

**STATEWIDE ASSESSMENT OF ENERGY USE
BY THE MUNICIPAL WATER AND
WASTEWATER SECTOR**

**FINAL REPORT 08-17
NOVEMBER 2008**

**NEW YORK STATE
ENERGY RESEARCH AND
DEVELOPMENT AUTHORITY**





NYSERDA

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Final Report

Prepared for the
**NEW YORK STATE
ENERGY RESEARCH AND
DEVELOPMENT AUTHORITY**

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ABSTRACT

Nationally, the energy used by the municipal water and wastewater treatment sector (sector) accounts for 35 percent of a typical municipality's energy budget (EFAB, 2001). Electricity constitutes between 25 and 40 percent of a typical wastewater treatment plant's (WWTP's) operating budget (CGE, 2000), and approximately 80 percent of all drinking water processing and distribution costs (EPRI, 2002). Baseline electricity use by the water and wastewater sector of New York is estimated to be between 2.5 and 3 billion kilowatt hours per year.

The New York State Energy Research and Development Authority (NYSERDA) contracted with Malcolm Pirnie, Inc. (Malcolm Pirnie) and its subconsultant, Strategic Power Management, LLC (SPM) to conduct an assessment of energy use by New York State's municipal water and wastewater treatment sector. Using information from publicly available datasets and supplemented with facility information obtained through mailed survey instruments, the overarching goal of the assessment was to evaluate the potential for energy efficiency and energy production improvements in the municipal water and wastewater sector of New York. Specific objectives of the study included:

- Estimating the baseline electricity use of the water and wastewater sector in New York
- Aggregating and analyzing electricity use by facility size and type
- Identifying regulatory, infrastructure, population, technological and organizational trends and assessing their effect on electricity use by the sector
- Evaluating the current biogas production and biogas-to-electricity generation at existing municipal anaerobic digesters and estimating the wastewater sector potential in New York
- Evaluating and characterizing the potential for pretreatment of high-strength wastes from the food and beverage manufacturing sector in New York
- Evaluating the load shape of the sector's electricity use and assessing opportunities for peak demand reduction and load flattening
- Identifying energy conservation measures and water conservation opportunities
- Identifying sector-specific barriers and opportunities in New York

KEY WORDS/DESCRIPTORS

Electric Energy Use by Municipal Water and Wastewater Sector; Trends and Impact on Electric Energy Use; Biogas Recovery; Biogas Generation Potential; Electric Production Potential; Energy Conservation Measures

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1. Purpose of the Statewide Energy Assessment

Nationally, the energy used by the municipal water and wastewater treatment sector (sector) accounts for 35 percent of a typical municipality's energy budget (EFAB, 2001). Electricity constitutes between 25 and 40 percent of a typical wastewater treatment plant's (WWTP's) operating budget (CGE, 2000) and approximately 80 percent of all drinking water processing and distribution costs (EPRI, 2002).

In response to a Request for Proposals issued by the New York State Energy Research and Development Authority (NYSERDA), Malcolm Pirnie, Inc. (Malcolm Pirnie) and its subconsultant, Strategic Power Management, LLC (SPM), were selected to conduct an assessment of energy use by New York State's municipal water and wastewater treatment sector. The overarching goal of the assessment was to evaluate the potential for energy efficiency and energy production improvements in the sector.

An Advisory Group, made up of representatives from water and wastewater utilities across the State, professional organizations, and regulatory agencies from both the energy and environmental arenas, was formed to support this effort. Participation by the Advisory Group ensured the varied interests of stakeholders were considered, which improved project credibility within the sector and maximized participation and cooperation during the data collection phases of the project.

2. Description of the Water and Wastewater Sector in New York

Nearly 95% of all New York State’s citizens are served by a public water supply and/or municipal wastewater treatment plant [New York State Department of Health (NYSDOH)]; this includes 702 wastewater treatment plants with a combined design treatment capacity of 3.7 billion gallons per day [New York State Department of Environmental Conservation (NYSDEC)] and nearly 2,900 community water supply systems that produce an estimated 3.1 billion gallons of drinking water per day (NYSDOH). Additionally, there are roughly 7,000 non-community water supply systems (NYSDOH). Water supply systems and treatment plants are typically categorized by size or population served. Tables 1 and 2 provide information on these facilities by total capacity/population served and the relative percentage of statewide treatment capacity/population served represented by each category.

Table 1
New York State Municipal Wastewater Treatment Plants by Category

Design Capacity	Number of WWTPs	Percent of Statewide Design Capacity
Less than 1 MGD	520	3.8
1 to 5 MGD	106	7.5
5 to 20 MGD	43	13.1
20 to 75 MGD	19	23.8
Greater than 75 MGD	14	51.8

Source: NYSDEC 2004 Descriptive Data.

