A Study on Technology Options and Energy Efficiency Standard Practices for Municipal Wastewater Treatment Plants (2016)

An Update of the 2006 Energy Baseline Study for Municipal Wastewater Treatment Plants

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1 Executive Summary

This final report presents the study activities and outcomes from a comprehensive review of literature, custom project reports and evaluations, and field surveys of the market saturation and market trends in municipal wastewater treatment plants. The first final report was completed and initially made available in October 2015, with the scope of updating the 2006 Baseline report prepared by BASE Energy, Inc. for PG&E. The initial report was peer reviewed by a number of stakeholders including experts from governments and the private sectors. As a response to the review comments provided by California Public Utilities Commission's (CPUC's) Energy Division staff under the regulatory framework on appropriate baseline, and on-going collaborative discussion about the improving the understanding of the concept and process for industry standard practice (ISP) studies, PG&E and BASE Energy collaborated closely since the spring of 2016 to refine the report so that we not only advance the understanding of technology options and standard practices in the selected sector, but also convey important information in alignment with the existing regulatory framework on appropriate baselines. Accordingly, the scope and goals of this final report have been revised and updated, taking advantage of the vast amount of data available from the initial project.

In this report, we first clarify the concept and definition of industry standard practice and use the definition to guide data analyses and discussion. Specifically, we consider that industry standard practice (ISP) represents the typical current equipment purchases or commonly used current trending practice absent the program. Second, we define the overarching goals of this study as 1) to advance understanding about technology options and energy efficiency measures' (EEMs') standard practices observed in the municipal waste water treatment (MWWT) sector within PG&E's service territories, and 2) to provide information and guidelines for California utility program developers and stakeholders to consider while developing and managing custom and/or deemed projects.

This report will present the results from the detailed study of technology options and EEM standard practices in municipal wastewater treatment plants (WWTPs). The report focuses on the following objectives:

- Identification of technology options and energy efficiency measures in WWTPs
- Determination of standard practice, or common practices, in municipal WWTPs
- Discussion of applicability issues of study findings to custom or deemed projects.

The objectives have been achieved through the following:

- Develop survey questionnaire, administer surveys, and analyze survey results from wastewater (WW) treatment facilities in PG&E service territory, wastewater design firms and wastewater vendors/distributors
- Perform literature reviews including reports on ex post reviews of EEM projects in the sector
- Develop understanding of standard or common practices for a selection of specific WW technologies/processes based on survey results and literature reviews
- Review with California Public Utility Commission staff about the how study results should be used in custom projects.

The wastewater treatment plant survey instrument was distributed to about 140 of PG&E's WWT customers with a response rate of about 30% (42 respondents). Separate survey questionnaire developed for design firms and vendors/distributors were administered with a response rate of 27% (9 respondents out of 30 vendors surveyed) and 31% (10 respondents out of 29 designers surveyed), respectively.

Table ES-1 summarizes survey results from the WWTPs related to adoption of energy efficient technologies in their plants. For the question "Which of the following energy efficiency technologies are being used at your plant?" The responses are summarized based on the 42 plants that participated in the survey, and are an indication of in-situ market saturation of the specific EEMs adopted in municipal WWTPs.

Table ES-1 Summary of Survey Results on Energy Efficient Technologies Implemented in WWTPs

Energy Efficient Technology Used	# of Plants that Responded	% of Responses (based on 42 plants total)
Variable Speed Drive – Pumps	28	67%
Variable Speed Drive – Blowers	13	31%
Variable Speed Drive – Compressors	4	10%
Automatic Dissolved Oxygen Control System	25	60%
Fine or Ultra-fine Bubble Diffusers	19	45%
Advanced Instrumentation & Control: Supervisory Control and Data Acquisition (SCADA)	25	60%
High Efficiency Blowers	11	26%
Variable Intensity Ultraviolet (UV) Lamps	6	14%
Dose Pacing Control for UV Systems	6	14%
Energy Efficient Sludge Dewatering Systems	12	29%
Energy Efficient Sludge Thickening Systems	14	33%
Advanced Grit Removal Systems	6	14%
# of WWTP That Use at Least One Energy Efficient Technology		*32 out of 42 (76%)*

Table ES-1 presents interesting ranges that represent the in-situ market saturation (or penetration) for a subset of technology options based upon the surveys administered to existing MWWT plants. Because industry standard practice represents the typical current equipment purchases or commonly used current trending practice absent the program, the survey data gathered from the MWWT plants alone was not always sufficient to indicate the current market trends or common practice for the technologies.

By analyzing and reviewing the survey data from vendors and designers and follow-up confirmations with vendors and designers about their understanding of some of the key survey questions, we have identified whether or not an EEM has become standard or common practice or trending toward standard practice based upon the market trend analysis. For example, we asked vendors and designers the question "How often do you recommend (a specific EEM) to your municipal WWT customers," while they were given the opportunities to select among "Less than or ~25% of the time," "~50% of the time," "Greater than 50% of the time," and "Not applicable."

Table ES-2 summarizes the technology options and common practices identified for the various WWTP technologies/processes. It is important to note that the common practices for various technologies/processes may vary depending on a variety of factors, such as system types, operating parameters, environmental factors, etc.

Table ES-2 Summary of Technology Options and Common Practices in WWTP

Technology/Process	Components	Technology Options and Common Practices*
Primary Treatment	Screening/Flocculation	• **Conventional** • Chemically Enhanced
Secondary Treatment (Mechanical Aeration)	Aerators	• Brush • Low Speed Surface • High Speed Vertical Turbine • Induced Surface • Submerged Turbine
	Aerator Control	• No Control • Manual Control • Timer Control • **Automatic Control based on Dissolved Oxygen (DO)**
Secondary Treatment (Diffused Aeration)	Blowers	• *Positive Displacement* (Constant/Variable Speed) • Multi-stage Centrifugal • Single-stage Centrifugal (Constant/Variable Speed) • *High Speed Turbo*
	Blower Control	• No Control • Manual Control • Timer Control • **Automatic Control based on Dissolved Oxygen (DO)**
	Diffusers	• Coarse Bubble • **Fine Bubble** • Ultra-Fine Bubble
Disinfection (Ultraviolet)	Lamps	• **Medium-Pressure, High-Intensity** • *Low-Pressure, High-Intensity* • Low-Pressure, Low-Intensity
	Control	• No Control • Manual Control • Control based on Flow • *Control based on Dosage*
Tertiary Treatment (Filtration)	Filtration	• Sand Filter • Membrane Bioreactor • Low-Pressure Membrane • High-Pressure Membrane • Dissolved Air Floatation • Cloth Media • Compressible Media
Sludge Management	Thickening	• Gravity Thickener • Gravity Belt Thickener • Dissolved Air Floatation • Centrifugal • Rotary Drum
	Dewatering	• Centrifuge • Belt Filter Press • Screw Press • Rotary Press • Vacuum Filtration • Drying Beds

Table ES-2 Summary of Technology Options and Common Practices in WWTP (continued)		
Process/Technology	**Components**	**Technology Options and Common Practices***
Sludge Management (continued)	Drying	• **Drying Beds** • Solar Drying • Mixed Drying (belt dryer with hot air) • Direct Heat Drying • Indirect Heat Drying
Pumping System	Type of Pump	• Water-driven • Hydraulic-oil driven • Electrical-drive • Pneumatic
	Pumps	• Efficiency varies depending on pump type, flow and head requirements
	Control	• No Control • On/Off Control • Throttle/Bypass Control • **Variable Speed Control**
Plant Control System	Controls	• Manual Control • **Supervisory Control and Data Acquisition (SCADA) System**
Anaerobic Digester	Mixing	• **Mechanical Mixing** • Gas Mixing
Sludge Treatment	Treatment	• Aerobic • **Anaerobic**

* Items in **Bold** are the considered as the common practice, or standard practices for each technology/process largely based on reviewing the survey results from vendors and designers, in corroboration with customers' responses, and the threshold assumptions made in this report. Items in *Italics* are those that are trending towards common (or standard practice). **Readers need to refer to Section 6 for more specific data, analyses, and discussion about what determines industry standard practice.**

We identify whether or not an EEM has become common practice (or standard practice), or trending toward standard practice based upon the survey data administered to customers, vendors, suppliers, and designers serving the MWWT market, in corroboration with additional literature reviews and analyses in this report. It's very important to note that there is no one ISP study fits all applications. This is especially true for custom projects that seek for appropriate baselines to qualify for utility program incentive under the current regulatory framework in California market. In essence, appropriate baselines for custom projects must be established or selected for each project individually (i.e., per customer basis), and cannot be universally established for all projects installing a technology independent of other site- or customer-specific considerations. In order to avoid free ridership effectively, project developers first need to credibly establish what the customer is planning to do before program intervention, then document higher-efficiency, higher-cost options for the customer to consider implementation as compared to all other viable measures that would meet the customer's functional and technical requirements.

While the data and information produced from this study is very useful for program and product teams to develop potential deemed programs; we should note that customer project developers must first analyze measure eligibility, determine measure code, and document program influence such as alternative measures beyond existing equipment to establish and justify appropriate baselines. Because ISP for a specific generic measure may vary based on customer subsector, facility size, customer size, as well as site-specific requirements or considerations, it's advised that results from this ISP study report shouldn't be simply used as a cook book to qualify incentives or eligibility in custom projects administered by IOUs in California.

In this regard, a primary principle of the custom programs promoting ratepayer-assisted energy efficiency activities should be to determine what a customer is proposing to implement and then seek to influence the customer to implement a more efficient, more costly alternative by providing advice, design expertise and financial incentives. Simply paying incentives to customers for what they are planning to implement independent of the program activity simply because it is more energy efficient than an ISP wouldn't be considered by CPUC a productive use of ratepayer funding. As the objective of using custom program financial incentives is to motivate a customer to do more, not to simply reward them for their normally occurring or planned business maintenance, upgrade and/or expansion activities, it's highly recommended that custom project developers first conduct thoughtful and credible reviews of the custom projects in terms of eligibility and influence, while seeking for relevant ISP study results.

2 Introduction

This final report presents the study activities and outcomes from a comprehensive review of literature, custom project reports and evaluations, and field surveys of the market saturation and market trends in municipal wastewater treatment plants. The first final report was completed and initially made available in October 2015, with the scope of updating the 2006 Baseline report prepared by BASE Energy, Inc. for PG&E. The initial report was peer reviewed by a number of stakeholders including experts from governments and the private sectors.

As a response to the review comments provided by California Public Utilities Commission's (CPUC's) Energy Division staff under the regulatory framework on appropriate baseline, and on-going collaborative discussion about the improving the understanding of the concept and process for industry standard practice (ISP) studies, PG&E and BASE Energy collaborated closely since the spring of 2016 to refine the report so that we not only advance the understanding of technology options and standard practices in the selected sector, but also convey important information in alignment with the existing regulatory framework on appropriate baselines.

Accordingly, the scope and goals of this final report have been revised and updated, taking advantage of the vast amount of data available from the initial project.

2.1 Project Goals and Technical Objectives

The overarching goals of this study are:

- to advance the understanding about technology options and EEM common practices observed in the municipal waste water treatment sector within PG&E's service territories, and
- to provide information and guidelines for California utility program developers and stakeholders to consider while developing and managing custom and deemed projects such as Integrated Energy Audits.

The technical objectives of this project include:

- to complete literature reviews on MWWT processes and technologies included in the 2006 MWWT baseline study, and update the list of process and technology options in wastewater treatment plants
- to develop information on common or standard practices for existing and new construction MWWT plants, as compared to findings from the 2006 baseline study, and
- to identify and review literatures including the ex post evaluation site specific reports for municipal waste water treatment facilities from the Statewide evaluations performed in 2010-2014, and
- to develop an analytical protocol for gathering and analyzing market data on EEM adoptions and practices in the municipal wastewater treatment sector.

2.2 Main Activities for Information Development in the Study

The main activities in this project include the following:

- Develop a condensed survey instrument for MWWT facilities in PG&E service territory
- Develop a comprehensive survey instrument for MWWT design engineering firms
- Develop a comprehensive survey instrument for MWWT equipment vendors and suppliers
- Administer surveys through the Internet and phone conversations with some of the customers, vendors, and designers
- Review literature on processes, technologies, and current energy efficiency trends in wastewater treatment facilities, including ex post evaluation site specific reports for municipal waste water treatment facilities from the Statewide evaluations performed in 2010-2014
- Review technologies and processes from 2006 Energy Baseline Study and update the list of technologies and processes in this industry
- Compile and analyze survey data in corroboration with literature reviews to identify technology options and recommend standard practices applicable to existing and retrofit constructions
- Review with subject matter experts and stakeholders including CPUC staff and consultants to seek common understanding and to develop recommendations for future ISP studies, and
- Provide recommendations for California IOU project developers to consider for custom project development, including overarching guideline on how to best use the data and information from this report.

2.3 Report Organization

This report will present the results from the detailed study of technology options and EEM standard practices in municipal wastewater treatment plants (WWTPs). The report focuses on the following objectives:

- Identification of technology options and energy efficiency measures in WWTPs
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The objectives have been achieved through the following:

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Following the Executive Summary and Introduction sections, Section 3 describes brief background information on the technologies for MWWT plants. . Section 4 discusses administration of the surveys developed as a part of this study. Section 5 includes the literature reviews performed in this study. Section 6 presents technology options and assessment methodology and findings of survey results from different groups of the participants that included customers (MWWTPs), vendors/suppliers, and designers. In this section, we analyzed the survey results by process and technology. For each process/technology, we compared the survey outcomes among three groups, and corroborate the information along with additional information gathered from literature reviews. Based upon specific thresholds that were assumed in this report, we've attempted to develop a list of EEMs that has become a common practice and/or trending toward a common practice. Such a list of EEMs is recommended as industrial standard practices based upon the data and information reviewed in this study. Caveats of the findings from this report and important guidelines of how to use the information for custom projects are also discussed under California's regulatory context. Section 7 includes a list of references reviewed in this study, followed by Section 8 on Glossary. Section 9 presents three survey instruments, followed by Section 10 with more details about the survey outcomes.

3 Wastewater Treatment Process Overview

3.1 Primary Treatment

Primary treatment involves removal of floating and suspended particulates in the wastewater stream. The main primary treatment processes are conventional primary treatment and chemically enhanced primary treatment.

Conventional primary treatment involves screening, settling and clarification.

Chemically Enhanced Primary Treatment (CEPT) is a type of chemical enhancement process that employs coagulation and flocculation in conventional primary clarifiers. In addition to suspended solids removal in conventional primary clarifiers, CEPT can also remove soluble organic matter that contributes to biological oxygen demand (BOD). Chemicals such as metal salts/polymers are added to the wastewater to enhance sedimentation, coagulation and flocculation of suspended solids, such as ballasted flocculation.

A comparison of the removal efficiencies (effectiveness of a process for removal of BOD and suspended solids from the wastewater) for a conventional versus chemically enhanced primary treatment system is shown in Table 3-1 below.

Table 3-1 Comparison of Removal Efficiencies[1]

Type of Primary Treatment	BOD Removal	TSS Removal
Conventional Primary Treatment	25% to 40%	50% to 70%
Chemically Enhanced Primary Treatment	50% to 80%	80% to 90%

[1] From Metcalf & Eddy (2013)

3.2 Secondary Treatment

3.2.1 Activated Sludge

The role of secondary treatment is to remove the material remaining after primary treatment. Secondary treatment is the process that removes biodegradable organic matter and suspended solids. This process typically removes approximately 70% to 85% of the biological oxygen demand (BOD) from the wastewater. Secondary treatment typically includes a biological process which may include:

- ***Rotating biological contactors (RBC)***: Consists of closely spaced, parallel discs mounted on a rotating shaft supported just above the surface of the wastewater. Wastewater flows through the disks and sludge is separated from the liquid stream.
- ***Trickling filters***: Trickling filters have been used to treat municipal and industrial wastewater for almost 100 years. This is a fixed biological reactor which uses rock or plastic packing where wastewater is distributed continuously. The wastewater is treated as it flows over the biofilm.

- ***Sequencing batch reactors (SBR)***: A fill-and-draw reactor where mixing, aeration and clarification all occur within the same tank. The five steps common to all SBR systems are: fill, react (aeration), settle (sedimentation/clarification), draw (decant) and idle.
- ***Aerated lagoons or ponds:*** Lagoons/ponds equipped with mechanical aerators or diffusers for providing aeration into the wastewater.
- ***Constructed wetlands***: Engineered systems designed and constructed to utilize natural processes involving wetland vegetation, soils and their associated microbial assemblages to assist in treating wastewater.
- ***Anaerobic biological treatment***: Typically used for treating more concentrated wastewater. This process takes place in the absence of air by microorganisms that do not require air to break down biodegradable material in the wastewater. The organic material from the process is converted to biogas, which can be used to generate power or hot water.
- ***Oxidation ditch:*** This consists of a ring or oval shaped channel equipped with mixers and mechanical aerators. The configuration of the system is to promote unidirectional wastewater flow such that aeration is sufficient to provide mixing in the system with a relatively long hydraulic retention time.

Some of the newer, emerging technologies for secondary treatment include:

- Aerobic granulation
- Biological aerated filter (BAF) or Biofilters
- Integrated fixed-film activated sludge
- Moving bed bioreactors

3.2.2 Disinfection

Disinfection is a subsequent part of the secondary treatment process used to destroy disease-causing organisms. Disinfection is typically accomplished using:

- Chlorine
- Ozone
- UV radiation
- Bromine

Chlorine is the most commonly used method of disinfecting wastewater in the world. Table 3-2 on the following page lists some of the advantages and disadvantages for each disinfection type.

Table 3-2 Types of Disinfection

Disinfection System	Advantage	Disadvantage
Chlorine	• Well-established technology • Effective disinfectant • Relatively inexpensive • Readily available	• Hazardous chemical • Long contact time required • Residual toxicity must be reduced through de-chlorination • Increased safety regulations
Ozone	• Effective disinfectant • More effective in destroying viruses, spores, cysts and oocysts • Shorter contact time • Less space requirement	• Dosage must be perfected to be effective • Safety concerns • Highly corrosive and toxic • Expensive • Energy-intensive
UV Radiation	• Effective disinfectant • No residual toxicity • More effective than chlorine in destroying most viruses, spores, and cysts • Improved safety compared to chemical disinfectants • Less space requirement • Less susceptible to volatile cost savings of chemicals	• Energy-intensive • Hydraulic design of UV system is critical • Relatively expensive • Potentially more maintenance intensive due to changing lamps

3.3 Tertiary Treatment

Tertiary treatment is any additional treatment beyond secondary treatment to further remove impurities from the wastewater. Filtration is commonly used as a tertiary process and involves removing organic matter and suspended solids beyond what secondary treatment can treat to meet more stringent discharge and reuse requirements. The three different categories of filtration systems use are:

- Depth filtration (sand filtration, porous medium filtration)
- Surface filtration (earth filtration, cloth or screen filtration)
- Membrane filtration (microfiltration, ultrafiltration, nano-filtration, reverse osmosis)

With the severe drought situation in California, reusing water has become a main topic for discussion. Options for treating water to reusable levels (ranked by particle removal performance from best to worst) include:

- Reverse osmosis (RO)
- Nano-filtration (NF)
- Membrane bioreactor (MBR)
- Ultrafiltration (UF)
- Microfiltration (MF)
- Particle Filtration

Figure 3-1 below shows the filtration performance of the various filtration technologies, which shows that the filter wastewater by MBR is comparable to microfiltration (MF) and ultrafiltration (UF).

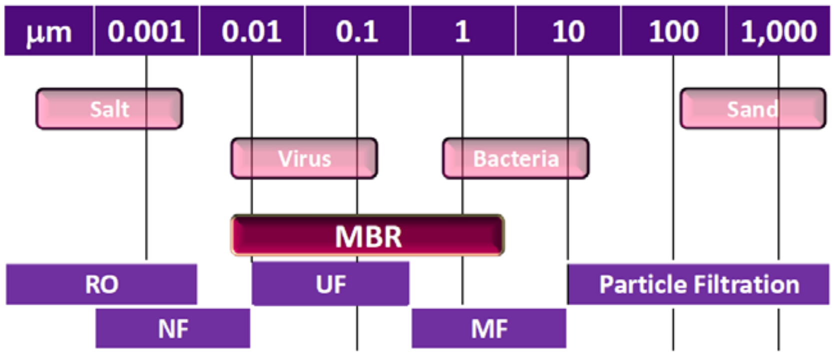

Figure 3-1 – Performance Comparisons of MBR to other Filtration Technologies (from Ovivo "Flat Plate MBRs – A Viable and Proven Technology"

3.4 Sludge Management

Sludge is generated from essentially all wastewater treatment processes from the primary treatment process through tertiary treatment. The U.S. EPA has established regulations for the reuse and disposal of solids generated from municipal wastewater treatment plants (Pakenas, 1995).

3.4.1 Sludge Thickening

Thickening is the first step to reduce the volume of sludge removed from the wastewater. Sludge thickening can increase the dry solids concentration anywhere from 1% to 8%. Thickening is generally accomplished by physical means including co-settling, gravity settling, flotation, centrifugation, gravity belt, and rotary drum.

The volume reduction attained by sludge concentration is beneficial to subsequent treatment processes, such as digestion, dewatering, drying and combustion from the following standpoints:

1. Capacity of tanks and equipment required
2. Quantity of chemicals required for sludge conditioning
3. Amount of heat required by digesters and amount of auxiliary fuel required for heat drying or incineration, or both

More details about the various sludge thickening equipment can be found in Section 6.8.

3.4.2 Sludge Dewatering

Sludge dewatering is typically one of the final steps for solid management at wastewater treatment plants. Sludge dewatering is removing water from sludge. Sludge dewatering can increase the total possible dry solids concentration to 32%. Since wastewater facilities usually pay for sludge disposal by weight, the more water that is removed from the sludge, the lighter the weight of the solids to be hauled off, which means the less cost to dispose of the sludge. Devices commonly used for dewatering (ranked by energy intensity from highest to lowest) include:

- Vacuum filtration
- Centrifuge
- Recessed chamber press
- Belt filter presses
- Screw press
- Rotary press
- Drying beds

More details about the various equipment can be found in Section 6.9.

3.4.3 Sludge Drying

Sludge drying process reduces mass and volume of the product, making its storage and transporting easier and also enables incineration or co-incineration of sludge. Sludge drying can increase the total possible dry solids concentration to 62% compared to 6% obtained by thickening and 32% by dewatering. Thermal drying can result in even higher dry solids concentration, greater than 90% solids. The main objectives for sludge drying include:

- Eliminating water from the sludge to reduce the volume of the sludge, thus reducing transportation costs for removal of the sludge offsite
- Sludge can easily be incinerated without any additional fuel
- Making sludge hygienic
- Stabilizing the sludge
- Making sludge into a fertilizer or soil conditioner

The main types of sludge dryers used in municipal wastewater treatment plants are:

- Sludge drying beds
- Solar drying
- Mixed drying (combination of belt dryer with hot air)
- Direct heat drying
- Indirect heat drying

3.4.4 Sludge Digestion

According to EPA's 2012 and 2008 Clean Watersheds Needs Survey (CWNS) databases, California has a total of 1221 municipal wastewater treatment plants. The following shows the number of WWTPs that have sludge digestion in the plant:

- Total number of WWTPs that have Aerobic Digestion: 93 plants
- Total number of WWTPs that have Anaerobic Digestion: 242 plants
- Total number of WWTPs that have Digestion Gas Utilization(not flared): 54 plants

Figures 3-2 to 3-4 show the histograms of WWTPs with aerobic digesters, anaerobic digesters and digestion gas utilization in CA, respectively. The histograms show the number of plants in various design capacity ranges in million gallons per day (MGD).

Based on these statistics, anaerobic digestion appears to be adopted more quickly for biosolids management than aerobic digestion especially in the smaller WWTP sizes (capacity ranges).

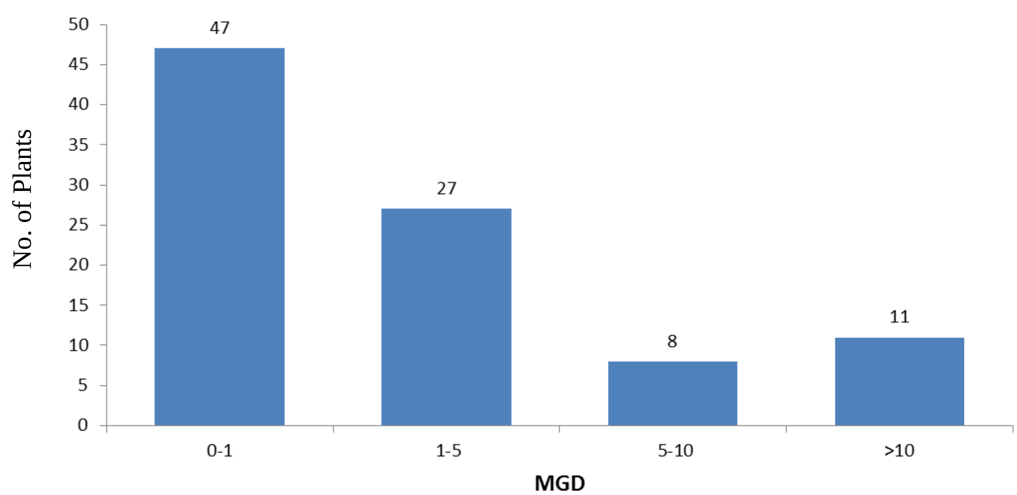

Figure 3-2 - WWTPs with Aerobic Digesters in CA

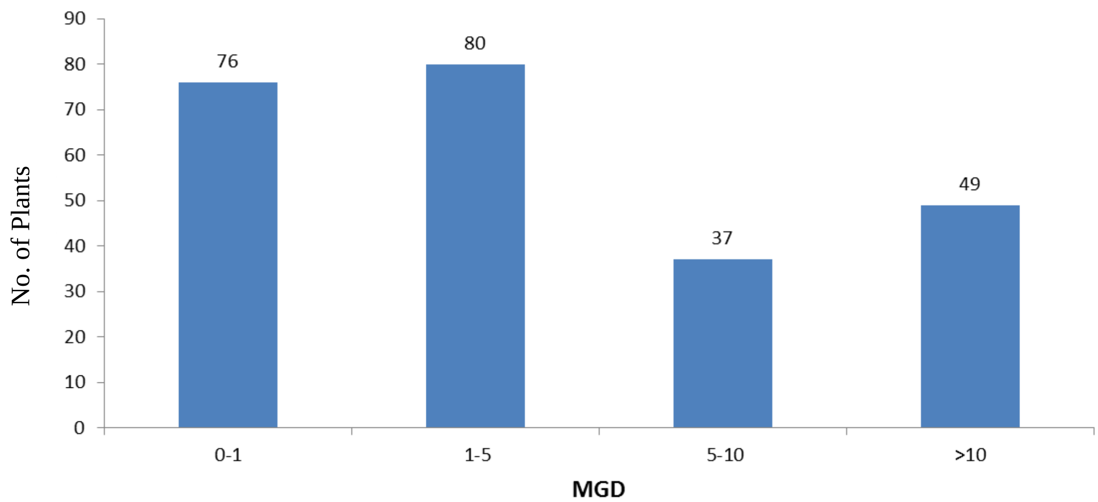

Figure 3-3 - WWTPs with Anaerobic Digesters in CA

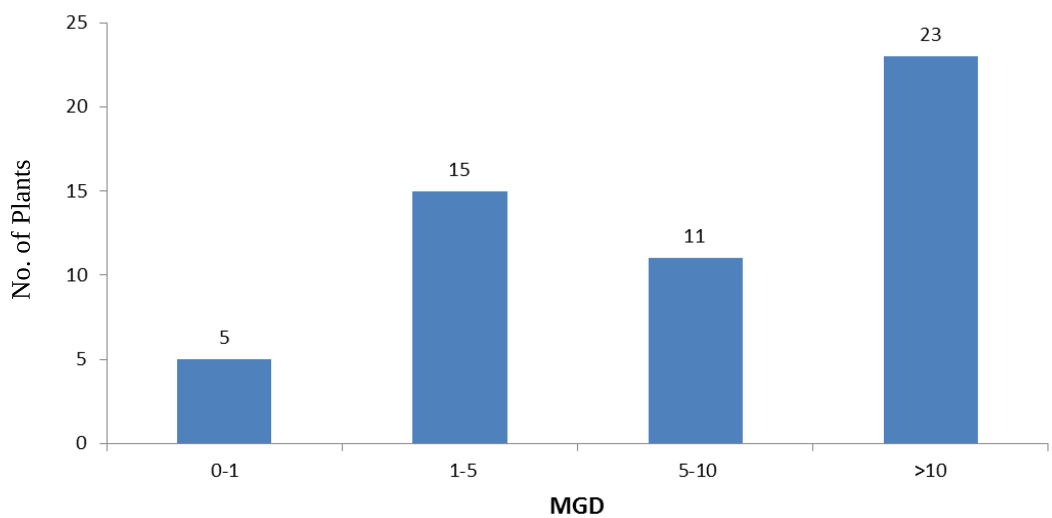

Figure 3-4 - WWTPs with Digestion Gas Utilization in CA

3.4.5 Combined, Heat and Power (CHP) Opportunities

The biogas produced from anaerobic digestion of biosolids can be used as fuel for the following applications:

- To fire boilers to maintain optimal digester temperatures
- To fire boilers and hot water heaters to provide space heating and domestic hot water
- To generate electricity for onsite use and/or to sell back to the grid, and to recover heat from cogeneration for other heat demand

According to EPA's CHP study (EPA, 2008), a total domestic wastewater influent flow rate of 4.5 MGD can generate roughly 100 kW of electricity. The EPA's CHP study evaluated three cogeneration technologies of microturbine CHP, fuel cell CHP and internal combustion engine CHP based on performance and WWTP sizes. The study concluded that:

- Microturbines are appropriate for a small WWTP with a minimum influent flow rate of 6.8 MGD.
- Fuel cells could be appropriate for a medium-size WWTP with a minimum influent flow rate of 10.7 MGD.
- Reciprocating engines are appropriate for a large WWTF with at least a 41.4 MGD influent flow rate.

It should be noted that some plants in California have successfully used a mixture of biogas and natural gas for power production for many years.

4 Survey Instrument Development, Administration, and Participant Responses

Survey instruments were developed to get a better understanding of equipment that is currently being used in existing municipal wastewater treatment plants, and also for design engineers and vendors/distributors of WWT technologies. The surveys were developed with the following objectives:

- To identify the technologies that are currently used in MWWT plants in PG&E service territory
- To identify energy efficiency issues in MWWTPs in PG&E service territory
- To identify market penetration of MWWT technologies
- To re-evaluate MWWT technologies to update common practices.

The surveys were distributed to:

- About 140 MWWT plants in PG&E service territory through email or phone calls with a response rate of about 30% (42 respondents).
- About 30 MWWT design engineering firms serving municipal MWWT plants in PG&E service territory with a response rate of about 33% (10 respondents).
- About 30 vendors/distributors of MWWT technologies with a response rate of about 30% (9 respondents).

