?
   - ☐ Solar aerators or mixers
   - ☐ High efficiency blowers
     - 2a10. If any, what type of high efficiency blowers does your plant use?
   - ☐ Variable intensity and/or self-cleaning UV lamps
   - ☐ Pipe internal friction-reducing coating
   - ☐ Screw press for sludge dewatering
   - ☐ Centrifuge for sludge dewatering
   - ☐ Other (please specify)

3. Has your plant engaged in any energy efficiency projects in the past five years?
   - ☐ Yes
   - ☐ No (please skip to question 4)
   - ☐ Don't know (please skip to question 4)

   3b. If yes, please tell us about the projects (please itemize).

4. Have there been energy audits of your facilities in the past 10 years?
   - ☐ Yes
   - ☐ No (please skip to question 5)
   - ☐ Don't know (please skip to question 5)

   4b. Who sponsored the audit?
   4c. Who performed the audit?
   4d. Have you implemented any of the measures recommended from the audit?
   - ☐ Yes
   - ☐ No (please skip to question 5)

   4e. Which measures were implemented?

5. To what extent are you concerned about the cost of energy for your plant?
   - ☐ A great deal
   - ☐ Very much
   - ☐ Somewhat
   - ☐ A small amount
   - ☐ Not at all

6. Has your plant had any expansion or retrofit projects since it was initially designed?
   - ☐ Yes
   - ☐ No (please skip to question 7)

   6a. To what extent is/was energy efficiency one of your considerations in your expansion or retrofit projects?
   - ☐ A great deal
   - ☐ Very much
   - ☐ Somewhat
   - ☐ A small amount
   - ☐ Not at all

   6b. What resources do you/have you used to ensure the expansion or retrofit projects are/were energy efficient?
   - ☐ Relied on the design firm
   - ☐ Conducted an in-house review
   - ☐ Worked with outside consultants
   - ☐ Partnered with PG&E
   - ☐ Did not consider energy efficiency in new design

7. Has your plant used PG&E rebates in its projects?
   - ☐ Yes
   - ☐ No (please skip to question 8)
   - ☐ Don't know (please skip to question 8)

   7a. For which projects did you use rebates?

8. Does your plant employ methods to control its peak demand?
   - ☐ Yes
   - ☐ No (please skip to question 9)

   8a. How do you control your peak demand? (Please check all that apply)
   - ☐ By flow equalization?
   - ☐ By aeration blower control?
   - ☐ By pumping control?
   - ☐ Other (please specify)

9. Is hydraulic (water) power used for any mechanical drives?
   - ☐ Yes
   - ☐ No (please skip to question 10)
   - ☐ Don't know (please skip to question 10)

   9a. If yes, for what type of application?

10. Does your plant produce any power from the flow of effluent into the receiving water?
   - ☐ Yes
   - ☐ No (please skip to question 11)
   - ☐ Don't know (please skip to question 11)

   10a. If yes, what is the average kW?

Now, we'd like to ask you some questions about current flow rates and treatment levels of your plant.

11. In million gallons per day (MGD), what is the design flow rate?

12. In million gallons per day (MGD), what is the average flow rate?

13. What percentage of flow is from industrial users?

14. What is the treatment level (please check all that apply)?
   - ☐ Primary
   - ☐ Secondary
   - ☐ Tertiary
   - ☐ Other (please specify)

15. Which of the following treatment processes are used at your plant? (please check all that apply)
   - ☐ Activated Sludge – Aeration Method
     - 15a. Which type(s) of Activated Sludge-Aeration Method process does your plant use?
       - ☐ Mechanical
       - ☐ Coarse Bubble
       - ☐ Fine Bubble
       - ☐ Pure Oxygen
   - ☐ Oxidation Ponds
   - ☐ Fixed Film
     - 15b. Which type(s) of Fixed Film process does your plant use?
       - ☐ Rotating Biological Contactor
       - ☐ Trickling Filter
       - ☐ Membrane Bioreactor
       - ☐ Other (please specify)
   - ☐ Nutrient Removal
     - 15c. Which type(s) of Nutrient Removal process does your plant use?
       - ☐ Biological Nitrification
       - ☐ Biological Denitrification
       - ☐ Biological Phosphorus Removal
       - ☐ Chemical Phosphorus Removal
       - ☐ Other (please specify)
   - ☐ Disinfection
     - 15d. Which type(s) of Disinfection process does your plant use?
       - ☐ Chemical
       - ☐ Ultraviolet (UV)
       - ☐ Ozone
   - ☐ Filtration
     - 15e. Which type(s) of Filtration process does your plant use?
       - ☐ RO
       - ☐ Dual Media
       - ☐ Other (please specify)
   - ☐ Sludge (biosolids) Treatment
     - 15f. Which type(s) of Sludge Treatment process does your plant use?
       - ☐ Thickening, vacuum filtration
       - ☐ Thickening, Belt filtration
       - ☐ Thickening, other
       - ☐ Dewatering, air drying
       - ☐ Dewatering, heat drying
       - ☐ Dewatering, press
   - ☐ Sludge (biosolids) Digestion
     - 15g. Which type(s) of Sludge Digestion process does your plant use?
       - ☐ Aerobic
       - ☐ Anaerobic
   - ☐ Sludge (biosolids) Conditioning
     - 15h. Which type(s) of sludge conditioning process does your plant use?
       - ☐ Composting
       - ☐ Other (Please specify)

15. Which of the following treatment processes are used at your plant? (please check all that apply)
- ☐ Sludge (biosolids) Use
  - 15i. Which type(s) of Sludge Use process does your plant use?
    - ☐ Land Application
    - ☐ Incineration
    - ☐ Other (Please specify)

Now, we'd like to ask you some questions about the load capability of your plant.

16. What was the average daily sludge (biosolids) production in 2005 (in dry tons/day)?

17. What were the average concentration levels of conventional pollutants in 2005? Please complete the following table.

Concentration (mg/l)	*Influent*	*Effluent*
a. Average BOD		
b. Average COD		
c. Average TSS		

Now, we'd like to ask you some questions about the energy production and usage at your plant.

18. Does your plant produce digester gas?
- ☐ Yes
- ☐ No (please skip to question 19)

18a. On average, how much gas is produced? Please indicate whether this is CFM, BTU/hr or any other unit (please specify unit)

18b. How is the digester gas consumed?
- ☐ Flare
  - 18b1. Do you continuously flare?
    Yes ☐ No ☐
  - 18b2. If yes approximately how many CFM do you use?
- ☐ Power production
- ☐ Boiler
- ☐ Other (please specify)

18c. Is the digester influent sludge pre-heated?
- ☐ Yes
- ☐ No

19. Does your plant use engine driven pumps?
- ☐ Yes
- ☐ No (please continue to question 20)

19a. What is the total engine horsepower? (hp)

19b. What is the engine fuel used? (please check all that apply)
- ☐ Digester gas
- ☐ Natural gas
- ☐ Diesel
- ☐ Other (please specify what it is and how much)

20. Is electricity generated on-site at your plant?
- ☐ Yes
- ☐ No (please continue to question 21)

20a. What is the fuel source? (please check all that apply)
- ☐ Digester gas
- ☐ Natural gas
- ☐ Other (please specify what it is and how much)

20b. What is the nominal production capacity? kW

We'd like to end the survey with some questions about the design of your plant.

21. In what year was the plant originally constructed?

22. What design firm did your plant use?

23. Was the plant constructed in phases?
- ☐ Yes
- ☐ No (please continue to question 24)

23a. In how many phases was the plant constructed?

23b. For each phase, please tell us what technology was added to plant, in what year, and which design firm your plant used.

Phase I

23b1. What technology was added in phase 1?

23b2. What year was the phase completed?

23b3. What design firm did your plant use for this phase?

Phase II (please complete if your plant was constructed in two or more phases)

23b4. What technology was added in phase 1?

23b5. What year was the phase completed?

23b6. What design firm did your plant use for this phase?

Phase III (please complete if your plant was constructed in three or more phases)

23b7. What technology was added in phase 1?

23b8. What year was the phase completed?

23b9. What design firm did your plant use for this phase?

We'd like to conclude the survey with some questions about you and contact information for your plant.

24. What is your plant's NPDES Permit Number?

25. What is your facility's name?

26. What is your facility's mailing address?

27. What is your name?

28. What is your work telephone number?

29. What is your email address?

You have reached the end of the survey.

In order to submit your survey via email, please save this file on your computer. Then, please send the completed survey via email (please don't forget to attach the survey) to wwt_survey@baseco.com.

If you would prefer to fax your survey, please return it via fax to 415-543-1601.

If you have any questions or experience any difficulties returning this survey, please contact Dr. Ganji at 415-543-1600.

Thank you for completing this survey. Your responses will better assist PG&E in making wastewater treatment more energy efficient.

Appendix B – Analysis of the WWTP Survey Results

This appendix includes a graphic representation of the survey (Appendix A) results.

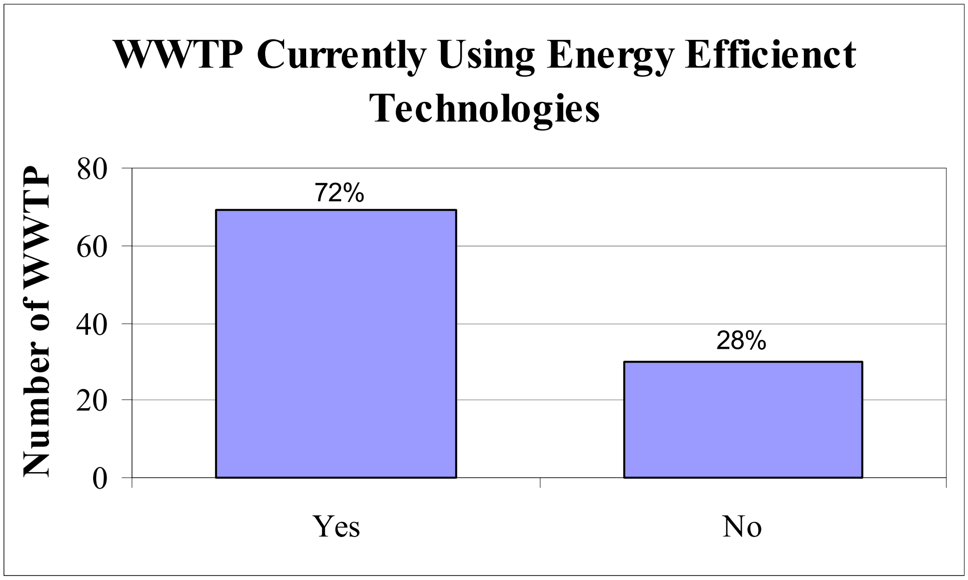


Figure B-1 Number of WWTP That Currently Use Energy Efficient Technologies (Question 1)

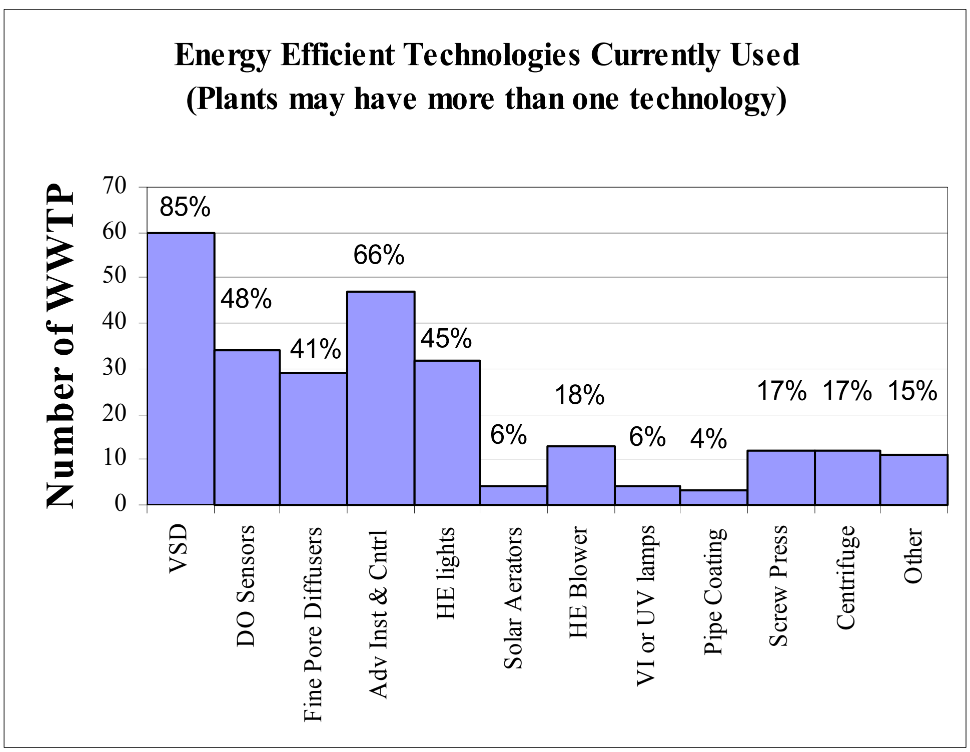


Figure B-2 Energy Efficient Technologies Currently Used (Question 2)

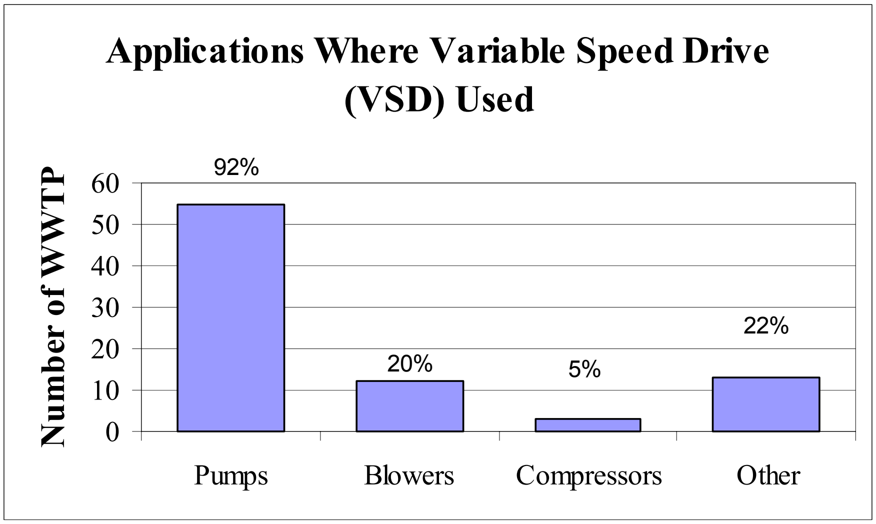


Figure B-3
Number of WWTP That Have an Application of Variable Speed Drive Units
(Question 2a0)

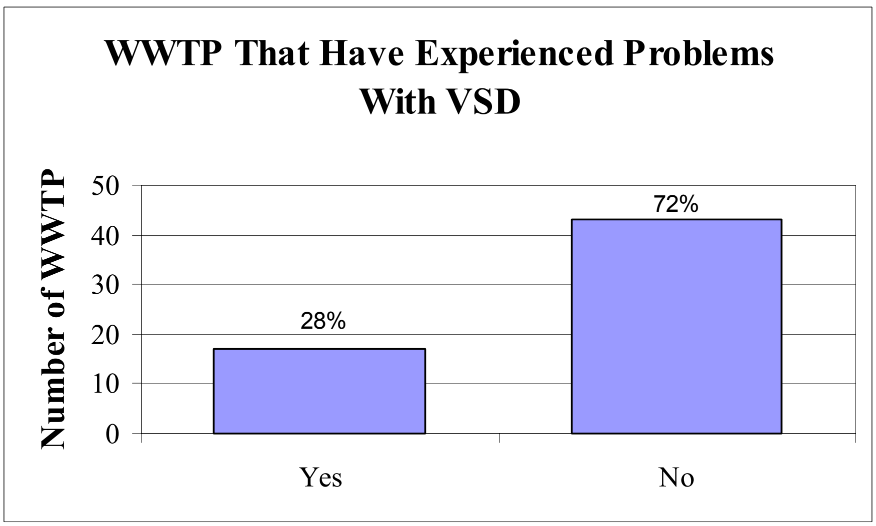


Figure B-4
Number of WWTP That Have Experienced Problems with VSD
(Question 2a1)