Table 2
New York State Drinking Water Supply Systems by Category

Population Served	Number of Systems	Percent of Statewide Population Served by Community Water Systems
Less than 3,300	2,525	3.8
3,300 to 50,000	293	21.6
50,000 to 100,000	11	4.7
Greater than 100,000	20	69.8

Source: USEPA Safe Drinking Water Information System.

3. Assessment Methodology

Written surveys, telephone correspondence, and a number of publicly available datasets were used to acquire the facility, process, and other physical information needed to meet the objectives of this study. Facilities could either provide energy use information directly through the survey instrument or provide written authorization for the team to contact their energy service providers for information. Additional detail on the assessment methodology, including copies of the survey instrument, is included in Appendix A.

3.1. Written Surveys

Malcolm Pirnie developed three survey instruments: a water system survey, a wastewater treatment system survey, and a survey for satellite wastewater collection systems – those municipalities that own and operate a wastewater collection system but do not have their own SPDES-permitted WWTP. Survey questions focused on the age of facilities and systems, treatment processes, types of equipment, quantity and characteristics of flow, and energy use.

To maximize participation in the survey, a targeted public outreach campaign was undertaken. The campaign included oral and written promotion at conferences, posting of promotional materials on NYSERDA’s website, and inclusion of promotional materials with the mailed surveys.

3.2. Publicly Available Datasets

Various regulatory agencies at the County, State, and Federal levels maintain datasets related to the sector. These publicly available datasets were used to identify those facilities to which the survey instrument was mailed and to fill in data gaps for surveys that were either received incomplete or not returned. These datasets include:

- Descriptive Data of Municipal Wastewater Treatment Plants in New York State (NYSDEC)
- Safe Drinking Water Information System (NYSDOH)
- Discharge Monitoring Reports [United States Environmental Protection Agency (USEPA) Permit Compliance System]
- Wastewater Collection System Survey (NYSDEC)

3.3. Facility Identification and Participation

To maximize the statistical significance of the study, a structured approach was followed. Initially, a wide range of facilities, representing various treatment processes or source

waters and varying size categories, were sent the survey instrument. Subsequently, follow-up efforts were focused primarily on facilities representing the largest percentage of the statewide treatment capacity or population served. However, a conscious effort was made to ensure adequate representation of smaller facilities and each of the treatment technologies found in the state.

Surveys were sent to 585 municipally owned WWTPs. These facilities represent 83% of the number of WWTPs and 99.9% of the total wastewater treatment capacity in the State. In addition, surveys were sent to 81 satellite communities. Surveys were sent to all non-transient community water systems serving greater than 1,000 people (a total of 683 systems). In addition, surveys were sent to 40 non-transient community water systems serving populations of less than 1,000. These 723 water systems provide water to over 99 percent of the State’s population that is served by community water systems.

Of the 585 WWTPs that were sent surveys, 174 facilities responded. These 174 facilities represent over 80 percent of the State’s design treatment capacity. Thirty-one of the 81 targeted satellite collection systems returned completed surveys. Of the 723 community water systems that were sent surveys, 179 facilities responded. These 179 facilities represent over 20 percent of the State’s population served by community water systems and over 45 percent of the State’s population served by community systems other than the New York City’s Croton and Catskill/Delaware systems. Survey response distributions are shown in Table 3 and Table 4.

**Table 3
Wastewater Treatment Plant Survey Response Distribution**

Flow Category	Number of Facilities Sent Surveys (Based on Design Flow)	Number of Facilities Responding (Based on Design Flow)
≤ 1.0 MGD	403	88
1.0 MGD to 5.0 MGD	105	34
5.0 MGD to 20 MGD	44	23
20 MGD to 75 MGD	19	16
> 75 MGD	14	13
Total	585	174

Table 4
Drinking Water Supply System Survey Response Distribution

Flow Category	Number of Facilities Sent Surveys	Number of Facilities Responding
≤ 3,300 people	387	83
3,300 to 50,000 people	302	80
50,000 to 100,000 people	13	8
> 100,000 people	21	8
Total	723	179

4. Baseline Electric Energy Use

The collected data were aggregated based on several characteristics (e.g., size, method of treatment, source water, etc). If a survey wasn't returned, or was returned incomplete, electric energy use was estimated by extrapolating the data provided by other survey respondents within the same size category. For example, in the 20 to 75 MGD size category, there are 19 WWTPs. Survey responses were received from 15 of the 19 facilities. To estimate the electric energy use of the four non-responding facilities, the average unit electric energy use (i.e., kilowatt-hours per million gallons (kWh/MG)) provided by each of the 15 respondents was multiplied by the actual volume of wastewater treated by the four non-responding facilities.