The survey forms are included in Section 9 of this report. Additional details of the survey results are presented in Section 10 of this report.

5 Literature Review

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.

Table 5-1 lists some of the major studies and R&D projects/reports that deal with energy efficiency of wastewater treatment facilities. Please refer to the 2006 baseline study for additional references.

Table 5-1 – Listing of Some Major Studies on Energy Efficiency of Wastewater Facilities

Report/Paper Title	Author and Publication Year	Sponsor	Content
Energy Baseline Study for Municipal Wastewater Treatment Plants	BASE Energy, Inc. (2006)	Pacific Gas and Electric Company	Determination of baselines for WWTP and identification of energy efficiency measures.
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
Measure, Application, Segment, Industry (MASI): Wastewater Treatment Facilities	Navigant Consulting, Inc. (2015)	Southern California Edison (SCE)	Market segmentation and characterization of wastewater treatment plants.
Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities	The Cadmus Group, Inc. (2010)	U.S. Environmental Protection Agency (EPA)	Description of conventional energy efficiency options for wastewater plants, as well as innovative and emerging technologies.
Water & Wastewater Industry Energy Best Practice Guidebook	Science Applications International Corporation (2006)	Wisconsin Focus on Energy	Guidebooks on benchmark results of selected Wisconsin WWTP and best practices discussion for the industry
Energy Saving Opportunities for Wastewater Facilities	Elliot (2003)	Energy Center of Wisconsin and Focus on Energy	Outlines major energy saving opportunities based on treatment process
Wastewater Treatment and Sludge Management	Smith (1995)	New Your State Energy Research & Development Authority (NYSERDA)	Discusses the details of energy usage and energy efficiency opportunities per process in WWTP and presents several case studies
A Guide to Net-Zero Energy Solutions for Water Resource Recovery Facilities	Tarrallo (2015)	Water Environment Research Foundation (WERF)	Predicted energy impact of various best practices and emerging technologies
Current Energy Position of New York State Wastewater Treatment Facilities	Andrews (2015)	WERF/NYSERDA	Presents survey of NY state wastewater plant energy use and trends in implementing energy efficient technologies and management practices.

6 Assessment of Industry Standard Practices (Findings, Discussion, and Conclusions)

Industry standard practice represents the typical current equipment purchases or commonly used current trending practice absent the program. In this section, we will present technology options and survey results from three groups of participants that included plant customers (MWWTPs), vendors/suppliers, and designers. We'll assess industry standard practices through analyzing the survey results by process and technology, in corroboration with additional literature reviews. For each process/technology, we'll compare the survey outcomes among applicable participation groups, and corroborate the information gathered from the participation groups along with additional information gathered from literature reviews.

Before and after the surveys were distributed to the three groups of participants, the project team held various communications with vendors and designers while developing the survey questions. The overarching understanding is that in the municipal wastewater treatment industry, technologies typically don't change within three-year periods. Additional published literature confirmed such understanding. For example, according to the 2013 EPA publication on Emerging Technologies, technologies are not considered 'established' until they have become widely available and have been implemented for more than five years. Since wastewater treatment plants must adhere to discharge guidelines, the industry tends to take a more conservative approach when selecting emerging or innovative technologies to install in their plant. Surveyed design engineers and vendors also affirmed that they typically don't recommend technologies to their customers until it has been widely marketed and available for at least three years (e.g., Question 7 from Design Engineer and Vendor surveys). They also confirmed through post-survey communications that they responded to the survey questions related to technology adoption or recommendation based upon experience in most recent three- to five-year time frames. It should also be noted that National Pollutant Discharge Elimination System (NPDES) and Waste Discharge Requirement (WDR) permit renewal cycles are usually five years. Thus, process or technology changes if any are typically made with five-year planning cycles unless there are urgent compliance issues or other issues (e.g., maintenance) that need to be addressed immediately.

Industry standard practice represents the typical current equipment purchases or commonly used current trending practice absent the program. In the following assessments, we first summarize technology options applicable to various processes in MWWTPs through reviews of previous studies, literature, and communications with subject matter experts; we then compiled and analyzed survey results from three groups of participants, followed by assessments on whether or not a technology has become common practice and/or trending toward common practice.

The following tasks were performed to establish the database for ISP assessments on each EEM:

- Review the list of technology options and EEMs from 2006 Energy Baseline Study for Municipal Wastewater Treatment Plants prepared by BASE
- Review the surveys previously developed for 2006 baseline study and develop a survey instrument for distribution to a pool of municipal wastewater plants in PG&E service territory. The results of the surveys to plant participants will be presented as mostly ***market saturation*** for this industry in the technology section.
- Develop a survey instrument for distribution to design engineers and vendors/distributors, respectively to understand how common individual EEMs are being recommended to or adopted by wastewater treatment customers. These will be presented as ***market trends*** for this industry in the technology section.
- Review survey results for each category (WWT plants, designers and vendors) to determine what is used in plants currently and what is being recommended in designs or when purchasing equipment. This involves corroborating the survey results to determine if there are similarities amongst the 3 surveyed customer categories; and when there is a difference, what the rationale would be to decide whether a technology is considered to be the common practice in industry. Because plant participants typically responded with in-situ market saturation information, we put more weights on the responses by designers and vendors/distributors to understand the market trending in recent a 3-to-5 years' time-frame.
- Review over 40 past WWT plant projects (new construction, expansion and retrofit) to see what EEMs were recommended and implemented
- Review dispositions from the CPUC Energy Division regarding wastewater related projects

Based on analysis of survey results and reviews of past project results, we'll recommend an understanding on whether or not a measure has become industrial standard practice based upon the information gathered and a set of assumptions made in this study. Specifically, a list of EEMs can be considered as common practice or industrial standard practice (ISP) based upon the data and information reviewed, corresponding to the numerical thresholds selected for the assessment in this report.

In order to be consistent in developing such a list of EEMs that are considered to be common practice (or standard practice), we explain the specific ISP threshold assumptions in the following. These are used for developing and establishing the list of EEMs that are considered to have become a common practice (or ISP) and/or trending toward a common practice (or ISP).

- **Common practice, or industry standard practice (ISP)**- If half or more of respondents (vendors and/or designers) indicate that they sell/recommend a particular EEM to customers "greater than or about 50% of the time"
- **Trending Toward ISP** – In this document, technology/process is considered to be 'trending toward ISP' if more than 30% of the respondents but less than 50% of respondents (mainly from design engineers/vendors survey) indicated that they sell/recommend a particular technology/process "greater than 50% of the time" in recent years.

- **Unclear** - difficult to determine what standard practice but there may be some technologies/process more common than others but not to ISP level yet

The updated EEMs will include the common practices, or industry standard practices, based on survey results from three groups of participants, i.e., plants (customers), vendors and suppliers, and designers, respectively. Because industry standard practice represents the typical current equipment purchases or commonly used current trending practice absent the program. The analyses of available data and information can advance our understanding about the measure's ISP status. In some cases, we also tried to analyze plausible implications for existing or new construction whenever it's possible.

- o **Existing Projects**– new equipment installed to replace or onto an existing system as either an integral additional component or substitution of a pre-existing add-on component with the primary purpose to improve the overall efficiency of the system. The common practices for this category are based on analysis of the plant information in corroboration to vendor and designer surveys. For example, a specific measure in retrofit application may be preliminary considered to be common practice in existing projects when at least 50% of the customer (plant) respondents to the survey indicate they have purchased/installed the measure "greater than 50% of the time," and this observation is further supported by the similar responses from vendors and/or designers.
- o **New Construction Projects** – new equipment installed in a newly constructed area, in an area subject to a major-renovation involving complete multi-system replacement or area re-construction, or equipment installed to increase the capacity of existing systems due to existing or anticipated new load handling requirements. In this report, our recommendation for understanding EEM common practices or ISP for this category are based on results of the Vendor and Design Engineer Surveys. For new construction applications, a specific measure is considered to be common practice ISP in new construction projects when at least 50% of the vendor and/or design engineer respondents to the survey (from Vendor and Design Firm surveys, respectively) indicate they have sold/recommended the measure "greater than 50% of the time."

Table 6-1 summarizes the results of the above procedure that we developed in determining the present common industry practices for the various WW technologies, and shows how these compared with the 2006 common practices. It is important to note that the common industry practices for the various technologies may vary depending on a variety of factors, such as secondary system types (e.g., lagoon, oxidation ditch, etc.), operating parameters, environmental factors, and permit requirements, etc.

<table>
<tr><th colspan="3">Table 6-1 Comparison of 2006 Common Practices versus 2016 Common Practices for Various Municipal Wastewater Treatment Technologies</th></tr>
<tr><th>Technology</th><th>2006 Common Practice</th><th>2016 Common Practice</th></tr>
<tr><td>Primary Treatment</td><td>N/A</td><td>Conventional Primary Clarifier</td></tr>
<tr><td rowspan="2">Aeration System (Mechanical Aerators)</td><td colspan="2">Constant Speed Motor</td></tr>
<tr><td>N/A</td><td>Unclear</td></tr>
<tr><td rowspan="3">Aeration System (Diffused Aeration)</td><td>Coarse-Bubble Diffuser</td><td>Fine-Bubble Diffuser</td></tr>
<tr><td>Inlet/Discharge Vane or No Control Multi-Stage Centrifugal</td><td>Trending towards Positive Displacement and High Speed Turbo Blower</td></tr>
<tr><td>Blowers with Average Efficiency from Fan System Assessment Tool</td><td>Average Blower Efficiency from 3 Different Manufacturers</td></tr>
<tr><td>Dissolved Oxygen Control</td><td>Manual Control</td><td>Automatic Dissolved Oxygen with Traditional Proportional Integral Derivative (PID) Control</td></tr>
<tr><td rowspan="2">Ultraviolet Radiation Disinfection</td><td>Medium-Pressure, High Intensity Lamps</td><td>Trending towards Low-Pressure, High Intensity Lamps</td></tr>
<tr><td>On/Off Control</td><td>Unclear but may be trending towards Control based on Dosage</td></tr>
<tr><td>Tertiary Treatment</td><td>N/A</td><td>Unclear</td></tr>
<tr><td>Sludge Dewatering</td><td>Centrifuge</td><td>Unclear</td></tr>
<tr><td>Sludge Thickening</td><td>Centrifuge Thickening System</td><td>Unclear</td></tr>
<tr><td rowspan="3">Pumps</td><td>Hydraulic Institute (HI) Achievable Efficiency</td><td>Average Pump Efficiency from at Least 3 Manufacturers</td></tr>
<tr><td colspan="2">Water or hydraulic-oil driven or pneumatic system</td></tr>
<tr><td>Control – Throttle/Bypass or No Control</td><td>Variable Speed Drive Control on Pumps</td></tr>
<tr><td>Air Compressor</td><td>Air Compressor Modulating w/ Unloading</td><td>CA Title 24</td></tr>
<tr><td>Motors</td><td>1992 EPAct Standard Efficiency Motors</td><td>NEMA Premium Efficiency Motors</td></tr>
<tr><td>Plant Control System</td><td>Manual Control</td><td>Supervisory Control and Data Acquisition (SCADA) Control System</td></tr>
<tr><td>Anaerobic Treatment System</td><td>N/A</td><td>Mechanical Mixing</td></tr>
<tr><td>Sludge Treatment</td><td>Aerobic Treatment System</td><td>Anaerobic Treatment System</td></tr>
</table>

Energy Efficiency Trends

Market Saturation

The survey that was distributed to municipal wastewater plants in PG&E territory asked the question "Which of the following energy efficient technologies are being used at your plant". Figure 6-1 below shows the distribution of answers from plant operators. Of the 42 plants who responded to the survey, 32 plants answered the question and the distribution of their responses is shown in this figure. It has been assumed that the 10 plants who did not respond to this question did not have any energy efficient technologies at their plant.

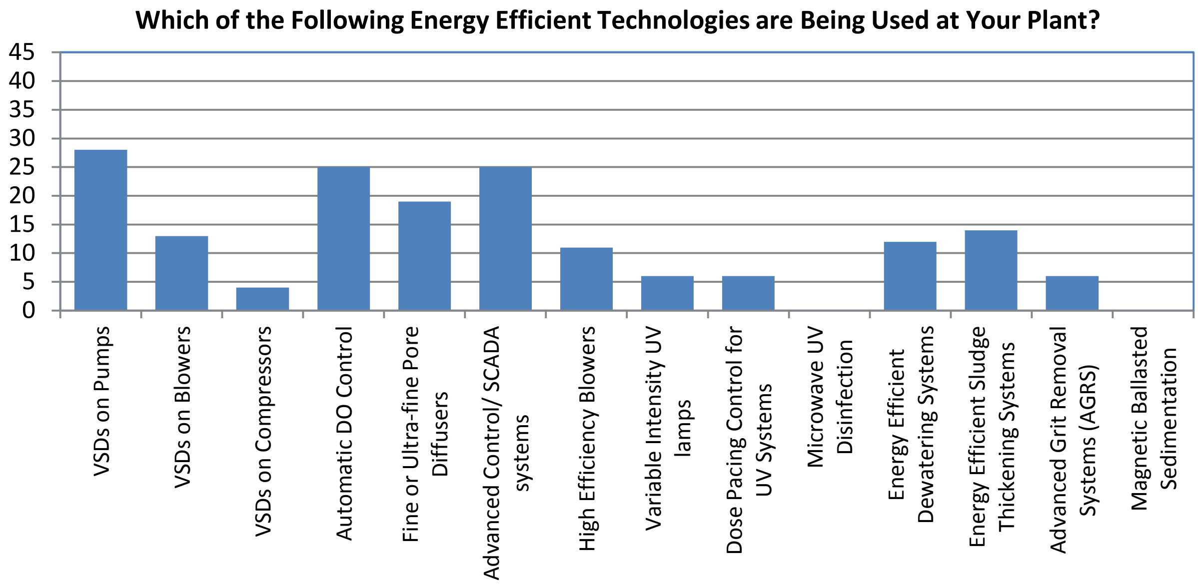

Figure 6-1 – Energy Efficiency Technologies Used in Surveyed WWTPs (based on a sample size of 42 plants with 32 plants responding to this particular question)

Market Trends

A similar question was posed to design engineers and vendors serving municipal wastewater treatment facilities to see how often these various technologies were being recommended to their customers. Figure 6-2 on the following page shows the distribution of answers from design firms, and Figure 6-3 shows the responses from the vendors/distributors.

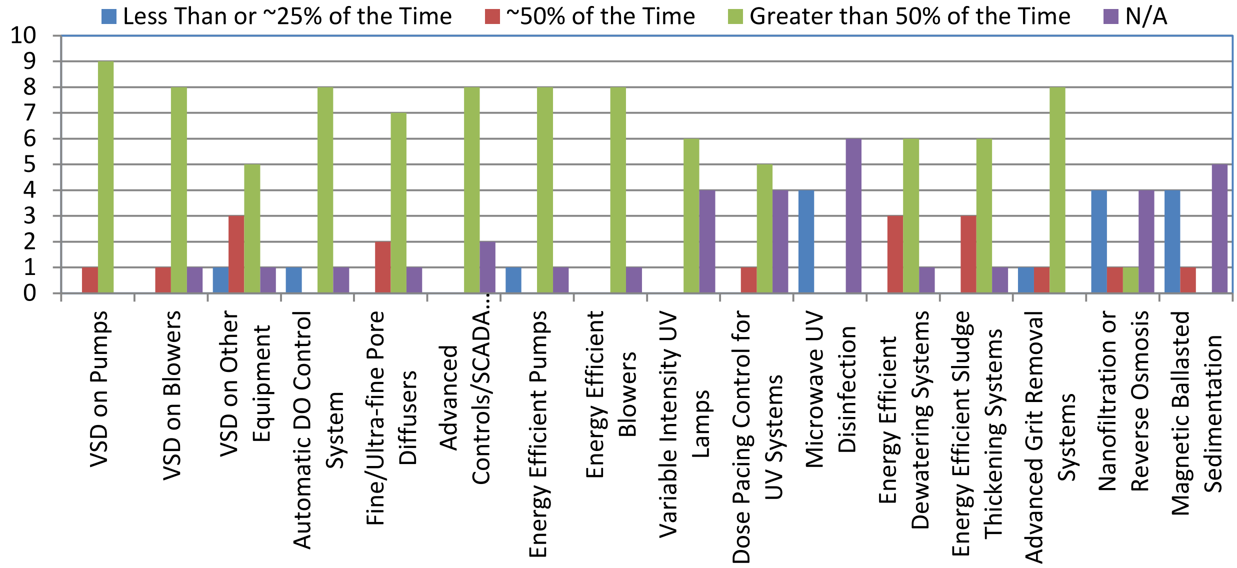

Figure 6-2 – Energy Efficiency Technologies Recommended by Design Engineers (Total of 10 responses)

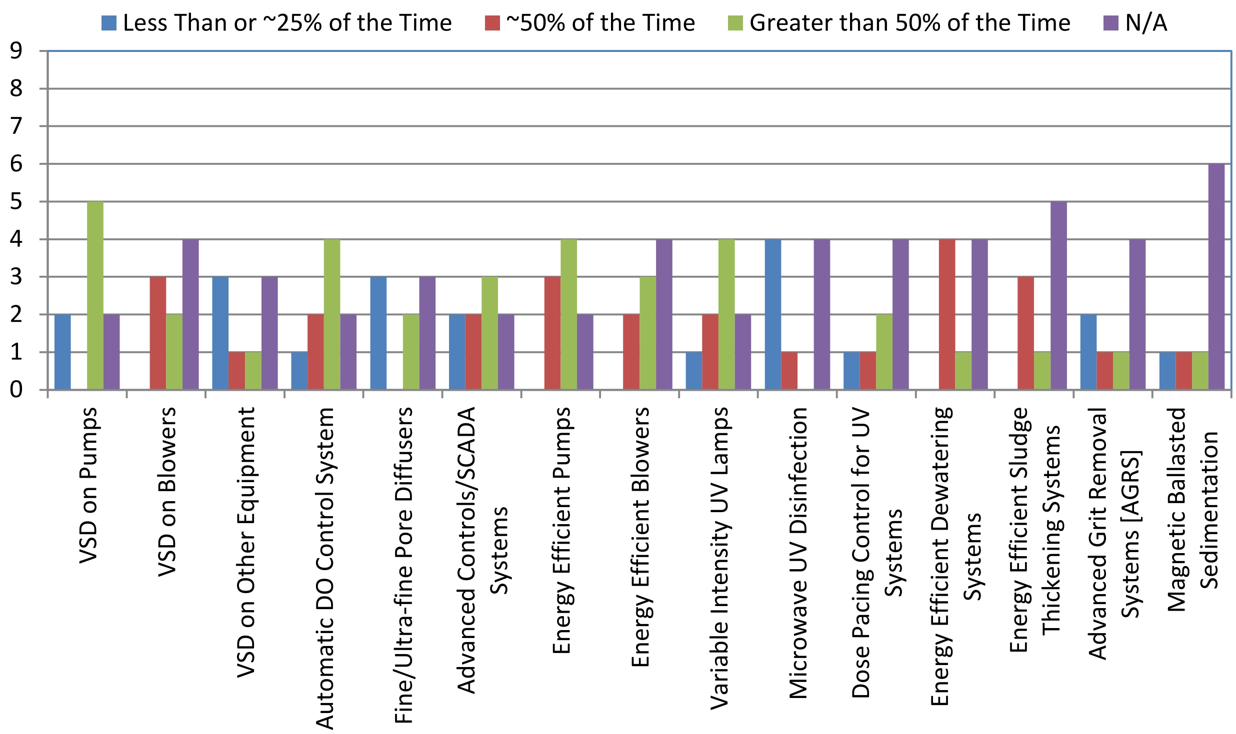

Figure 6-3 – Energy Efficiency Technologies Commonly Purchased by Customers
(Based on 9 responses from by Vendors/Distributors)

6.1 Pumping Systems

Pumps are one of the most energy consuming pieces of equipment in wastewater treatment facilities to transport wastewater/sludge. Pumps can be found in all stages of the treatment process, from pumping influent wastewater into the treatment system to pumping the treated effluent out of plant.

For pumping systems, the two energy efficiency measures typically recommended are:

- High Efficiency Pumps
- Variable Speed Drives

6.1.1 High Efficiency Pumps

Centrifugal, progressive cavity and positive displacement pumps are the most common pumps used in municipal wastewater treatment plants.

In the 2006 baseline study, the baseline was established based on the 'high efficiency' pump performance calculated by the Pumping System Assessment Tool (PSAT) program, which has been developed under the Department of Energy (DOE) sponsorship using the "Hydraulic Institute Achievable Efficiency Estimate Curves" for the selected pump type. The achievable pump efficiencies are taken as the baseline efficiencies.

However, this tool had limited pump type selections and in many instances resulted in higher efficiencies than what is actually available in the market. It is thus recommended that the pump efficiencies from at least 3 manufacturers be averaged to be the basis for the typical efficiency based on the pump type, flow, total head and other parameters (e.g. solids size).

Market Trends

Design engineers and vendors were surveyed the question of "How often do you recommend the Energy Efficient Pumps to your municipal WWT customers?" The options available for them to select from were:

- Less Than of ~25% of the Time
- ~50% of the Time
- Greater than 50% of the Time
- Not Applicable

The results were as follows:

- 80% of the *design engineers* who responded said they would recommend energy efficient pumps to their clients more than 50% of the time
- 44% of the *vendors/distributors* said that energy efficient pumps are purchased by their customers more than 50% of the time.

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years, as mentioned earlier.

Market Saturation

This question was not posed to wastewater treatment plants as many plant operators are not familiar with what would be considered a high efficiency pump. Plant operators typically select pumps based on manufacturers they are familiar with or similar pumps that the facility already has.

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

Based on a review of the wastewater treatment projects performed in the past (over 40 projects), high efficiency pumps were recommended in over 80% of the projects with program support. As ISP represents the typical current equipment purchases or commonly used current trending practice absent the program. It's unclear whether or not in the broader market, this has become ISP. However actual implementation of high efficiency pumps in new construction projects was approximately 40% of the time. This shows that there is still room for improvement and by promoting high efficiency pumps more, this can be achievable. Based on the survey results from the designers and vendors, high efficiency pumps may be ***trending toward ISP***.

Table 6.1-1 Common Practice for High Efficiency Pumps

Project Type	Survey Results
Existing*	This question was not evaluated in WWT Plant survey since facility personnel may not know what constitutes as a high efficiency pump. The pump efficiency varies based on pump type and operating factors. Facility typically selects pumps they are currently using in the plant.
New Construction	Designers and vendors responded that they typically recommend energy efficient pumps to their customers. Again, the efficiency for pumps varies based on pump type and operating factors.

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

6.1.2 Variable Speed Drives

Variable speed drives (VSDs) reduce the electrical energy consumed by a motor by matching the motor's speed to the load, allowing the motor to continually adjust relative to the power needed. In wastewater treatment facilities, typical equipment to which VSDs are applicable includes pumps and blowers.

According to 2014 Industry Standard Practice Study (ISP-000B) performed by ASWB Engineering under the discretion of Southern California Edison Company, variable speed drives on influent, effluent and return and waste activated sludge pumps for WWT plants of all sizes are considered industry standard practice for new load projects.

Market Trends

The survey polled design engineers/vendors the question of "How often do you recommend Variable Speed Drive (VSD) on Pumps to your municipal WWT customers". The options presented were:

- Less than or ~25% of the time
- ~50% of the time
- Greater than 50% of the time
- Not applicable

The results of the survey are as follows:

- ***Design engineers***: 90% (9 out of 10 firms surveyed) said they would recommend VSDs on pumps to their clients more than 50% of the time
- ***Vendors/Distributors***: 55.5% (5 out of 9 firms surveyed) said that VSDs on pumps are purchased by their customers more than 50% of the time.

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Market Saturation

The survey polled municipal WW customers the question of "Which of the following energy efficient technologies are being used at your plant?" The results of this for plants have Variable Speed Drives on Pumps were:

- ***WWT Plants***: 87.5% who responded to the energy efficiency question (28 out of 32 plants) said they had VSDs on pumps in their facility

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

The survey results confirm that VSDs are common in the municipal wastewater treatment industry with 90% of the design firms responding to the survey stating that they recommend VSDs to their customers more than 50% of the time and over 55% of vendors stating VSDs are purchased by their customers more than 50% of the time. Also, based on previous experience with over 40 facilities, especially with new construction projects, which constitute ~50% of BASE Energy's experience in this industry, VSDs are recommended close to 100% of the time (with an implementation rate of over 80%). The survey results and our experience with WWT plants confirm the recommendation by ISP-000B that variable speed drives are considered ***industry standard practice*** for existing and new construction facilities.

The common practice considered for this measure is:

Table 6.1-2 Common Practice for Variable Speed Drives on Pumps

Project Type	Survey Results
Existing*	A majority of WWTPs stated they had VSDs on the pumps in their plant.
New Construction	Pumps with VSDs installed were considered ISP by the Designers and Vendors

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

6.2 Mechanical Aerators

Mechanical aeration systems introduce air from the atmosphere into the wastewater by agitating the wastewater with propellers, blades or brushes.

The two typical groups of mechanical aerators are surface aerators and submerged aerators. Table 6.2-1 below shows the various types of mechanical aerators typically used and their respective oxygen transfer rates (Environmental Dynamics, Inc., 2003).

Table 6.2-1 Types of Mechanical Aerators

Type of Mechanical Aerator	lbs O_2/hp-hr
Brush Aerators	2.5 to 3.5
Slow Speed Surface Aerators	3.0 to 3.5
Vertical Turbine (High Speed Surface) Aerators	2.5 to 3.25
Induced Surface Aerators	1.0 to 1.5
Submerged Turbine (Turbine mixer & compressor)	1.5 to 2.5

Market Trends

The survey polled design engineers/vendors the question of "How often do you recommend the following surface aerators (vertical turbine aerators, brush aerators, low speed mechanical aerators, jet aerators, others) to your municipal WWT customers". The options presented for each type of surface aerator were:

- Less than or ~25% of the time
- ~50% of the time
- Greater than 50% of the time

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figures 6.2-1 and 6.2-2 on the following page show the responses by design engineers and vendors when asked the question of "How often do you recommend the following diffusers to your municipal WWT customers?" There is a discrepancy in the design engineer and vendor responses in terms of which is the more recommended mechanical aerator. For design engineers, low-speed aerators seem to be a more common practice but for vendors vertical turbines were the more common aerator. It seems that vertical turbines are the more common mechanical aerator but low-speed aerators are likely to become a common practice in the next few years.

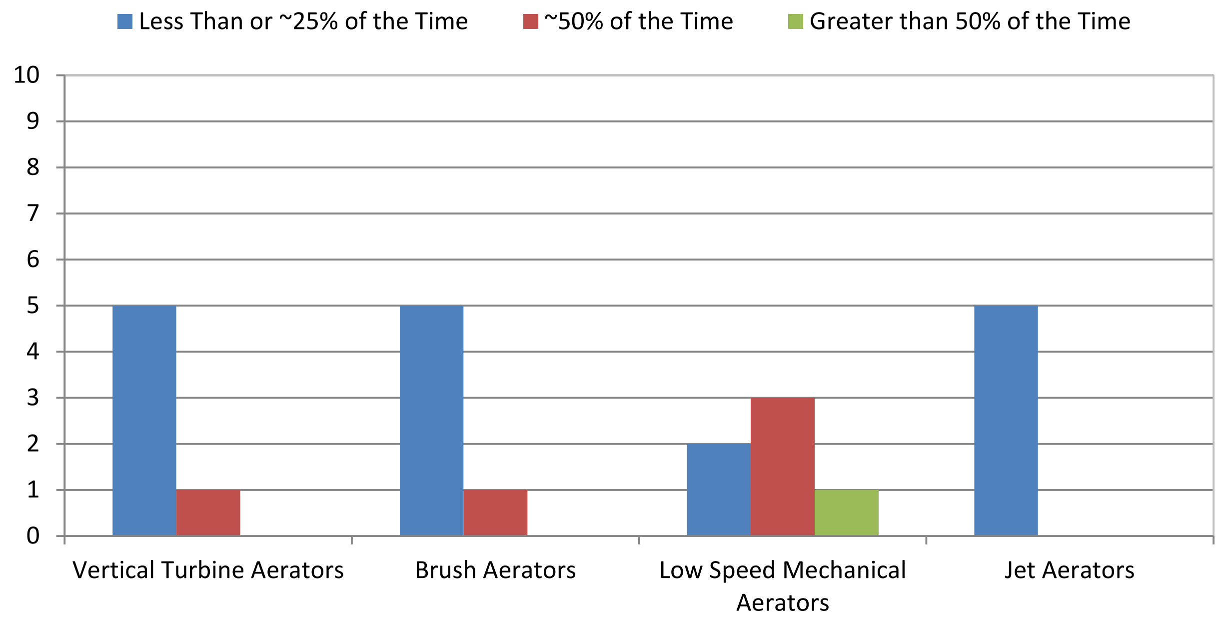

Figure 6.2-1 – Mechanical Aerators Recommended by Design Engineers (6 out of 10 firms surveyed)

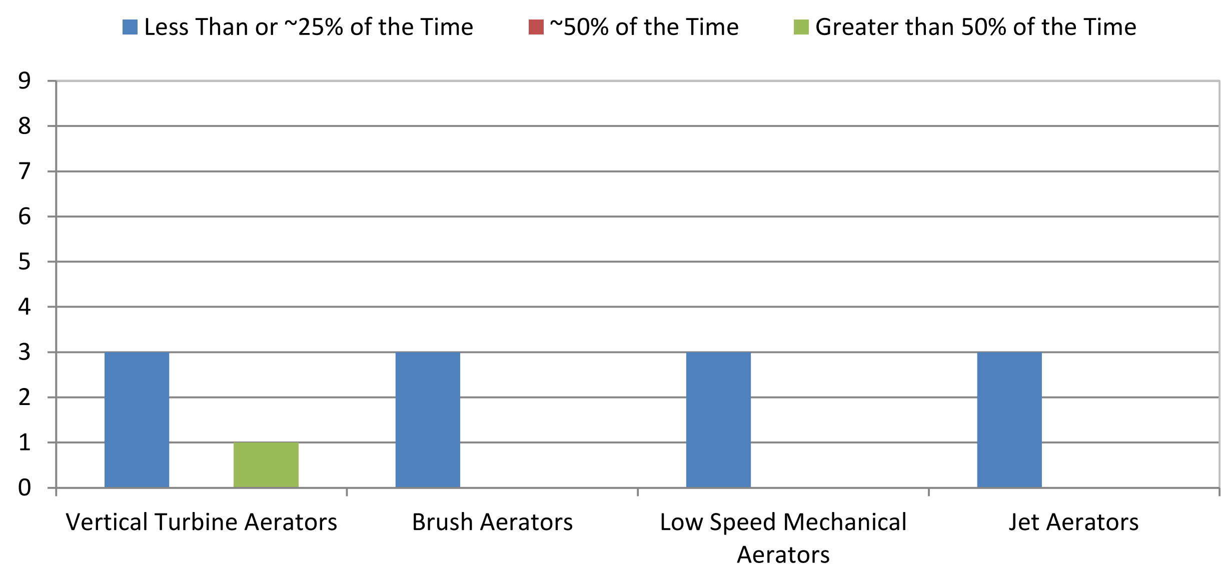

Figure 6.2-2 – Mechanical Aerators Typically Purchased According to Vendors/Distributors (4 out of 9 firms surveyed)

Market Saturation

The survey polled municipal WW customers the question of "For the treatment processes that apply to your plant, please check all the Mechanical Aeration equipment (brush aerators, vertical turbine aerators, low speed mechanical aerators, other) that apply." The results of this were:

Table 6.2-2 Statistics of Mechanical Aerator Use from Survey Results

Aerator Type	# of WWTP
Brush Aerators	---
Vertical Turbine (High Speed Surface) Aerators	6
Low-Speed Mechanical Aerators	3
Other	2
Total Responses	**11**

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

Based on the survey results, design firms recommend the more energy efficient low-speed mechanical aerators more often but it wasn't clear if customers actually implemented the low-speed mechanical aerators. According to the results from the plant survey (Table 6.2-2), over 50% of the wastewater plants responded that vertical turbine aerators are installed in their plant. For existing facilities, vertical turbines are the common practice. For new construction projects, over 50% of the design engineers who responded to this question responded that they recommend low-speed mechanical aerators approximately 50% of the time or more. 33% of the vendors who responded to the survey said their customers purchased high-speed vertical turbine aerators more than 50% of the time. Thus, it is ***unclear*** what is considered as the industry standard practice for this technology.