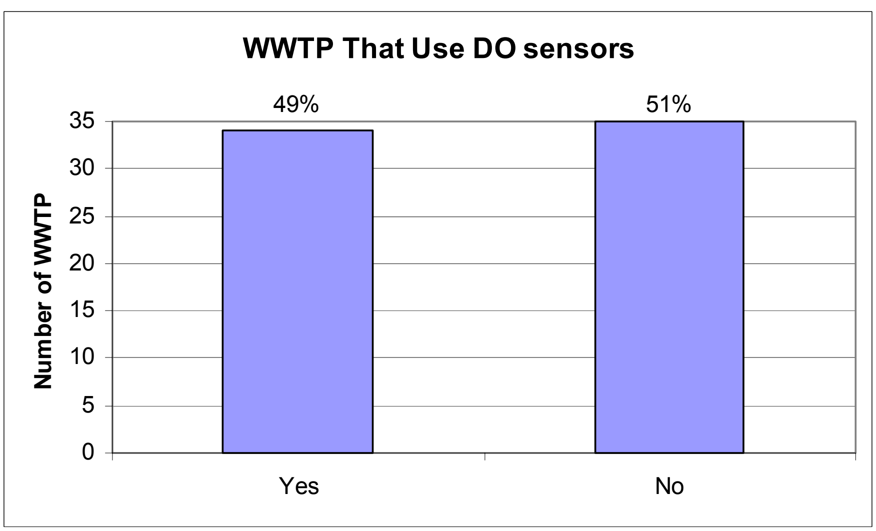


Figure B-5
Number of WWTP That Use Dissolved Oxygen Sensors for Control
(Question 2)

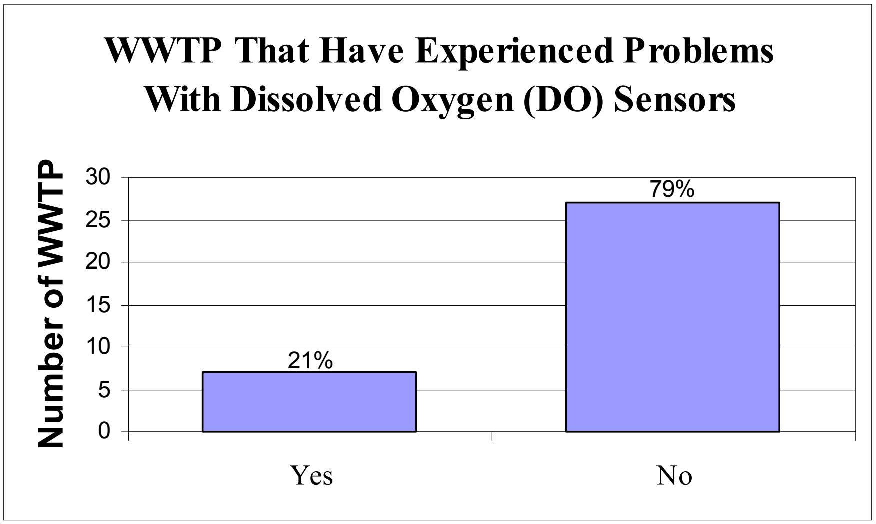


Figure B-6
Number of WWTP That Have Experienced Problems with Dissolved Oxygen Sensors
(Question 2a4)

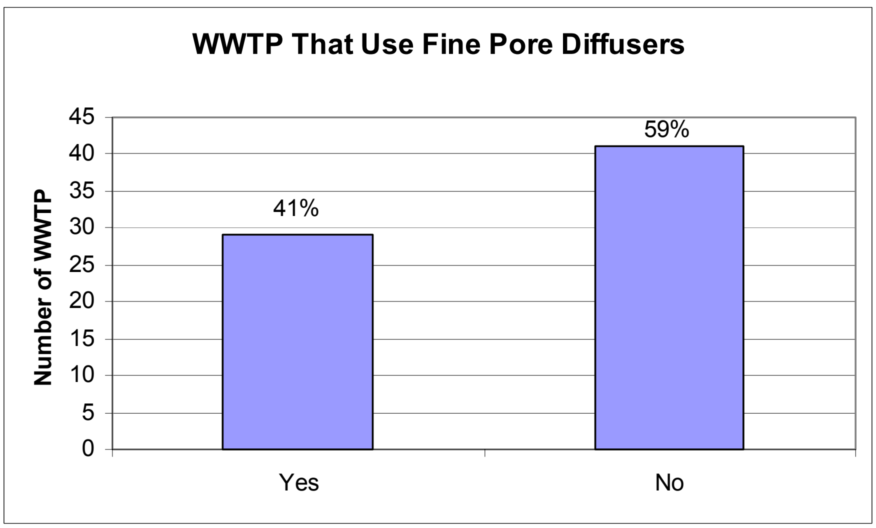


Figure B-7
Number of WWTP that Use Fine Pore Diffusers
(Question 2)

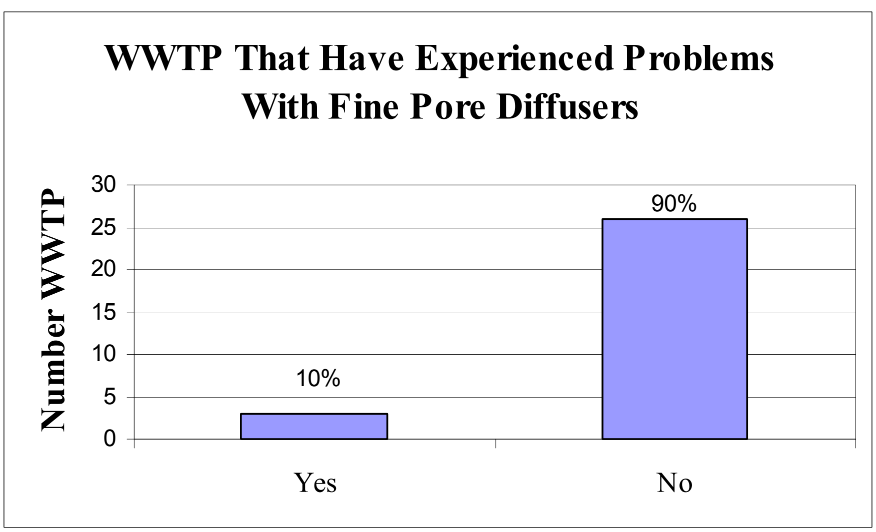


Figure B-8
Number of WWTP That Have Experienced Problems While Using Fine Pore Diffusers
(Question 2a5)

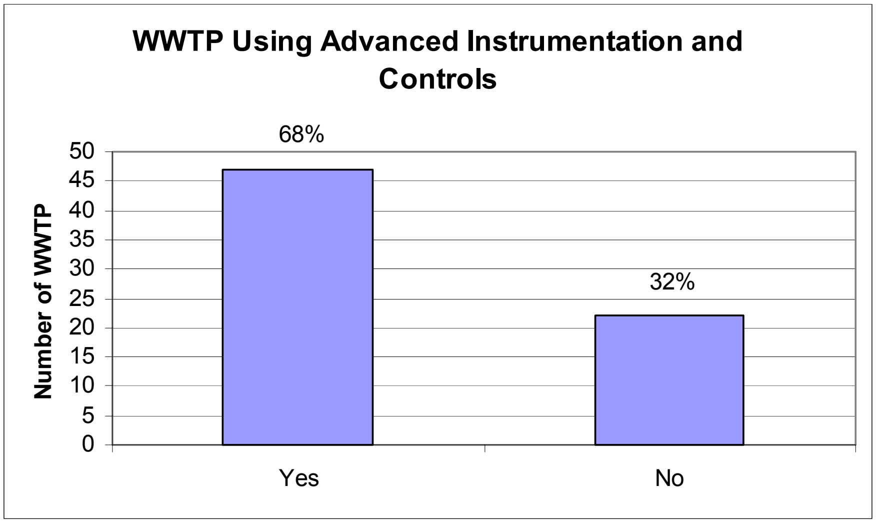


Figure B-9
Number of WWTP That Use Advanced Instrumentation and Control or SCADA Systems
(Question 2)

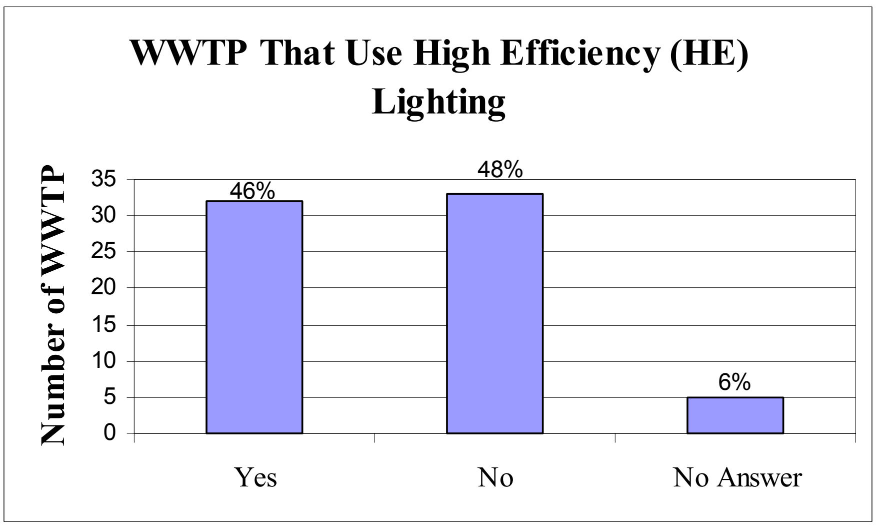


Figure B--10
Number of WWTP That Use High Efficiency Lighting
(Question 2)

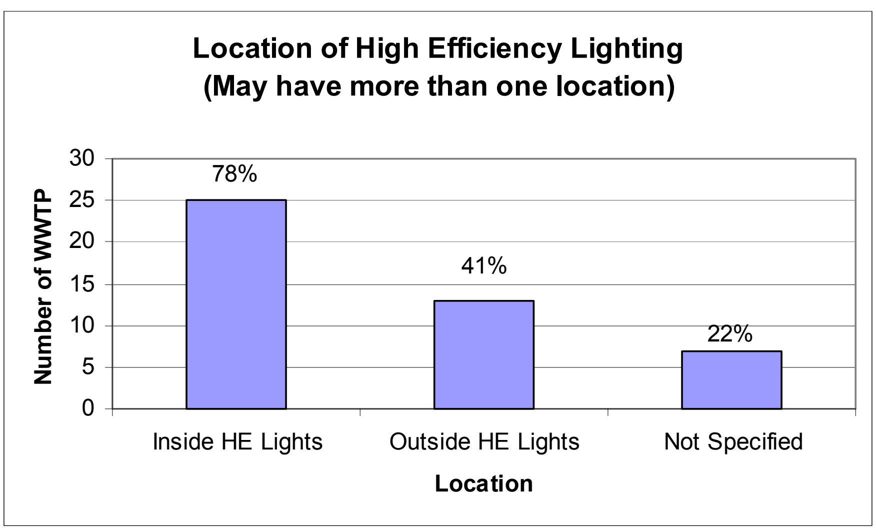


Figure B-11
Location of the High Efficiency Lights
(Question 2a8 and 2a9)

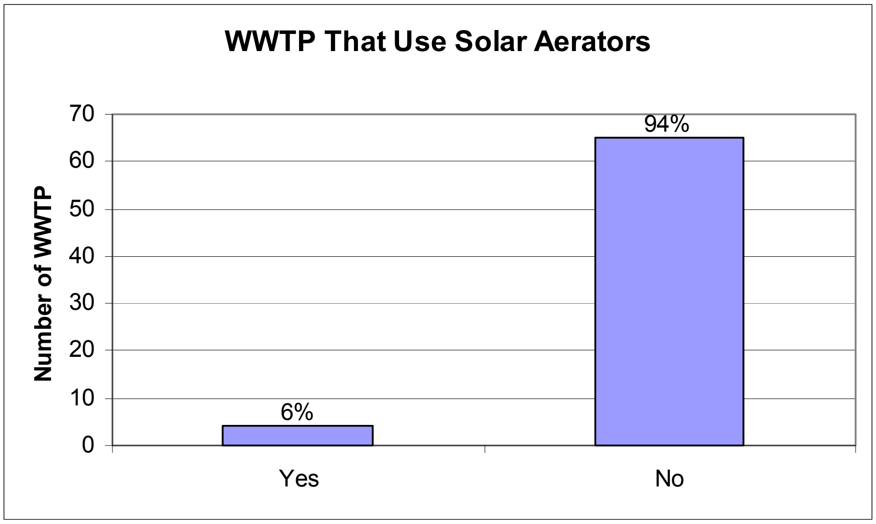


Figure B-12
Number of WWTP That Use Solar Aerators (Question 2)

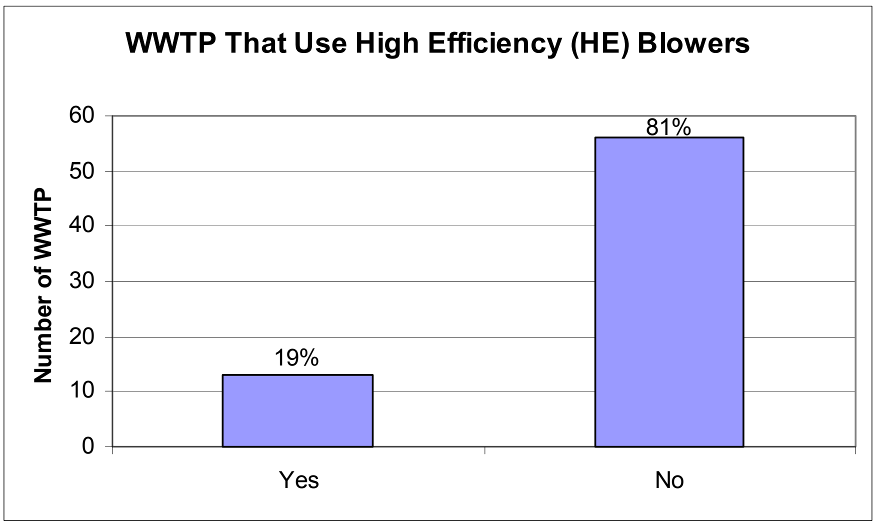


Figure B-13
Number of WWTP That Use High Efficiency Blowers
(Question 2)

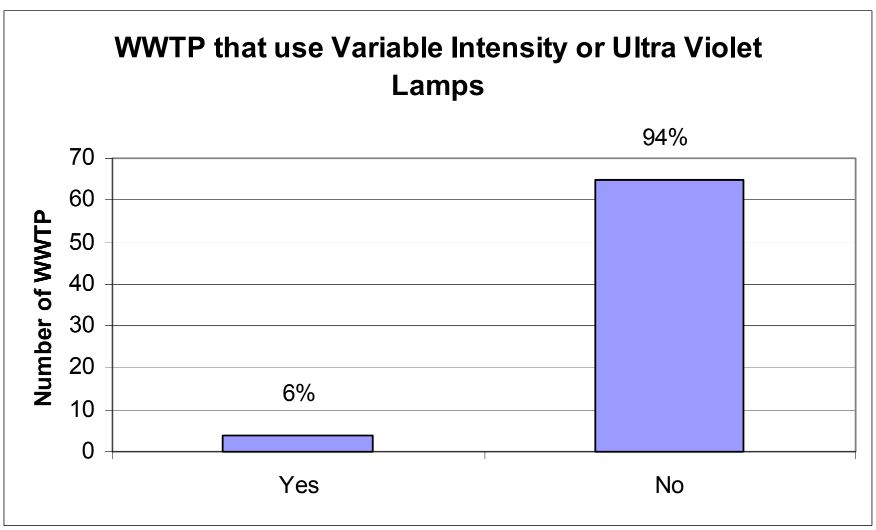


Figure B-14
Number of WWTP That Use Variable Intensity or Ultra-Violet Lamps (Question 2)