Using this methodology, the baseline electric energy use for the sector was estimated to be 2.5 to 3.0 billion kWh per year; roughly two-thirds of the electricity is consumed by wastewater treatment systems (1.75 to 2.0 billion kWh). Tables 5 and 6 provide comparisons of electric energy use by size and population categories.

Table 5
Electric Energy Use by Design Capacity - Wastewater Treatment Systems

Category/Design Capacity	Energy Use (kWh/MG)
National Average ¹	1,200
Statewide Average	1,480
- Less than 1 MGD	4,620
- 1 to 5 MGD	1,580
- 5 to 20 MGD	1,740
- 20 to 75 MGD	1,700
- Greater than 75 MGD	1,100

¹ National average energy use shown includes collection, conveyance and treatment.

² New York State average energy uses shown includes collection, conveyance, treatment and energy use by satellite systems served within each category.

Table 6
Electric Energy Use by Population Served - Water Supply Systems

Category/Population Served	Energy Use (kWh/MG) ³
National Average ¹	1,400
Statewide Average ¹	705 (890)
- Less than 3,300	1,080
- 3,300 to 50,000	980
- 50,000 to 100,000	810
- Greater than 100,000	600 (640)

¹ Includes raw water pumping, treatment and finished water distribution.

² Numbers shown in parentheses exclude New York City's Cat/Del and Croton watershed systems; due to several factors including the systems' current Filtration Avoidance Determination and the very large population served, these systems significantly affect statewide averages.

Tables 7 and 8 provide comparisons of the percentage of electric energy used by the various size and population categories, including the percentage of statewide treatment capacity provided by each category.

Table 7
Percent Electric Energy Use by Size – Wastewater Treatment Systems

Size Category	% of Electric Energy Use	% of Treatment Capacity
Less than 1 MGD	11.0	3.8
1 to 5 MGD	8.5	7.5
5 to 20 MGD	14.0	13.1
20 to 75 MGD	26.8	23.8
Greater than 75 MGD	39.7	51.8

Table 8
Comparison of Treatment Capacity to Electric Energy Use – Water Supply Systems

Size Category	% of Electric Energy Use	% of Population Served
Less than 3,300	6.1	3.8
3,300 to 50,000	31.0	21.5
50,000 to 100,000	5.6	4.7
Greater than 100,000	57.3	70.0

Tables 9 and 10 provide comparisons of electric energy use at wastewater treatment plants by secondary treatment technology. Due to the fact that both flow and biochemical oxygen demand (BOD) are criteria used to design WWTPs, data were aggregated to show both the impact of BOD (kWh/lb of influent BOD) and flow (kWh/MG) on electric energy use.

Slightly different conclusions are drawn from the different comparisons. However, recognizing that secondary treatment is used to remove BOD, and that secondary treatment typically represents the greatest percentage of electric energy used at a WWTP, the values associated with BOD loading are probably the most representative in many cases. For example, when comparing larger WWTPs, many large systems are served by combined sewer systems and receive exaggerated flow rates and, subsequently, dilute influent loadings, while others are served by separate sewers.

**Table 9
Electric Energy Use by Secondary Treatment Technology: BOD-based**

Size Category	Activated Sludge (kWh/lb BOD)	Fixed Film (kWh/lb BOD)	Lagoons (kWh/lb BOD)
Less than 1 MGD	4.1	3.3	1.5
1 to 5 MGD	2.2	1.1	1.1
5 to 20 MGD	1.7	1.0	Not Applicable
20 to 75 MGD	1.3	1.2	Not Applicable
Greater than 75 MGD	2.0	Not Applicable	Not Applicable

**Table 10
Electric Energy Use by Secondary Treatment Technology: Flow-based**

Size Category	Activated Sludge (kWh/MG)	Fixed Film (kWh/MG)	Lagoons (kWh/MG)
Less than 1 MGD	4,100	3,600	2,530
1 to 5 MGD	1,340	1,380	2,170 ¹
5 to 20 MGD	1,570	1,140	Not Applicable
20 to 75 MGD	1,630	1,060	Not Applicable
Greater than 75 MGD	1,070	Not Applicable	Not Applicable

¹ The value shown is based on data from only two facilities, both of which serve multiple Significant Industrial Users representing 30 to 60% of the flow treated. In addition, one of the lagoon WWTPs is required to provide tertiary treatment.