The common practice considered for this measure is:

Table 6.2-3 Common Practice for Mechanical Aerators

Project Type	Survey Results
Existing*	High-Speed Vertical Turbine Aerators
New Construction	Unclear with High-Speed Vertical Turbine Aerators and Low-Speed Mechanical Aerators being more common compared to other options

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options

The following are energy efficiency options for this system:

- Low-speed mechanical aerators
- Brush aerators
- Fine bubble diffused aeration systems
- Mechanical aerators with multiple impellers
- Ultra-fine bubble diffused aeration system

6.3 Blowers

Blowers are typically used in secondary and tertiary treatment processes for providing aeration to the wastewater or activated sludge. The main types of blowers used in WWTPs include the following as shown in Table 6.3-1 below as well as their nominal efficiencies.

Table 6.3-1 Typical Blowers Used in WWT Plants

Blower Type	Nominal Blower Efficiency (%)	Nominal Blower Turndown (% of Rated Flow)
Positive Displacement	45-65	50
Multi-Stage Centrifugal (inlet throttled)	50-70	60
Multi-Stage Centrifugal (variable speed)	60-70	50
Single-Stage Centrifugal (integrally geared)	70-80	45
Single-Stage Centrifugal, Gearless (e.g. High-Speed Turbo)	70-80	50

Source: Extracted from EPA United States Environmental Protection Agency "Evaluation of Energy Conservation Measures for Wastewater Treatment Facilities (EPA 832-R10-005)", September 2010)

Market Trends

The survey polled design engineers/vendors the question of "How often do you recommend the following types of blowers to your municipal WWT customers:

- positive displacement (constant-speed)
- positive displacement (variable-speed)
- multi-stage centrifugal
- single-stage centrifugal (constant-speed)
- single-stage centrifugal (variable-speed)
- high-speed turbo blower

The options presented for each type of blower were:

- Less than or ~25% of the time
- ~50% of the time
- Greater than 50% of the time
- Not applicable

The results for the surveyed vendors/distributors were as follows:

- ***Designers***: High Speed Turbo Blowers and Positive Displacement Blowers with VSD were the more common blowers, typically recommended ~50% of the time to customers, but unclear whether customers selected this for installation
- ***Vendors***: High Speed Turbo Blowers and Positive Displacement Blowers with VSD were the more common blowers, typically recommended ~50% of the time to customers, but unclear whether customers selected this for installation

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figures 6.3-1 and 6.3-2 on the following page show the results graphically.

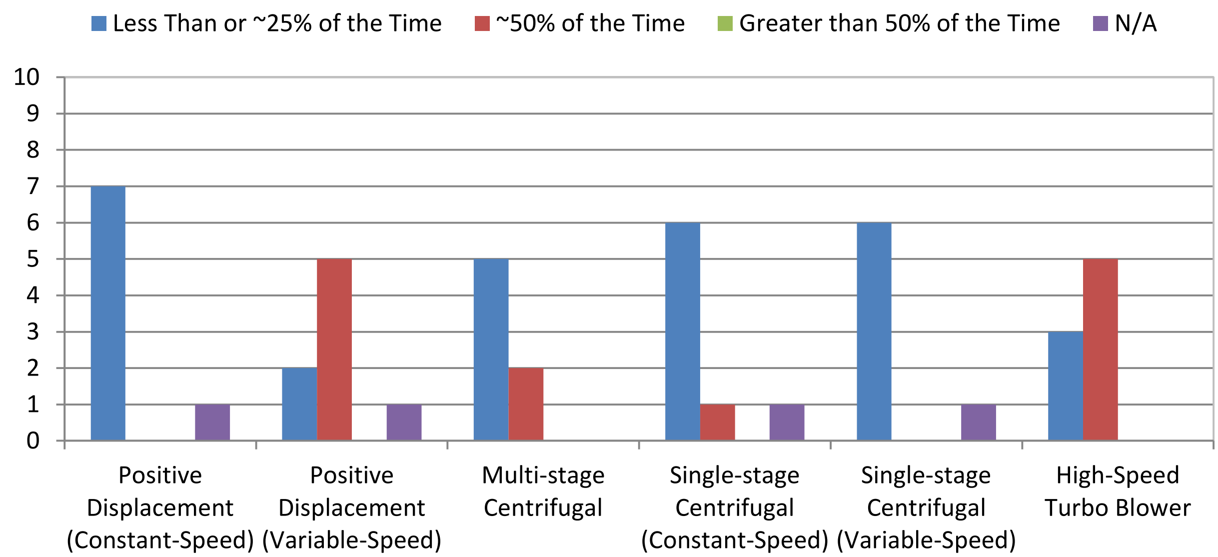

Figure 6.3-1 – Aeration Blowers Recommended by Design Engineers (8 out of 10 firms surveyed)

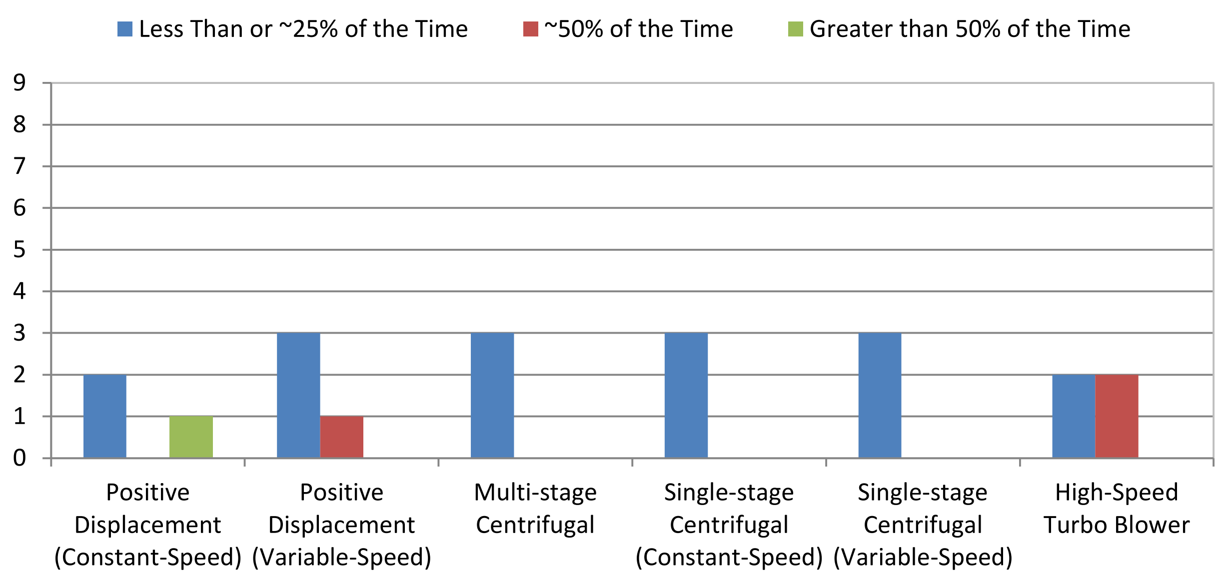

Figure 6.3-2 – Aeration Blowers Typically Purchased According to Vendors/Distributors (4 out of 9 firms surveyed)

Market Saturation

Based on the survey for wastewater treatment plants that had diffused aeration systems, the type of blower that was used and the number of facilities that used the various types of blowers are shown in Table 6.3-2 below. A total of 24 plants responded to this question out of the 42 surveyed plants.

Table 6.3-2 Survey Results for Blowers Used in WWT Plants (24 out of 42 plants)

Blower Type	Constant Speed	Variable Speed	Inlet Throttled	Discharge Throttled	Inlet Guide Vanes	Discharge Variable Diffuser Vanes
Positive Displacement	2	---	---	---	---	---
Multi-Stage Centrifugal	6	3	4	1	---	1
Single-Stage Centrifugal	2	---	2	---	3	1
High-Speed Turbo Blower	1	10	2	3	---	1

Our surveyed results show that high speed turbo blowers were installed in the 26% plants surveyed (total of 11 plants out of 42 surveyed) with multi-stage centrifugal blowers coming in second (total of 8 plants out of 42 surveyed). Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

The surveys show that the High Speed Turbo Blowers appear to be the more widely recommended (~50% of the time) blowers although it is unclear whether plants actually implement them in their facility. Plant survey results show that ~26% of the plants surveyed had high speed turbo blowers installed and 19% had multi-stage centrifugal blowers installed. One design-engineering firm mentioned that recommending positive displacement blowers for small plants are typical; and recommending turbo blowers for medium to large plants are typical. Based on the survey results, it is still difficult to say what is considered common practice for blowers in this industry as different operation conditions may call for different types of blowers. It appears that high speed turbo blowers and positive displacement (variable speed) blowers are ***trending towards becoming ISP*** in the next few years.

Table 6.3-3 Common Practice for Aeration Blowers

Project Type	Survey Results
Existing*	Multi-stage Centrifugal and High Speed Turbo Blowers
New Construction	Trending towards Positive Displacement and High Speed Turbo Blowers

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options

- High-speed gearless blowers (i.e. Turbo blowers, Turblex blowers)
- Centrifugal blowers with VSD
- Single-stage centrifugal blowers with energy efficient load modulation (i.e. variable speed drives, inlet guide vanes, variable diffuser vanes)

6.4 Diffusers

Diffused aeration is a subsurface system where air is introduced into the wastewater by diffusers. The types of diffusers commonly used in municipal wastewater treatment systems are shown in Table 6.4-1 below.

Table 6.4-1 Oxygen Transfer Efficiency for Various Diffusers Ranked by Efficiency

	Size of Bubbles (mm)	Oxygen Transfer Rate (lb/hp-hr)	Range of Standard Oxygen Transfer Efficiency* (SOTE)
Coarse bubble	3 – 50mm	1.5 – 3.5	6-12%
Fine bubble	2 – 3 mm	3.5 – 6.5	18-32%
Ultra-fine bubble	0.2 – 1 mm	10 – 27	37.5-45%

*At 15 feet submergence in clean water based on information from various diffuser manufacturers

The various types of diffusers include discs, tubes, domes and plates. In addition, there are many different materials utilized for each type of diffusers, which include ceramic, plastics or flexible perforated membranes. The oxygen transfer efficiencies vary based on the material and type of diffusers installed. Table 6.4-2 below summarizes the clean water oxygen transfer efficiency for various diffuser types and material.

Table 6.4-2 Oxygen Transfer Efficiency Variation for Diffuser Material and Types

Diffuser Material and Type		Range of Standard Oxygen Transfer Efficiency* (SOTE)
Ceramic	Discs	26-33
	Domes	25-40
	Plates	27-39
Plastic	Discs	24-35
	Tubes	26-36
Perforated Membrane	Discs	16-38
	Tubes	22-29

Source: EPA Design Manual – Fine Pore Aeration Systems (1989)

Market Trends

The survey polled design engineers/vendors the question of "How often do you recommend the following diffusers (coarse bubble diffusers, fine bubble diffusers, ultra-fine bubble diffusers, others) to your municipal WWT customers". The options presented for each type of surface aerator were:

- Less than or ~25% of the time
- ~50% of the time
- Greater than 50% of the time
- Not applicable

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figures 6.4-1 and 6.4-2 show the results of the survey.

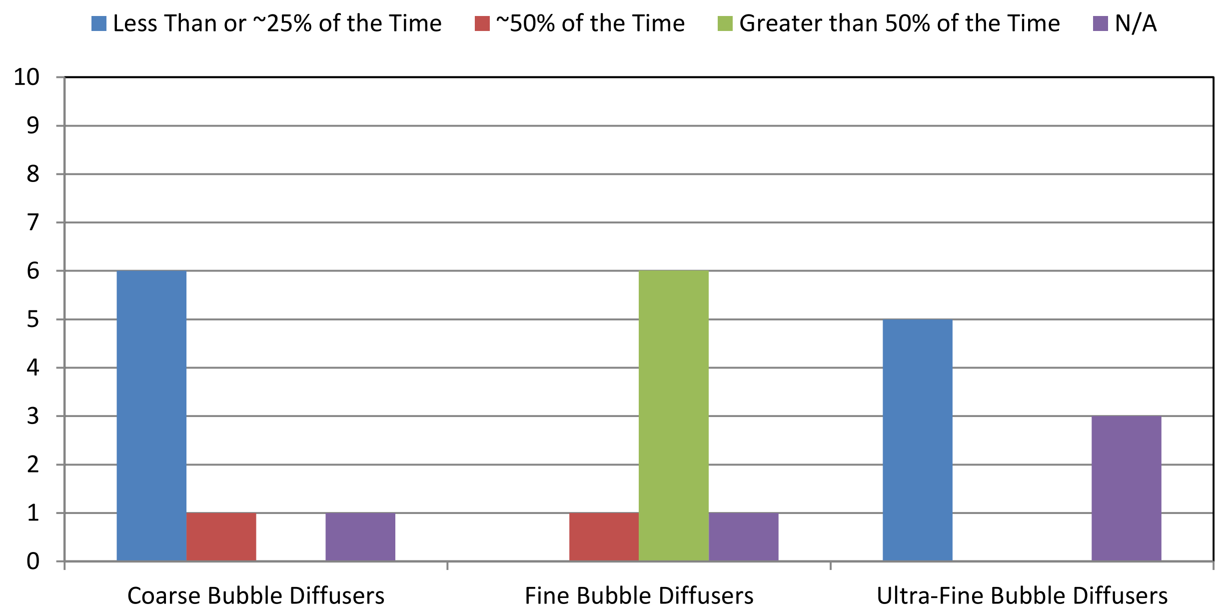

Figure 6.4-1 Survey Results from Design Engineers (8 out of 10 firms responded)

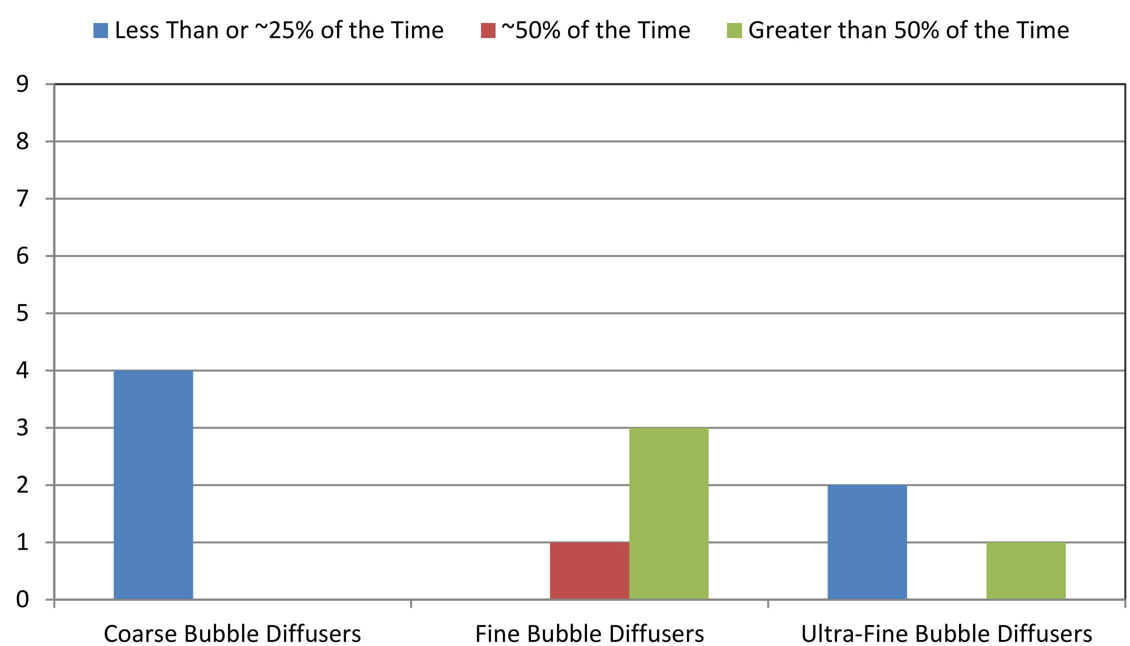

Figure 6.4-2 Survey Results from WWT Vendors (4 out of 9 companies responded)

From Figures 6.4-1 and 6.4-2 it can be seen that fine bubble diffusers are the most common type of diffusers recommended by design engineers and vendors.

Market Saturation

The survey polled municipal WW customers the question of "For the treatment processes that apply to your plant, please check all the Diffused Aeration systems (coarse bubble, fine bubble, ultra-fine bubble, other) that apply." The results of this are shown in Table 6.4-3 below. A total of 23 plants responded to this question out of the 42 surveyed plants.

Table 6.4-3 Survey Results for Diffusers Used in WWT Plants (23 out of 42 plants)

Diffuser Type	WWTP
Coarse Bubble	2
Fine Bubble	19
Ultra-fine Bubble	2
Total Responses	**23**

From Table 6.4-3 it can be seen that fine bubble diffusers are the most common type of diffusers installed in existing wastewater treatment plants.

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

Based on Market Trends and Market Saturation survey results for diffusers, among the 3 typical options available in the market for diffused air systems, fine bubble diffusers are common technology used in wastewater treatment plants and recommended for installation. The survey shows that fine bubble diffusers are considered ***industry standard practice*** for diffused aeration systems for existing and new construction projects.

Table 6.4-4 Common Practice for Diffused Aeration System

Project Type	Survey Results
Existing*	Fine Bubble Diffusers
New Construction	Fine Bubble Diffusers are ISP

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options

- Ultra-fine bubble diffusers
- Panel diffusers (membrane-type diffusers built onto rectangular panels)
- Aerostrip (long strip diffuser with large aspect ratio)

6.5 Automatic Dissolved Oxygen Control

Installing sensors to detect the amount of dissolved oxygen in the wastewater and adjusting the aeration needs accordingly results in significant energy savings due to not having to over-aerate the water.

Market Trends

The survey polled design firms and vendors 2 questions related to automatic dissolved oxygen control system:

- What type of surface aerator control (no control, manual control, timer control, automatic control, other) do your customers choose? The options were:
  - Less than or ~25% of the time
  - ~50% of the time
  - Greater than 50% of the time
  - Not applicable
- How often is automatic dissolved oxygen control recommended in the design of diffused aeration systems? The options were:
  - Less than or ~25% of the time
  - ~50% of the time
  - Greater than 50% of the time
  - Other

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figures 6.5-1 and 6.5-2 show the results of the survey.

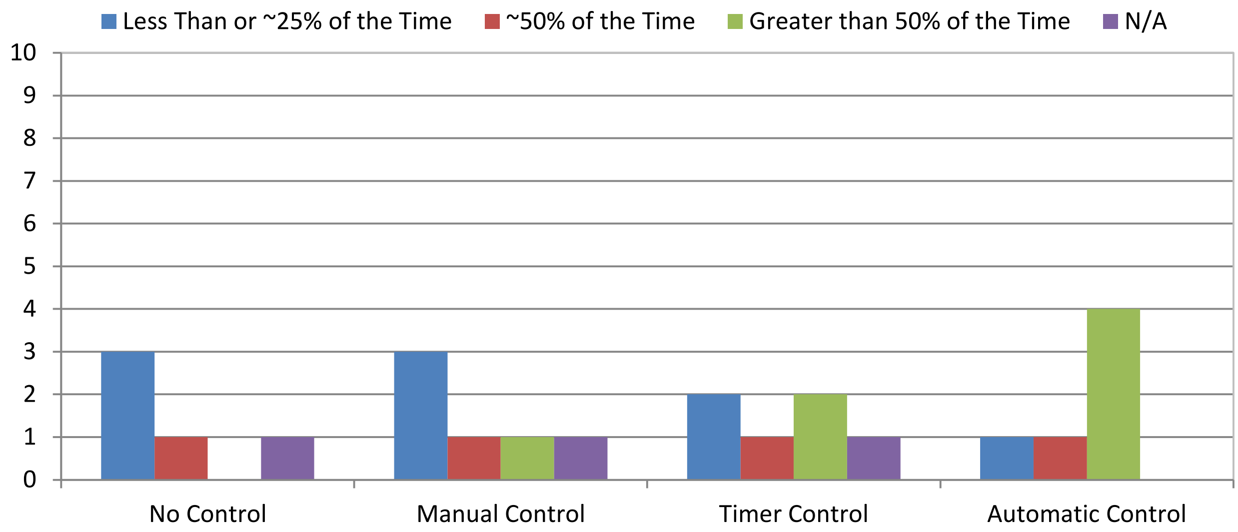

Figure 6.5-1 Survey Results from Design Engineers (4 out of 10 firms responded)

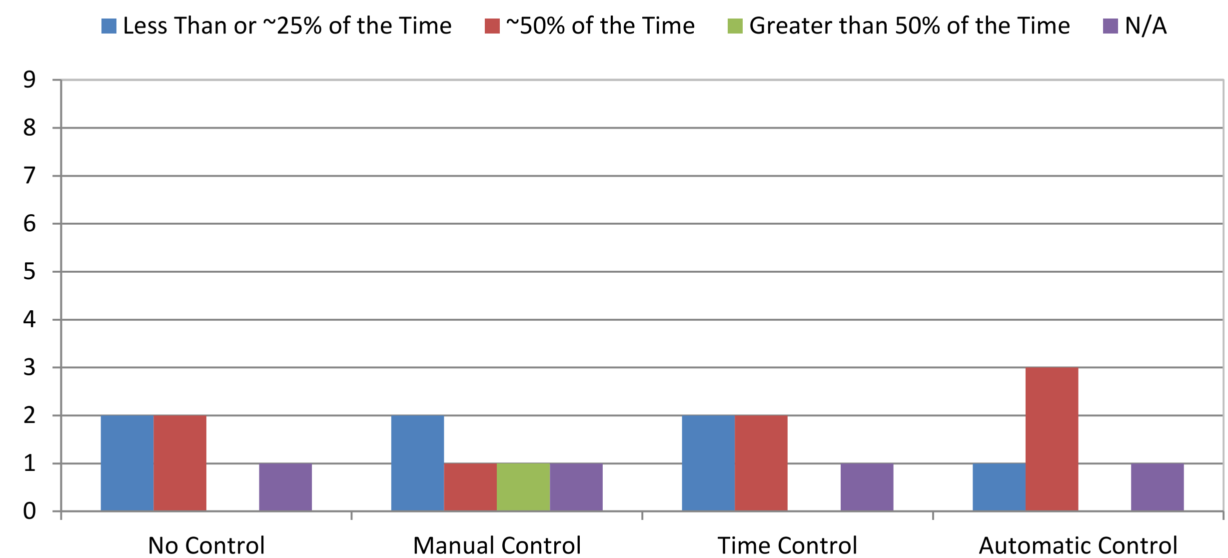

Figure 6.5-2 Survey Results from WWT Vendors (5 out of 9 companies responded)

<u>Market Saturation</u>

The survey polled municipal WW customers the question of "Which of the following energy efficient technologies are being used at your plant - whether they had an Automated Dissolved Oxygen (DO) system to control aeration equipment". A total of 25 plants out of the 42 surveyed plants responded saying that they had an Automated Dissolved Oxygen (DO) system to control aeration equipment in their plant.

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

Approximately 60% of the wastewater plants surveyed do have an automatic dissolved oxygen control in place and designers and vendors typically include this as a part of their design or equipment recommendation. Thus, automatic dissolved oxygen control is considered ***industry standard practice*** in municipal wastewater treatment plants for existing and new construction projects.

Table 6.5-1 Common Practice for Dissolved Oxygen Control Systems

Project Type	Survey Results
Existing*	Automatic Dissolved Oxygen Control
New Construction	Automatic Dissolved Oxygen Control is ISP

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options	
Technology	**Description**
Most Open Valve (MOV) Control	Controlling the amount of throttling on the discharge side of the blowers to what is required to properly split the air flow
Integrated Air Flow Control	Control system that eliminates the pressure control loop common in automatic DO control systems
Respirometry	Measuring the oxygen uptake rate by a biomass sample from the aeration basin to predict oxygen requirement of the WW as it enters the basin.
Critical Oxygen Point Control Determination	Control method based on respirometric measurements to allow optimal DO setpoint to be determined.
Off-Gas Analysis	Using the test to determine the process oxygen transfer efficiency based on gas-phase mass balance of oxygen entering the aeration basin and oxygen leaving the basin at the WW surface as a parameter for aeration system control
Bioprocess Intelligent Optimization System (BIOS)	Optimization control that simulates performance based on on-line measurements of temperature, ammonia, nitrate, and influent WW flow rate.

6.6 Filtration Systems

Filtration involves removing organic matter and suspended solids beyond what secondary treatment can treat to meet more stringent discharge and reuse requirements.

Market Trends

Table 6.6-1 shows the results of the vendors' response to the survey question "Which of the following are most commonly purchased by your customers? (Please check all that apply)."

- Sand Bed Filters
- Membrane Bioreactors
- Low-Pressure Membrane Filters
- High-Pressure Membrane Filters
- Dissolved Air Floatation
- Cloth Media Filters
- Compressible Media Filters
- Other

A total of 4 vendors out of the 9 surveyed firms responded to this question. The surveyed design engineering firms did not have responses for this question.

Table 6.6-1 Filtration Systems Survey Results from Vendors

Filtration System	Vendors
Membrane Bioreactors	2
Low-Pressure Membrane	2
High-Pressure Membrane	---
Dissolved Air Floatation	1
Cloth Media Filter	2
Compressible Media Filter	2
Sand Filter	2
Total Responses (may have more than one answer)	**4**

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Market Saturation

Table 6.6-2 shows the type of filtration that is currently used in wastewater treatment plants. A total of 17 plants responded to this question out of the 42 surveyed plants.

Table 6.6-2 Filtration Systems Survey Results from Plants	
Filtration System	**WWTP**
Membrane Bioreactors	3
Low-Pressure Membrane	---
High-Pressure Membrane	2
Dissolved Air Floatation	---
Cloth Media Filter	4
Compressible Media Filter	1
Sand Filter	8
Total Responses (may have more than one answer)	**17**

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

<u>Survey Results</u>

Based on Market Trends and Market Saturation survey results, among the options presented for filtration application, sand filters appear to be industrial standard practice for existing projects since 50% of the plants responding to this question in the survey stated that they have sand filters in their plants. The vendor survey did not show a particular technology being common practice, thus it is ***unclear*** what the common practice is for new construction projects.

Table 6.6-3 Common Practice for Filtration Systems	
Project Type	**Survey Results**
Existing*	Sand Filter
New Construction	Unclear (Membrane Bioreactor, Low-Pressure Membrane, Cloth Media Filter, Compressible Media Filter, Sand Filter were more common options)

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

More efficient options include those shown in the box below, which are not yet common, or are starting to gain momentum for common adoption.

<u>Energy Efficiency Options</u>

- Cloth media filter
- Compressible media filter

6.7 Disinfection

As mentioned previously the main three types of disinfection commonly used in municipal wastewater treatment plants are:

- Chemical (Chlorine, Chlorine Dioxide)
- Ozone
- Ultraviolet (UV)

Market Trends

The survey polled design engineers/vendors the question of "Which of the following Disinfection technologies (if applicable) do you typically recommend to your customers". The options provided were:

- Chemical
- Ozone
- Ultraviolet Disinfection
- Other

The survey of design engineers and vendors found the disinfection systems recommended in Table 6.7-1. A total of 5 vendors out of the 9 surveyed firms. The surveyed design engineering firms did not have responses for this question.

Table 6.7-1 Disinfection Survey Results*

Disinfection System	Vendors
Chlorine	2
Ozone	1
UV Radiation	4
Total Responses *(may have more than one answer)*	**5**

*Design engineering firms did not have responses for this question.

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Market Saturation

Based on the survey for wastewater treatment plants that utilized Disinfection Systems in their plant which asked them to select all the systems that apply (ultraviolet, chemical, ozone, other), the results are shown in Table 6.7-2 below. A total of 30 plants responded to this question out of the 42 surveyed plants.

Table 6.7-2 Disinfection Survey Results

Disinfection System	WWTP
Chlorine	19
Ozone	---
UV Radiation	12
Total Responses *(may have more than one answer)*	**30**

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

According to survey results, chlorine and UV radiation are the common technologies used for disinfection in wastewater treatment plants. The vendors surveyed in this project typically recommended UV systems to their customers.

Chlorine disinfection typically has minimal energy usage with just a pump for the chemical to be injected into the wastewater stream. Ultraviolet radiation is more energy intensive but less hazardous for handling. Sections 6.7.1 and 6.7.2 following will discuss the technologies used in UV disinfection systems.

6.7.1 Ultraviolet Lamps

The main components of a UV disinfection system are mercury arc lamps, a reactor, and ballasts. UV lamp efficiency has increased over time. The three common types of UV lamps are:

- Medium-pressure, high-intensity (MPHI) UV lamps *(least energy efficient)*
- Low-pressure, high-intensity (LPHI) UV lamps
- Low-pressure, low-intensity (LPLI) UV lamps *(most energy efficient)*

Market Trends

The survey polled design engineers/vendors the question of "How often are the following types of UV lamps (medium-pressure UV lamps, low-pressure high-intensity UV lamps, low-pressure low-intensity UV lamps, or other) recommended/purchased by your municipal WWT customers". The options presented for each type of lamp were:

- Less than or ~25% of the time
- ~50% of the time
- Greater than 50% of the time
- Not applicable

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figure 6.7-1 shows the results of the survey for the vendors. The surveyed design engineering firms did not have responses for this question.