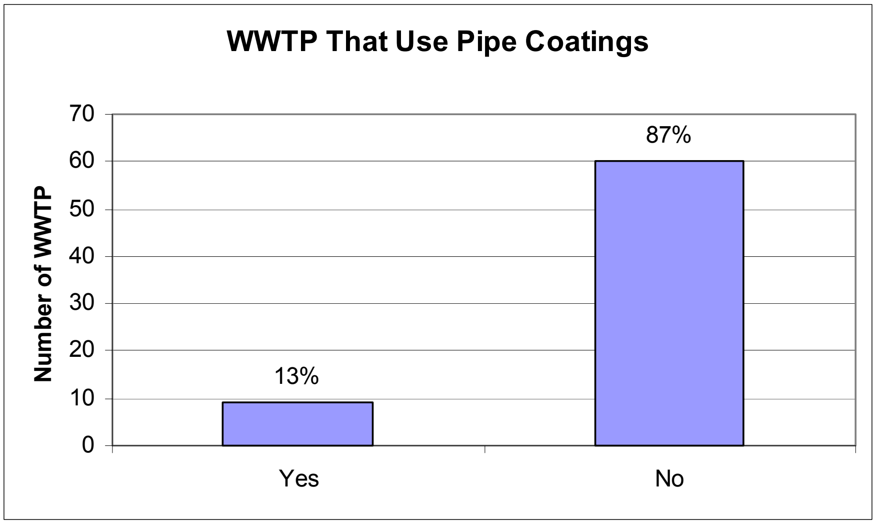


Figure B-15
Number of WWTP That Use Pipe Internal Friction Reducing Coatings (Question 2)

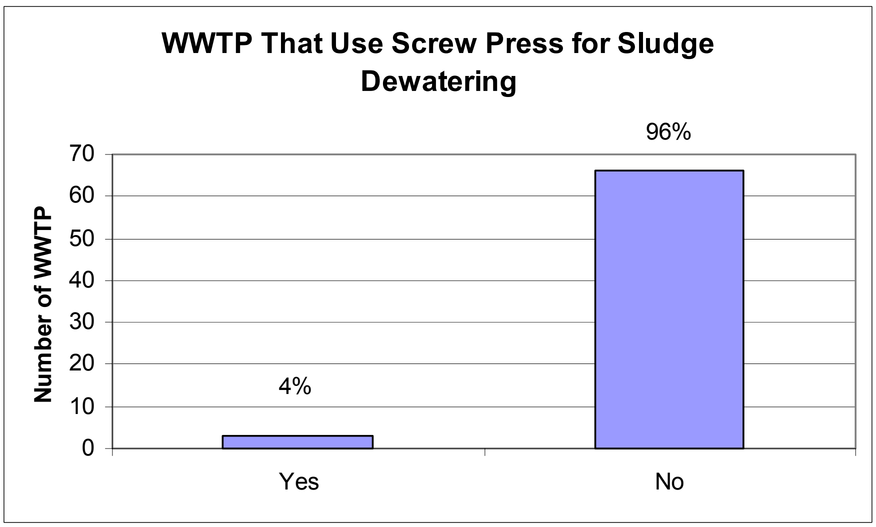


Figure B-16
Number of WWTP That Use Screw Press for Sludge Dewatering (Question 2)

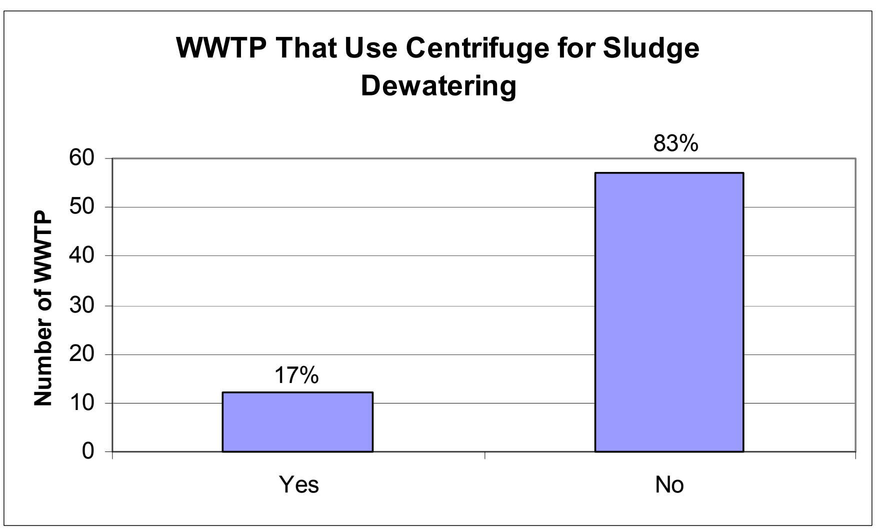


Figure B-17
Number of WWTP That Use a Centrifuge for Sludge Dewatering (Question 2)

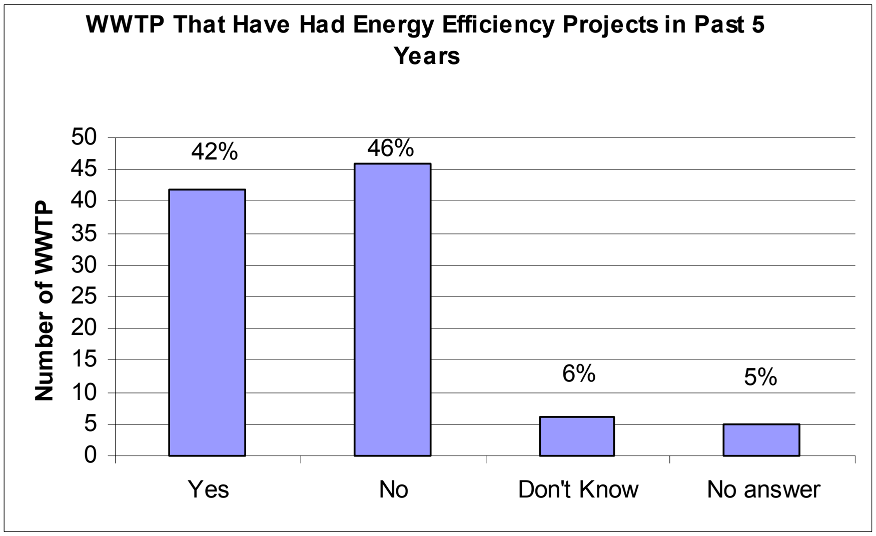


Figure B-18
Number of WWTP Which Have Had an Energy Efficiency Project in the Last Five Years (Question 3)

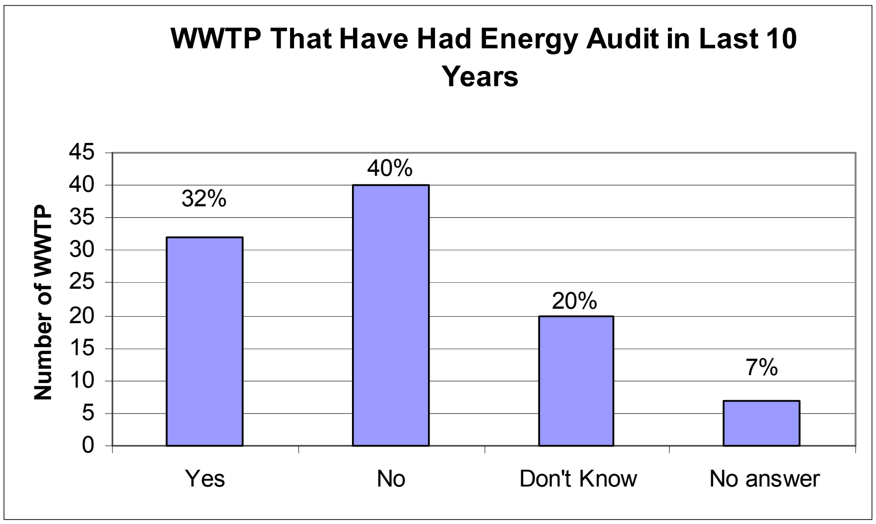


Figure B-19
Number of WWTP Which Have Had an Energy Audit in the Last Ten Years (Question 4)

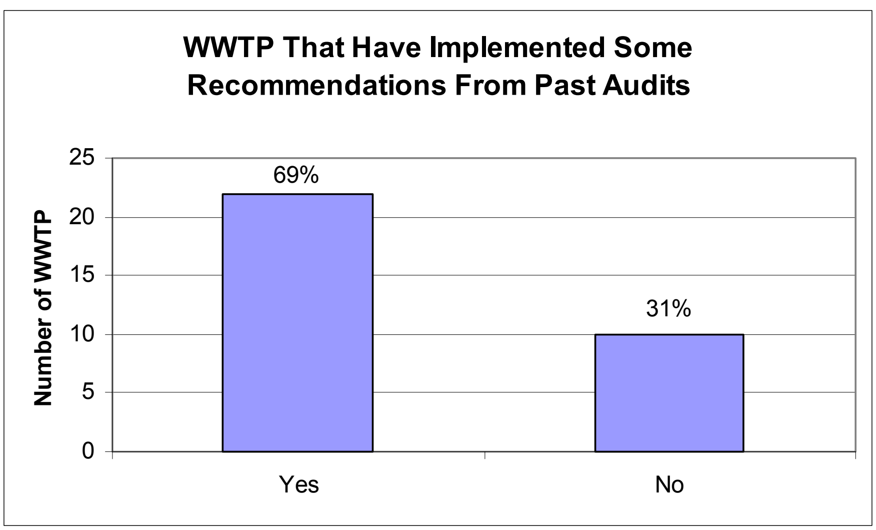


Figure B-20
Number of WWTP Which Have Implemented Some or All of the Audit Recommendations (Question 4d)

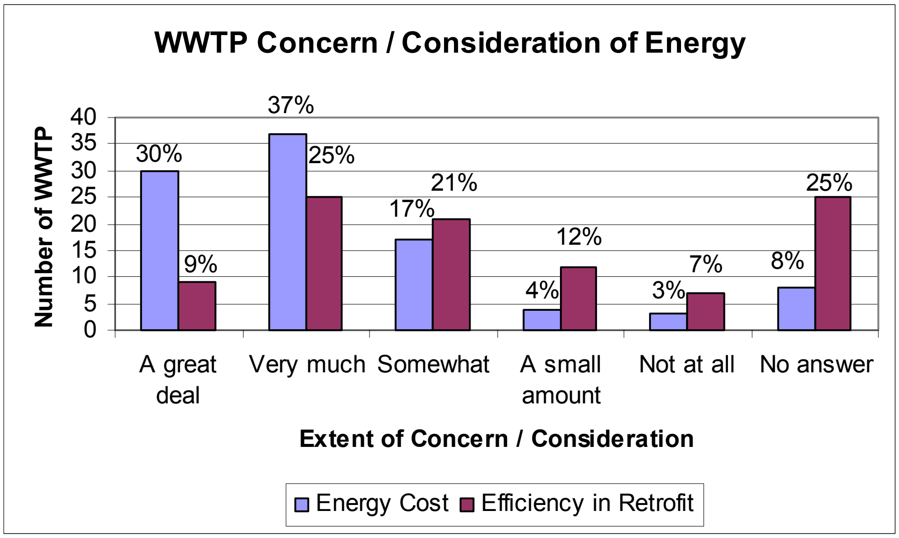


Figure B-21
To What Extent the WWTPs Are Concerned About the Cost of Energy for Their Plant, and To What Extent Energy Efficiency Was Considered in Retrofits (Question 5 and 6a)

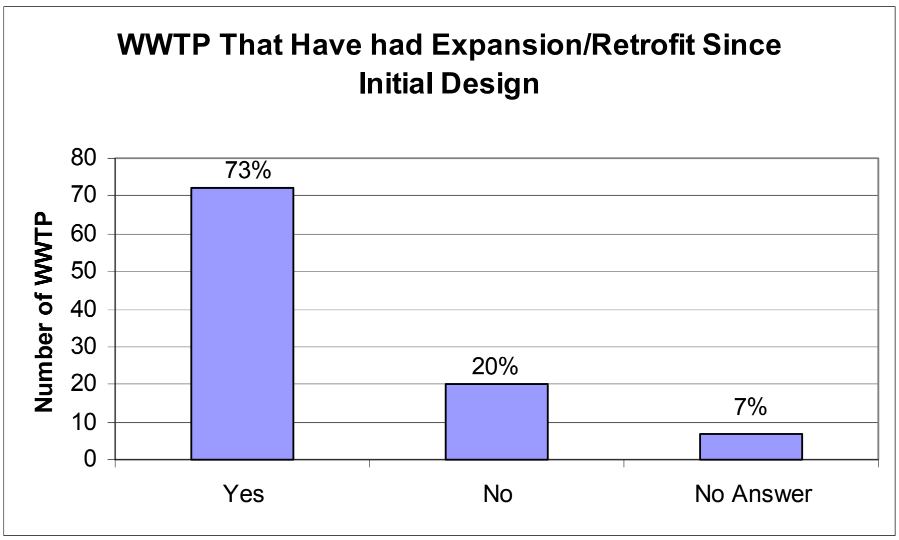


Figure B-22
Number of WWTP That Have Undergone an Expansion or Retrofit Since Their Initial Construction (Question 6)

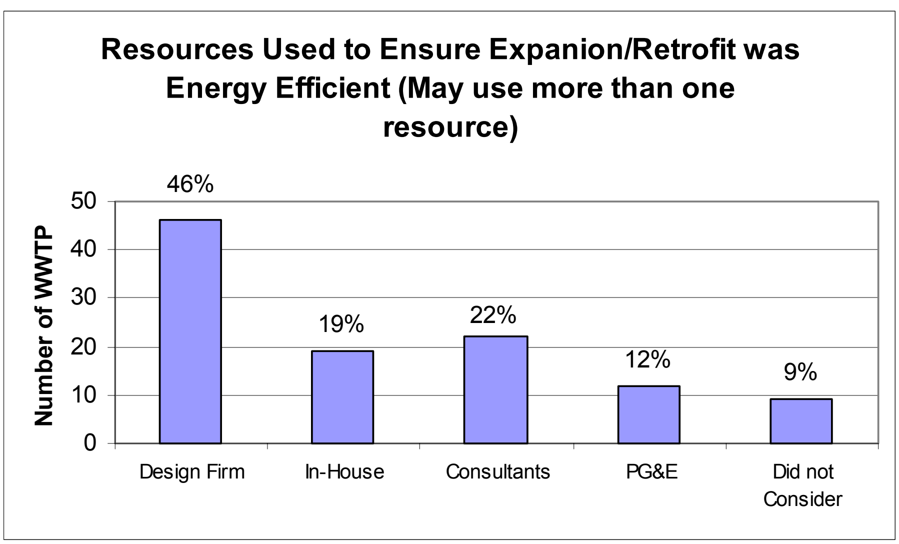


Figure B-23
Resources That the WWTP Have used To Ensure That the Expansion and/or Retrofit Projects Are/Were Energy Efficient (Question 6b)