Table 11 shows a comparison of electric energy use in drinking water supply systems based on source water type. If a water system survey respondent reported using multiple water sources (i.e., groundwater and surface water), the data were captured under each source type for use in extrapolating data for non-respondents and, subsequently, for calculating baseline averages for each source type.

**Table 11
Electric Energy Use by Source Water Types**

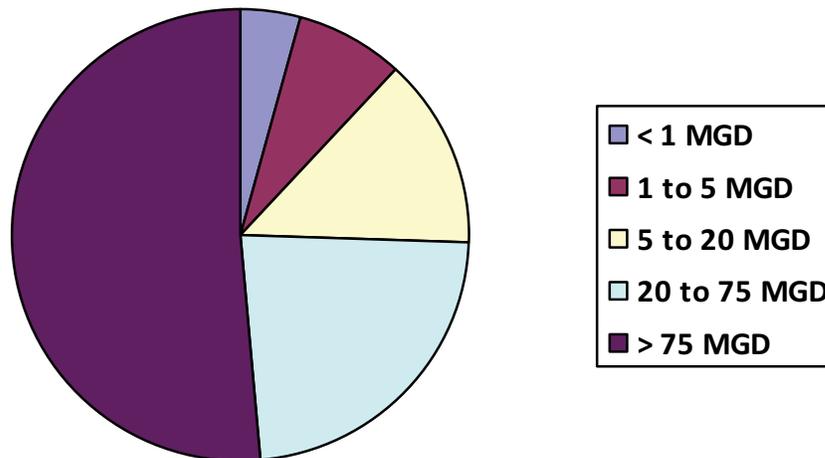
Size Category	Groundwater (kWh/MG)	Purchased Water (kWh/MG)	Surface Water (kWh/MG)
Less than 3,300	920	730	1,380
3,300 to 50,000	1,030	600	1,000
50,000 to 100,000	820	Not Applicable	810
Greater than 100,000	1,060	220	470

4.1. Interpretation of Findings

4.1.1. Wastewater Treatment Systems

Relatively few facilities (14) provide the majority of the State’s wastewater treatment capacity (51.8%), and these facilities consume the largest percentage of electric energy (39.7%). Figure 1 illustrates the breakdown of statewide wastewater treatment design capacity by size category.

Figure 1: Breakdown of Treatment Capacity at WWTPs in New York State



As shown in Table 10, larger WWTPs tend to be more energy efficient on a flow basis than their smaller counterparts. Table 9, however, shows that energy efficiency decreases on a BOD basis at the largest WWTPs. This decrease may be due to a number of factors including dilution of the influent as a result of combined sewers or excessive inflow/infiltration, operating at average flows significantly less than design capacity, the availability of electricity at lower than average costs, or being required to meet stringent effluent limits.

Based on the findings of this assessment, municipal wastewater treatment systems in New York State use approximately 25 percent more electricity, on a per unit basis, than their national counterparts. This may be due to the fact that the state has more stringent effluent limits and/or that nearly 90 percent of the State’s wastewater flow is treated using some form of activated sludge treatment, which is typically more energy intensive than fixed film or lagoon systems. In addition, nearly 30 percent of survey respondents reported providing tertiary or advanced treatment. A comparison of electric energy used by facilities that provide secondary treatment and those providing advanced or tertiary treatment is shown in Table 12.

Table 12
Comparison of Electric Energy Use¹: Facilities Providing Secondary Treatment vs. Facilities Providing Tertiary/Advanced Treatment

Size Category	Secondary Treatment (kWh/MG)	Tertiary/Advanced Treatment (kWh/MG)	Percent Increase for Tertiary/Advanced
Less than 1 MGD	3,400	5,160	52%
1 to 5 MGD	1,130	2,230	97%
5 to 20 MGD	1,460	1,960	34%
20 to 75 MGD	1,550	2,200	42%
Greater than 75 MGD	1,070	Not Applicable	---

¹ Treatment only, excludes electricity associated with collection system.

4.1.2. Drinking Water Supply Systems

As with wastewater systems, the per unit electric energy use (kWh/MG) associated with large facilities is significantly less than that associated with small facilities, and the largest percentage of electric energy (57.3%) is consumed by the few largest facilities (21) that provide the majority of the State’s drinking water capacity (70% on a population basis).