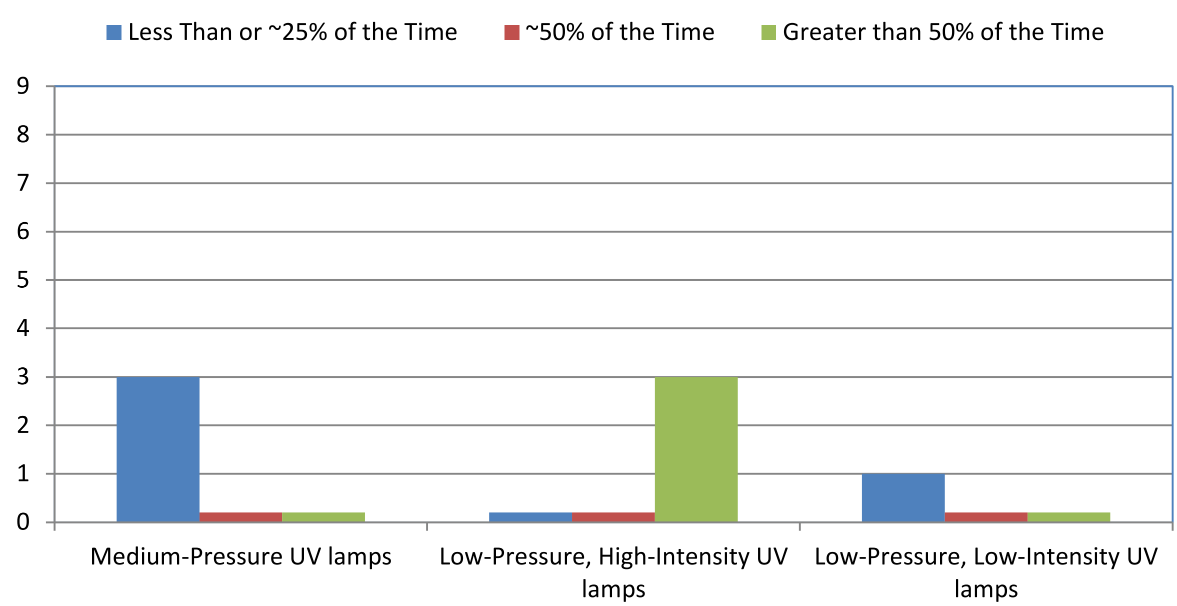

Figure 6.7-1 Survey Results from Vendors (3 out of 9 firms responded)

Market Saturation

Table 6.7-3 shows the type of UV lamps that are currently used in wastewater treatment plants. A total of 10 plants responded to this question out of the 42 surveyed plants.

Table 6.7-3 UV System Survey Results*

UV Lamps	WWTP
Medium-Pressure, High-Intensity	6
Low-Pressure, High-Intensity	1
Low-Pressure, Low-Intensity	3
Total Responses	**10**

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

According to the plant survey, 60% of the plants who responded to the survey question stated they used medium-pressure high-intensity lamps in their plant, which appears to be the ***industry standard practice*** in existing plants. However, for new construction facilities it appears that low-pressure, high-intensity lamps are considered to be ***trending towards industry standard practice***. According to survey results, low-pressure high-intensity lamps are recommended by a majority of vendors who answered the survey question over 50% of the time. However, only 30% of the vendors actually responded to the question and no design firms responded, thus it is difficult to determine what the market saturation of low-pressure high intensity UV lamps is.

In order to better understand the market trends for each individual measures, we put more weight on the data gathered from the surveys administered to vendors, suppliers, and/or designers. In this example, after considering the survey responses from vendors, along with additional literature review of disposition reports, we were able to recommend that low-pressure, high-intensity UV lamps is trending toward industry standard practice (common practice) as one-third of the vendors indicated that they recommend this product “Greater than 50% of the time.” In the meanwhile, it’s also clear that low-pressure, low-intensity UV lamps are not standard practice yet because only one-tenth of the vendors indicated that they recommend this product “more than 50% of the time.”

Table 6.7-4 Common Practice for UV Systems

Project Type	Survey Results
Existing*	Medium-Pressure, High-Intensity

New Construction	Trending towards Low-Pressure, High-Intensity

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options

- Low-Pressure, Low-Intensity UV Lamps
- UV LEDs – an emerging technology

6.7.2 Control Strategy

Due to the energy-intensiveness of UV systems, proper control of the UV system while maintaining desired levels for disinfection is crucial.

Market Trends

The survey polled design engineers/vendors the question of "For projects where UV systems are recommended/purchased, what type of control (no control, manual control, control based on flow, control based on dosage, other) does your customer typically select". The options presented for each type of lamp were:

- Less than or ~25% of the time
- ~50% of the time
- Greater than 50% of the time
- Not applicable

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figure 6.7-2 shows the results of the survey for the vendors. The surveyed design engineering firms did not have responses for this question

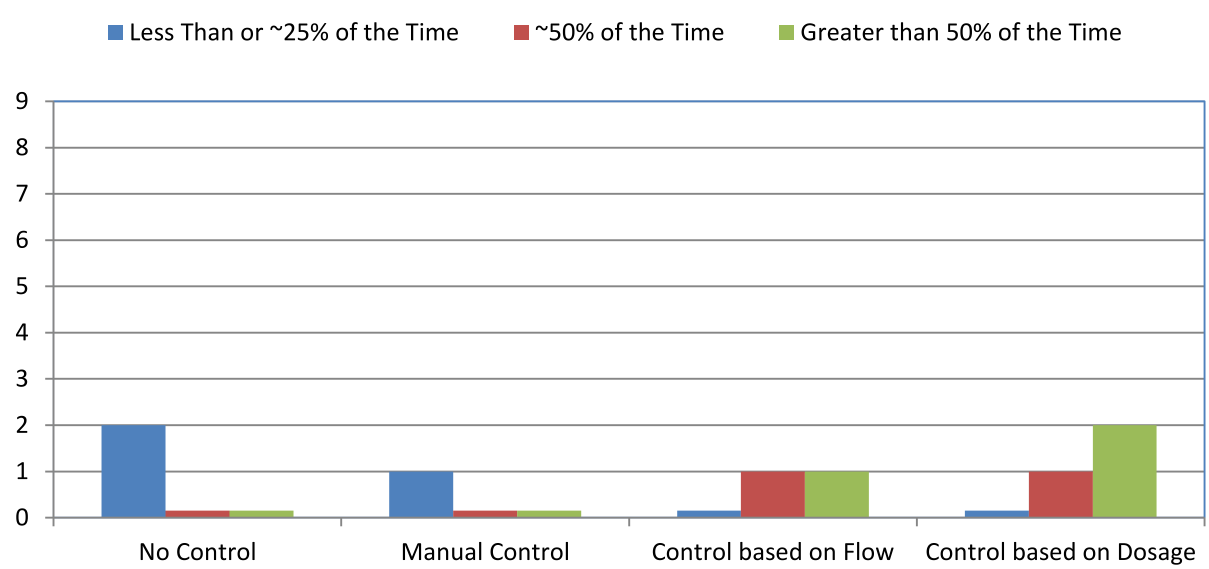

Figure 6.7-2 Survey Results from Vendors (3 out of 9 firms responded)

Market Saturation

Table 6.7-5 shows the type of UV system control that is currently used in wastewater treatment plants. A total of 10 plants responded to this question out of the 42 surveyed plants. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Table 6.7-5 Survey Results for Control of UV Systems

Control Strategy	WWTP
No Control (on all the time)	---
Manual Control	2
Control based on Flow	6
Control based on Dosage	5
Total Responses (may have more than one answer)	**10**

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility.

Common Practice in the Industry

Based on the survey results, it is common for UV systems to be controlled based on some type of parameter. Flow-pacing is a much simpler option since the UV operation is based solely on the influent flow rate. For existing projects, controlling the UV system based on flow is considered ***industry standard practice*** based on the results from the plant survey. For new construction projects, the common practice is ***unclear*** from the survey results since only 3 out of 9 vendors responded to this question and no design firms responded. It appears that dosage control ***may be trending towards standard practice*** but not at this time yet.

Table 6.7-6 Common Practice for Control of UV Systems

Project Type	Survey Results
Existing*	Control based on Flow
New Construction	May be trending towards Control based on Dosage

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options

- Control UV System based on Dose Pacing
- Control UV Lamps with Turbidity Sensors – optimizes the number or intensity of operating UV lamps based on total suspended solids, levels and flow. This reduces energy consumption while ensuring adequate exposure to UV light

6.8 Sludge Thickening Systems

Thickening sludge increases the solids content of the sludge, which is beneficial to subsequent processes such as digestion, dewatering, drying and combustion. The more common sludge thickening methods are shown in Table 6.8-1 below.

TABLE 6.8-1 COMMON SLUDGE THICKENING METHODS*

Method	Type of Solids	Solids Concentration	Solids Capture Efficiency[£]	Energy Requirements
Gravity Thickener	Treated/Untreated Primary and waste activated	Varies greatly	98%	Minimal
Gravity Belt Thickener	Waste activated sludge	3% to 6+%	90-98%	Low
Dissolved Air Floatation Thickener	Untreated Primary and waste activated	2% to 3%	85-98%	High
Centrifugal Thickener	Waste activated sludge	4% to 6%	90-95%	High
Rotary Drum Thickening	Waste activated sludge	4% to 6+%	90-98%	Medium

*Extracted from Metcalf & Eddy "Wastewater Engineering Treatment and Reuse", 2003.
[£] Amount of water content in the sludge that can be removed by the thickener

Market Trends

The survey polled design engineers/vendors the question of "How often are the following sludge thickening equipment (gravity thickener, gravity belt thickener, dissolved air floatation, rotary drum thickener, centrifugal thickener, or other) recommended/purchased by your municipal WWT customers". The options presented for each type of sludge thickening equipment were:

- Never
- Rarely
- Sometimes
- Often
- Always
- Not Applicable

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier. Figures 6.8-1 and 6.8-2 on the following page show the results of the surveys administered to the design engineers and vendors/distributors graphically.

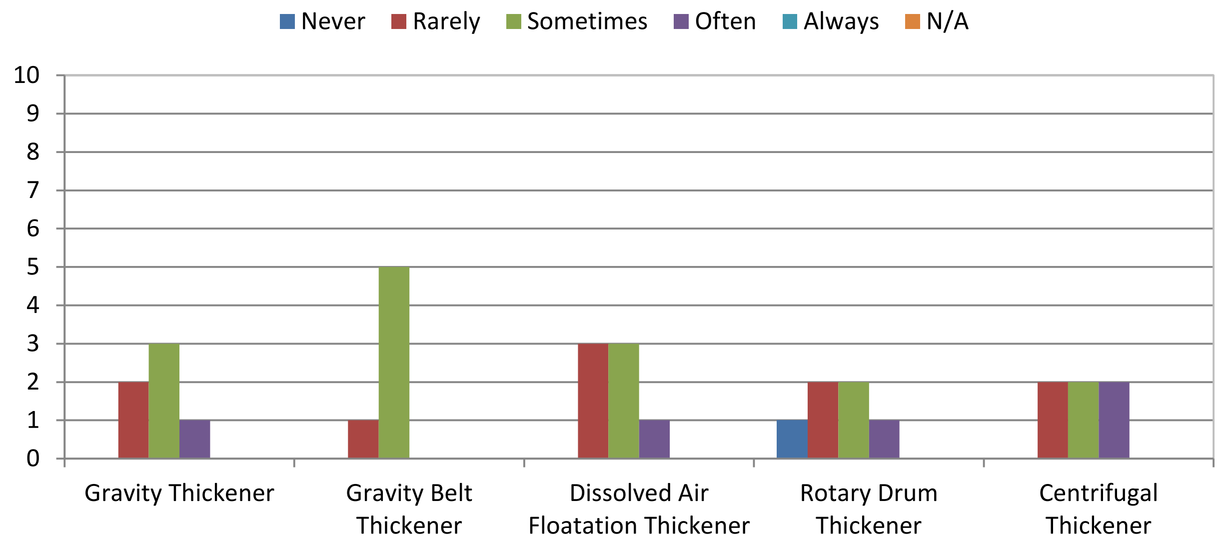

Figure 6.8-1 – Sludge Thickening Equipment Recommended by Design Engineers
(7 out of 10 firms surveyed)

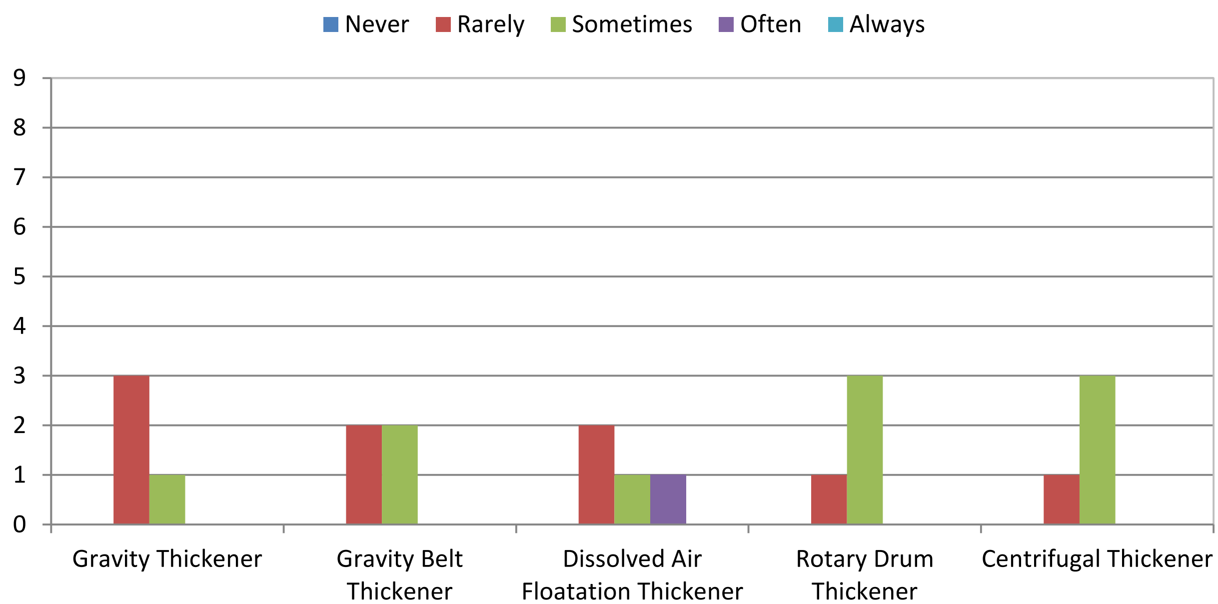

Figure 6.8-2 – Sludge Thickening Equipment Typically Purchased According to Vendors/Distributors
(4 out of 9 firms surveyed)

Market Saturation

For sludge thickening, the more common equipment used in the municipal wastewater plants are summarized In Table 6.8-2 below. A total of 19 plants out of the 42 surveyed plants responded to the question of the type(s) of sludge thickening equipment in their facility.

Table 6.8-2 Survey Results for Sludge Thickening Systems

Thickening Equipment	WWTP
Gravity Thickener	4
Gravity Belt Thickener	5
Dissolved Air Floatation Thickener	5
Rotary Drum Thickener	3
Centrifugal Thickener	1
Totals (may have more than one answer)	**19**

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

The survey results show that both the Gravity Belt Thickener and Dissolved Air Floatation Thickener have the highest number of units installed in WWTPs (5 plants each). The difference was the number of times designers and vendors have recommended each, which turned out to be comparable.

Based on the plant survey results and looking at the market saturation data, dissolved air floatation thickener appears to be the more common practice for sludge thickening compared to other sludge thickening technologies but the common practice is still ***unclear***.

Table 6.8-3Common Practice for Sludge Thickening System

Project Type	Survey Results
Existing*	Gravity Belt Thickener & Dissolved Air Floatation Thickener
New Construction	Unclear (Dissolved Air Floatation System & Centrifuge are the more common options)

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options

- Gravity Belt Thickener
- Rotary Drum Thickener
- Gravity Thickener

6.9 Sludge Dewatering Systems

Sludge dewatering is done to reduce the moisture content of sludge and biosolids. The dewatering equipment selected depends on the type of sludge, characteristics of the dewatered product, operating costs, regulations and space available. Sludge dewatering can be done using mechanical equipment or by natural evaporation and percolation.

Table 6.9-1 Comparison of Common Mechanical Dewatering Alternatives*

	Belt Filter Press	Centrifuge	Screw Press	Rotary Press
Performance				
% Discharge Solids	20%	25%	20%	15-28%
Solids Capture Efficiency	85-95%	85-90%	90-95%%	>98%
Operator Attention Requirement	High	Low	Low	Low
Energy Requirement	Medium	High	Low	Low
Maintenance	Medium	High	High	Unsure
Wash water Requirements	High	Low	Low	Medium
Physical				
Physical Footprint	Large	Small	Medium	Small
Other Factors				
Odor Potential	High	Low	Low	Low
Noise Level	Low	Low	Low	Low
Capital Costs				
Equipment Costs	Low	High	Medium	High

* Extracted from Brown and Caldwell (2009)

Other mechanical dewatering equipment includes vacuum filtration and recessed-plate filter press, both of which are not too commonly used in California municipal wastewater treatment plants.

Sludge that is aerobically digested is not as responsive to mechanical dewatering. This type of sludge would need to utilize natural dewatering options such as sludge drying beds, solar drying, mixed drying (combination of belt dryer with hot air), direct heat drying or indirect heat drying.

<u>Market Trends</u>

The survey polled design engineers/vendors the question of "How often are the following sludge dewatering equipment (belt filter press, centrifuge, recessed chamber, vacuum filtration, screw press, rotary press, drying beds, or other) recommended/purchased by your municipal WWT customers". The options presented for each type of sludge thickening equipment were:

- Never
- Rarely
- Sometimes
- Often
- Always
- Not Applicable

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figures 6.9-1 and 6.9-2 on the following page show the results of the surveys administered to the design engineers and vendors/distributors graphically.

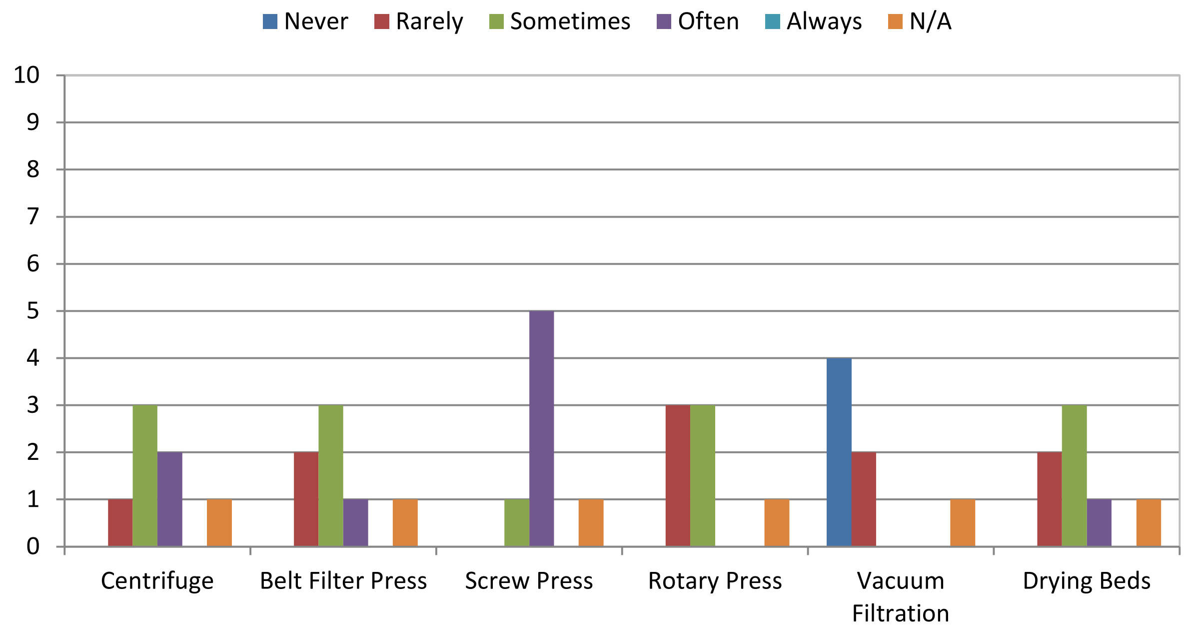

Figure 6.9-1 – Sludge Dewatering Equipment Recommended by Design Engineers (7 out of 10 firms surveyed)

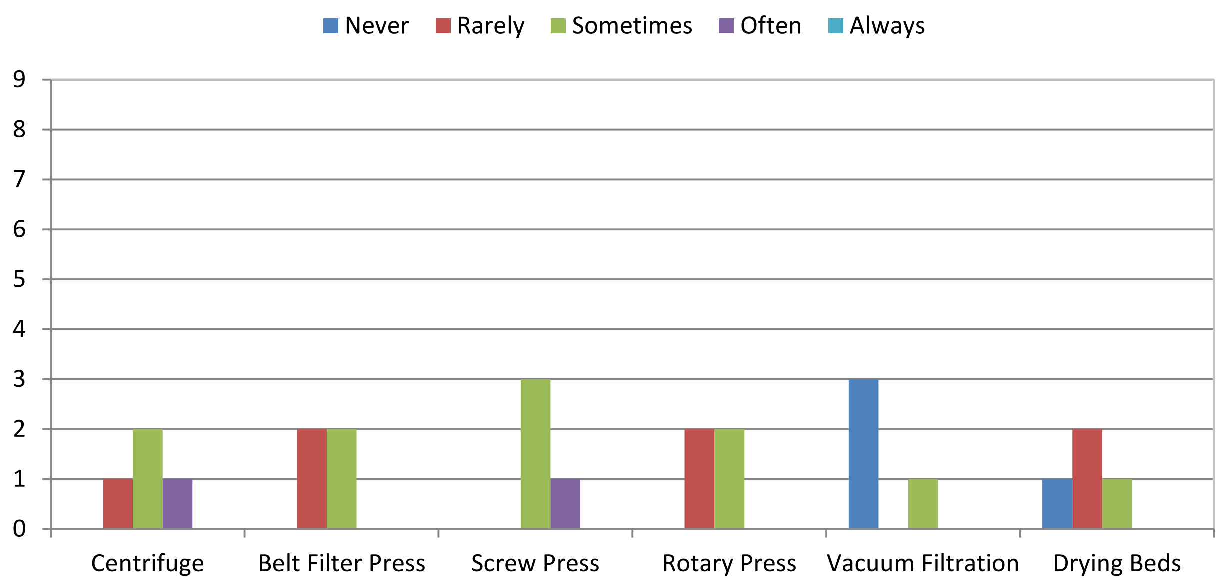

Figure 6.9-2 – Sludge Dewatering Equipment Typically Purchased According to Vendors/Distributors (4 out of 9 firms surveyed)

Market Saturation

For sludge dewatering, the more common equipment used in the municipal wastewater plants are shown in Table 6.9-2. A total of 27 plants out of the 42 surveyed plants responded to the question of the type(s) of sludge dewatering equipment in their facility.

TABLE 6.9-2 Survey Results for Sludge Dewatering Systems

Dewatering Equipment	WWTP
Belt Filter Press	5
Centrifuge	8
Recessed Chamber Press	---
Vacuum Filtration	---
Screw Press	2
Rotary Press	2
Drying Beds	11
Totals (may have more than one answer)	**27**

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

The survey results show that centrifuge and screw press are the more common sludge dewatering technology recommended by design engineers and vendors. Centrifuge and drying beds appear to be the more common equipment used for dewatering in existing plants. For new construction projects, screw press seems to be trending towards becoming common practice, but since only 50% of the design firms and 10% of the vendors responding that this is the case, it is still ***unclear*** what the common practice for sludge dewatering systems are.

Table 6.9-3 Common Practice for Sludge Dewatering System

Project Type	Survey Results
Existing*	Centrifuge and Drying Beds
New Construction	Unclear (Centrifuge and Screw Press were the more common options of the technologies)

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Options

- Screw Press
- Rotary Press
- Drying Beds

6.10 Primary Treatment

Primary treatment involves the basic processes to remove suspended solids and biological oxygen demand (BOD) from the wastewater stream before it enters the energy-intensive secondary treatment. The more solids and BOD that can be removed in the primary treatment stage, the less energy is required in the secondary treatment stage. The two types of primary treatment described previously in Section 3.1 are:

- Conventional primary treatment – screening, settling and clarification
- Chemically-enhanced primary treatment – chemical enhancement process that employs coagulation and flocculation by adding chemicals such as metal salts/polymers

Market Trends

The survey polled design engineers/vendors the question of "How often do you recommend the following primary treatment processes (conventional primary, chemically enhanced primary) to your municipal WWT customers?" The options presented for each were:

- Never
- Rarely
- Sometimes
- Often
- Always
- Not Applicable

Responses from design engineers and vendors typically allude to market trends in new construction projects as well as retrofits, and are typically based on their responses about recommendations and sales within the recent 3-5 years since as mentioned earlier.

Figure 6.10-1 shows the type of primary treatment selected by wastewater plants according to design engineers and Figure 6.10-2 shows the same according to vendors/distributors.

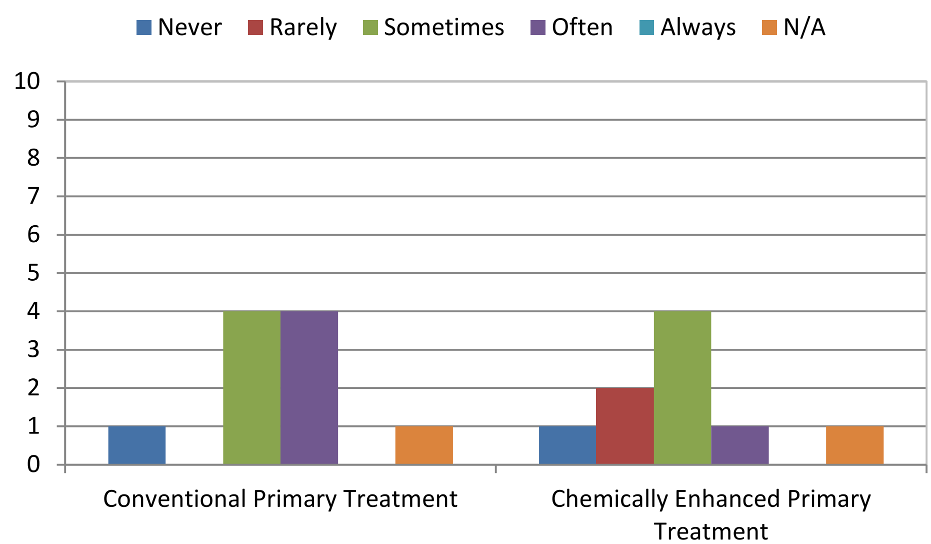

Figure 6.10-1 – Primary Treatment Selected by WW Customers according to Design Engineers (10 out of 10 firms surveyed)

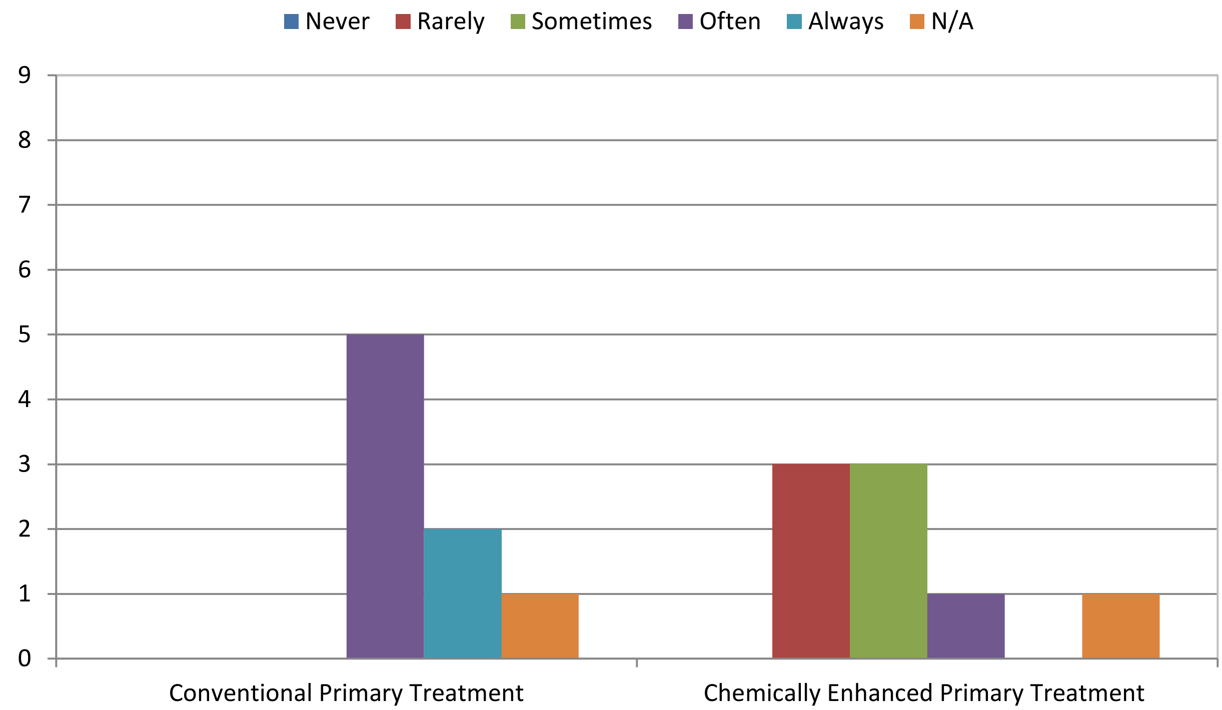

Figure 6.10-2 – Primary Treatment Selected by Customers according to Vendors/Distributors (8 out of 9 firms surveyed)

Market Saturation

All plants have some type of primary treatment. The survey of wastewater treatment plants surveyed plants whether they had chemically enhanced primary sedimentation (e.g. ferric chloride, poly aluminum chloride, aluminum sulfate) or advanced primary treatment in their facility. Results showed that 9 out of the 42 plants (21% of the surveyed plants) who responded had some sort of chemically-enhanced primary treatment in their facility.

Responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; therefore, we will corroborate the market trend information derived from the survey responses in vendor/supplier and designer groups to understand whether or not the measure has become common practice (or ISP), or trending toward ISP.

Common Practice in the Industry

Based on the survey results, since only 21% of the surveyed municipal WWT plants had chemically enhanced primary treatment systems, conventional primary treat still appears to be the common practice in the industry for existing and new construction projects and considered as ***industry standard practice***.

Table 6.10-1 Common Practice for Primary Treatment System

Project Type	Common Practice
Existing*	Conventional Primary Treatment
New Construction	Conventional Primary Treatment is ISP

* It should be noted that responses from wastewater plants typically allude to practices in existing facilities as they are responding to what is currently at their facility. The in-situ market saturation information alone is insufficient to indicate market trend; thus survey responses from the vendor/supplier and design engineers should be evaluated as well to understand whether or not the measure has become common practice (or ISP), or trending toward ISP

Energy Efficiency Option

- Chemically enhanced primary treatment system

6.11 Other Energy Efficient Technologies

Table 6.11-1 below summarizes other energy efficient technologies that were explored that may not be as common or have as much potential energy savings as the other technologies in this section.