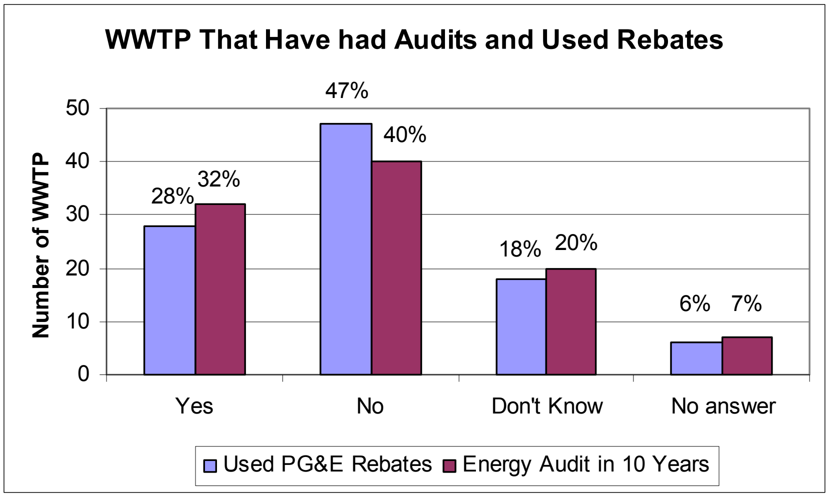


Figure B-24
Number of WWTP That Have Had Audits in the Past Ten Years (Question 4) and That Have Used PG&E Rebates in Its Projects
(Question 7)

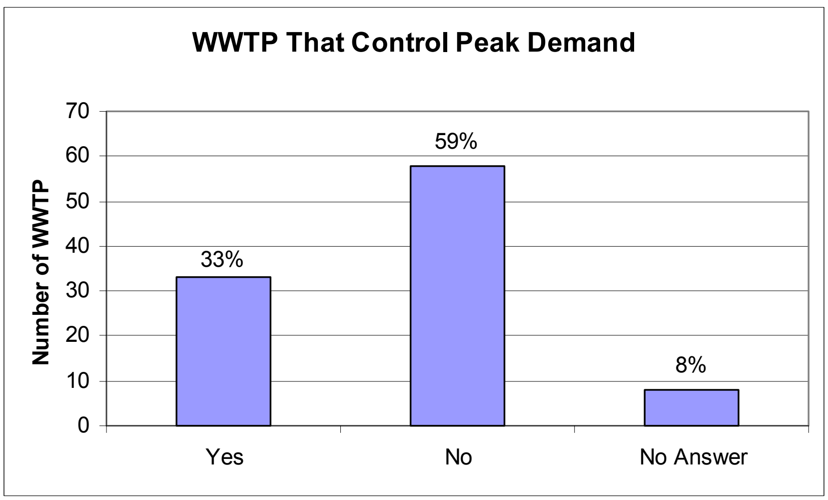


Figure B-25
Number of WWTP That Control Peak Demand
(Question 8)

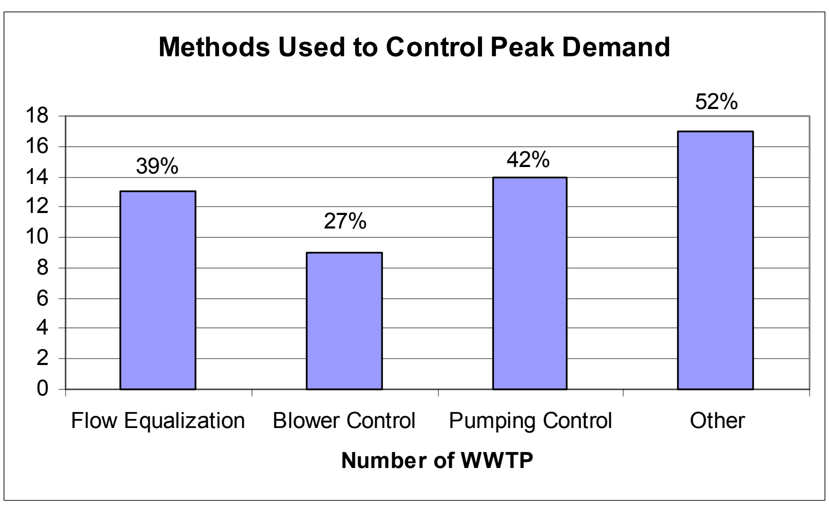


Figure B-26
Methods Employed by WWTP to Control Their Peak Demand
(Question 8a)

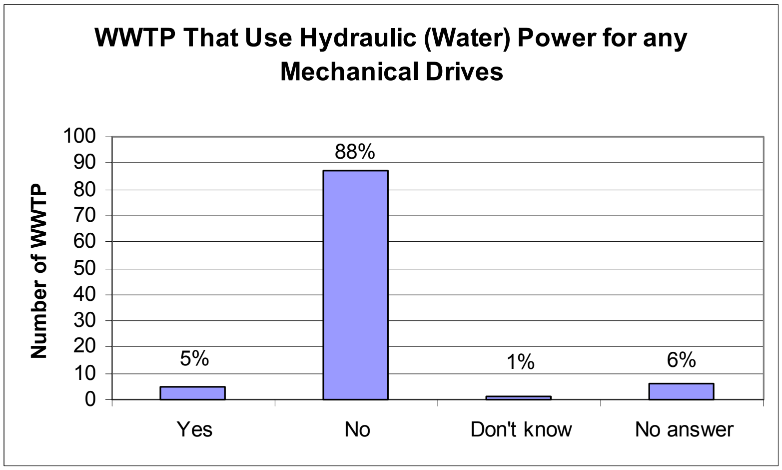


Figure B-27
Number of WWTP That Use Water Power for any Mechanical Drives (Question 9)

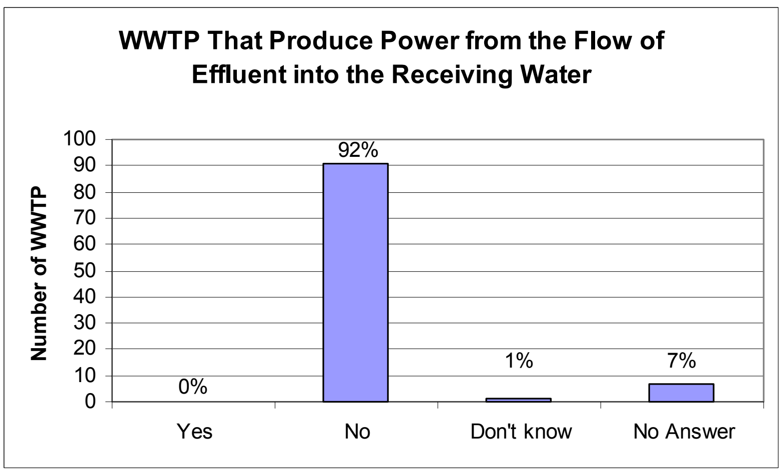


Figure B-28
Number of WWTP That Produce Power from the Flow of Effluent Water (Question 10)

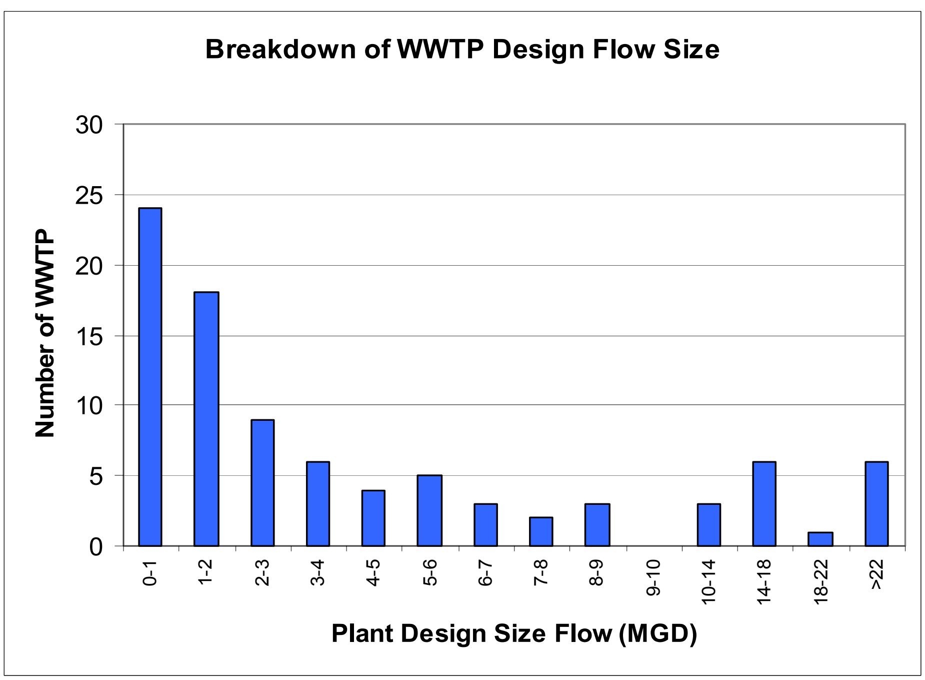


Figure B-29
Breakdown of the Design Flow Rate of WWTP (Question 11)

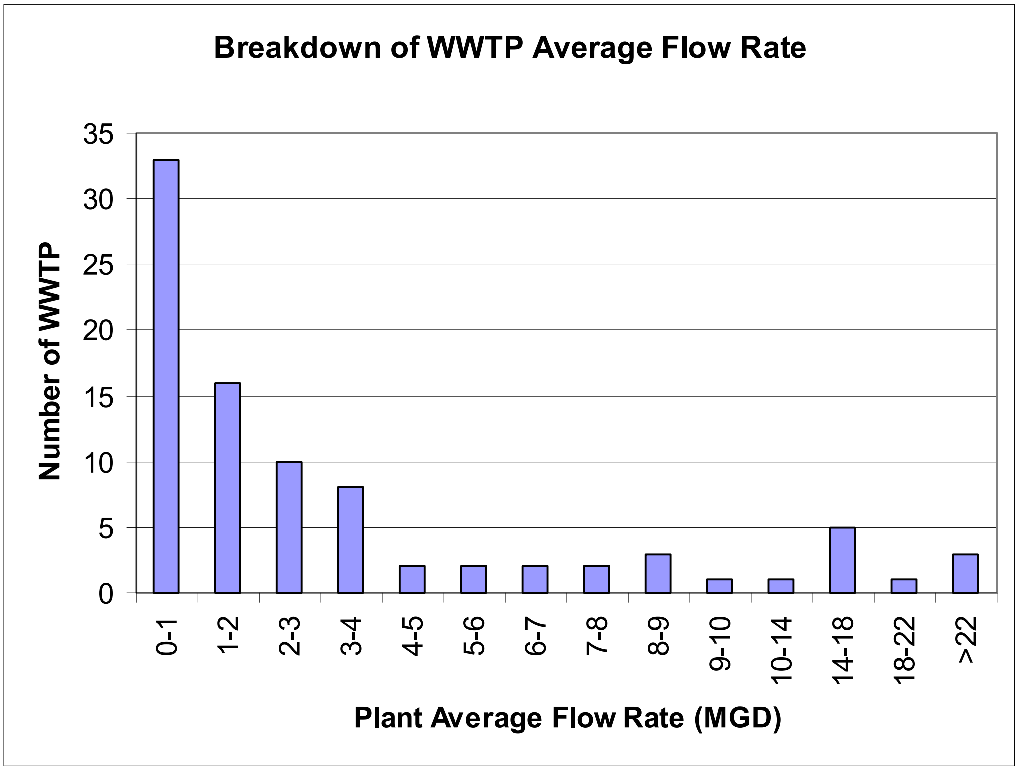


Figure B-30 Breakdown of the Average Flow Rate of WWTP (Question 12)

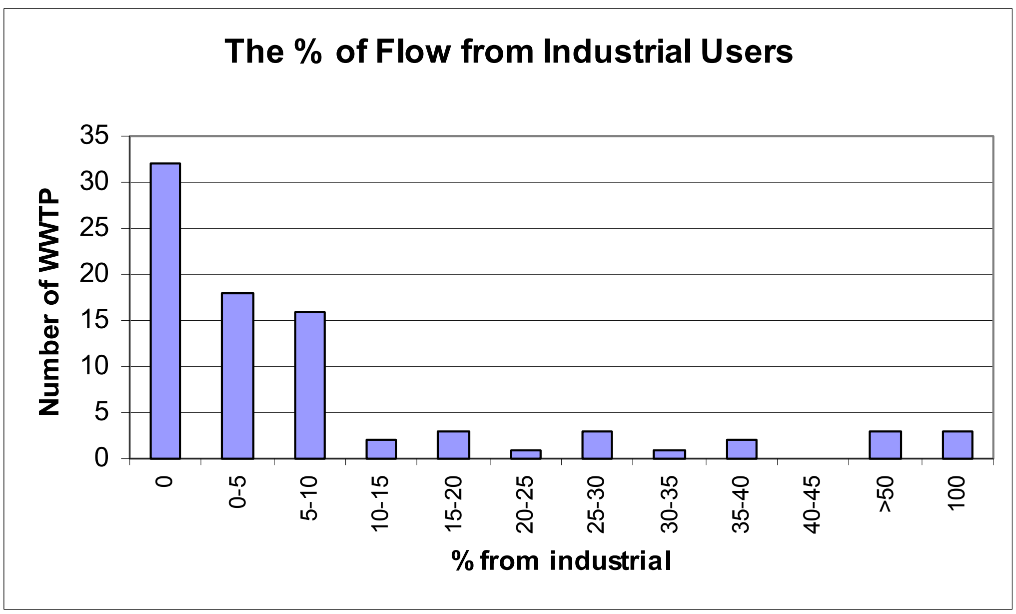


Figure B-31 Breakdown of the Percentage of Flow That Comes From Industrial Users (Question 13)

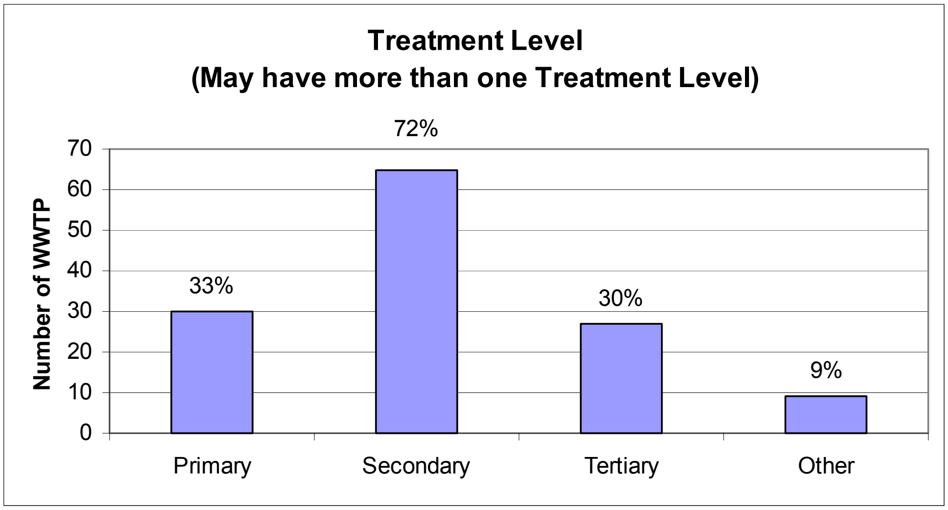


Figure B-32
Treatment Levels of the WWTP – They May Have More Than One Level of Treatment (Question 14)

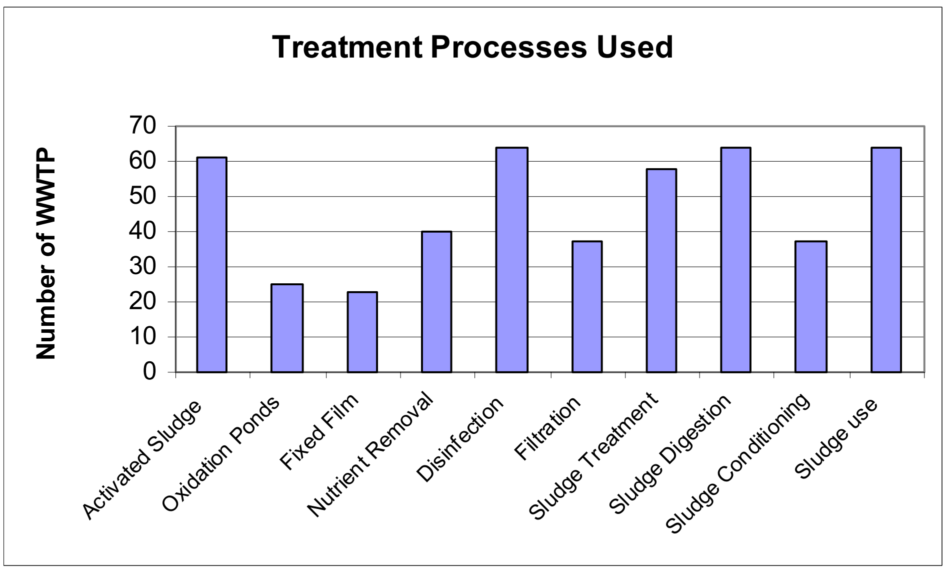


Figure B-33
Treatment Processes Used at WWTP (Question 15)