For systems serving more than 100,000 people, on a per unit basis the electric energy consumed by surface water source systems is less than 50% of the electric energy consumed by groundwater source systems. In large part this is due to the fact that both the New York City Croton and Catskill/Delaware systems, and the City of Syracuse system, are currently operating under Filtration Avoidance Determinations. (Under a Filtration Avoidance Determination, conventional treatment is not required.) Combined, these systems serve nearly half of the State’s population, and, therefore, the statewide electric energy use average is significantly impacted (reduced). Additionally, several large systems (e.g., City of Albany) are designed such that raw water conveyance and finished water distribution systems are primarily operated by gravity.

With respect to smaller systems, the electric energy consumed by surface water source systems serving less than 3,300 people is approximately 50% greater than electric energy consumed by groundwater source systems serving the same number of people. For

systems serving between 3,300 and 100,000 people, electric energy use is comparable between surface water and groundwater source systems.

Construction of a conventional filtration facility for New York City's East of Hudson (Croton) watershed, which provides approximately 10 percent of New York City's water supply, and construction of an ultraviolet disinfection facility for the West of Hudson watershed, which provides the remaining 90 percent of the City's supply, are currently planned or underway. Combined, it is estimated that these projects will increase annual drinking water system energy use by approximately 35,000,000 kWh, or roughly 5%. Given the magnitude of the potential energy use associated with these facilities, it is imperative that the facilities be designed to operate efficiently.

Based on the findings of this assessment, New York State drinking water supply systems use, on average, 40 percent less electricity on a per unit basis than their national counterparts. This is due, in part, to the factors described above. However, when the New York City supply is excluded, the statewide average is still lower than the national average, which highlights New York State's abundance of high quality surface water and relatively shallow groundwater located in close proximity to population centers.

4.2. Recommendations Based on Baseline Electric Energy Use

4.2.1. Wastewater Treatment Systems

As illustrated in Table 5, the greatest opportunities for energy efficiency improvements on a per unit basis (kWh/MG) are at small WWTPs; however, these facilities only represent about 10% of the energy used. Most studies to date on the topic of energy efficiency in the wastewater sector have focused solely on the amount of energy use per million gallons of design capacity or per million gallons of wastewater that is treated. Had this study done the same, a significant opportunity at large WWTPs may have been overlooked. On a flow-based basis (kWh/MG) the largest systems are by far the most efficient. However, by also aggregating data on load basis (kWh/pound BOD), it became apparent in this study that significant opportunities also remain at the largest WWTPs in New York State; these facilities represent 40% of the energy used by the wastewater sector.

4.2.2. Drinking Water Supply Systems

As shown in Table 6, the smallest community water systems are generally the least energy efficient on a per unit basis (kWh/MG). However, as with wastewater systems, these facilities account for only a small percentage of the overall energy use. As illustrated in Table 11, based on the relatively higher unit electricity use (kWh/MG), small surface water systems and large groundwater systems appear to offer reasonable opportunity for energy efficiency improvements. When the proportion of overall statewide electric energy use is considered, large (greater than 100,000) groundwater

sources appear to provide the greatest opportunity for energy efficiency improvements. As shown in Table 8, small to mid-sized facilities represent 31% of the statewide electric energy use, while serving only 21.5% of the population. Facilities in this size range are also prime candidates for energy efficiency improvements, as they represent a substantial portion of the overall population served by public water systems but do not appear to have fully benefited from the economies of scale associated with the largest systems.

5. Trends with the Potential to Impact Electric Energy Use

Concern over climate change and an increased interest in sustainability and smart growth are helping drive the move toward energy efficiency in the municipal sector. However, because characterizing the potential impacts of climate change on the sector was not within the scope of this project, we have not attempted to do so in this report. Two separate studies are currently being funded by NYSERDA to assess the effects of climate change on the sector: *Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State* and *Development of New York State Greenhouse Gas Abatement Cost Curves*.

5.1. Regulatory Trend

5.1.1. Wastewater Sector

The following initiatives have the potential to significantly influence the electric energy use associated with the State's wastewater treatment systems:

- **Swimmable Hudson Initiative** – By mid-2009, this initiative requires that the effluent discharged to the Hudson River by more than 40 existing WWTPs be disinfected. For many of the facilities, ultraviolet disinfection may be the preferred technology as a result of extremely stringent proposed chlorine residual requirements. If ultraviolet disinfection is widely implemented, it is estimated that electricity use will increase by approximately 10,500,000 kWh per year. Recognizing the important role that ultraviolet disinfection will play in future regulatory compliance within the sector, NYSERDA has funded a number of studies related to ultraviolet disinfection and continues to support projects aimed at improving the energy efficiency and effectiveness of the technology.
- **WWTP Capacity Regulations** – These regulations require that WWTPs implement a program to reduce hydraulic loading through inflow and infiltration reduction projects or increase treatment capacity once the annual average flow for a calendar year has exceeded 95 percent of the facility's design flow. Approximately 86 facilities will be required to take action pursuant to this regulation, the majority of which are less than 1 MGD. Recognizing that facilities tend to opt to increase capacity rather than eliminate inflow and infiltration, it is estimated that compliance with this regulation could result in an increase of up to 18,000,000 kWh per year through increases in equipment size and overall treatment capacity.