Table 6.11-1 Summary of Other Best Practices for Wastewater Treatment Industry

Technology	Baseline	Sample Energy Efficiency Measure
Hydraulic Driven Systems	Water or hydraulic-oil driven system	Electrical-driven system
Pneumatic Pumps	Pneumatic	Electrical-driven
Lighting	CA Title 24 Standards	Lighting Power Intensity for an Area is Lower than CA Title 24
Sludge Drying Beds	May vary depending on land availability	Sludge Drying Beds (non-heated)

Table 6.11-2 shows measures that were considered in the 2006 baseline study and during the course of this study. The study showed that these technologies were considered to be common practice in this industry.

Table 6.11-2 Summary of Other Best Practices Considered to be Industry Standard Practice

Technology	Baseline	Source
Air Compressor	Air Compressor with VSD Control	CA Title 24
Control System	Supervisory Control and Data Acquisition (SCADA) System	Survey Results
Dissolved Oxygen Control	Automatic Dissolved Oxygen Control System	Survey Results and Literature Survey
Pumps	Variable Speed Drive	Survey Results and ISP-000B
Motors	NEMA Premium Efficiency	CA Title 24
Anaerobic Digestion Mixing	Mechanical Mixing	Survey Results
Biogas Re-Use	Used for Boiler	Survey Results
Sludge Treatment	Anaerobic Treatment	Survey Results and Literature Survey

The following tables summarize other major energy related findings from the survey.

- Table ES-5 summarizes the on-site power generation finding.
- Table ES-6 summarizes the maintenance practices in these plants.
- Table ES-7 summarizes the reuse of recycled wastewater.

Table ES-5 Summary of On-Site Power Generation Findings

Digester Gas Practices			Total # of Responses	Response Count	Percentage
Plant Produces Digester Gas	Yes		32	16	50%
	No			16	50%
How Digester Gas is Consumed?		Flare	16	14	88%
		Electricity Generation		8	50%
		Boiler		12	75%
Electricity Generated on-Site at Plant	Yes		32	13	41%
	No			19	59%
Fuel Source for On-Site Electricity Generation		Digester Gas	13	8	62%
		Natural Gas		6	46%
		Solar		7	54%

Table ES-6 Summary of Maintenance Practices

Maintenance Practices		# of Responses	# of Plants Reporting Practices	Percentage
Diffused Aeration Systems				
Air Distribution Piping Inspection		21	15	71%
Calibrating DO Sensors		18	14	78%
Diffuser Cleaning	Acid Washing	12	3	25%
	Detergent Washing		1	8%
	High-Pressure Water Jetting		2	17%
	High and Low Pressure Water Hosing		5	42%
	Drying		1	8%
	Air Bumping		5	42%
Mechanical Aeration Systems				
Inspect and Clean Impeller		13	8	62%
Check for Unusual Vibration		12	9	75%
Change Gear Reducer Oil & Lubricate Motor Bearings		12	7	58%
Ultraviolet Disinfection Systems				
Online Mechanical Cleaning		6	5	83%
Online Chemical Cleaning			2	33%
Calibrate UV Intensity Sensors		11	4	36%

Table ES-7 Summary of Recycled Water Use*

	# of Responses	# of Plants	Percentage
YES, Treated effluent is reclaimed & reused	31	21	68%
NO, Treated effluent is not reclaimed nor reused	31	10	32%

*Plants who responded “YES” had between 5 to 100% of the water reused with the average amount of treated being used of approximately 49.7%.

6.12 Review of CPUC Energy Division Dispositions

Table 6.12-1 below summarizes dispositions by the CPUC Energy Division for wastewater-related technologies.

Table 6.12-1 Summary of Energy Division Dispositions for Wastewater Related Projects

ED Project No.	Energy Efficiency Measure	Industry Standard Practice Stated in Project	Energy Division Decision	Survey Results for Industry Standard Practice
E019 (2010-12)	Control the Pumping Flow with VSDs	Constant Speed Pumps	VSDs are considered standard practice since facility already has VSDs at sister plants and on other pumps at the plant.	VSDs on pumps are considered industry standard practice for new construction projects
E024 (2010-12)	Aeration System Improvements and Aerobic Digester Blower Replacement	Coarse Bubble Diffuser and No SCADA Control of DO	Fine bubble diffusers and DO SCADA control system are industry standard practice. Since facility previously used a fine bubble diffuser, using coarse bubble is considered regressive baseline.	Fine bubble diffusers and automatic DO control are considered industry standard practice especially if plant had used them previously
E054 (2010-12)	Install Single Stage Aeration Blowers with Integrated VSDs and Automated Dissolved Oxygen Controls	Multi-stage Centrifugal Aeration Blower with Manually Adjusted DO Level Controls	This system was installed as back-up to the two new HE single-stage units) and automatic DO level controls (baseline cannot be regressed to manually-adjusted DO controls)	Constant speed multistage centrifugal blowers with inlet valve throttling and high speed turbo blowers are the more common blowers used based on survey.
	VSDs on Influent & Effluent Pumps	Influent & Effluent Pump Motors **without** VSDs	The WWTP already had VSDs controlling existing influent and effluent pumps, therefore regressing back to pumps without VFDs is not allowed.	VSDs on pumps are considered industry standard practice for new construction projects
	Low-Pressure UV Disinfection System	**Medium**-Pressure UV Disinfection	ISP baseline for new construction is Low-Pressure UV disinfection	For existing facilities, medium-pressure high intensity lamps still appear to be the common practice. Designers and vendors do indicate that low-pressure high intensity lamps are the more recommended technology.

6.13 Discussion and Recommendations

6.13.1 Scope of the Final Report

As mentioned earlier, the first final report was completed and initially made available in October 2015, with the scope of updating the 2006 Baseline report prepared by BASE Energy, Inc. for PG&E. The initial report was peer reviewed by a number of stakeholders including experts from governments and the private sectors. As a response to the review comments provided by California Public Utilities Commission's (CPUC's) Energy Division staff under the regulatory framework on appropriate baseline, and on-going collaborative discussion about the improving the understanding of the concept and process for industry standard practice (ISP) studies, PG&E and BASE Energy collaborated closely since the spring of 2016 to refine the report so that we not only advance the understanding of technology options and standard practices in the selected sector, but also convey important information in alignment with the existing regulatory framework on appropriate baselines. Accordingly, the scope and goals of this final report have been revised and updated, taking advantage of the vast amount of data available from the initial project.

6.13.2 Concept and Definition of ISP

In this report, we consider that industry standard practice (ISP) represents the typical current equipment purchases or commonly used current trending practice absent the program. Section 6 presents technology options and survey results from different groups of the participants that included customers (MWWTPs), vendors/suppliers, and designers. In this section, we analyzed the survey results by process and technology. For each process/technology, we compared the survey outcomes among three groups of participants, and corroborate the information along with additional information gathered from literature reviews. Based upon specific thresholds that were assumed in this report, we've developed a list of EEMs that have become a common practice (standard practice) and/or trending toward a common practice. Such a list of EEMs is recommended for industrial standard practices based upon the data and information reviewed in this study.

We have identified whether or not an EEM has become common practice (or standard practice), or trending toward standard practice based upon the survey data administered to customers, vendors, suppliers, and designers serving the MWWT market, in corroboration with additional literature reviews and analyses in this report. For example, while a higher market penetration rate such as 60% for Automatic Dissolved Oxygen Control System may be good to indicate that this EEM has become common practice in existing plants, a lower market penetration rate such as 14% for Variable Intensity Ultraviolet (UV) Lamps may be insufficient to indicate that this EEM isn't common practice to-date because this penetration data alone doesn't directly represent today's market trend. In order to better understand the market trends for each individual measures, we put more weight on the data gathered from the surveys administered to vendors, suppliers, and/or designers. In this example, after considering the survey responses from vendors, along with additional literature review of disposition reports, we were able to recommend that low-pressure, high-intensity UV lamps is trending toward industry standard practice (common practice) as one-third of the vendors indicated that they recommend this product “Greater than 50% of the time.”

It’s very important to note that there is no one ISP study fits all applications. This is especially true for custom projects that seek for appropriate baselines to qualify for utility program incentive under the regulatory framework in California market. In essence, appropriate baselines for custom projects must be established or selected for each project individually (i.e., per customer basis), and cannot be universally established for all projects installing a technology independent of other site- or customer-specific considerations. In order to avoid free ridership effectively, project developers first need to credibly establish what the customer is planning to do before program intervention, then document higher-efficiency, higher-cost options for the customer to consider implementation as compared to all other viable measures that would meet the customer’s functional and technical requirements.

6.13.3 Custom Project Development and Appropriate Baseline

While the data and information produced from this study can be very useful for program and product teams to develop potential deemed programs; we were advised by CPUC staff that customer project developers must first analyze measure eligibility, determine measure code, and document program influence such as alternative measures beyond existing equipment to establish and justify appropriate baselines. Because ISP for a specific generic measure may vary based on customer subsector, facility size, customer size, as well as site-specific requirements or considerations, it’s advised that results from this ISP study report shouldn’t be simply used as a cook book to qualify incentives or eligibility in custom projects administered by IOUs in California.

To ensure cost effectiveness of utility program under CPUC policy framework, a primary principle of the custom programs promoting ratepayer-assisted energy efficiency activities should be to determine what a customer is proposing to implement and then seek to influence the customer to implement a higher-efficiency, higher-cost alternative by providing advice, design expertise and financial incentives. Simply paying incentives to customers for what they are planning to implement independent of the program activity simply because it is more energy efficient than an ISP wouldn’t be considered by CPUC a productive use of ratepayer funding. As the objective of using custom program financial incentives is to motivate a customer to do more, not to simply reward them for their normally occurring or planned business maintenance, upgrade and/or expansion activities, it’s highly recommended that custom project developers first conduct thoughtful and credible reviews of the custom projects in terms of eligibility and influence, while seeking for relevant ISP study results.

In addition, because many of the systems in these facilities have redundant equipment, baseline document should clearly describe that the cost of redundant equipment and systems are not an eligible project cost, future custom project development may consider including such cost information for analysis. This may be an area to include in future project development.

6.13.4 Recommendations

Through the course of developing the survey questionnaire, analyzing the survey results and literature review, we've also summarized the lessons learned and recommendations from this study.

1) Development and advancements in WWT technologies and processes are very slow, quite different from fast moving technologies such as lighting and even HVAC systems. Therefore, a longer time frame such as a three- to five-year period instead of recent 12 months is more appropriate for assessing market trend.
2) As this survey was conducted to study the various technologies within the municipal wastewater treatment industry, it was challenging to develop a survey that was not too lengthy that could well deter respondents from participating in the survey yet detailed enough to provide the information needed to determine ISP or trend toward ISP. Some respondents commented that the survey was too long detailed and took more time than anticipated to complete.
3) In reviewing responses from the survey to determine standard practices, developing a more standardized approach to quantify the results would help determine standard practices easier. For example, in-situ market saturation (or penetration) for a subset of technology alone was not sufficient to indicate the current market trends or standard practice for the technologies. We put more weight on the survey data from vendors and designers and follow-up confirmations with them to identify whether or not an EEM has become standard or common practice or trending toward standard practice based upon the market trend analysis.
4) The original scope of work for this study was developed in 2015, mainly to serve as an update of the old 2006 baseline report. The initial final report was completed in late 2015 for stakeholder reviews. As a result of comprehensive reviews and in-depth discussion with CPUC, we have made a major revision from its previous version, in terms of scope of work, overarching goals, specific technical objectives in consultation with CPUC staff, and the results.
5) In the future, it's important to determine clear scope and objectives of the studies, to understand and to develop survey instrument with questions that will help advance the understanding of market trends of technologies.
6) The understanding of how ISP should be defined and analyzed has evolved as we obtained more clarifies through various collaborative reviews and discussion with the Commission Staff over the course of custom project reviews and various ISP studies between 2015 and 2016. Definitions of the terms such as "Market Saturation (or Penetration)," "Market Trend," "Common Practice" and "Standard Practice" were not quite clear at the beginning, which caused confusion at times, and delays, during the update of this report. The bottom-line is that the existing statewide guidance document on ISP studies initially developed by SCG exhibits inconsistencies in concept descriptions, easily causing confusions among various stakeholders. In addition, the role, purpose, and applicability of ISP studies are unclear to readers and practitioners. It's necessary and critical to review and revise this statewide living document.

6.14 Conclusions

Industry standard practice represents the typical current equipment purchases or commonly used current trending practice absent the program. In this study, we achieved the goals of advancing understanding about technology options and EEM standard practices observed in the municipal waste water treatment (MWWT) sector within PG&E's service territories, and producing information and guidelines for California utility program developers and stakeholders to consider while developing and managing custom and deemed projects. In summary, we have:

- Summarized technology options and energy efficiency measures in WWTPs
- Determined EEM standard practice, or common practices, in municipal WWTPs
- Discussed applicability issues of studying findings to custom or deemed projects.

Table 6.14.1 summarizes the survey results about in-situ adoption of energy efficient technologies in the sector.

Table 6.14.1 Summary of Survey Results on Energy Efficient Technologies Implemented in WWTPs

Energy Efficient Technology Used	# of Plants that Responded	% of Responses (based on 42 plants total)
Variable Speed Drive – Pumps	28	67%
Variable Speed Drive – Blowers	13	31%
Variable Speed Drive – Compressors	4	10%
Automatic Dissolved Oxygen Control System	25	60%
Fine or Ultra-fine Bubble Diffusers	19	45%
Advanced Instrumentation & Control: Supervisory Control and Data Acquisition (SCADA)	25	60%
High Efficiency Blowers	11	26%
Variable Intensity Ultraviolet (UV) Lamps	6	14%
Dose Pacing Control for UV Systems	6	14%
Energy Efficient Sludge Dewatering Systems	12	29%
Energy Efficient Sludge Thickening Systems	14	33%
Advanced Grit Removal Systems	6	14%
# of WWTP That Use at Least One Energy Efficient Technology	*32 out of 42 (76%)*	

Because industry standard practice represents the typical current equipment purchases or commonly used current trending practice absent the program, the survey data gathered from the MWWT plants alone was not always sufficient to indicate the current market trends or common practice for the technologies. By analyzing and reviewing the survey data from vendors and designers and follow-up confirmations with vendors and designers about their understanding of some of the key survey questions, we have identified whether or not an EEM has become standard or common practice or trending toward standard practice based upon the market trend analysis. For example, we asked vendors and designers the question "How often do you recommend (a specific EEM) to your municipal WWT customers," while they were given the opportunities to select among "Less than or ~25% of the time," "~50% of the time," "Greater than 50% of the time," and "Not applicable."

Table 6.14.2 summarizes the technology options and common practices identified for the various WWTP technologies/processes. It is important to note that the common practices for various technologies/processes may vary depending on a variety of factors, such as system types, operating parameters, environmental factors, etc.

Table 6.14.2 Summary of Technology Options and Common Practices in WWTP		
Technology/Process	**Components**	**Technology Options and Common Practices***
Primary Treatment	Screening/Flocculation	• **Conventional** • Chemically Enhanced
Secondary Treatment (Mechanical Aeration)	Aerators	• Brush • Low Speed Surface • High Speed Vertical Turbine • Induced Surface • Submerged Turbine
	Aerator Control	• No Control • Manual Control • Timer Control • **Automatic Control based on Dissolved Oxygen (DO)**
Secondary Treatment (Diffused Aeration)	Blowers	• *Positive Displacement* (Constant/Variable Speed) • Multi-stage Centrifugal • Single-stage Centrifugal (Constant/Variable Speed) • *High Speed Turbo*
	Blower Control	• No Control • Manual Control • Timer Control • **Automatic Control based on Dissolved Oxygen (DO)**
	Diffusers	• Coarse Bubble • **Fine Bubble** • Ultra-Fine Bubble
Disinfection (Ultraviolet)	Lamps	• **Medium-Pressure, High-Intensity** • *Low-Pressure, High-Intensity* • Low-Pressure, Low-Intensity
	Control	• No Control • Manual Control • Control based on Flow • *Control based on Dosage*
Tertiary Treatment (Filtration)	Filtration	• Sand Filter • Membrane Bioreactor • Low-Pressure Membrane • High-Pressure Membrane • Dissolved Air Floatation • Cloth Media • Compressible Media
Sludge Management	Thickening	• Gravity Thickener • Gravity Belt Thickener • Dissolved Air Floatation • Centrifugal • Rotary Drum
	Dewatering	• Centrifuge • Belt Filter Press • Screw Press • Rotary Press • Vacuum Filtration • Drying Beds

Table 6.14.2 Summary of Technology Options and Common Practices in WWTP (continued)		
Process/Technology	**Components**	**Technology Options and Common Practices***
Sludge Management (continued)	Drying	• **Drying Beds** • Solar Drying • Mixed Drying (belt dryer with hot air) • Direct Heat Drying • Indirect Heat Drying
Pumping System	Type of Pump	• Water-driven • Hydraulic-oil driven • Electrical-drive • Pneumatic
	Pumps	• Efficiency varies depending on pump type, flow and head requirements
	Control	• No Control • On/Off Control • Throttle/Bypass Control • **Variable Speed Control**
Plant Control System	Controls	• Manual Control • **Supervisory Control and Data Acquisition (SCADA) System**
Anaerobic Digester	Mixing	• **Mechanical Mixing** • Gas Mixing
Sludge Treatment	Treatment	• Aerobic • **Anaerobic**

* Items in **Bold** are the considered as the common practice, or standard practices for each technology/process largely based on reviewing the survey results from vendors and designers, in corroboration with customers' responses, and the threshold assumptions made in this report. Items in *Italics* are those that are trending towards common (or standard practice). **Readers need to refer to Section 6 for more specific data, analyses, and discussion about what determines industry standard practice.**

This market-based ISP study has advanced the understanding about technology options and EEM common practices observed in the municipal waste water treatment sector within PG&E's service territories, and provided information and guidelines for California utility program developers and stakeholders to consider while developing and managing custom and deemed projects such as Integrated Energy Audits. Because ISP for a specific generic measure may vary based on customer subsector, facility size, customer size, as well as site-specific requirements or considerations, it's advised that results from this ISP study report shouldn't be simply used as a cook book to qualify incentives or eligibility in custom projects administered by IOUs in California. For custom projects, project developers need to first analyze measure eligibility, determine measure code, and document program influence such as alternative measures beyond existing equipment to establish and justify appropriate baselines. Under the existing regulatory framework, a primary principle of the custom programs promoting ratepayer-assisted energy efficiency activities is to determine what a customer is proposing to implement and then seek to influence the customer to implement a higher-efficiency, higher-cost alternative by providing advice, design expertise and financial incentives. Simply paying incentives to customers for what they are planning to implement independent of the program activity simply because it is more energy efficient than an ISP wouldn't be considered by CPUC a productive use of ratepayer funding.

As the objective of using custom program financial incentives is to motivate a customer to do more, not to simply reward them for their normally occurring or planned business maintenance, upgrade and/or expansion activities, it's highly recommended that custom project developers first conduct thoughtful and credible reviews of the custom projects in terms of eligibility and influence, while seeking for relevant ISP study results.

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8 Glossary

CPUC - California Public Utilities Commission. CPUC is a regulatory agency that regulates investor owned utilities in the state of California, including electric power, telecommunications, natural gas and water companies.

Industry Standard Practice (ISP). ISP represents the typical current equipment purchases or commonly used current trending practice absent the program. In this report, we consider a technology/process has become ISP if more than half of the respondents (vendors, designers) indicated that they sell/recommend the measure "greater than 50% of the time," in corroboration with survey results from plants surveys along with literature reviews.

In-situ Market Saturation, or Market Penetration Indicates how well a technology has been diffused within the municipal wastewater industry historically.

Market Trend – What is the technology adoption trend within the municipal wastewater industry for a particular application within the recent few years, with time frame varying by segments.

Trending Toward ISP – in this document, technology/process is considered to be 'trending toward ISP' if more than 30% of the respondents but less than 50% of respondents (mainly from design engineers/vendors survey) indicated that they sell/recommend a particular technology/process "greater than 50% of the time" in recent years.

9 Survey Instruments

This section contains the surveys instruments administered to:

- Municipal wastewater treatment plants
- Wastewater design engineering firms
- Vendors/distributors of wastewater equipment

9.1 Wastewater Treatment Plants Survey

Municipal WWT Baseline (Plants)

1. **Wastewater Treatment Plant Energy Efficiency Survey**

Considering ***municipal*** wastewater treatment (WWT) facilities consume about 2% of energy in the PG&E service territory, PG&E has contracted with BASE Energy, Inc. of San Francisco to perform a survey of WWT facilities with the objective of providing financial incentives for implementation of energy efficient technologies.

This survey will ask a variety of questions on wastewater treatment and energy efficiency at your facility. You have been selected to participate in this survey because of your role at your facility. The information you provide will assist PG&E in better understanding the details of the ***municipal*** wastewater treatment landscape. The survey will take approximately 5 -10 minutes of your time.

Please answer the questions on the following pages regarding your facility.

Municipal WWT Baseline (Plants)

2. **Contact Information**

We'd like to ask some questions about you and contact information for your plant.

1. What is your facility's name?

2. What is your name?

3. What is your work telephone number?

4. What is your email address?

Municipal WWT Baseline (Plants)

3. **General Questions**

5. In Million Gallons per Day (MGD), what are the average and design flow rates at your facility?

6. In Milligrams per Liter (mg/L), what is the average influent Biochemical Oxygen Demand (BOD) level at your facility?

7. In what year was the plant originally constructed?

8. Has your plant had any expansion or retrofit projects since it was initially designed?

If yes, please specify the year of the most recent retrofit or expansion

9. Which of the following energy efficient technologies are being used at your plant? (Please check all that apply)

- [ ] Variable Speed Drives on Pumps
- [ ] Variable Speed Drives on Blowers
- [ ] Variable Speed Drives on Compressors
- [ ] Automated Dissolved Oxygen (DO) sensors to control aeration equipment
- [ ] Fine or Ultra-fine Pore Diffusers in your aeration system
- [ ] Advanced instrumentation and control/SCADA systems
- [ ] High efficiency blowers
- [ ] Variable intensity Ultraviolet (UV) lamps
- [ ] Dose Pacing Control for UV Systems
- [ ] Microwave UV Disinfection
- [ ] Energy Efficient Dewatering Systems (e.g., screw press, rotary press, belt press)
- [ ] Energy Efficient Sludge Thickening Systems (e.g., screw press, rotary press, belt press, gravity tickener)
- [ ] Advanced Grit Removal Systems [AGRS] (e.g., HeadCell, GritKing, PISTAGrit, HydroGrit)
- [ ] Magnetic Ballasted Sedimentation

Other (please specify)

10. What is the treatment level at your facility? (Please check all that apply)

- [ ] Primary
- [ ] Secondary
- [ ] Tertiary

Other (please specify)

Municipal WWT Baseline (Plants)

4. **Primary Treatment**

For the treatment processes that apply to your plant, please check the relevant item/items:

11. Chemically Enhanced Primary Sedimentation or Advanced Primary Treatment: (Please check all that apply)

- [ ] Ferric Chloride
- [ ] Poly Aluminum Chloride (PACl)
- [ ] Aluminum Sulfate (alum)

Other (please specify)

Municipal WWT Baseline (Plants)

5. Secondary Treatment

12. Mechanical Aeration: (Please check all that apply)

- [ ] Brush Aerators
- [ ] Direct Drive Surface Aerators (e.g. vertical turbines)
- [ ] Low Speed Mechanical Aerators

Other (please specify)

13. Diffused Aeration (Please check all that apply)

- [ ] Coarse Bubble
- [ ] Fine Bubble
- [ ] Ultra-fine Bubble

Other (please specify)

14. Hybrid systems: (Please check all that apply)

- [ ] Jet Systems
- [ ] U-tube Aerators
- [ ] Submerged Turbine

Other (please specify)

15. For Diffused aeration, what type of blower is used at your facility? (Please check all that apply)

	Constant Speed	Variable Speed	Inlet Throttled	Discharge Throttled	Inlet Guide Vanes	Discharge Variable Diffuser Vanes
Positive Displacement	☐	☐	☐	☐	☐	☐
Multi-stage Centrifugal	☐	☐	☐	☐	☐	☐
Single-stage Centrifugal	☐	☐	☐	☐	☐	☐
High-speed Turbo Blower	☐	☐	☐	☐	☐	☐

Other (please specify)

16. Biological Treatment: (Please check all that apply)

- [ ] Rotating Biological Contactor
- [ ] Trickling Filter
- [ ] Sequencing Batch Reactor (SBR)
- [ ] Anaerobic biological treatment

Other (please specify)

Municipal WWT Baseline (Plants)

6. Tertiary Treatment

17. Nutrient Removal: (Please check all that apply)

- [ ] Biological Nitrification
- [ ] Biological Denitrification
- [ ] Biological Phosphorus Removal
- [ ] Chemical Phosphorus Removal

Other (please specify)

18. Filtration: (Please check all that apply)

- [ ] Membrane Bioreactors
- [ ] Low-pressure Membrane
- [ ] High-pressure Membrane (Nano filtration or reverse osmosis)
- [ ] Magnetic Ballasted sedimentation
- [ ] Dissolved Air Flotation (DAF)
- [ ] Cloth Media Filter (e.g. Disc Filter, Drum Filter)
- [ ] Compressible Media Filter
- [ ] Sand Filter

Other (please specify)

19. Disinfection: (Please check all that apply)

- [ ] Ultraviolet (UV)
- [ ] Chemical (e.g., Chlorine, Chlorine Dioxide, Liquid Chlorine, Dechlorination)
- [ ] Ozone

Other (please specify)

20. If you have Ultra Violet (UV) disinfection, please specify the lamp and control type below: (Please check all that apply)

	Manual Control	Dose-paced Control	Flow-paced Control
Low-pressure and low-intensity	☐	☐	☐
Medium pressure and high-intensity	☐	☐	☐
Low-pressure and high-output	☐	☐	☐

Other (please specify)

Municipal WWT Baseline (Plants)

7. Sludge Management

21. Sludge Thickening: (Please check all that apply)

- ☐ Gravity Thickeners
- ☐ Gravity Belt Thickeners
- ☐ Dissolved Air Flotation Thickener
- ☐ Rotary Drum Thickeners
- ☐ Centrifugal Thickeners

Other (please specify)

22. Sludge Dewatering: (Please check all that apply)

- [ ] Belt Filter Press Dewatering
- [ ] Centrifuge Dewatering
- [ ] Recessed Chamber Press Dewatering
- [ ] Vacuum Filtration
- [ ] Screw Press Dewatering
- [ ] Rotary Press Dewatering
- [ ] Drying Beds

Other (please specify)

23. Sludge Drying: (Please check all that apply)

- [ ] Sludge drying beds
- [ ] Solar drying
- [ ] Mixed drying (combination of belt dryer with hot air)
- [ ] Direct heat drying
- [ ] Indirect heat drying

Other (please specify)

24. Sludge (biosolids) Digestion: (Please check all that apply)

- [ ] Aerobic - Mechanical Aeraion
- [ ] Aerobic - Fine Bubble Aeraion
- [ ] Aerobic - Coarse Bubble Aeraion
- [ ] Aerobic - Venturi Air Injection
- [ ] Anaerobic - Mechanical Mixing
- [ ] Anaerobic - Gas Mixing
- [ ] Anaerobic - Pumped Jet Mixing

Other (please specify)

Municipal WWT Baseline (Plants)

8. On-site Power Generation

25. Does your plant produce digester gas?

- ◯ YES
- ◯ NO

26. If your plant produces digester gas, how is the digester gas consumed? (Please check all that apply)

- ☐ Flare
- ☐ Power production
- ☐ Boiler

If digester gas is used for power production, what is the production capacity?

27. Is electricity generated on-site at your plant?

- ◯ YES
- ◯ NO

If yes, what is the electricity production capacity?

28. If electricity is generated on-site, what is the fuel source? (check all that apply)

- ☐ Digester gas
- ☐ Natural gas
- ☐ Solar

Other (please specify)

Municipal WWT Baseline (Plants)

9. Maintenance Practices

Please indicate which of the followings measures are the most common maintenance practices performed at your facility:

29. Diffused Aeration: Air distribution piping inspection (e.g., air leak inspection)

- ◯ YES
- ◯ NO

How frequent?

[ ]

30. Diffused Aeration: Calibrating DO sensors

- ◯ YES
- ◯ NO

How frequent?

[ ]

31. Diffused Aeration: Diffuser cleaning (check all that apply)

- ☐ Refiring
- ☐ Silicate-phosphorus washing
- ☐ Alkaline washing
- ☐ Acid washing
- ☐ Detergent washing
- ☐ High pressure water jetting
- ☐ Flaming
- ☐ High and low pressure water hosing
- ☐ Withholding influent
- ☐ Sandblasting
- ☐ Chlorine washing
- ☐ Steam cleaning
- ☐ Gasoline washing
- ☐ Drying
- ☐ Ultrasonic
- ☐ Air bumping

How often?

[ ]

32. Mechanical Aeration : Inspect and clean impeller

◯ YES

◯ NO

How frequent?

33. Mechanical Aeration: Check for unusual vibration

◯ YES

◯ NO

How frequent?

34. Mechanical Aeration: Change gear reducer oil and lubricate motor bearings

◯ YES

◯ NO

How frequent?

35. UV Disinfection: Clean fouling on UV lamp sleeves

☐ OMC – Online Mechanical Cleaning (e.g. O-ring brush)

☐ OCC – Online Chemical Cleaning

How frequent?

36. UV Disinfection: Calibrating UV intensity sensors

◯ YES

◯ NO

How frequent?

37. Is the treated effluent reclaimed and reused at your facility or neighboring facilities (e.g. for agriculture, landscaping, cleaning, etc.)?

◯ YES

◯ NO

If yes, what percent of the treated effluent is reclaimed?

38. In the comment field below, please provide any feedback that you may have in regards to this survey:

Municipal WWT Baseline (Plants)

10. **Thank You!!**

Thank you very much for taking the time to complete this survey! Your responses will assist PG&E in developing programs that will make municipal wastewater treatment plants more energy efficient!

If you have any questions or experience any difficulties returning this survey, please contact Sandra Chow at (415) 543-1600.

9.2 Survey for Wastewater Design Engineers

Municipal WWT Baseline (Design Engineering Firms)

1. **Wastewater Treatment Plant Energy Efficiency Survey - Design Engineering Firms**

Considering that ***municipal*** wastewater treatment (WWT) facilities consume about 2% of energy in the PG&E service territory, PG&E has contracted with BASE Energy, Inc. of San Francisco to perform a survey of ***municipal*** WWT facilities with the following objectives:

- Determine current industry standard practices in these facilities
- Determine the extent of penetration of energy efficient technologies in these facilities
- Determine a baseline for consideration of providing incentive for energy efficient improvements

This survey will ask a variety of questions on your design practices with ***municipal*** WWT facilities. The information you provide will assist PG&E in better understanding the details of the municipal wastewater treatment landscape. The survey will take approximately 5-10 minutes of your time.