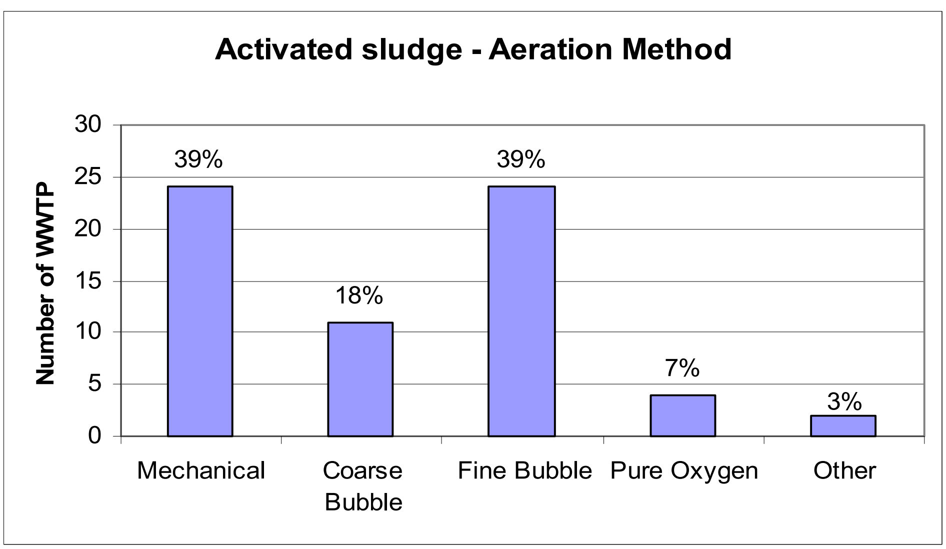


Figure B-34
Breakdown of Methods Used for Activated Sludge Treatment (Question 15a)

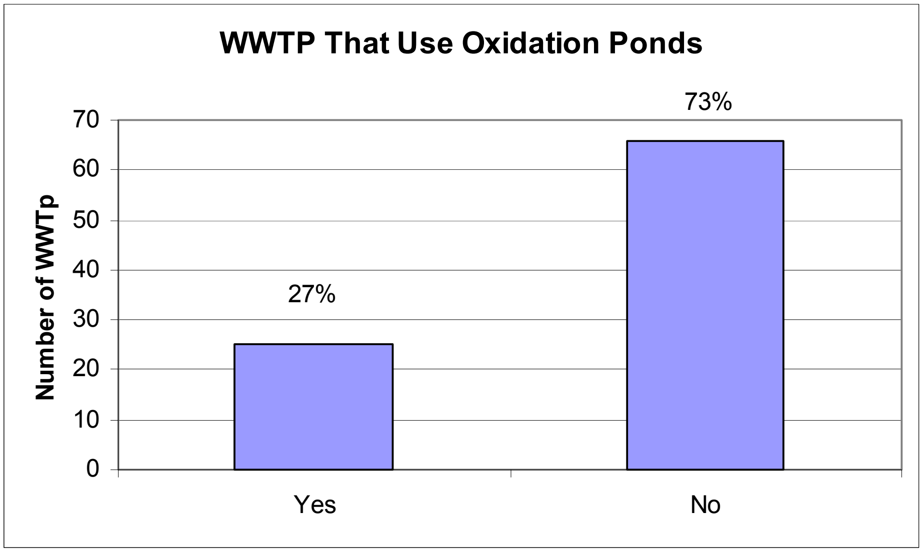


Figure B-35
Number of WWTP That Use Oxidation Ponds
(Question 15)

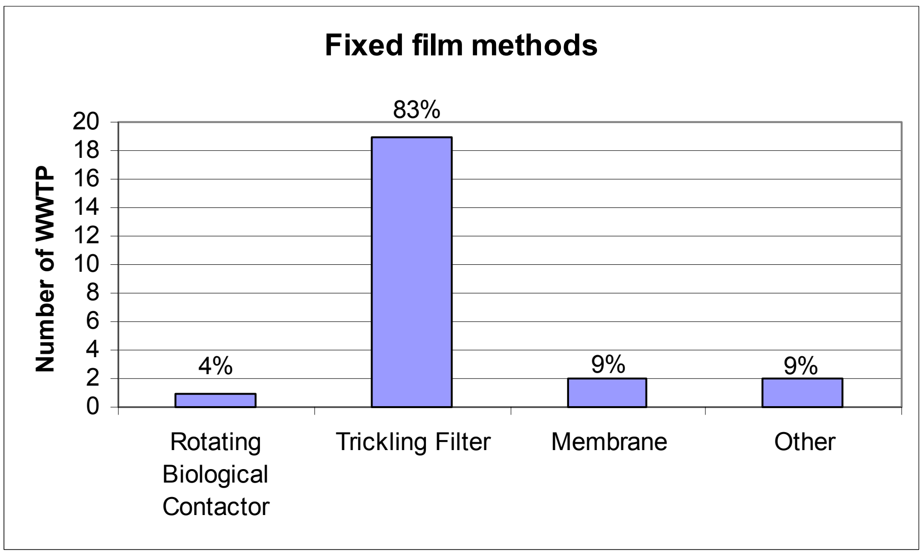


Figure B-36
Breakdown of Methods Used for Fixed Film Treatment
(Question 15b)

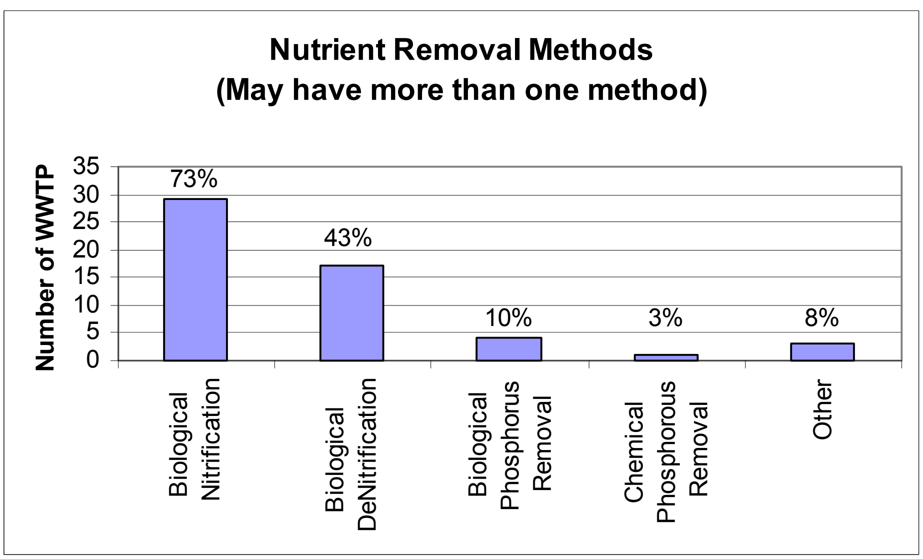


Figure B-37
Breakdown of Methods Used for Nutrient Removal Treatment
(Question 15c)

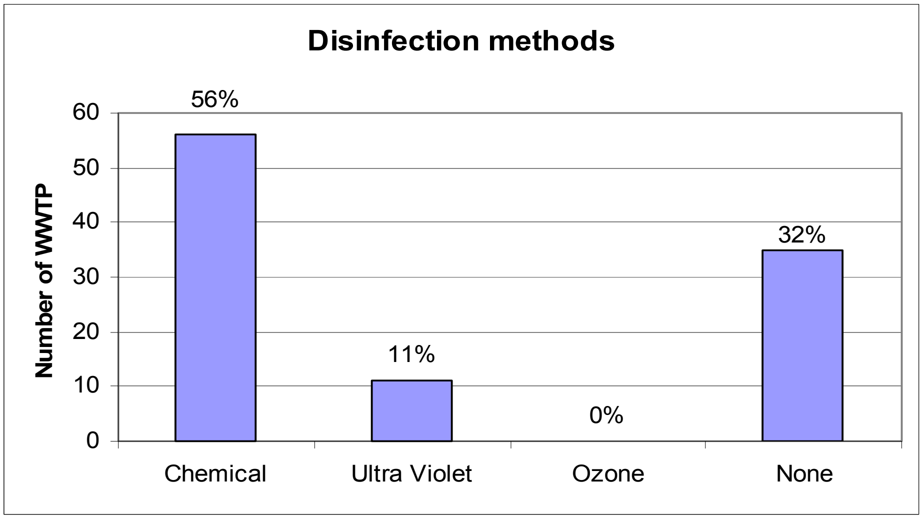


Figure B-38 Breakdown of Methods Used for Disinfection Treatment (Question 15d)

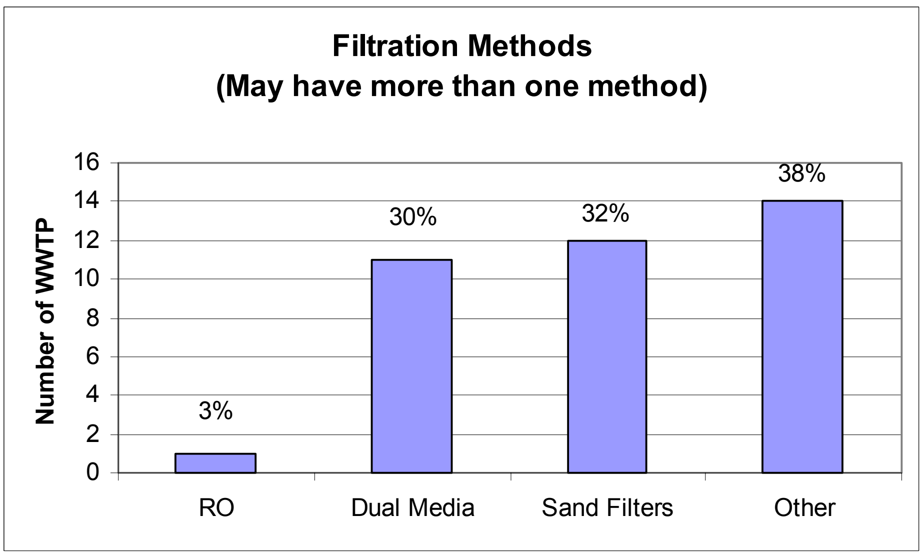


Figure B-39 Breakdown of Methods Used for Filtration (Question 15e)

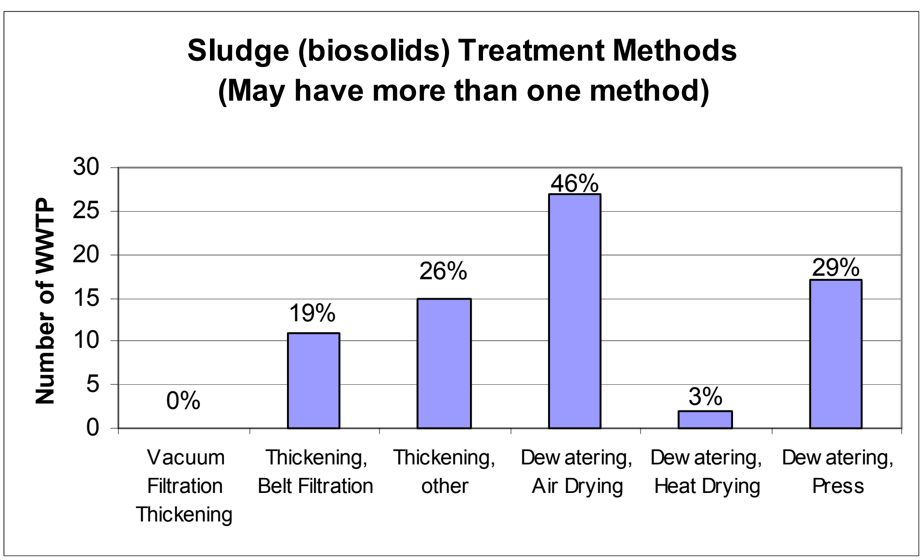


Figure B-40 Breakdown of Methods Used for Sludge (biosolids) Treatment (Question 15f)

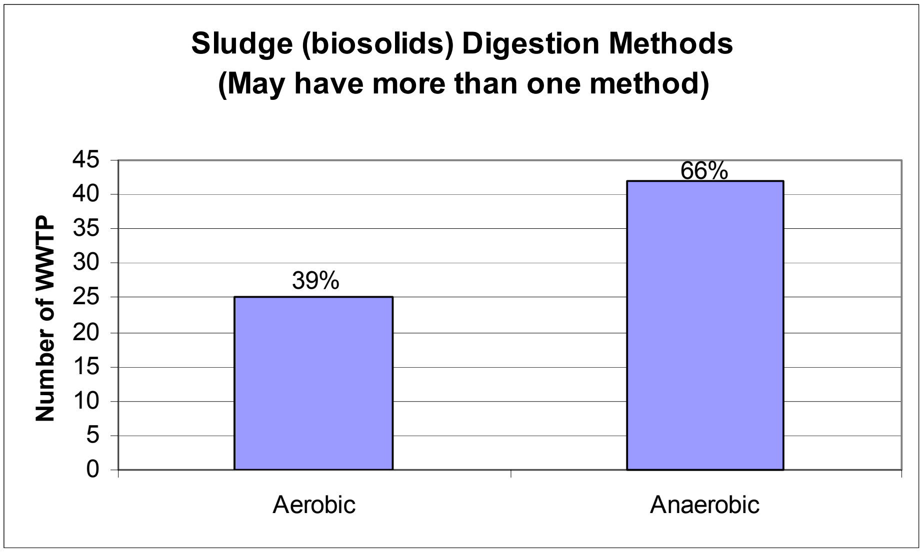


Figure B-41
Breakdown of Methods Used for Sludge (biosolids) Digestion Treatment (Question 15g)

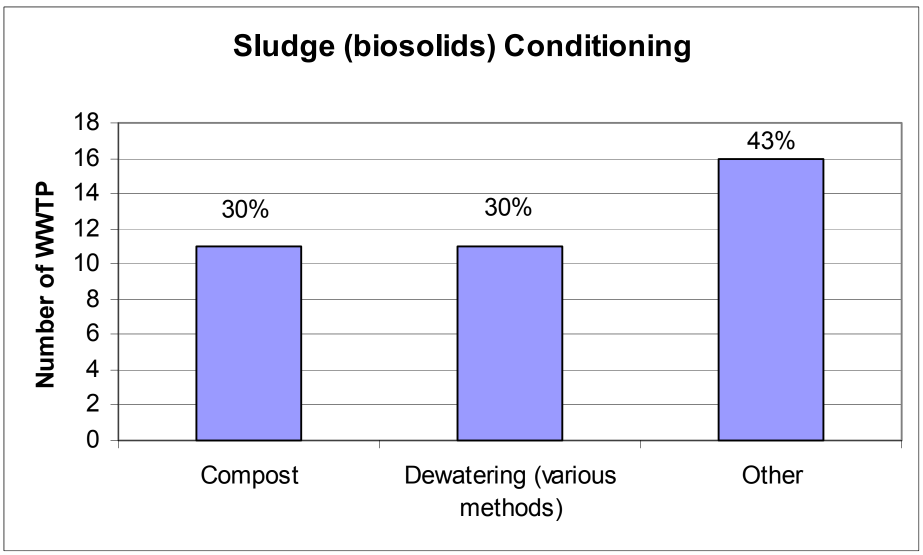


Figure B-42
Breakdown of Methods Used for Sludge (biosolids) Conditioning Treatment (Question 15h)