- **Combined Sewer Overflow Regulations** – These regulations require combined sewers to be abated through sewer separation, satellite treatment, or WWTP expansion. The timeline for compliance varies throughout the state. The overall effect on electricity use in the sector will be dependent upon the methods selected to abate combined sewer overflows, but it could be significant.
- **Watershed-Specific Initiatives** – These initiatives require advanced treatment of wastewater, often focusing on nutrient or pathogen removal, in an effort to reduce receiving water impairment or provide additional watershed protection. Representative initiatives include the New York City Watershed Protection Program, the Great Lakes Initiative, the Long Island Sound Initiative, and the Chesapeake Bay Initiative. Nutrient removal initiatives related to the Long Island Sound and the Chesapeake Bay have the potential to significantly affect electricity use within the wastewater sector as some of the largest WWTPs in the state (greater than 50% of the statewide design capacity) will be required to comply with these initiatives. As reported previously, facilities that are required to provide advanced treatment consume 30 to 100 percent more electricity on a per unit basis than facilities required to provide only secondary treatment. Assuming a 40% increase in electricity use for affected WWTPs, it is estimated that compliance with nitrogen removal requirements for the Long Island Sound alone will result in an increase of approximately 250,000,000 kWh per year.
- **Emissions Regulations** – New regulations focusing on emissions from distributed electrical generation have the potential to impact both the use of emergency generators for peak reduction and the use of biogas for on-site electricity generation. Currently, it is estimated that approximately 45,000,000 kWh per year of electricity is generated at WWTPs using biogas and that nearly twice this amount is readily achievable. If half of the existing facilities choose to cease electrical production rather than upgrade their equipment, over 20,000,000 kWh per year of additional electricity will need to be provided by the grid.

5.1.2. Drinking Water Sector

As noted above, construction of additional treatment is currently planned or is underway for New York City’s water supply. These projects will extend New York City’s Filtration Avoidance Determination and could lead to permanent avoidance of the requirement to construct conventional filtration to treat water from the City’s West of Hudson watershed. However, should conventional treatment be required in the future, electricity use would increase by an estimated 130 million kWh per year. If Syracuse were required to provide conventional treatment, the effect would be significantly smaller, likely less than 9 million kWh per year.

Other regulatory initiatives that have the potential to significantly influence electric energy consumption include:

- **Long Term 2 Enhanced Surface Water Treatment Rule** – This rule requires the installation of enhanced treatment for water treatment systems at greater risk of microbial contamination. Ultraviolet disinfection, ozone, and microfiltration are some of the preferred treatment technologies, and all can be fairly energy intensive. The timeline for compliance varies based on system size and risk potential. However, by 2014, all water utilities required to comply with this regulation are to have implemented any necessary additional treatment. Excluding New York City, which is identified above, and assuming 5% of the remaining total volume of drinking water that is distributed by public water supplies implements additional treatment in the form of ultraviolet disinfection, it is estimated that compliance with this rule will result in an increase of approximately 3,000,000 kWh per year. Should the actual number of water utilities that are affected be larger or smaller, a corresponding effect on electric energy use will take place.
- **Disinfection and Disinfectant By-Product Rule** – This rule requires water suppliers to meet more stringent limits for disinfection by-products within their distribution system. While there are a number of less energy intensive compliance options available, several utilities have already installed ultraviolet or ozone disinfection technologies to comply with this rule, and it is anticipated that others will follow their lead. However, many of the utilities affected by the Disinfection and Disinfectant By-Product Rule are also affected by Long Term 2 Enhanced Surface Water Treatment Rule, and as such, the energy impacts of compliance with this Rule are already captured above.

5.1.3. Summary of Effects

Table 13 provides a summary of the potential impacts of relevant regulatory initiatives on electric energy consumption. Excluding the construction of conventional filtration for the West of Hudson watershed, as well as watershed-specific initiatives not related to the Long Island Sound, the regulatory initiatives have the potential to increase the electric energy consumption of New York’s water and wastewater sector by nearly 300,000,000 kWh per year, or roughly 10 % above the current baseline, over the next decade. The application of conventional filtration for the West of Hudson watershed would increase sector-wide electric energy use by an additional 5%.