Municipal WWT Baseline (Design Engineering Firms)

2. **Contact Information**

1. What is your firm's name?

2. What is your name?

3. What is your work telephone number?

4. What is your e-mail address?

Municipal WWT Baseline (Design Engineering Firms)

3. **General Questions**

5. In your design practice, do you emphasize *energy efficiency* features of a process/technology?

- ◯ Yes
- ◯ No

Comments

6. How would you rank your municipal WWT customers' major criteria for selecting equipment with similar technical performance?

	Unimportant	Somewhat Important	Important	Very Important	Most Important	N/A
Preference in Equipment/Brand	◯	◯	◯	◯	◯	◯
Initial Capital Cost	◯	◯	◯	◯	◯	◯
Energy Efficiency	◯	◯	◯	◯	◯	◯
Estimated Operating Cost (Non-energy related)	◯	◯	◯	◯	◯	◯
Estimated Maintenance Involved	◯	◯	◯	◯	◯	◯
Available Utility Incentives	◯	◯	◯	◯	◯	◯

Comments

7. When a new technology/process/equipment enters the market, when are you more likely to recommend this to your municipal WWT customers?

- ◯ <3 years after the technology is marketed
- ◯ Approximately 3 years after the technology is marketed
- ◯ 3-5 years after the technology is marketed
- ◯ 5+ years after the technology is marketed

Comment

8. How often do you recommend the following energy efficient technologies to your municipal WWT customers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
Variable Speed Drive (VSD) on Pumps				
Variable Speed Drive (VSD) on Blowers				
Variable Speed Drive (VSD) on Other Equipment				
Automatic Dissolved Oxygen Control System				
Fine/Ultra-fine Pore Diffusers				
Advanced Controls/SCADA Systems				
Energy Efficient Pumps				
Energy Efficient Blowers				
Variable Intensity UV Lamps				
Dose Pacing Control for UV Systems				
Microwave UV Disinfection				
Energy Efficient Dewatering Systems (e.g. screw press, rotary press, belt press)				
Energy Efficient Sludge Thickening Systems (e.g. screw press, rotary press, belt press, gravity thickener)				
Advanced Grit Removal Systems (e.g. HeadCell, GritKing, PISTAGrit, HydroGrit)				

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
Nanofiltration or Reverse Osmosis	○	○	○	○
Magnetic Ballasted Sedimentation	○	○	○	○

Other (please specify)

9. In the case of retrofit or facility expansion, for each of the following technologies, which are your customers more likely to do when selecting equipment?

	Purchase equipment based on lowest price available	Purchase same equipment as existing	Purchase more energy efficient equipment	N/A
Pumps	○	○	○	○
Blowers	○	○	○	○
Aeration Diffusers	○	○	○	○
UV System Equipment	○	○	○	○
Sludge Dewatering System	○	○	○	○
Sludge Thickening System	○	○	○	○
Other Equipment	○	○	○	○

Comments

Municipal WWT Baseline (Design Engineering Firms)

4. **Primary Treatment**

The questions in this section pertain to primary treatment of wastewater. If your firm is not involved with this stage of the process, please skip to the next section.

10. How often do your municipal WWT customers select the following primary treatment processes?

	Never	Rarely	Sometimes	Often	Always	N/A
Conventional Primary Treatment (screening, settling, clarification)	◯	◯	◯	◯	◯	◯
Chemically Enhanced Primary Treatment (adding chemicals such as metal salts/polymers to sedimentation - coagulation + flocculation)	◯	◯	◯	◯	◯	◯

Comments

Municipal WWT Baseline (Design Engineering Firms)

5. Secondary Treatment

The questions in this section pertain to secondary treatment level of wastewater. Please only answer questions that apply, skip ones that don't.

11. Does the size of the municipal wastewater treatment plant affect the type of secondary treatment system that you recommend?

◯ Yes

◯ No

Please elaborate on how the size of the plant affects the system recommended:

12. How often do you design for wastewater treatment plants of the following sizes?

	Never	Rarely	Sometimes	Often	Always	N/A
Less than or 1 MGD	○	○	○	○	○	○
1 MGD to 5 MGD	○	○	○	○	○	○
5 MGD to 10 MGD	○	○	○	○	○	○
Greater than 10 MGD	○	○	○	○	○	○

13. In the boxes below, please indicate the influent flow (MGD) ranges used in your practice to classify municipal WWTPs into Small, Medium, and Large sized plants?

Influent flow range for ***Small*** plants (in MGD)	
Influent flow range for ***Medium*** plants (in MGD)	
Influent flow range for ***Large*** plants (in MGD)	
We do not have any size classification	
Comments	

14. What type of secondary treatment options do you typically propose for your municipal WWT customers? (Please check all that apply)

- [ ] Surface aerators (i.e. vertical turbines, brush, etc)
- [ ] Diffused aeration system
- [ ] Hybrid systems (i.e. jet aerators, u-tube aerators)
- [ ] Trickling filters
- [ ] Rotating biological contactor
- [ ] Bioreactor systems
- [ ] Anaerobic biological treatment
- [ ] Other (please specify)

15. How important do your municipal WWT customers see the following criteria in selecting the type of secondary treatment system?

	Unimportant	Somewhat Important	Important	Very Important	Most Important	N/A
Lowest Initial Capital Cost	◯	◯	◯	◯	◯	◯
Past Experience with Similar Facilities	◯	◯	◯	◯	◯	◯
Energy Efficiency of System	◯	◯	◯	◯	◯	◯
Lowest Operating Cost (Non-energy related)	◯	◯	◯	◯	◯	◯

Other (please specify)

Municipal WWT Baseline (Design Engineering Firms)

6. **Surface Aeration Systems**

This section includes questions in regards to selecting surface aerators. Please skip this section if it does not apply to your design practice.

16. How often do you recommend the following surface aerators to your municipal WWT customers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time
Vertical Turbine Aerators	◯	◯	◯
Brush Aerators	◯	◯	◯
Low Speed Mechanical Aerators	◯	◯	◯
Jet Aerators	◯	◯	◯

Other (please specify)

17. Which type of surface aerator control do your customers choose?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
No Control (aerators need to operate continuously)	○	○	○	○
Manual Control (customer monitors dissolved oxygen and manually turns on/off aerators)	○	○	○	○
Time Control	○	○	○	○
Automatic Control (based on measured dissolved oxygen level)	○	○	○	○

Comments

Municipal WWT Baseline (Design Engineering Firms)

7. Diffused Aeration Systems

This section includes questions regarding the selection of diffused aeration systems. Please answer questions that apply; skip ones that don't.

18. How often do you recommend the following diffusers to your municipal WWT customers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
Coarse Bubble Diffusers	○	○	○	○
Fine Bubble Diffusers	○	○	○	○
Ultra-Fine Bubble Diffusers	○	○	○	○

Other (please specify)

19. How often do you recommend the following types of blowers to your customers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
Positive Displacement (Constant-Speed)	◯	◯	◯	◯
Positive Displacement (Variable-Speed)	◯	◯	◯	◯
Multi-stage Centrifugal	◯	◯	◯	◯
Single-stage Centrifugal (Constant-Speed)	◯	◯	◯	◯
Single-stage Centrifugal (Variable-Speed)	◯	◯	◯	◯
High-Speed Turbo Blower	◯	◯	◯	◯

Other (please specify)

20. How often is automatic dissolved oxygen control recommended?

◯ Less than or ~25% of the time

◯ ~50% of the time

◯ Greater than 50% of the time

Other (please specify)

Municipal WWT Baseline (Design Engineering Firms)

8. **Tertiary Treatment**

The questions in this section pertain to tertiary treatment of wastewater in the facility. Please answer questions that apply; skip ones that don't.

21. With the current drought in California, how many more municipal WWT customers express interest in installing systems to recycle/re-use water compared to non-drought years?

- ◯ No, it's been the same as before
- ◯ Yes, ~10% more
- ◯ Yes, ~25% more
- ◯ Yes, ~50% more

Comments

22. What type of tertiary treatment options do you typically recommend to your municipal WWT customers? (Please check all that apply)

- ☐ Nutrient Removal
- ☐ Filtration
- ☐ Disinfection
- ☐ Other (please specify)

Municipal WWT Baseline (Design Engineering Firms)

9. **Nutrient Removal** (*Please skip if Not Applicable*)

23. If *Nutrient Removal* was selected previously, which of the following do you typically recommend to those customers? (Please check all that apply)

- ☐ Biological Nitrification
- ☐ Biological De-nitrification
- ☐ Biological Phosphorus Removal
- ☐ Chemical Phosphorus Removal
- ☐ Other (please specify)

Municipal WWT Baseline (Design Engineering Firms)

10. **Filtration** (*Please skip if Not Applicable*)

24. If *Filtration* was selected previously, which of the following do you typically recommend to those customers? (Please check all that apply)

- ☐ Sand Bed Filters
- ☐ Membrane Bioreactors
- ☐ Low-Pressure Membrane Filters
- ☐ High-Pressure Membrane Filters (i.e. nano filtration, reverse osmosis)
- ☐ Dissolved Air Flotation
- ☐ Cloth Media Filters (e.g. Disc Filter, Drum Filter)
- ☐ Compressible Media Filters
- ☐ Other (please specify)

Municipal WWT Baseline (Design Engineering Firms)

11. **Disinfection** *(Please skip if Not Applicable)*

25. If *Disinfection* was selected previously, which of the following do you typically recommend to those customers? (Please check all that apply)

- ☐ Ultraviolet Disinfection
- ☐ Ozone
- ☐ Chemical
- ☐ Other (please specify)

Municipal WWT Baseline (Design Engineering Firms)

12. **Ultraviolet Disinfection**

The questions in this section pertain to Ultraviolet Disinfection for tertiary treatment of wastewater. Please skip this section if it doesn't apply.

26. How often do you recommend the following types of UV lamps to your municipal WWT customers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
Medium-Pressure UV lamps	○	○	○	○
Low-Pressure, High-Intensity UV lamps	○	○	○	○
Low-Pressure, Low-Intensity UV lamps	○	○	○	○

Other (please specify)

27. For projects where UV systems are recommended, what type of control does your customer typically select?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
No Control (on all the time)	○	○	○	○
Manual Control (facility manually controls banks of lamps in operation)	○	○	○	○
Control based on Flow	○	○	○	○
Control based on Dosage	○	○	○	○

Other (please specify)

Municipal WWT Baseline (Design Engineering Firms)

13. **Sludge Management**

The questions in this section pertain to Sludge Management. Please skip this section if it doesn't apply.

28. How often do you recommend the following *sludge thickening* equipment in your municipal WWT designs?

	Never	Rarely	Sometimes	Often	Always	N/A
Gravity Thickener	○	○	○	○	○	○
Gravity Belt Thickener	○	○	○	○	○	○
Dissolved Air Floatation Thickener	○	○	○	○	○	○
Rotary Drum Thickener	○	○	○	○	○	○
Centrifugal Thickener	○	○	○	○	○	○

Other (please specify)

29. How often do you recommend the following *sludge dewatering* equipment in your municipal WWT designs?

	Never	Rarely	Sometimes	Often	Always	N/A
Centrifuge	○	○	○	○	○	○
Belt Filter Press	○	○	○	○	○	○
Screw Press	○	○	○	○	○	○
Rotary Press	○	○	○	○	○	○
Vacuum Filtration	○	○	○	○	○	○
Drying Beds	○	○	○	○	○	○

Other (please specify)

30. How often do you recommend the following *sludge drying* technologies in your municipal WWT designs?

	Never	Rarely	Sometimes	Often	Always	N/A
Sludge Drying Beds	○	○	○	○	○	○
Solar Drying	○	○	○	○	○	○
Mixed Drying (combination of belt dryer with hot air)	○	○	○	○	○	○
Direct Heat Drying	○	○	○	○	○	○
Indirect Heat Drying	○	○	○	○	○	○

Other (please specify)

31. For projects that include sludge digestion, how often do you recommend each of the following?

	Never	Rarely	Sometimes	Often	Always	N/A
Aerobic Digestion	○	○	○	○	○	○
Anaerobic Digestion	○	○	○	○	○	○

32. For projects utilizing *Aerobic Digestion*, which aeration do you typically recommend? (Please check all that apply)

- ☐ Mechanical Aeration
- ☐ Coarse Bubble Aeration
- ☐ Fine Bubble Aeration
- ☐ Other (please specify)

33. For projects utilizing *Anaerobic Digestion*, which mixing do you typically recommend? (Please check all that apply)

- ☐ Mechanical Mixing
- ☐ Gas Mixing
- ☐ Pumped Jet Mixing
- ☐ Other (please specify)

34. Which of the following systems do you usually recommend for Anaerobic Digestion projects? (Please check all that apply)

- ☐ Upflow Packed-Bed Attached Growth Reactor
- ☐ Upflow Attached Growth Anaerobic
- ☐ Expanded-Bed Reactor (Anaerobic Expanded Bed Reactor)
- ☐ Downflow Attached Growth Process
- ☐ Anaerobic Contact Process
- ☐ Anaerobic Sequencing Batch Reactor (ASBR)
- ☐ Upflow Anaerobic Sludge Blanket (UASB)
- ☐ Anaerobic Fluidized Bed Reactor (ANFLOW)
- ☐ Other (please specify)

35. In the comment field below, please provide any feedback that you may have in regards to this survey:

Municipal WWT Baseline (Design Engineering Firms)

14. **Thank You!**

Thank you very much for taking the time to complete this survey! Your responses will assist PG&E in developing programs that will make municipal wastewater treatment plants more energy efficient!

If you have any questions or experience any difficulties returning this survey, please contact Sandra Chow at (415) 543-1600.

9.3 Survey for Wastewater Vendors/Distributors

Municipal WWT Baseline (Vendors and distributers)

1. **Wastewater Treatment Plant Energy Efficiency Survey - Vendors and Distributers**

You have been selected to take part of this survey due to your role at your company. PG&E (Pacific Gas and Electric company) has contracted with BASE Energy, Inc. of San Francisco to perform a survey of equipment suppliers for *municipal* wastewater treatment (WWT) facilities. Your input will help PG&E determine the level of financial incentives for installation of energy efficient wastewater technologies.

This survey will ask a variety of questions on your recently sold equipment to *municipal* WWT facilities. The information you provide will assist PG&E in better understanding the details of the *municipal* wastewater treatment landscape. The survey will take approximately 5-10 minutes of your time.

Municipal WWT Baseline (Vendors and distributers)

2. **Contact Information**

1. What is your company's name?

2. What is your name?

3. What is your work telephone number?

4. What is your e-mail address?

Municipal WWT Baseline (Vendors and distributers)

3. **General Questions**

The following section will ask some general questions about energy efficient equipment sale.

5. Do you identify, emphasize and promote energy efficiency features of the products in your sales to municipal WWTPs?

- [ ] Yes
- [ ] No

Comments

6. How would you rank your customers' major criteria for selecting equipment with similar technical performance?

	Unimportant	Somewhat Important	Important	Very Important	Most Important	N/A
Preference in Equipment/Brand	○	○	○	○	○	○
Initial Capital Cost	○	○	○	○	○	○
Energy Efficiency	○	○	○	○	○	○
Estimated Operating Cost (Non-energy related)	○	○	○	○	○	○
Estimated Maintenance Involved	○	○	○	○	○	○
Available Utility Incentives	○	○	○	○	○	○

Comments

7. When a new technology process/equipment enters the market, when are your customers more likely to purchase these technologies?

○ <3 years after the technology is marketed

○ Approximately 3 years after the technology is marketed

○ 3-5 years after the technology is marketed

○ 5+ years after the technology is marketed

Comment

Municipal WWT Baseline (Vendors and distributers)

4. Energy Efficient Technologies

8. Which of the following energy efficient technologies for municipal WWTPs are commonly purchased by your customers? (Check all that apply)

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
Variable Speed Drive (VSD) on Pumps	○	○	○	○
Variable Speed Drive (VSD) on Blowers	○	○	○	○
Variable Speed Drive (VSD) on Other Equipment	○	○	○	○
Automatic Dissolved Oxygen Control System	○	○	○	○
Fine/Ultra-fine Pore Diffusers	○	○	○	○
Advanced Controls/SCADA Systems	○	○	○	○
Energy Efficient Pumps	○	○	○	○
Energy Efficient Blowers	○	○	○	○
Variable Intensity Ultraviolet (UV) Lamps	○	○	○	○
Microwave UV Disinfection	○	○	○	○
Dose Pacing Control for UV Systems	○	○	○	○
Energy Efficient Dewatering Systems (e.g. screw press, rotary press, belt press)	○	○	○	○

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
Energy Efficient Sludge Thickening Systems (e.g. screw press, rotary press, belt press, gravity thickener)	◯	◯	◯	◯
Advanced Grit Removal Systems [AGRS] (e.g. HeadCell, GritKing, PISTAGrit, HydroGrit)	◯	◯	◯	◯
Magnetic Ballasted Sedimentation	◯	◯	◯	◯

Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

5. **Purchasing Decisions**

9. In the case of retrofit or facility expansion, for each of the following technologies, which are your customers more likely to do when selecting equipment?

	Purchase equipment based on lowest price available	Purchase same equipment as existing	Purchase more energy efficient equipment	N/A
Pumps	◯	◯	◯	◯
Blowers	◯	◯	◯	◯
Aeration Diffusers	◯	◯	◯	◯
UV System Equipment	◯	◯	◯	◯
Sludge Dewatering System	◯	◯	◯	◯
Sludge Thickening Systems	◯	◯	◯	◯
Other Equipment	◯	◯	◯	◯

Comments

Municipal WWT Baseline (Vendors and distributers)

6. **Primary Treatment**

The question in this section pertain to primary treatment of wastewater. Please only answer if this applies, skip if it doesn't.

10. How often do your municipal WWT customers select the following primary treatment processes?

	Never	Rarely	Sometimes	Often	Always	N/A
Conventional Primary Treatment (screening, settling, clarification)	○	○	○	○	○	○
Chemically Enhanced Primary Treatment (adding chemicals such as metal salts/polymers to sedimentation - coagulation + flocculation)	○	○	○	○	○	○

Comments

Municipal WWT Baseline (Vendors and distributers)

7. **Secondary Treatment**

The questions in this section pertain to secondary treatment level of wastewater. Please only answer questions that apply, skip ones that don't.

11. Does the size of the wastewater treatment plant affect the type of secondary treatment system in your sale?

○ Yes

○ No

Please elaborate on how the size of the WWTP affects the secondary treatment system selected:

12. How often do you provide equipment/services for municipal wastewater treatment plants of the following sizes?

	Never	Rarely	Sometimes	Often	Always	N/A
Less than or 1 MGD						
1 MGD to 5 MGD						
5 MGD to 10 MGD						
Greater than 10 MGD						

13. In the boxes below, please indicate the influent flow (MGD) ranges used in your practice to classify municipal WWTPs into Small, Medium, and Large sized plants?

Influent flow range for **Small** plants (in MGD)

Influent flow range for **Medium** plants (in MGD)

Influent flow range for **Large** plants (in MGD)

We do not have any size classification

Comment

Municipal WWT Baseline (Vendors and distributers)

8. Secondary Treatment (continued)

14. What type of secondary treatment options are most commonly purchased by your municipal WWTP customers? (Please check all that apply)

- [ ] Surface aerators (i.e. vertical turbines, brush, etc.)
- [ ] Diffused aeration system
- [ ] Hybrid systems (i.e. jet aerators, u-tube aerators)
- [ ] Trickling filters
- [ ] Rotating biological contactor
- [ ] Bioreactor systems
- [ ] Anaerobic biological treatment
- [ ] Other (please specify)

15. How important do your customers see the following criteria in selecting the type of secondary treatment system to purchase?

	Unimportant	Somewhat Important	Important	Very Important	Most Important	N/A
Lowest Initial Capital Cost	○	○	○	○	○	○
Past Experience with Similar Facilities	○	○	○	○	○	○
Energy Efficiency of System	○	○	○	○	○	○
Lowest Operating Cost	○	○	○	○	○	○

Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

9. **Surface Aeration Systems**

This section includes questions in regards to selecting surface aerators. Please skip this section if it does not apply to your line of products that are offered.

16. What type of secondary treatment equipment is most commonly purchased by your municipal WWTP customers? (Check all that apply)

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time
Vertical Turbine Aerators	◯	◯	◯
Brush Aerators	◯	◯	◯
Low Speed Mechanical Aerators	◯	◯	◯
Jet Aerators	◯	◯	◯

Other (please specify)

17. Which type of surface aerator control do your customers choose?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time	N/A
No Control (aerators need to operate continuously)	◯	◯	◯	◯
Manual Control (customer monitors dissolved oxygen and manually turns on/off aerators)	◯	◯	◯	◯
Time Control	◯	◯	◯	◯
Automatic Control (based on measured dissolved oxygen level)	◯	◯	◯	◯

Comments

Municipal WWT Baseline (Vendors and distributers)

10. **Diffused Aeration Systems**

This section includes questions regarding the selection of diffused aeration systems. Please answer questions that apply; skip ones that don't.

18. How often do your municipal WWTP customers purchase the following diffusers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time
Coarse Bubble Diffusers	○	○	○
Fine Bubble Diffusers	○	○	○
Ultra-Fine Bubble Diffusers	○	○	○

Other (please specify)

19. How often do your customers purchase the following types of blowers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time
Positive Displacement (Constant-Speed)	○	○	○
Positive Displacement (Variable-Speed)	○	○	○
Multi-stage Centrifugal	○	○	○
Single-stage Centrifugal (Constant-Speed)	○	○	○
Single-stage Centrifugal (Variable-Speed)	○	○	○
High-Speed Turbo Blower	○	○	○

Other (please specify)

20. How often is automatic dissolved oxygen control purchased by your customers?

- ○ Less than or ~25% of the time
- ○ ~50% of the time
- ○ Greater than 50% of the time

Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

11. **Tertiary Treatment**

The questions in this section pertain to tertiary treatment of wastewater in the facility. Please answer questions that apply; skip ones that don't.

21. With the current drought in California, how many more municipal WWT customers express interest in installing systems to recycle/re-use water compared to non-drought years?

- ◯ No, it's been the same as before
- ◯ Yes, ~10% more
- ◯ Yes, ~25% more
- ◯ Yes, ~50% more
- ◯ Other (please specify)

22. What type of tertiary treatment options are most commonly purchased by your municipal WWTP customers? (Please check all that apply)

- ☐ Nutrient Removal
- ☐ Filtration
- ☐ Disinfection
- ☐ Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

12. **Nutrient Removal**

The question in this section pertain to Nutrient Removal. Please skip this section if it doesn't apply.

23. If *Nutrient Removal* was selected previously, which of the following are most commonly purchased by your customers? (Please check all that apply)

- [ ] Biological Nitrification
- [ ] Biological De-nitrification
- [ ] Biological Phosphorus Removal
- [ ] Chemical Phosphorus Removal
- [ ] Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

13. **Filtration**

The question in this section pertain to Filtration. Please skip this section if it doesn't apply.

24. If *Filtration* was selected previously, which of the following are most commonly purchased by your customers? (Please check all that apply)

- [ ] Sand Bed Filters
- [ ] Membrane Bioreactors
- [ ] Low-Pressure Membrane Filters
- [ ] High-Pressure Membrane Filters (i.e. nano filtration, reverse osmosis)
- [ ] Dissolved Air Flotation
- [ ] Cloth Media Filters (i.e. Disc Filter, Drum Filter)
- [ ] Compressible Media Filters
- [ ] Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

14. **Disinfection**

The question in this section pertain to Disinfection. Please skip this section if it doesn't apply.

25. If *Disinfection* was selected previously, which of the following are most commonly selected by your customers? (Please check all that apply)

- [ ] Ultraviolet Disinfection
- [ ] Ozone
- [ ] Chemical
- [ ] Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

15. **Ultraviolet Disinfection**

The questions in this section pertain to Ultraviolet Disinfection for tertiary treatment of wastewater. Please skip this section if it doesn't apply.

26. How often are the following types of UV lamps purchased by your municipal WWTP customers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time
Medium-Pressure UV lamps	○	○	○
Low-Pressure, High-Intensity UV lamps	○	○	○
Low-Pressure, Low-Intensity UV lamps	○	○	○

Other (please specify)

27. For projects where UV systems are purchased, what type of control is most commonly purchased by your customers?

	Less Than or ~25% of the Time	~50% of the Time	Greater than 50% of the Time
No Control (on all the time)	○	○	○
Manual Control (facility manually controls banks of lamps in operation)	○	○	○
Control based on Flow	○	○	○
Control based on Dosage	○	○	○

Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

16. **Sludge Management**

The questions in this section pertain to Sludge Management. Please skip this section if it doesn't apply.

28. How often are *sludge thickening* equipment purchased by your municipal WWTP customers?

	Never	Rarely	Sometimes	Often	Always
Gravity Thickener	○	○	○	○	○
Gravity Belt Thickener	○	○	○	○	○
Dissolved Air Floatation Thickener	○	○	○	○	○
Rotary Drum Thickener	○	○	○	○	○
Centrifugal Thickener	○	○	○	○	○

Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

17. **Sludge Management** *(continued)*

29. How often are *sludge dewatering* equipment purchased by your customers?

	Never	Rarely	Sometimes	Often	Always
Centrifuge	○	○	○	○	○
Belt Filter Press	○	○	○	○	○
Screw Press	○	○	○	○	○
Rotary Press	○	○	○	○	○
Vacuum Filtration	○	○	○	○	○
Drying Beds	○	○	○	○	○

Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

18. Sludge Management (*continued*)

30. How often are *sludge drying* technologies purchased by your customers?

	Never	Rarely	Sometimes	Often	Always
Solar Drying	○	○	○	○	○
Mixed Drying (combination of belt dryer with hot air)	○	○	○	○	○
Direct Heat Drying	○	○	○	○	○
Indirect Heat Drying	○	○	○	○	○

Other (please specify)

Municipal WWT Baseline (Vendors and distributers)

19. Sludge Digestion

31. For projects that include sludge digestion, how often each of the following is purchased by your municipal WWTP customers?

	Never	Rarely	Sometimes	Often	Always
Aerobic Digestion	○	○	○	○	○
Anaerobic Digestion	○	○	○	○	○

Municipal WWT Baseline (Vendors and distributers)

20. **Anaerobic Digestion** (*Please skip this section if this does not apply*)

32. Which of the following systems are most commonly purchased by your customers for Anaerobic Digestion projects? (Please check all that apply)

- ☐ Upflow Packed-Bed Attached Growth Reactor
- ☐ Upflow Attached Growth Anaerobic
- ☐ Expanded-Bed Reactor (Anaerobic Expanded Bed Reactor)
- ☐ Downflow Attached Growth Process
- ☐ Anaerobic Contact Process
- ☐ Anaerobic Sequencing Batch Reactor (ASBR)
- ☐ Upflow Anaerobic Sludge Blanket (UASB)
- ☐ Anaerobic Fluidized Bed Reactor (ANFLOW)
- ☐ Other (please specify)

33. For projects utilizing Anaerobic Digestion, what type of mixing is most commonly purchased by your customers? (Please check all that apply)

- ☐ Mechanical Mixing
- ☐ Gas Mixing
- ☐ Pumped Jet Mixing
- ☐ Other (please specify)

34. In the comment field below, please provide any feedback that you may have in regards to this survey:

Municipal WWT Baseline (Vendors and distributers)

21. Thank you for your responses!

Thank you very much for taking the time to complete this survey! Your responses will assist PG&E in developing programs that will make municipal wastewater treatment plants more energy efficient!

If you have any questions or experience any difficulties returning this survey, please contact Sandra Chow at (415) 543-1600.