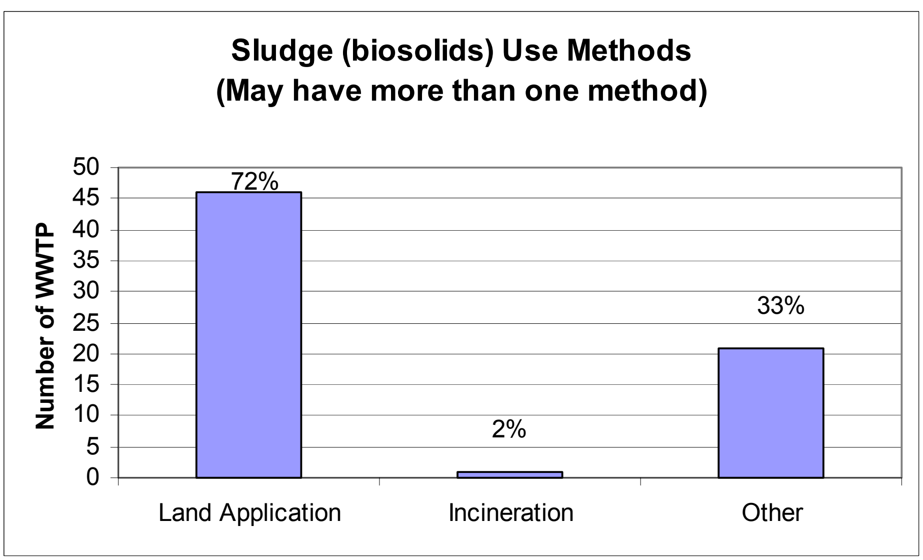


Figure B-43
Breakdown of Methods Used for Sludge (biosolids) Use (Question 15i)

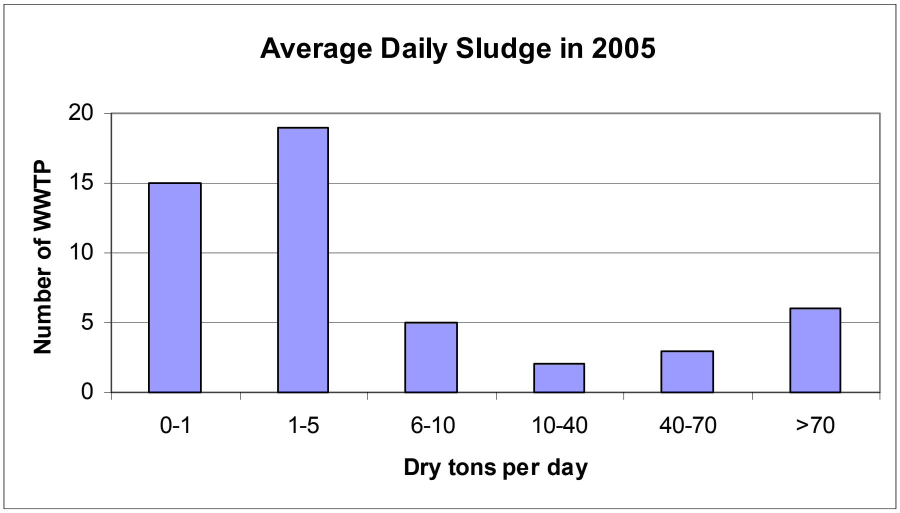


Figure B-44
The Average Daily Sludge Production in 2005
(Question 16)

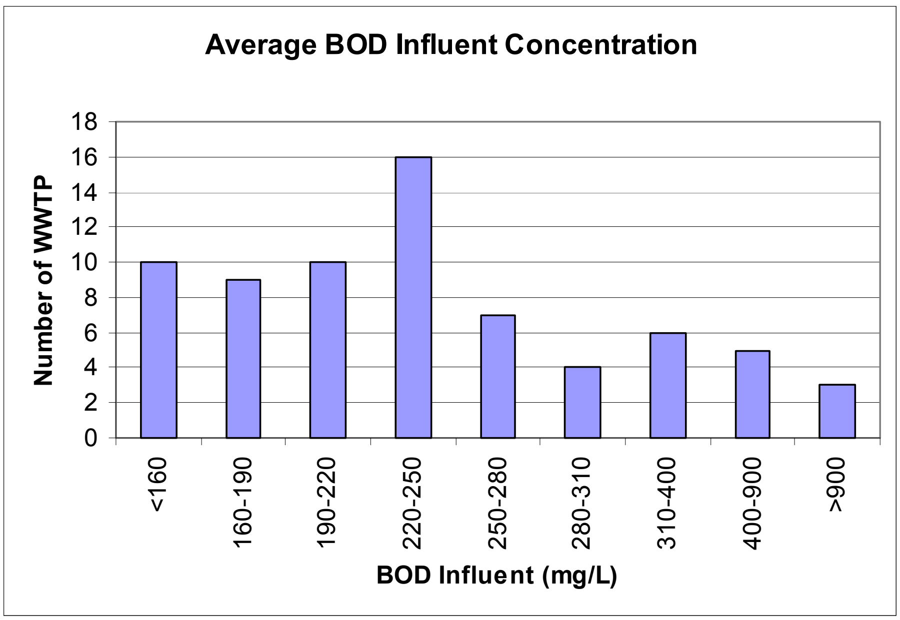


Figure B-45
Breakdown of the Average Conventional BOD Pollutant Influent in 2005
(Question 17)

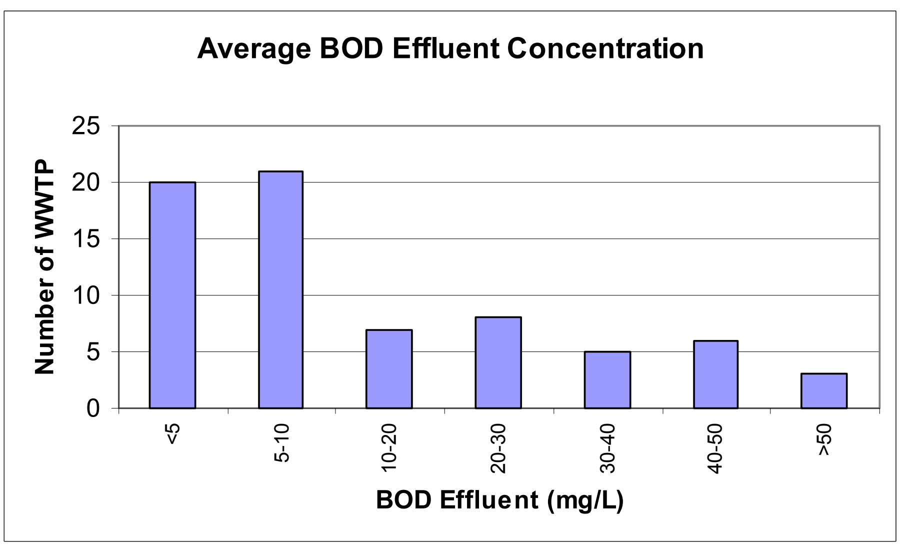


Figure B-46
Breakdown of the Average Conventional BOD Pollutant Effluent in 2005
(Question 17)

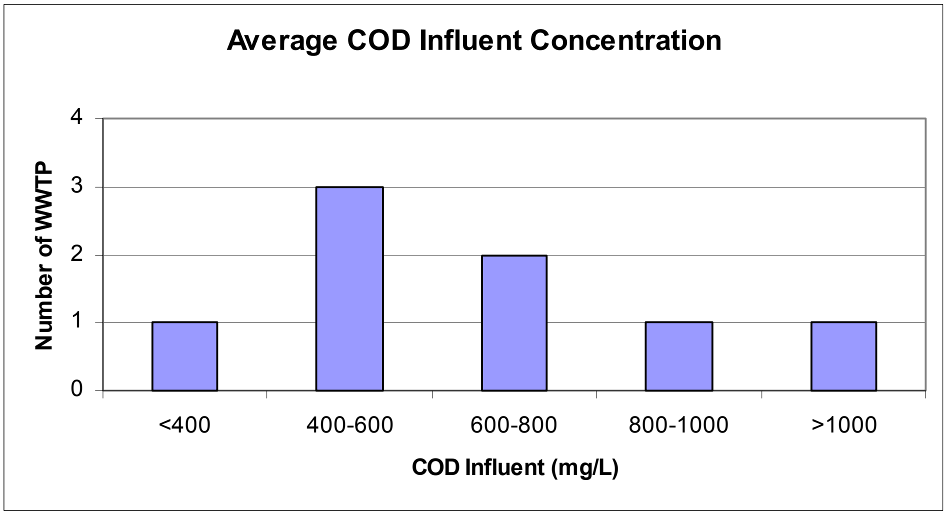


Figure B-47
Breakdown of the Average Conventional COD Pollutant Influent in 2005 (Question 17)

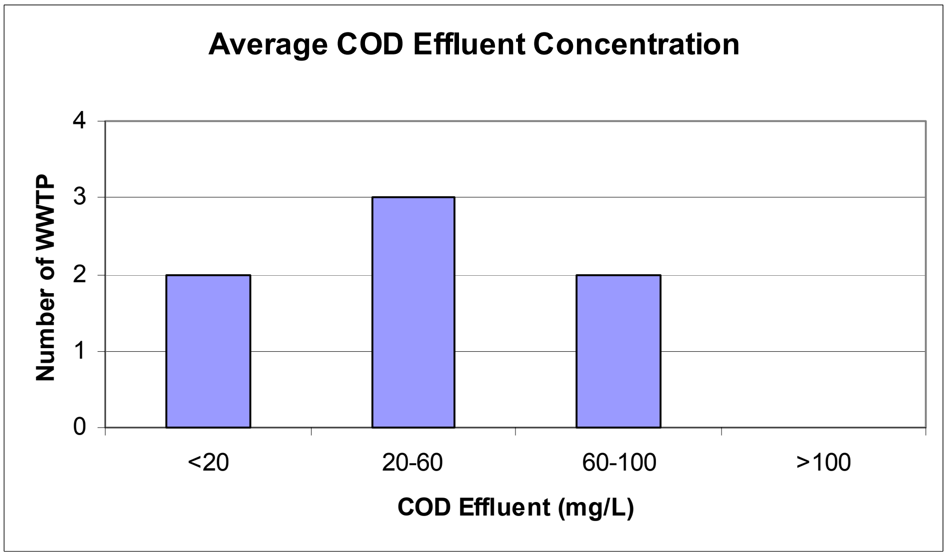


Figure B-48
Breakdown of the Average Conventional COD Pollutant Effluent in 2005 (Question 17)

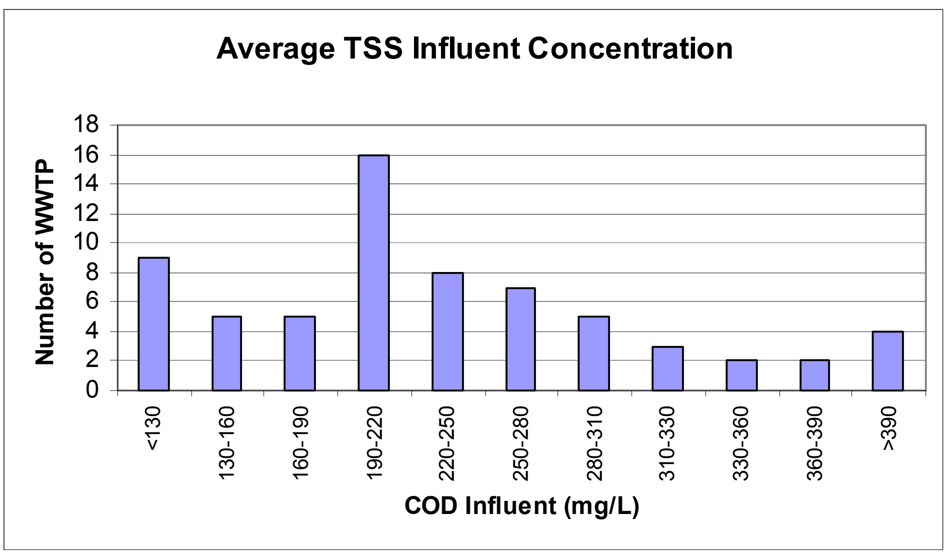


Figure B-49
Breakdown of the Average Conventional TSS Pollutant Influent in 2005 (Question 17)

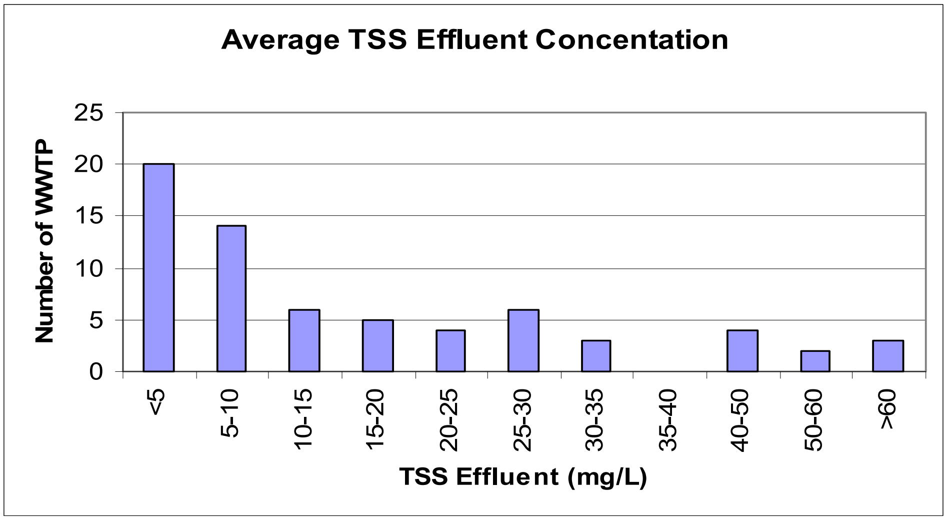


Figure B-50
Breakdown of the Average Conventional TSS Pollutant Effluent in 2005 (Question 17)

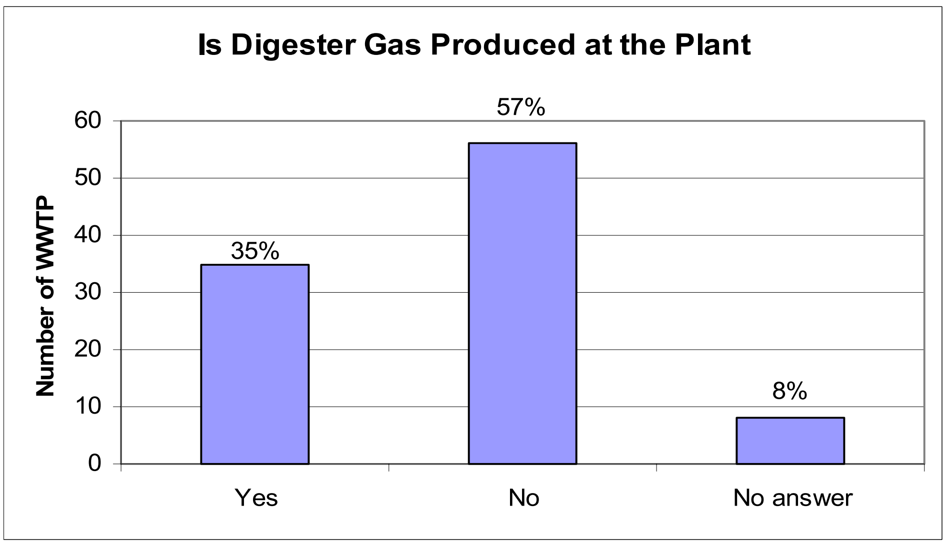


Figure B-51
Number of WWTP That Produce Digester Gas (Question 18)