**Table 13
Potential Impacts of Regulatory Initiatives on Electric Energy Consumption**

Regulatory Initiative	Potential Increase in Energy Consumption (kWh)	Potential Impact on Energy Consumption¹ (%)
Swimmable Hudson Initiative	10,500,000	<1
WWTP Capacity Regulations	18,000,000	<1
Watershed-specific Initiatives²	250,000,000	~8.3
Emissions Regulations	20,000,000 ³	<1
Long Term 2 Enhanced Surface Water Treatment Rule	3,000,000	<1
Disinfection and Disinfectant By Product Rule	----- ⁴	----- ⁴
Conventional Filtration for NYC's West of Hudson Watershed and Syracuse	139,000,000	~4.6
Combined Sewer Overflow Regulations	----- ⁵	----- ⁵

1 - Over current NYS baseline of approximately 3 billion kWh/year for municipal water and wastewater sector

2 - Only increase associated with Long Island Sound Initiative shown

3 - Additional grid-supplied power required

4 - Included with above

5 - Overall effect dependent on abatement method selected by the system

5.2. Infrastructure Trends

Aging infrastructure, both at treatment facilities and within collection and distribution systems, has the potential to significantly influence energy use within the sector. Outdated treatment processes, obsolete control equipment, and equipment nearing the end of its useful life can result in greater than necessary energy consumption. One such example is electric motors; over the past decade, typical electric motor efficiencies have increased 3%. Recognizing that a majority of the sector's electric use is associated with motor operation, replacing aging electric motors with newer, more efficient motors could reduce electrical consumption within the sector by as much as 40,000,000 kWh per year.

Of equal or greater importance is the condition of the buried infrastructure (i.e., pipes). Inflow, infiltration, and combined sewers result in increased pumping associated with wastewater systems, while leaky distribution systems result in increased pumping associated with water systems. It is not unusual for inflow and infiltration to represent as much as 30% of the flow being treated at a WWTP, or as much as 40% of finished drinking water to be unaccounted for, with much of the loss due to leakage. Throughout the sector, reductions in electric energy use of 5 to 10% (150,000,000 to 300,000,000 kWh per year) are possible through improvements of buried infrastructure. However, the

costs for repairing widespread leakage or inflow and infiltration are often difficult to justify based solely on electrical savings.

A number of communities across New York State have begun implementing capital improvement and asset management programs. If designed appropriately, these programs should provide the communities with the ability to strategically improve energy efficiency through scheduled, targeted rehabilitation and replacement of equipment with higher efficiency alternatives.

5.3. Population and Growth Trends

The US Census Bureau Decennial Census (April 2000) reported that the overall population in New York will increase 2.37 % (456,000 people) within the ten-year period from 2005-2015. Areas of the state south of Greene County will account for approximately 90 percent of this projected population increase. Treatment facilities operated by the New York City Department of Environmental Protection (NYCDEP) have reserve capacity to absorb the projected increases in population. Five downstate counties, which make up nearly 75 percent of the projected population increase, also have ample reserve capacity. Assuming a linear relationship between population being served and energy consumption, the projected population growth over the next 10 years will have a nearly negligible impact on the overall statewide energy use of the sector.

5.4. Technological Trends

Trends in technology have the potential to both increase and decrease energy use in the sector. More efficient motors, more effective and user friendly advanced control systems, more frequent installation of variable speed drives, and newer, more efficient treatment processes have the potential to decrease energy use in the sector. However, as regulatory requirements become more stringent and the types of contaminants and organisms that are targeted change, more energy consuming treatment technologies may be necessary. Examples of these types of technologies include ultraviolet disinfection, ozone treatment, membrane filtration, and activated sludge processes modified for nutrient removal. However, as newer technologies emerge, it is important that cradle-to-grave energy use be considered, not simply the energy consumed at the point of installation. For example, while ultraviolet disinfection consumes significantly more electricity at the point of installation than the more traditional chlorine disinfection, the energy needed to produce the chlorine and the environmental benefits of using ultraviolet disinfection may offset that increase.

5.5. Organizational Trends

There are some trends in the sector toward consolidation and privatization of operations as financial constraints make it more difficult for municipalities to meet the water and wastewater needs of their constituents. In general, both of these changes may offer the opportunity for improved energy efficiency in the sector. Consolidation may eliminate smaller, less-efficient facilities; may provide greater financial flexibility; and may allow a single entity the opportunity to standardize and optimize operations. Privatization may afford a community greater financial alternatives and has the potential to result in improved energy efficiency if incentives are offered to the private operator. It is difficult to quantify the potential effect on energy use of these organizational trends.