10 Survey Results

10.1 Wastewater Treatment Plants Responses

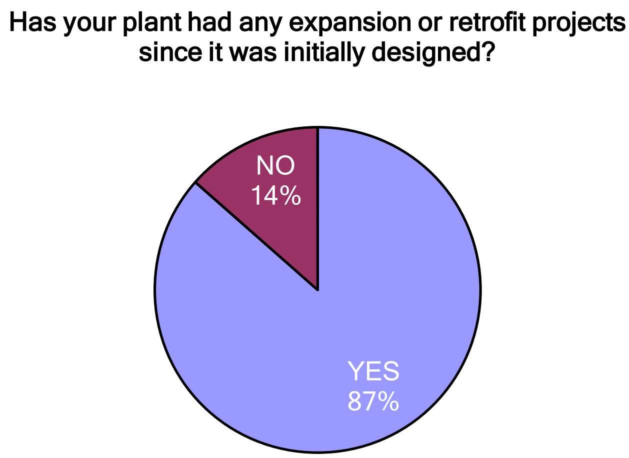


Figure 9.1-1 Has Plant Has Any Expansion/Retrofit Projects since Initial Design (Based on 37 out of 42 surveyed plants)

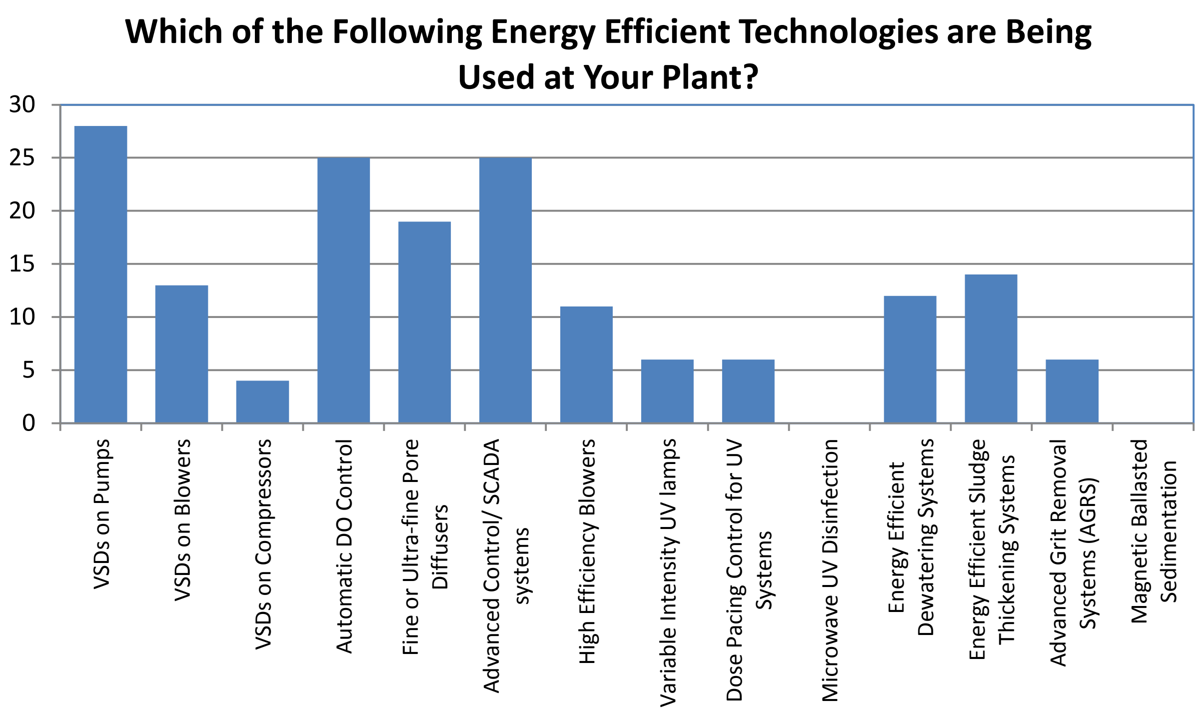


Figure 9.1-2 Energy Efficient Technologies Used at Plant (Based on the responses from 32 out of 42 surveyed plants)

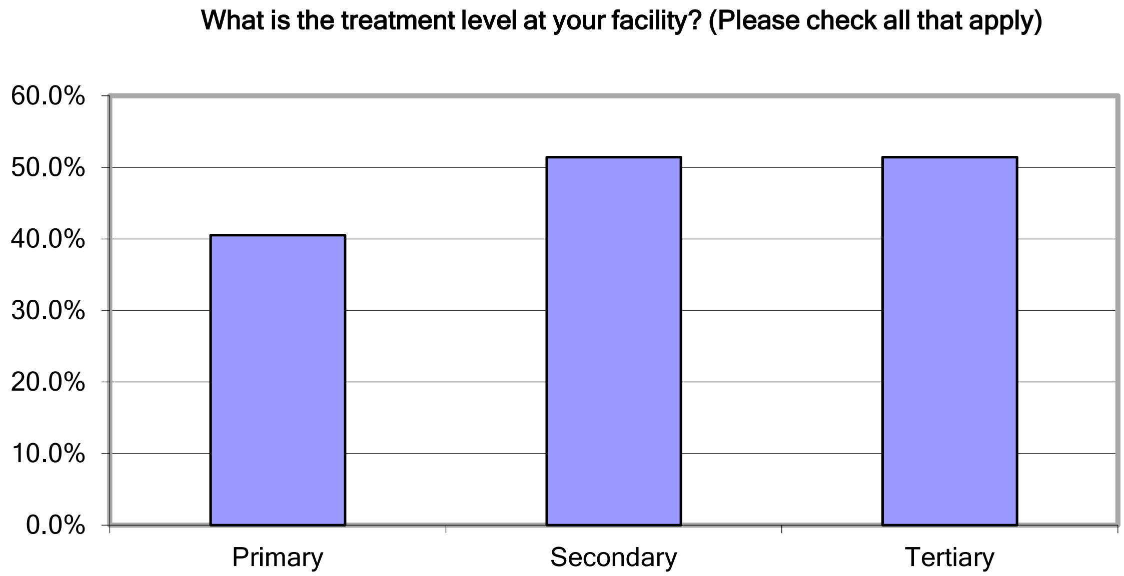


Figure 9.1-3 Treatment Level at Plant (Based on 37 out of 42 surveyed plants)

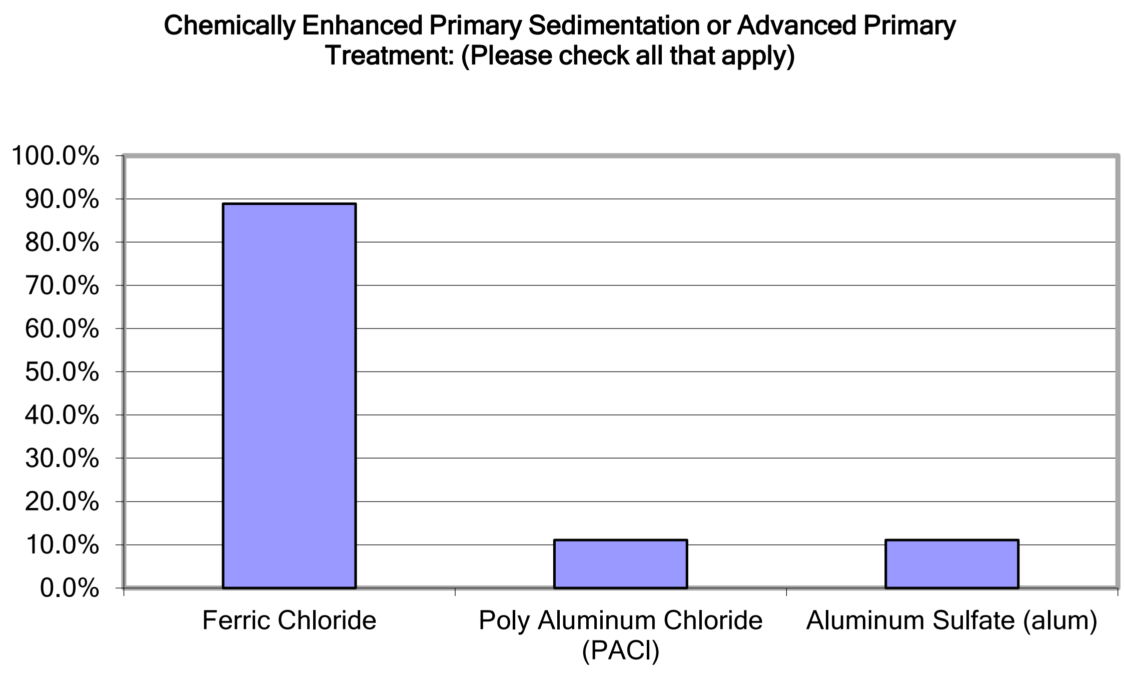


Figure 9.1-4 Chemically Enhanced Primary Treatment (Based on 9 responses out of 42 surveyed plants)

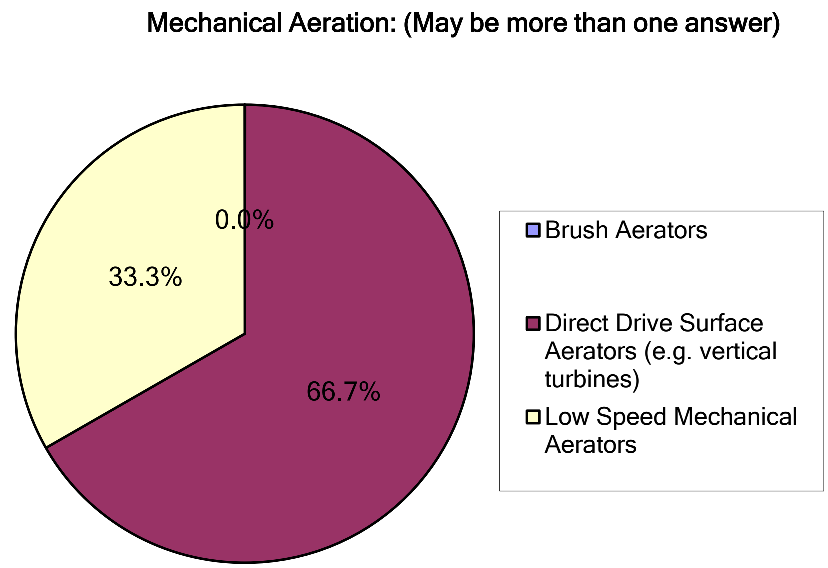


Figure 9.1-5 Mechanical Aerators Used (Based on 9 responses out of 42 surveyed plants)

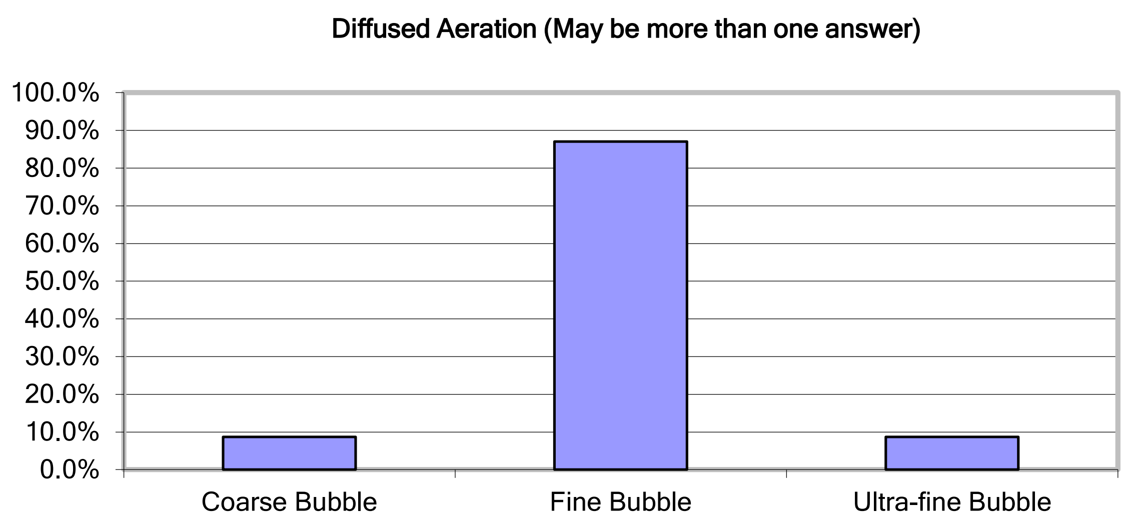


Figure 9.1-6 Diffusers Used (Based on 23 responses out of 42 surveyed plants)

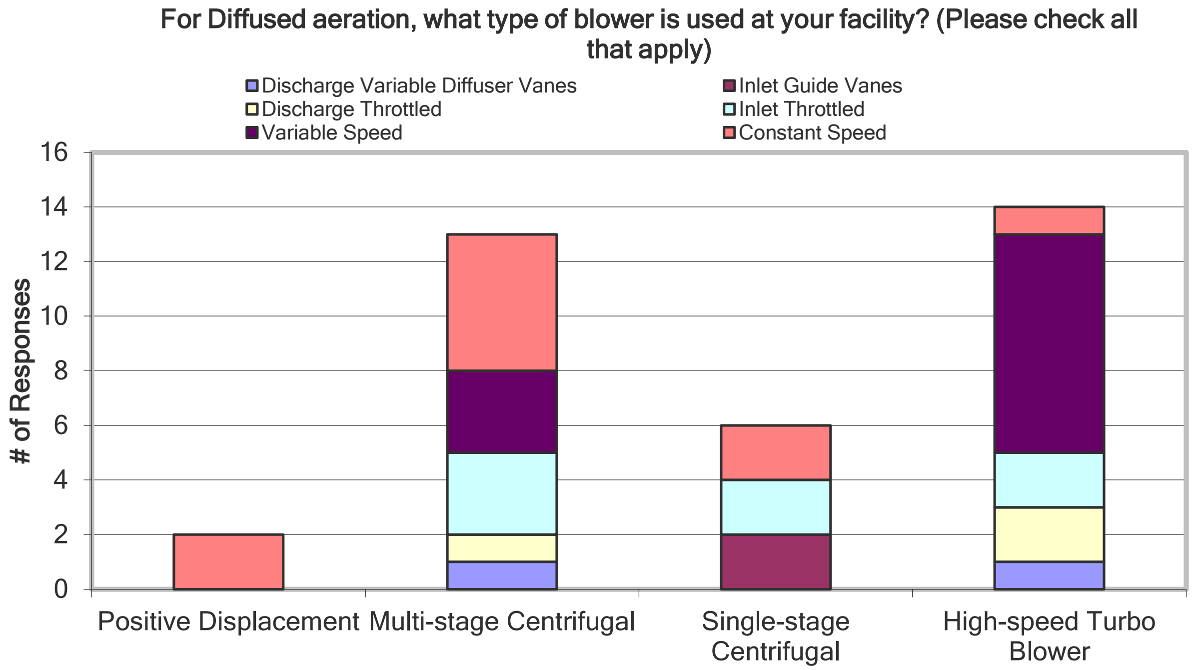


Figure 9.1-7 Blowers Used for Diffused Aeration System (Based on 24 responses out of 42 surveyed plants)

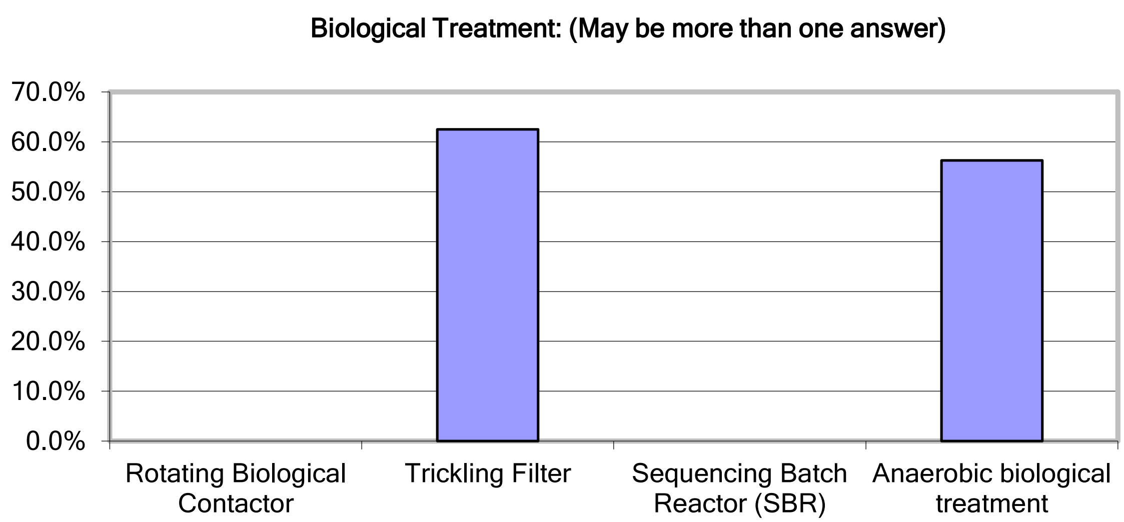


Figure 9.1-8 Biological Treatment (Based on 16 responses out of 42 surveyed plants)

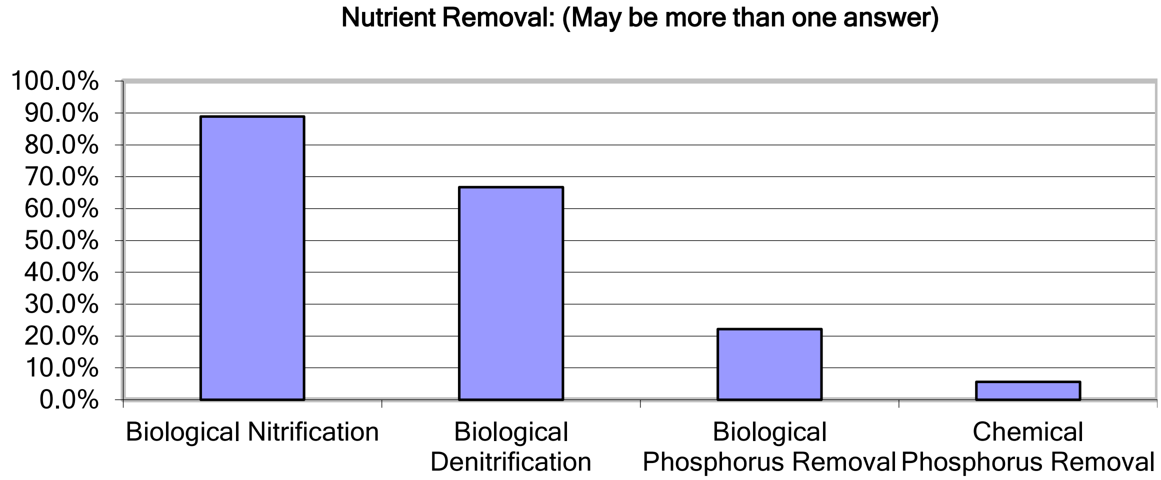


Figure 9.1-9 Nutrient Removal (Based on 15 responses out of 42 surveyed plants)

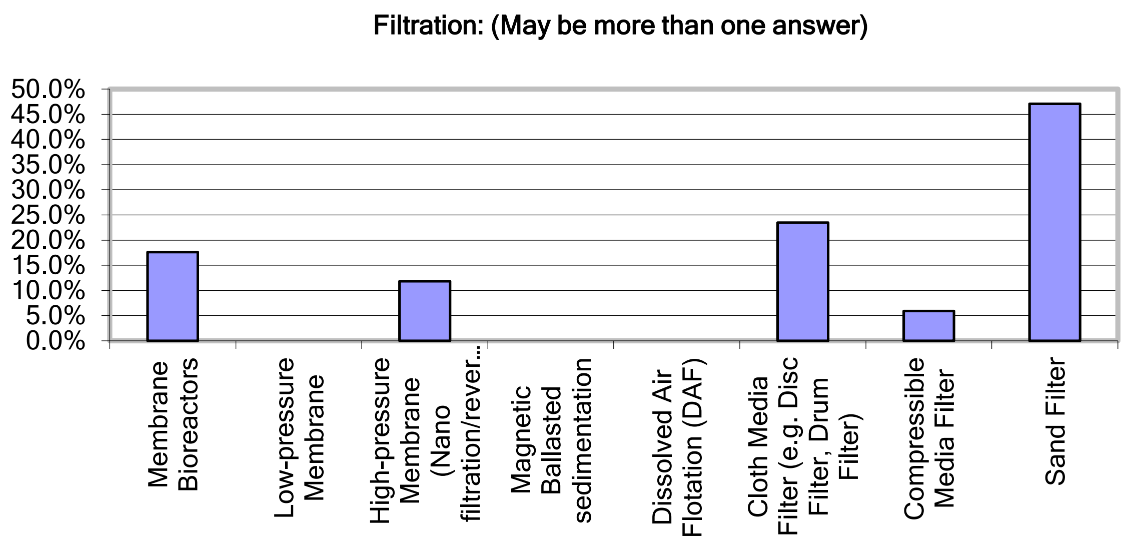


Figure 9.1-10 Filtrations (Based on 18 responses out of 42 surveyed plants)

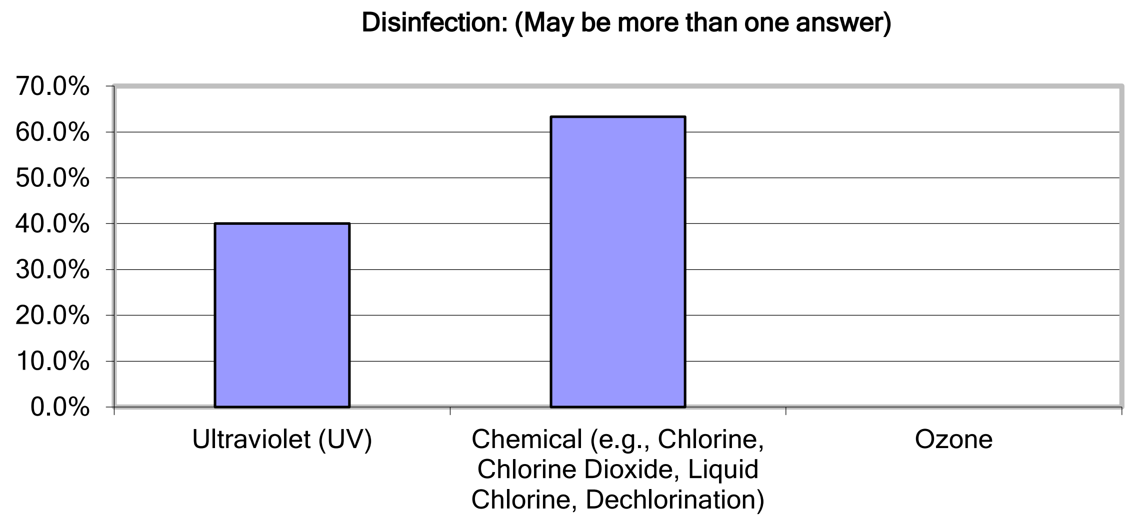


Figure 9.1-11 Disinfection (Based on 30 responses out of 42 surveyed plants)

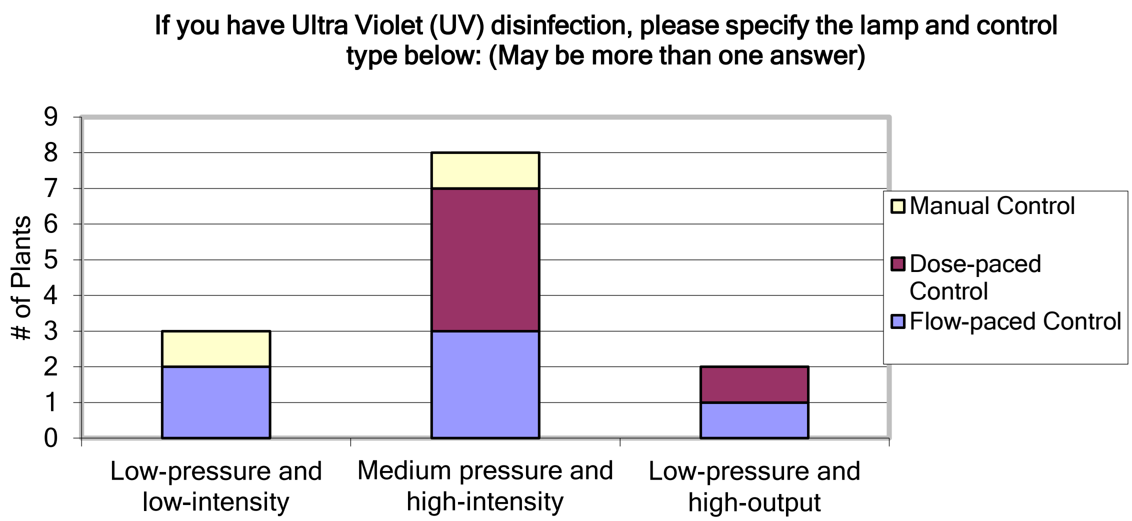


Figure 9.1-12 UV Lamps (Based on 10 responses out of 42 surveyed plants)

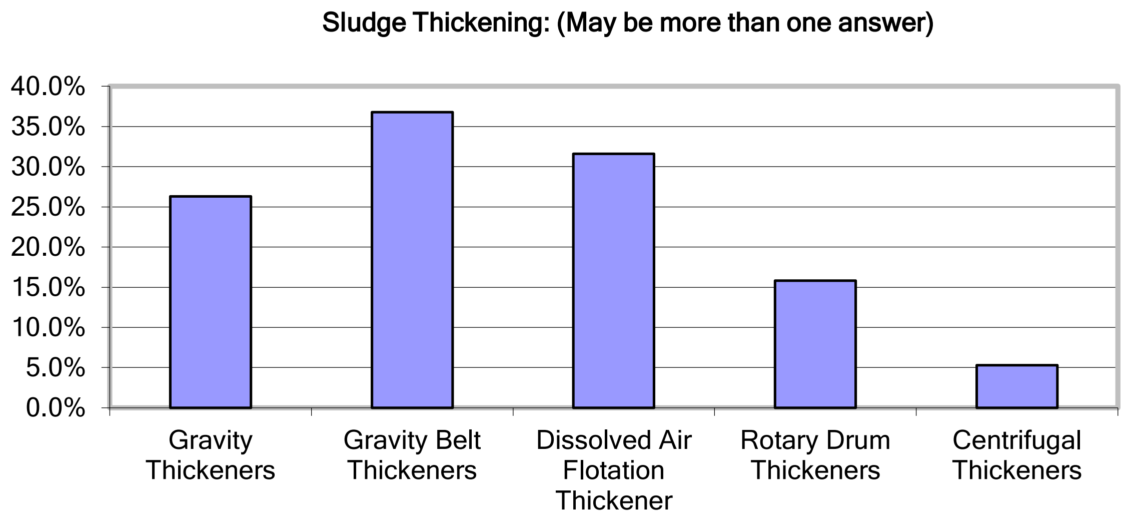


Figure 9.1-13 Sludge Thickening (Based on 19 responses out of 42 surveyed plants)

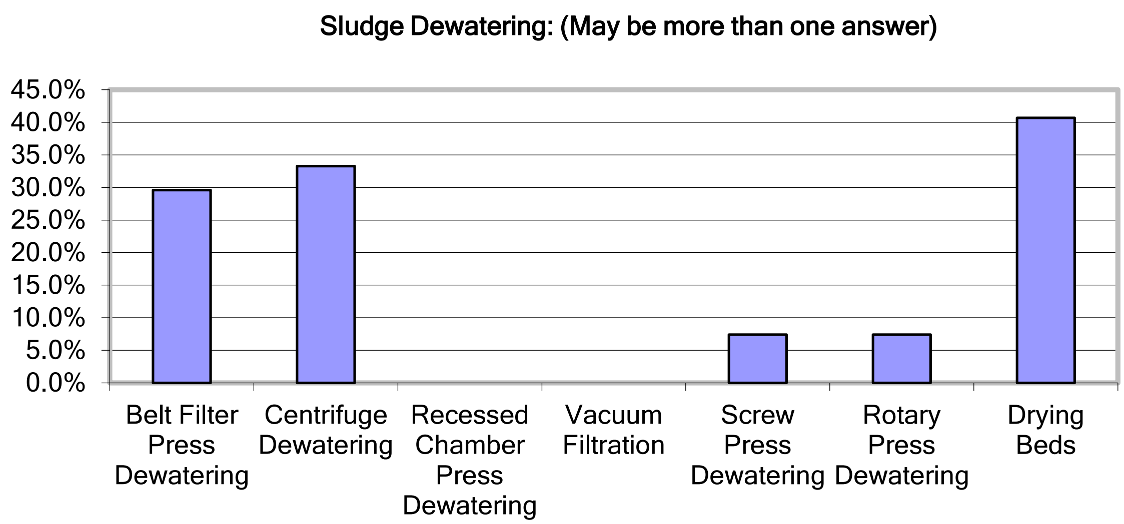


Figure 9.1-14 Sludge Dewatering (Based on 27 responses out of 42 surveyed plants)

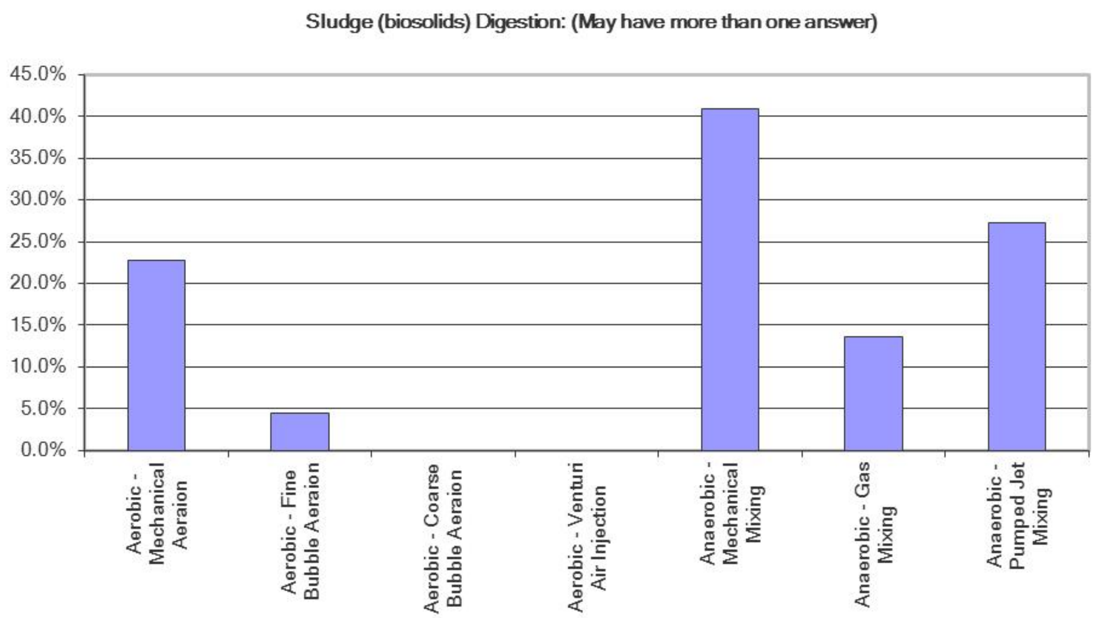


Figure 9.1-15 Sludge Digestion (Based on 26 responses out of 42 surveyed plants)

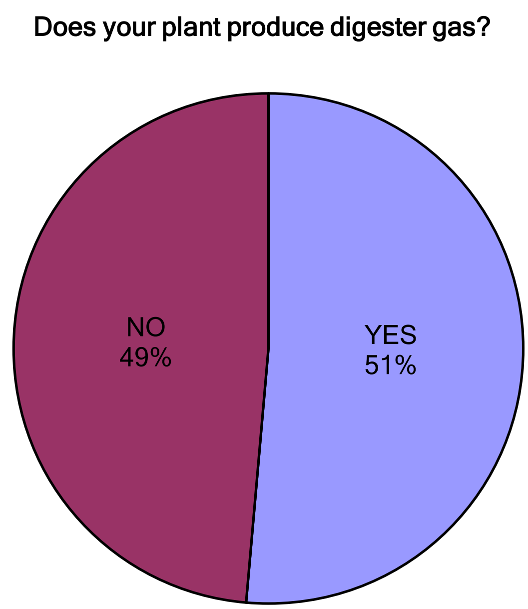


Figure 9.1-16 Digester Gas Produced? (Based on 37 responses out of 42 surveyed plants)

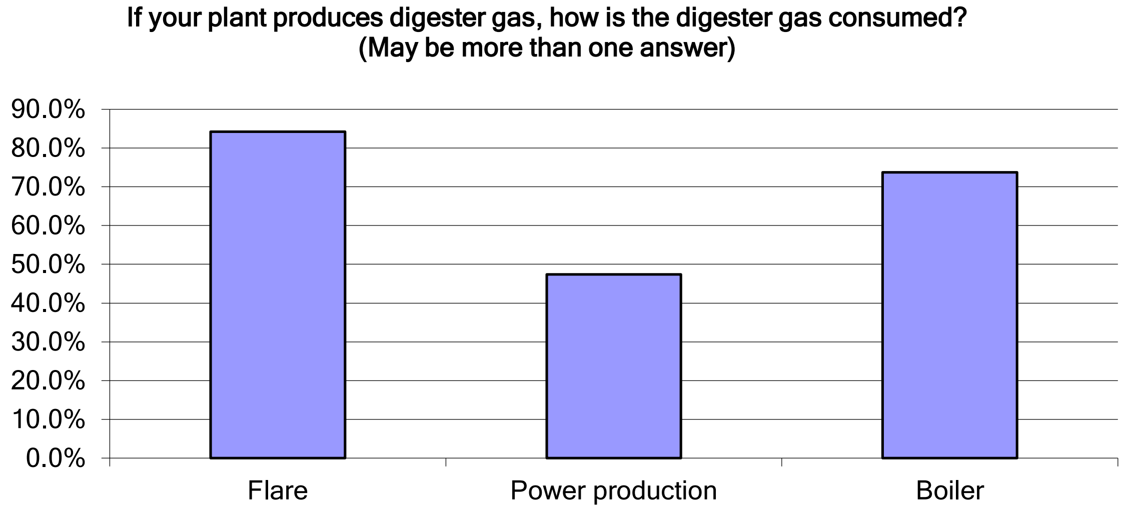


Figure 9.1-17 How is Digester Gas Consumed? (Based on 19 responses out of 42 surveyed plants)