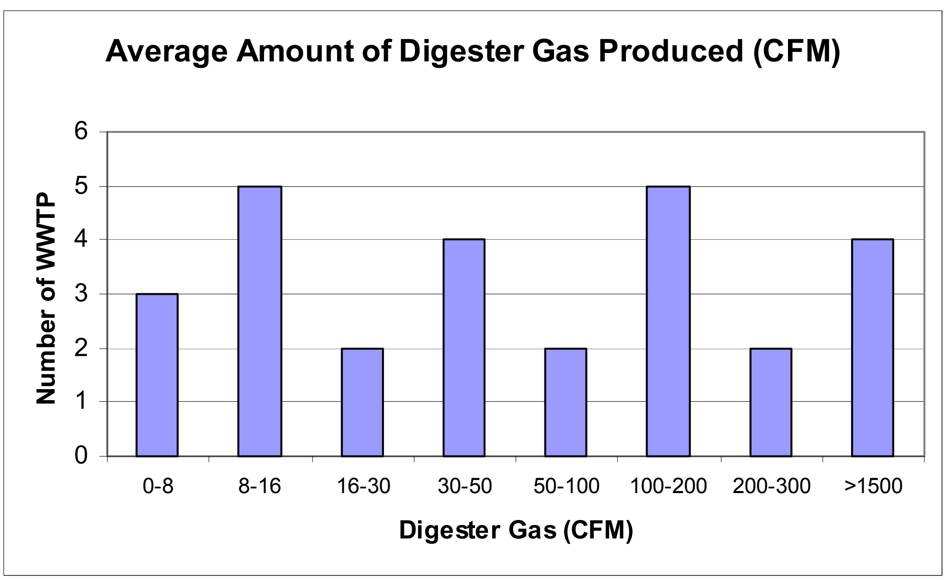


Figure B-52
Average Amount of Digester Gas That is Produced (Question 18a)

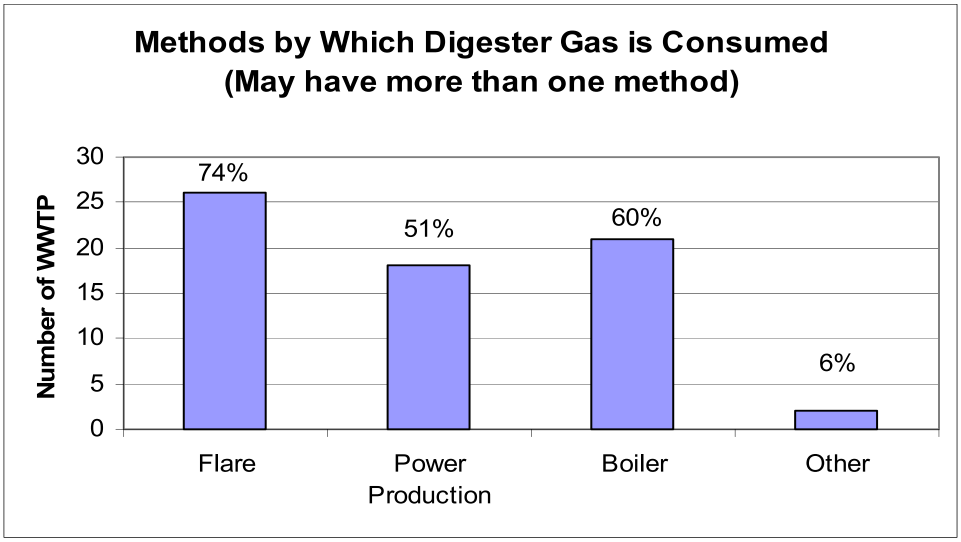


Figure B-53
Methods of Consuming the Digester Gas
(Question 18b)

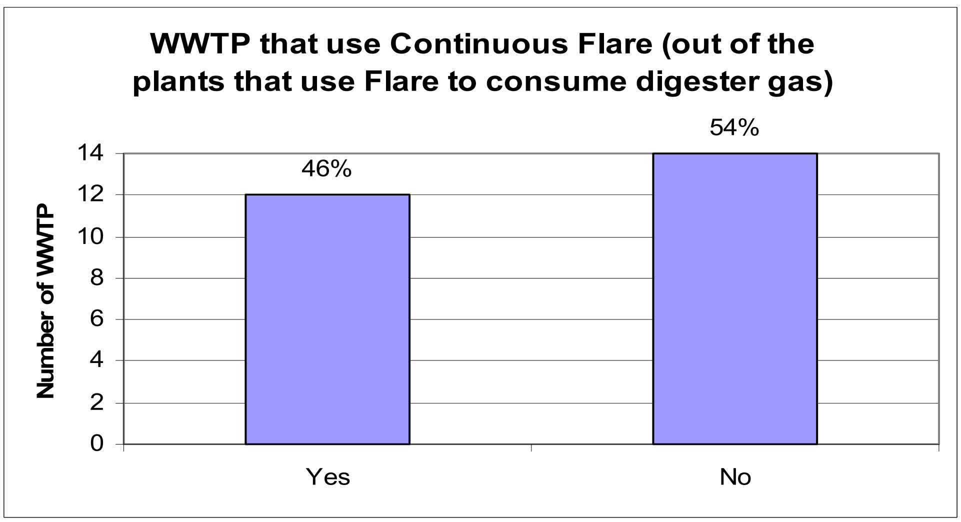


Figure B-54
Number of WWTP That Continuously Flare Digester Gas, Of the WWTP That Flare
(Question 18b1)

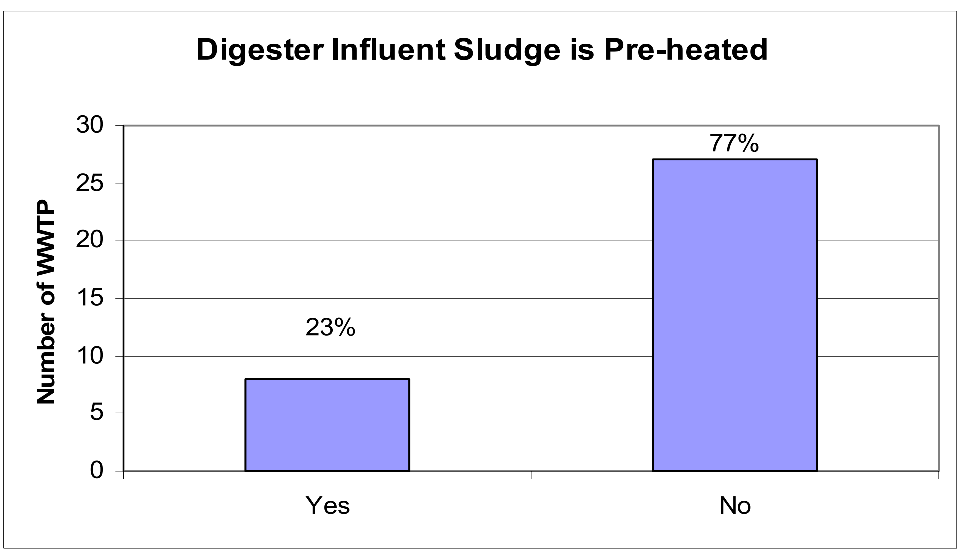


Figure B-55
Number of WWTP Which Pre-Heat the Digester Influent Sludge
(Question 18c)

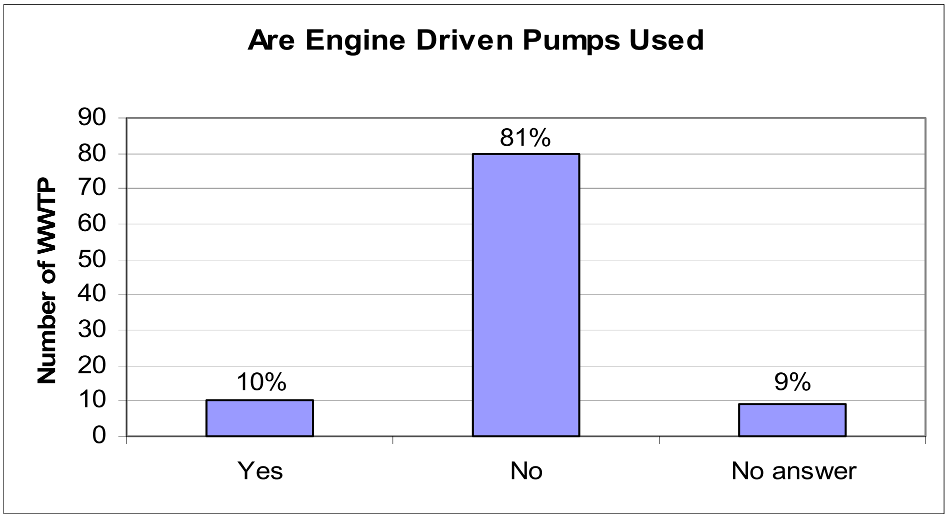


Figure B-56
Number of WWTP that Use Engine Driven Pumps (Question 19)

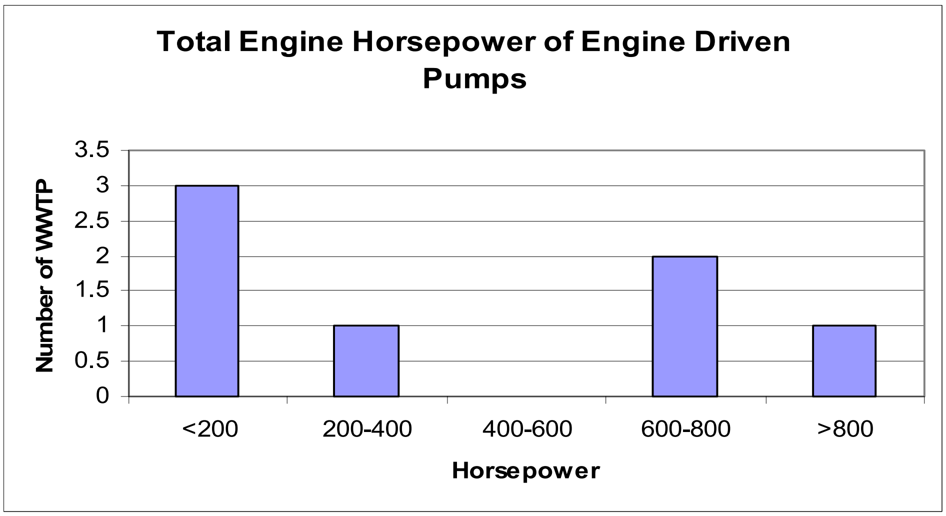


Figure B-57
Breakdown of Total Engine Horsepower, per WWTP, of the Engine Driven Pumps (Question 19a)

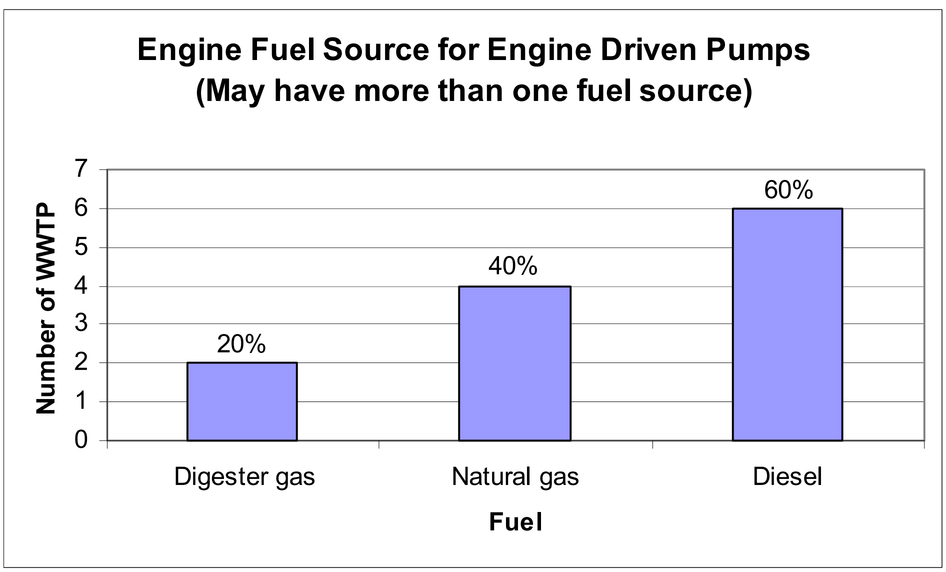


Figure B-58
Fuel Source for Engine Driven Pumps (Question 19b)

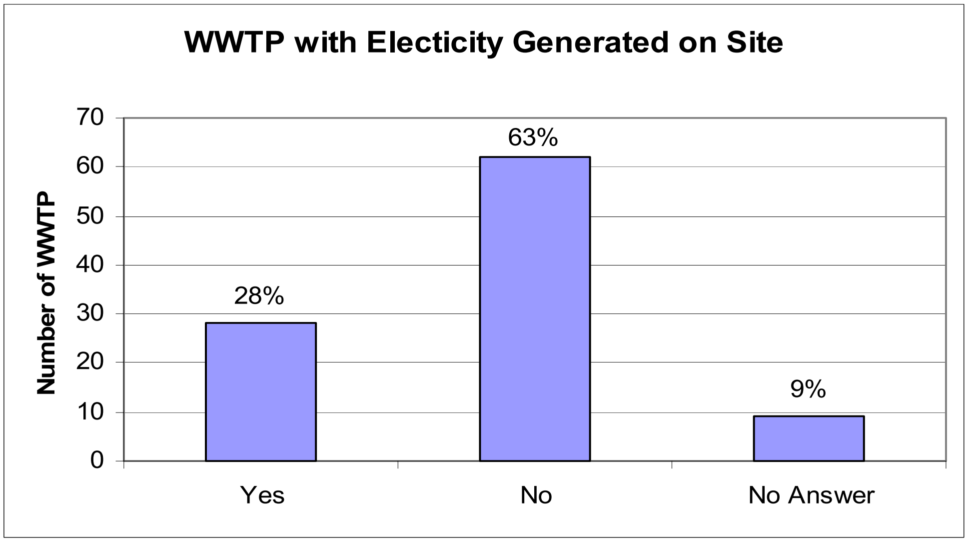


Figure B-59
Number of WWTP That Generate Electricity on Site (Question 20)

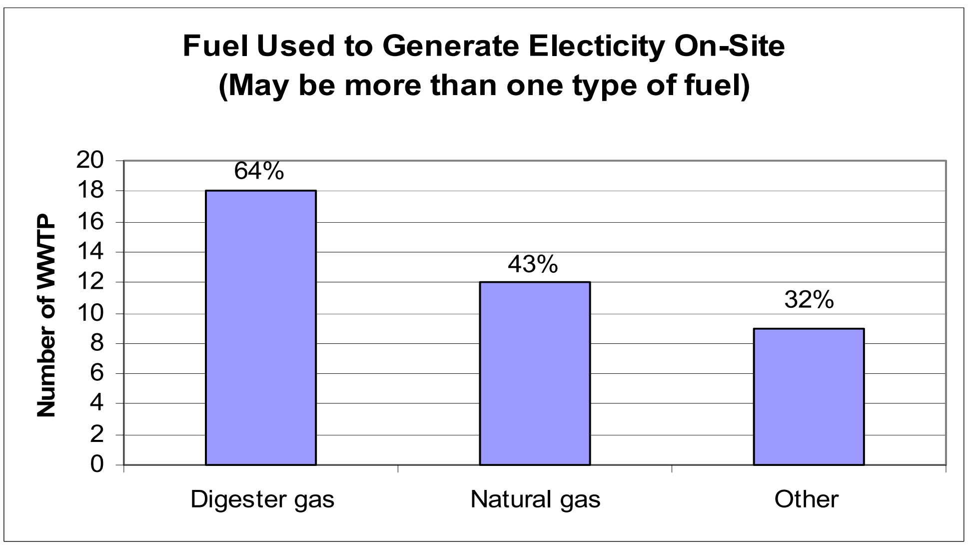


Figure B-60
Fuel Source used to Generate Electricity on Site (Question 20a)

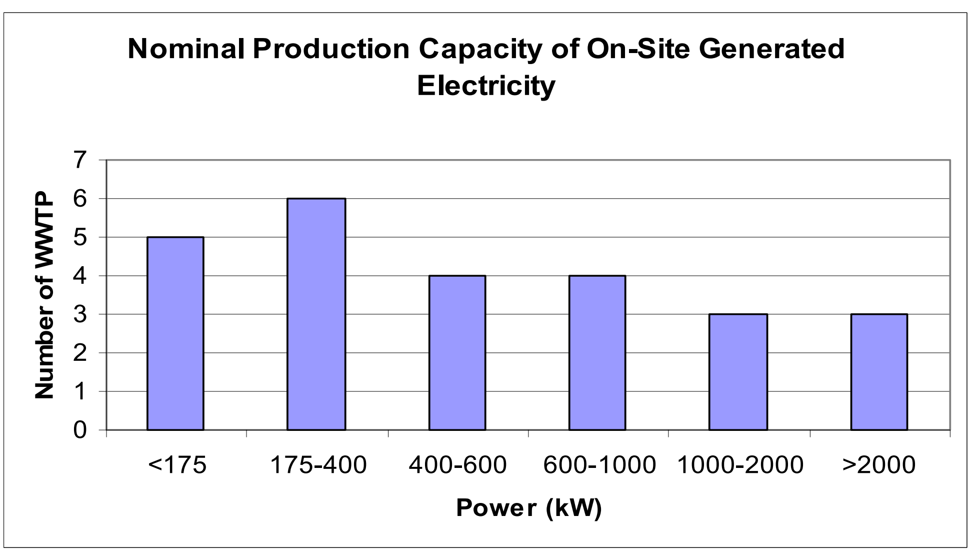


Figure B-61
Nominal Production Capacity of on Site Generated Electricity (Question 20b)

Appendix C – Analysis Methods for Calculation of Energy Efficiency against the Baselines

The analysis methods for calculation of the energy efficiency measures are provided in a separate document.

Appendix D – Energy Intensity of Wastewater Treatment Plants

The survey conducted as a part of this study was utilized to determine the energy intensity of samples of wastewater plants in PG&E territory. The following process was followed to determine energy intensity data.

1. Information including the name and address of 99 plants that had responded to the survey was provided to PG&E to supply BASE with the most recent annual electrical energy (kWh) consumption for at least one full year.
2. PG&E provided BASE electrical energy consumption for 73 plants.
3. The plants that had provided the following data were selected from the survey results:
    a. The plant had provided average and/or design MGD
    b. The plant had provided treatment stage (primary, secondary or tertiary)
    c. PG&E could provide the annual energy consumption for the plant
    d. Plants (with Criteria a, b, c) with self generation had stated the level of self-generation
4. For plants with self generation it has been assumed that the generator would work throughout the year at 75% capacity (or at full capacity with up-time of 75%) and the electric power is consumed by the plant itself. This was added to PG&E supplied electrical energy consumption to obtain the total annual electrical energy consumption.

Table D-1 shows the number of samples satisfying the above criteria that were used in presentation of energy intensity data.

Table D-1 – Number of Plants Energy Intensity Data was Developed For

Plant Type	Number of Plants
Plant with Primary Treatment Only	4
Plant with Secondary Treatment	32
Plants with Tertiary Treatment	20
Total Number of Plants a, b and c Criteria	56
Plant with self-generation (Criteria d)	17

Figures D-1 through D-4 show the energy intensity in terms of annual kWh per average MGD for secondary, tertiary, all plants by treatment type and all plants in general. Because of small sample for primary treatment, the data may not be representative of the industry so they were not calculated.

The average value of energy intensity for the surveyed plants is shown in Table D-2 below.

Table D-2 – Average Energy Intensity of Surveyed Plants

Plant Type	Energy Intensity (annual kWh/MGD)
Secondary	771,357
Tertiary	1,144,277
Overall	907,836

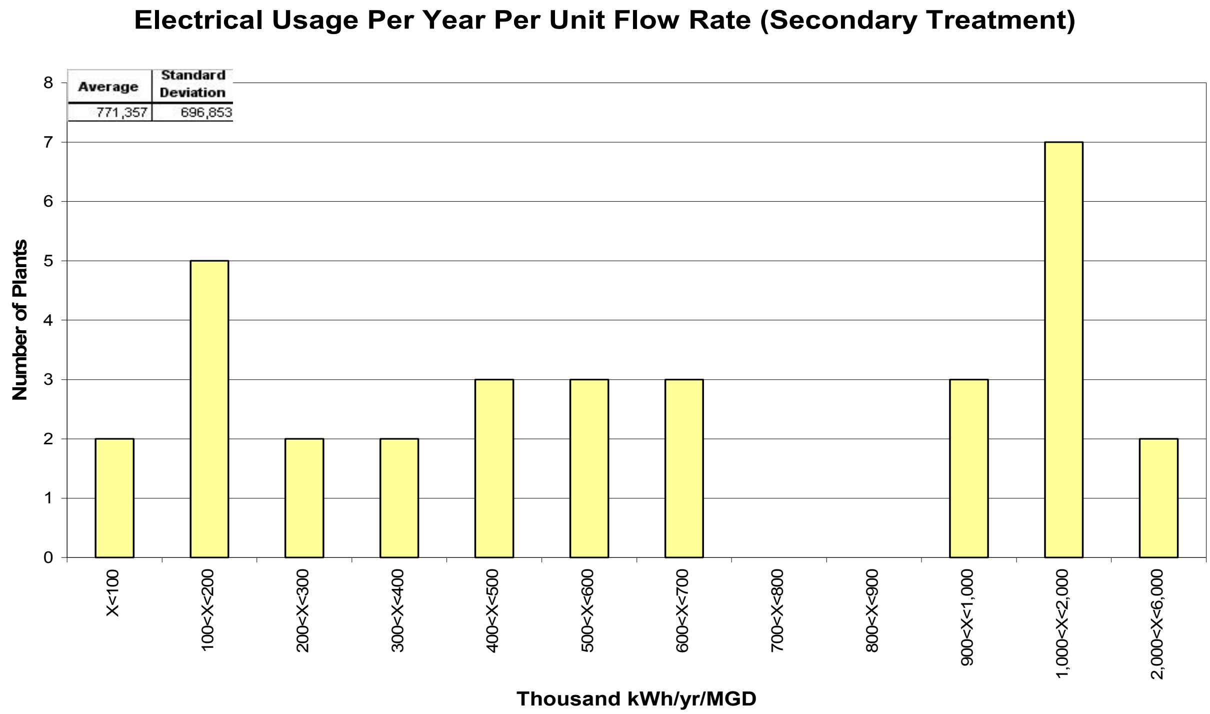


Figure D-1 – Annual Electrical Usage Per Unit Flow Rate (Secondary Treatment)

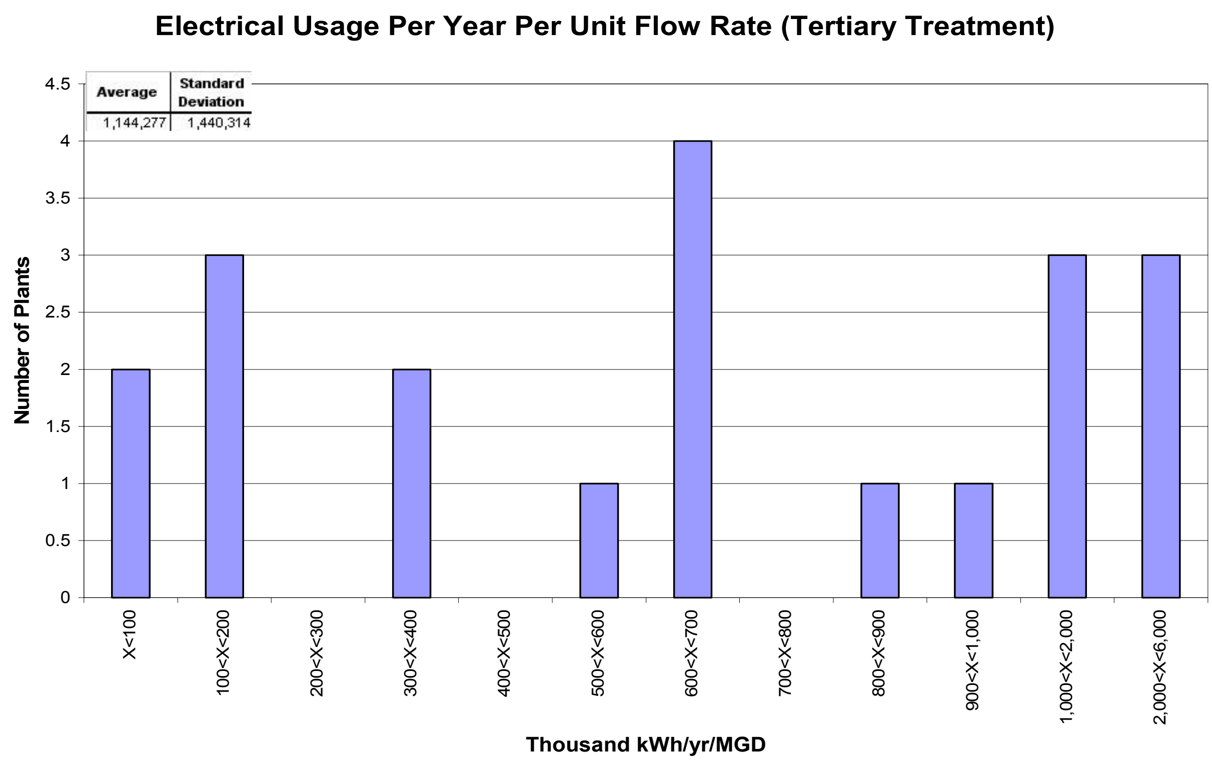
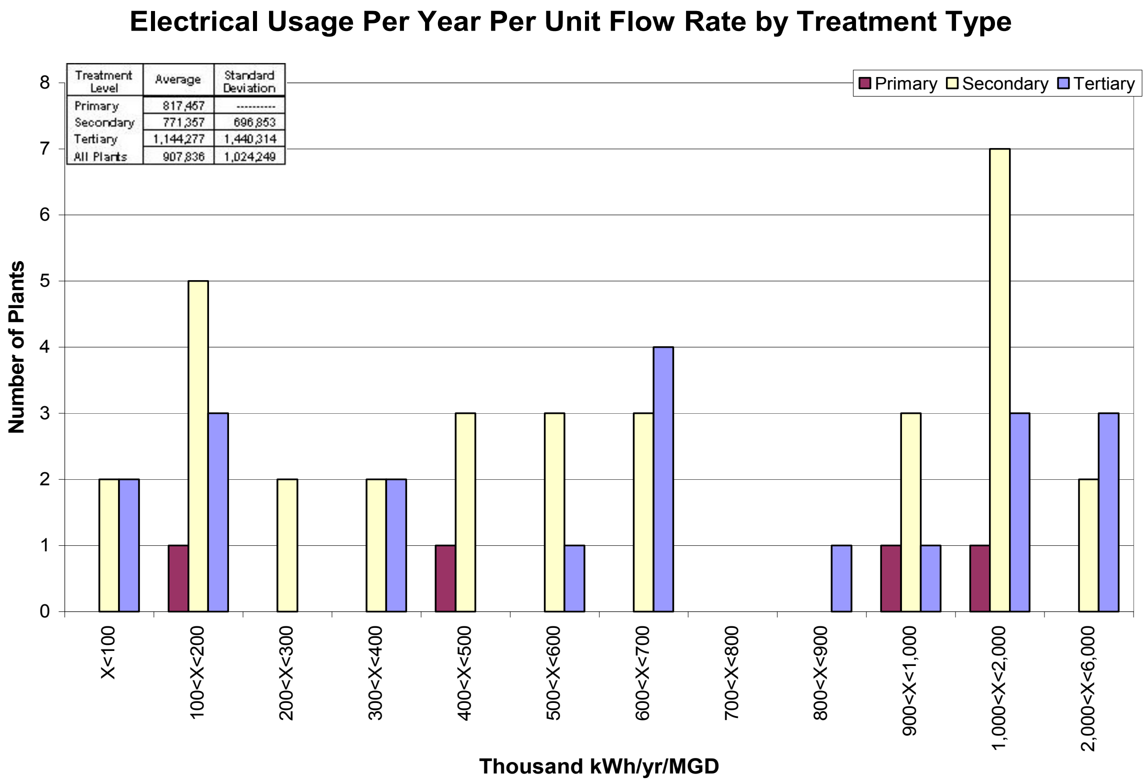


Figure D-2 – Annual Electrical Usage Per Unit Flow Rate (Tertiary Treatment)



Treatment Level	Average	Standard Deviation
Primary	817,457	----------
Secondary	771,357	696,853
Tertiary	1,144,277	1,440,314
All Plants	907,836	1,024,249

Figure D-3 – Annual Electrical Usage Per Unit Flow Rate by Treatment Type

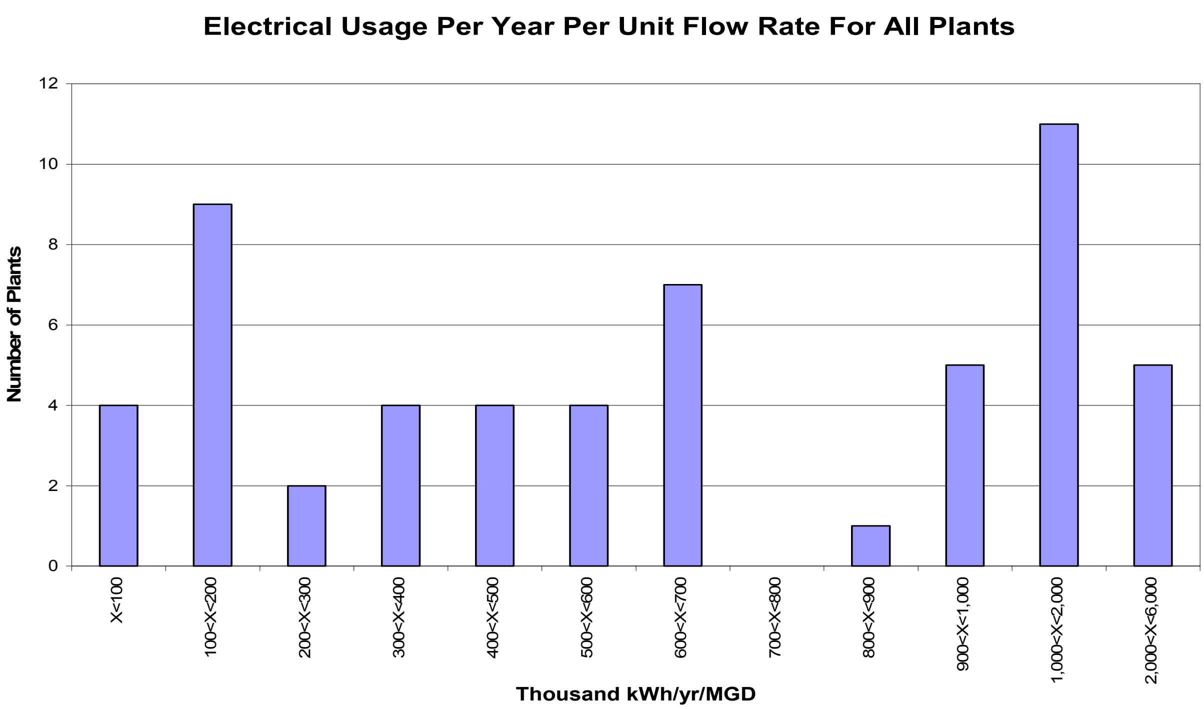


Figure D-4 – Annual Electrical Usage Per Unit Flow Rate (All Plants)