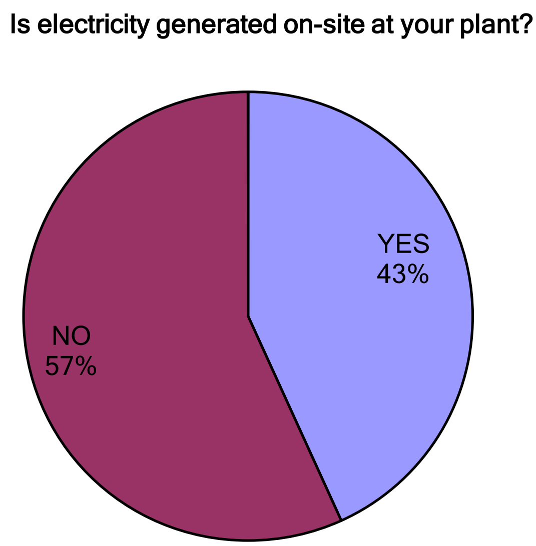


Figure 9.1-18 Is Electricity Generated On-Site? (Based on 37 responses out of 42 surveyed plants)

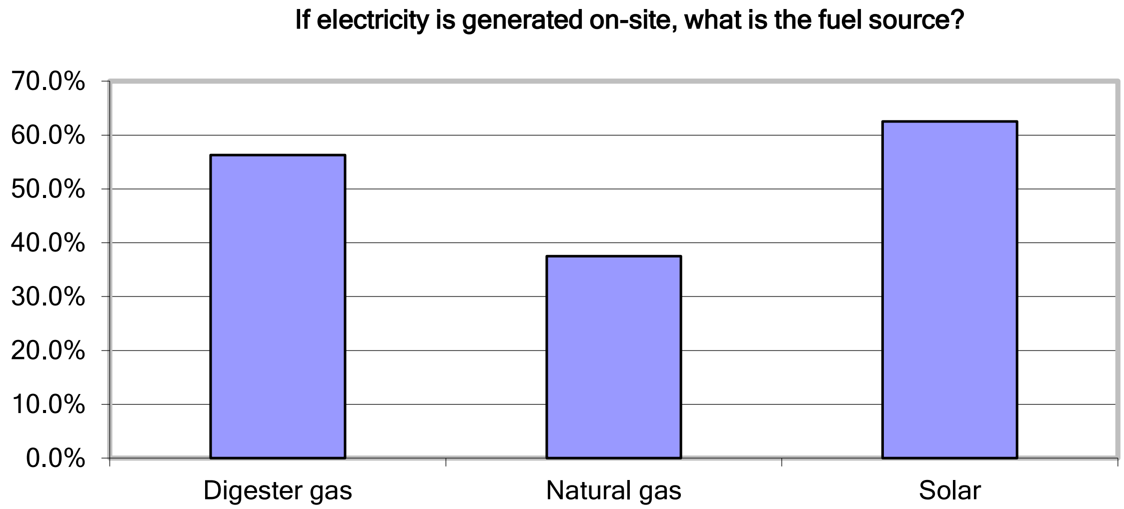


Figure 9.1-19 Fuel Source for Electricity Generated On-Site (Based on 16 responses out of 42 surveyed plants)

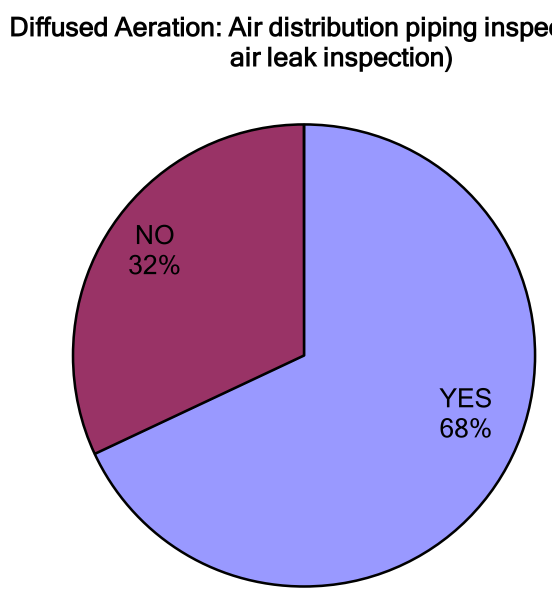


Figure 9.1-20 Diffused Aeration – Air Distribution Piping Inspection (Based on 25 responses out of 42 surveyed plants)

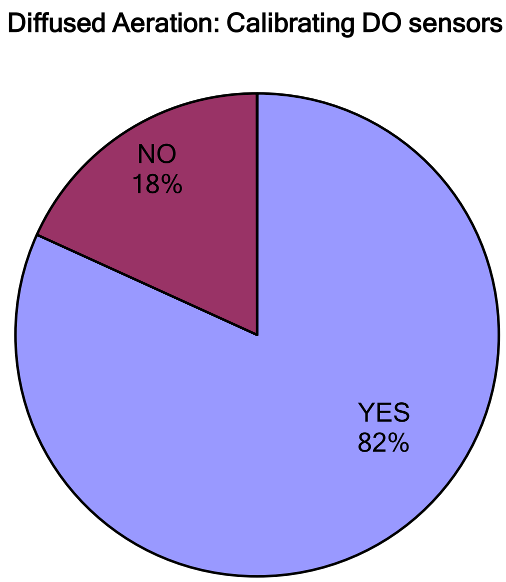


Figure 9.1-21 Diffused Aeration – Calibrating DO Sensors (Based on 22 responses out of 42 surveyed plants)

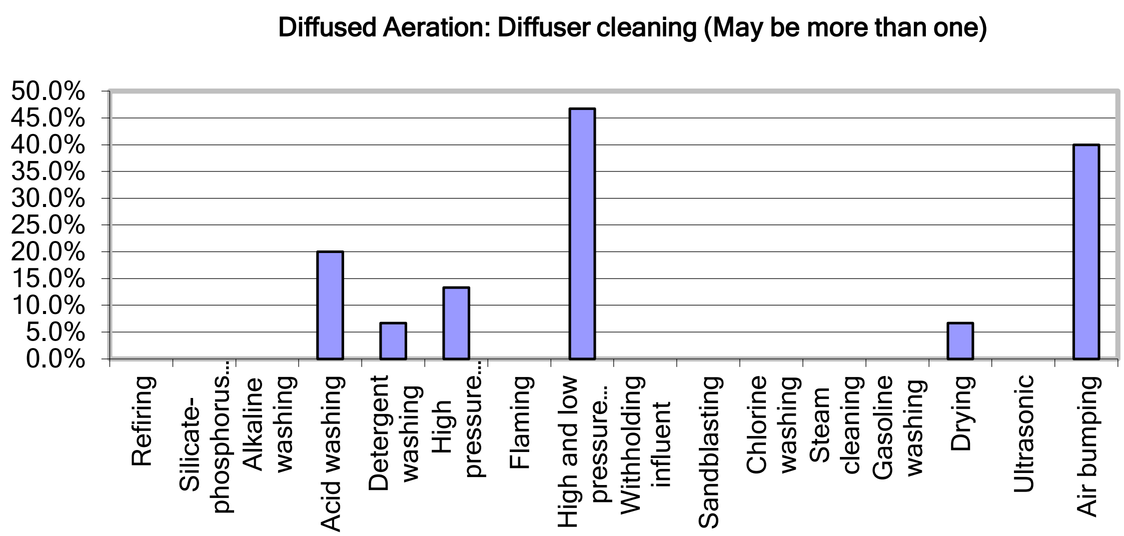


Figure 9.1-22 Diffused Aeration – Cleaning Diffusers (Based on 15 responses out of 42 surveyed plants)

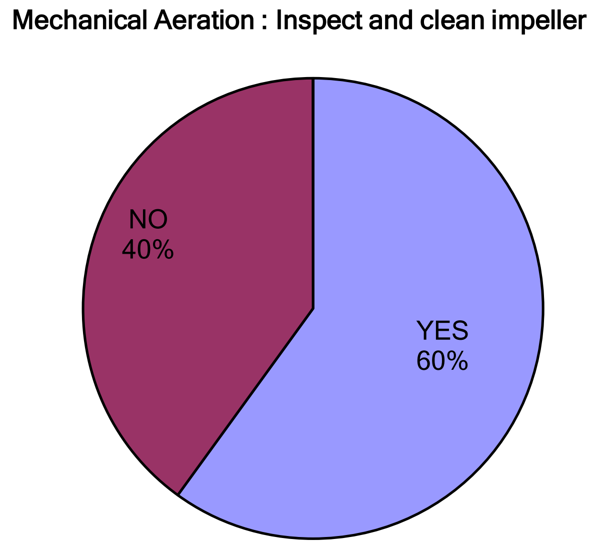


Figure 9.1-23 Mechanical Aeration – Inspect and Clean Impeller (Based on 15 responses out of 42 surveyed plants)

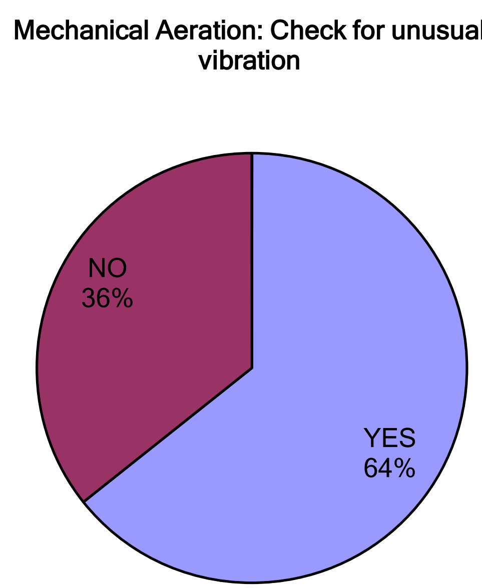


Figure 9.1-24 Mechanical Aeration – Check for Unusual Vibration (Based on 14 responses out of 42 surveyed plants)

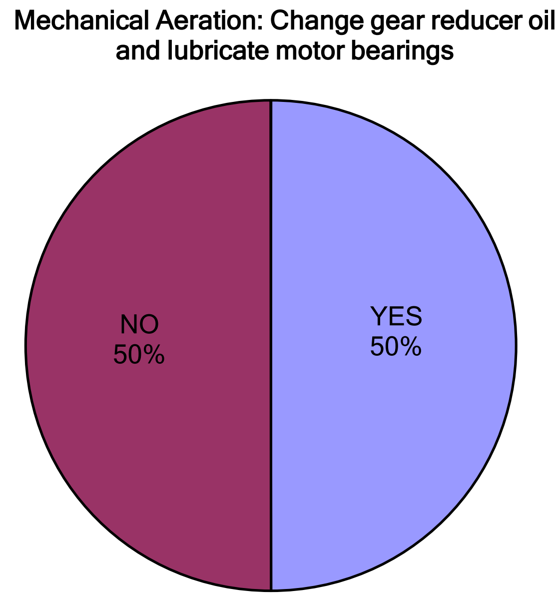


Figure 9.1-25 Mechanical Aeration – Change Gear Reducer Oil & Lubricate Bearings (Based on 14 responses out of 42 surveyed plants)

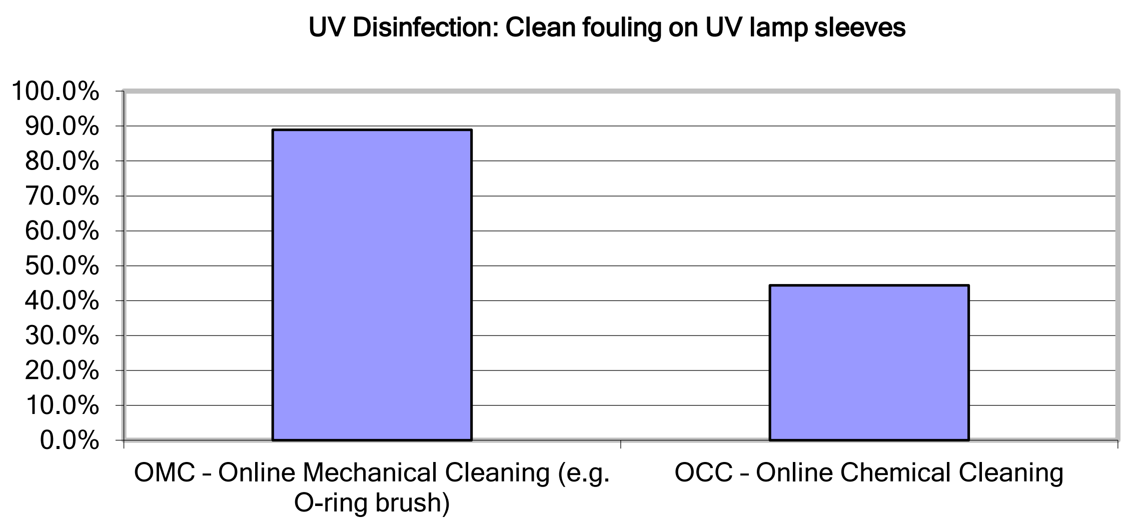


Figure 9.1-26UV Disinfection System – Clean Fouling on UV Lamp Sleeves (Based on 9 responses out of 42 surveyed plants)

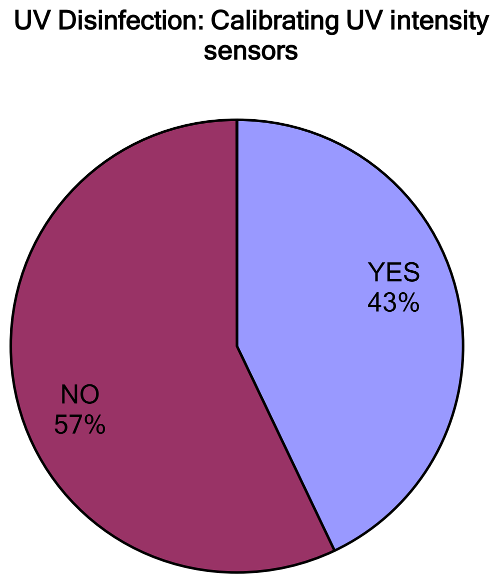


Figure 9.1-27UV Disinfection System – Calibrating UV Intensity Sensors (Based on 14 responses out of 42 surveyed plants)

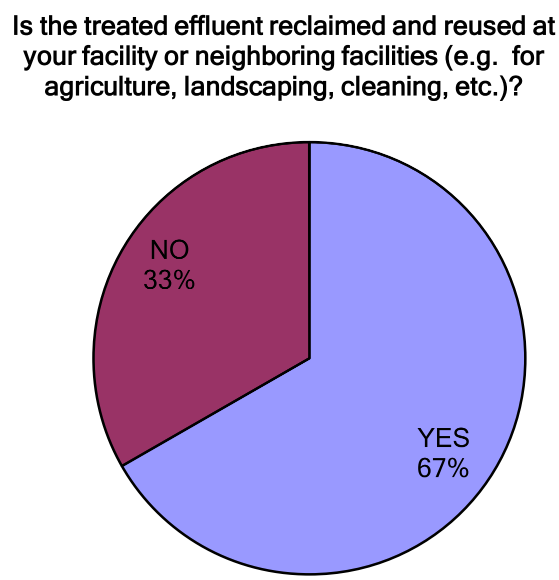
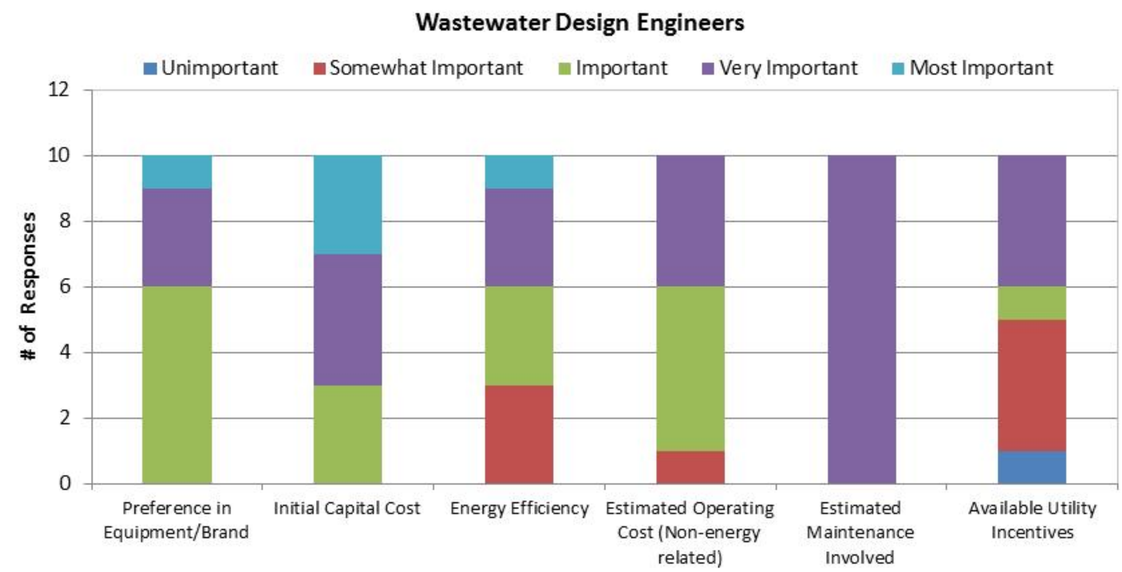


Figure 9.1-28 Is Treated Effluent Reclaimed and Reused? (Based on 36 responses out of 42 surveyed plants)

10.2 Wastewater Design Firm and Vendors/Distributors Responses

Included in this section are the results for the more general energy efficiency questions. Other results from the Wastewater Design Firm and Vendors/Distributors surveys will be included as a separate file.



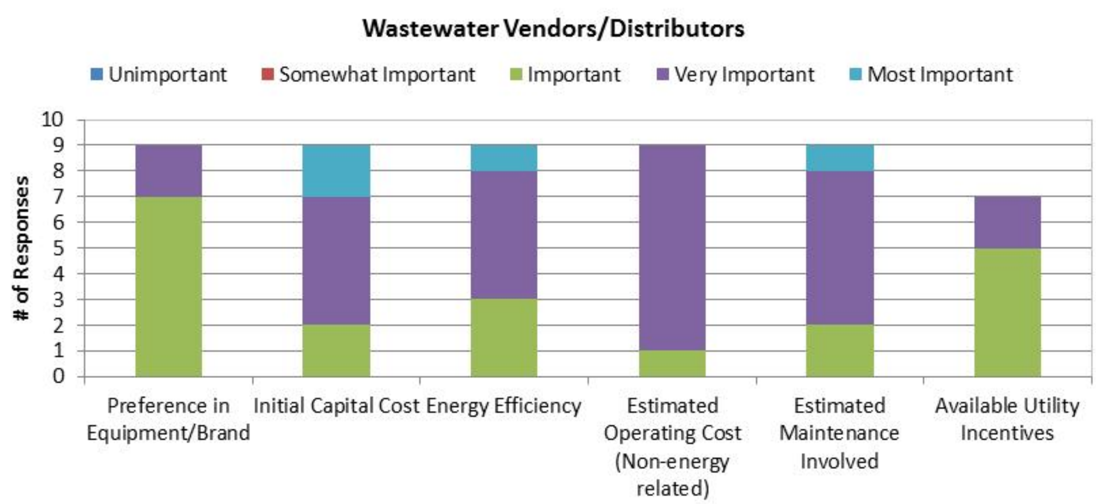


Figure 9.2-1 How Would You Rank Your Customers' Major Criteria in Selecting Equipment with Similar Technical Performance?

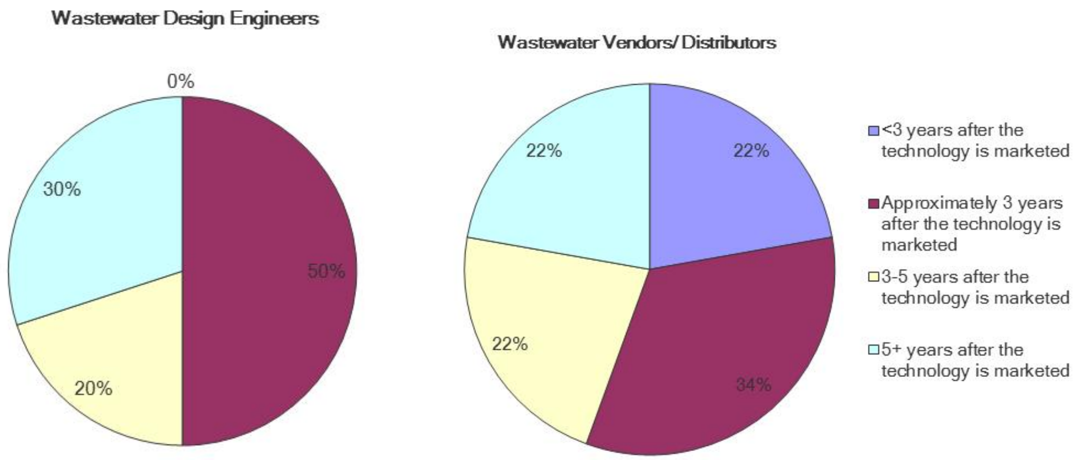
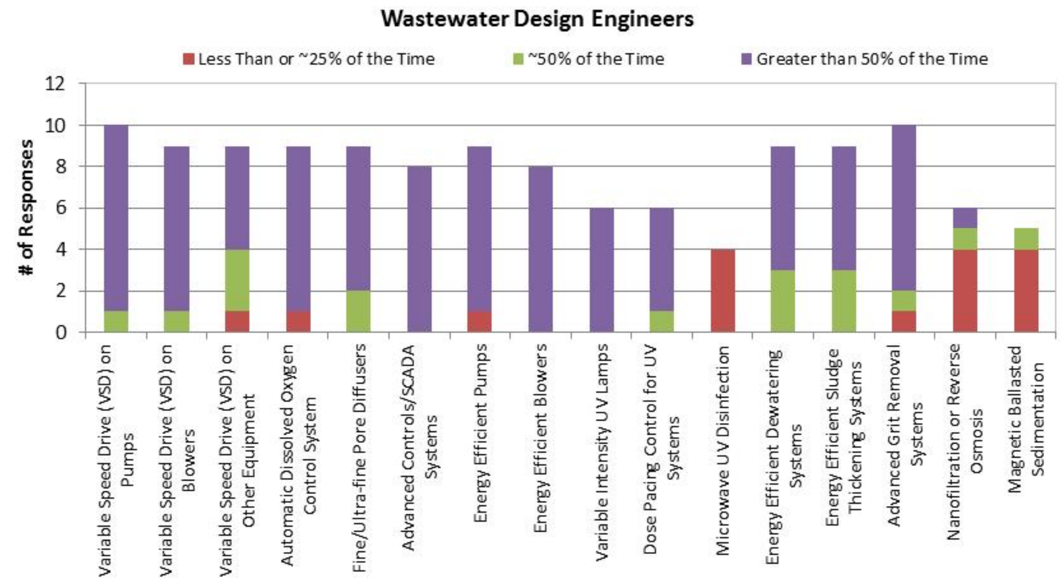


Figure 9.2-2 When a new technology process/equipment enters the market, when are your customers more likely to purchase these technologies?



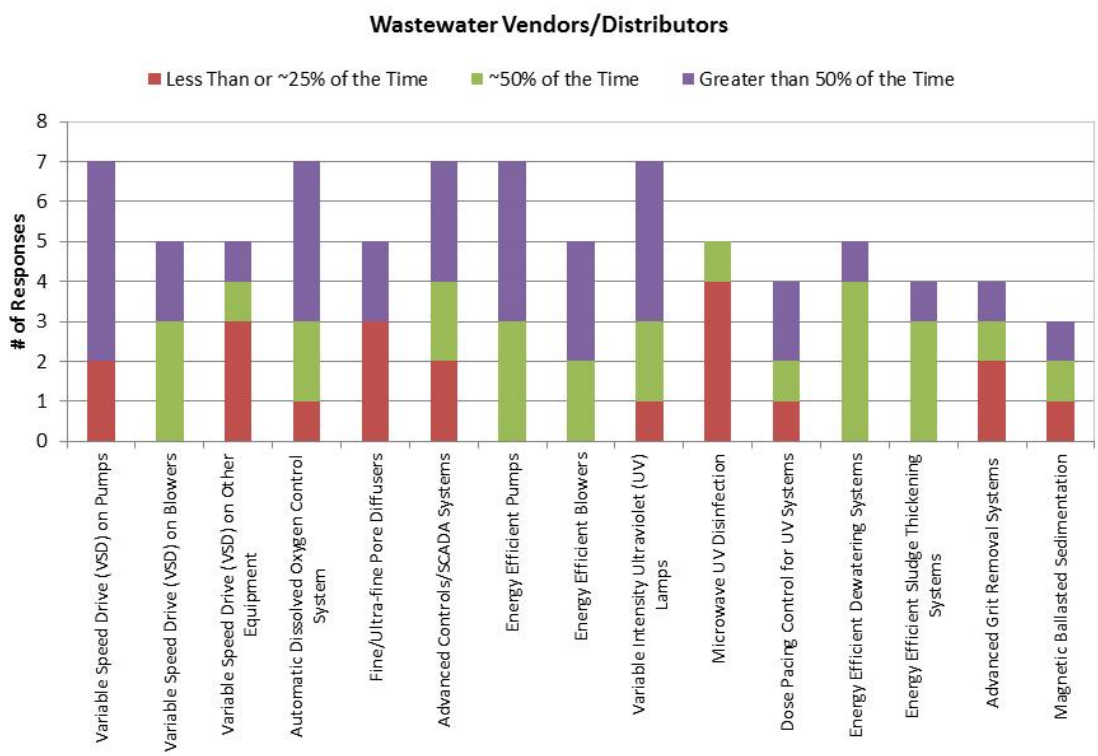
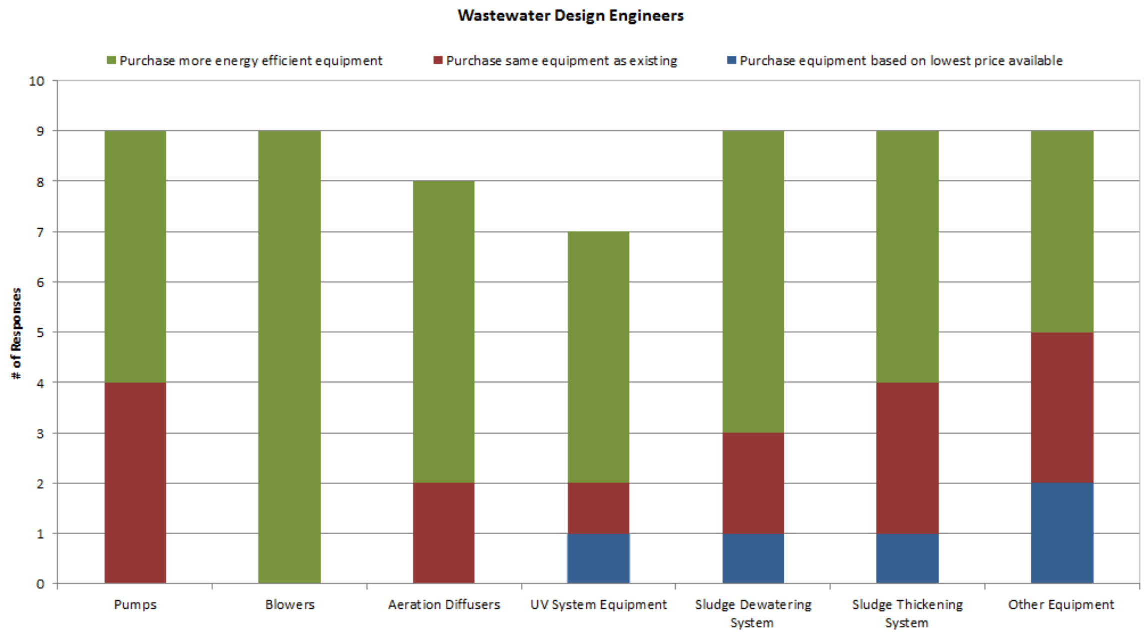


Figure 9.2-3 Which of the following energy efficient technologies for municipal WWTPs is commonly purchased by your customers? (May have more than one answer)



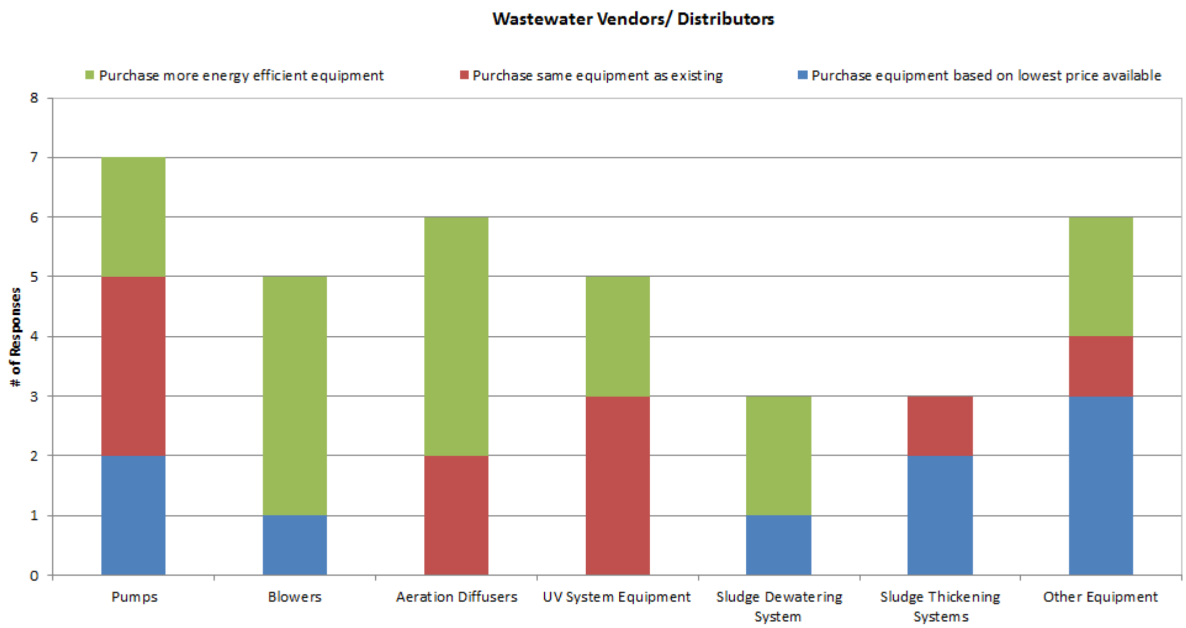


Figure 9.2-3 In the case of retrofit or facility expansion, for each of the following technologies, which are your customers more likely to do when selecting equipment?