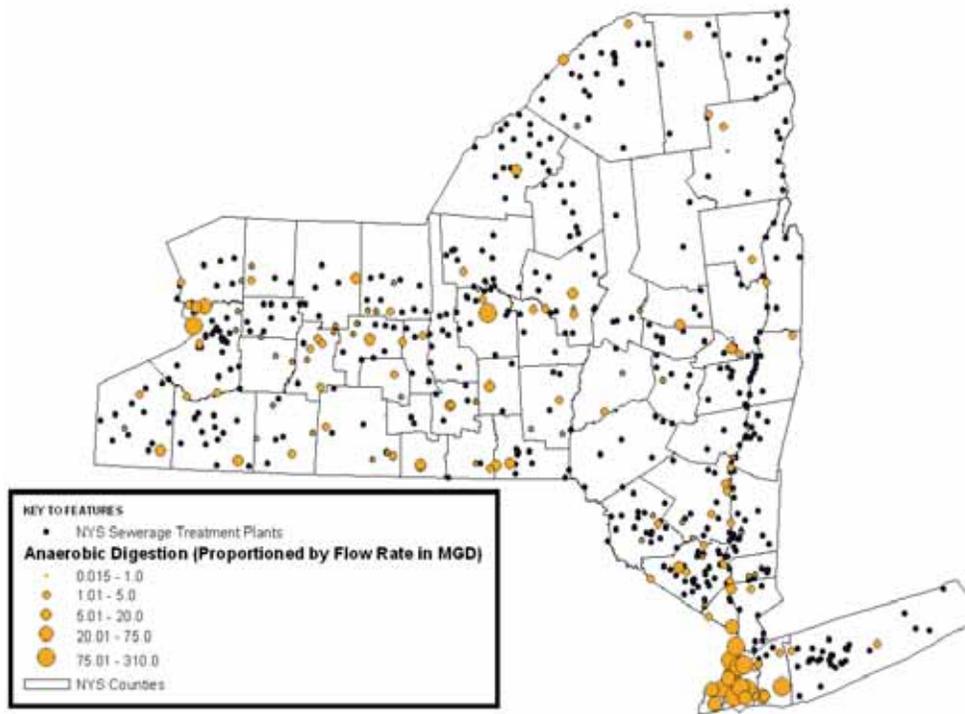
6. Biogas Recovery and Use at WWTPs

In November 2007, a market characterization report was issued by NYSERDA – “Market Characterization Report: Anaerobic Digester Gas-to-Electricity for the Municipal Wastewater Sector in New York.” This report is included as Appendix B. A brief summary of the information detailed in the Market Characterization Report is presented in this section.

6.1. Use of Anaerobic Digesters

In New York, 145 WWTPs have anaerobic digestion (AD) facilities in place. These 145 WWTPs represent approximately 75% of the State’s overall wastewater treatment capacity. Figure 2 illustrates the geographic distribution of WWTPs in New York and highlights those that have anaerobic digestion facilities. The relative size (design capacity) of the WWTPs is indicated by the size of the symbol on the map. It should be noted that several of the WWTPs with anaerobic digestion facilities do not currently operate their digesters or operate their digesters at reduced rates.

Figure 2: Distribution of WWTPs in New York State



6.2. Estimating Methodology

Biogas production potential was estimated based on influent organic loading or total solids, actual average daily flow rate, and volatile solids destruction. If a facility did not report specific performance data, the following assumptions were used: 1) 70% of the total solids generated at a facility are volatile solids, 2) a volatile solids destruction rate of 50% is achieved through anaerobic digestion, and 3) 15 cubic feet of biogas is generated for every one pound of volatile solids that is destroyed.

6.3. Biogas Generation Potential

It is estimated that the biogas production of the 145 WWTPs with AD facilities is 5.2 billion cubic feet (cf) per year. It is necessary to estimate biogas production because very few, if any, WWTPs with AD facilities have accurate gas metering of the total biogas production. Were all of the State's 590 WWTPs to install AD facilities, it is estimated that the biogas production potential of these 590 WWTPs would be 6.7 billion cf per year.

6.4. Electrical Production Potential

Electrical production potential was somewhat conservatively estimated assuming the average heating value of biogas is 550 British thermal units per cubic foot (BTU/cf) and the electrical conversion efficiency is 25%. Based on these assumptions, the electrical production potential of the 145 WWTPs with existing AD facilities was calculated as 24 megawatts (MW). Were all 590 of the State's WWTPs to install digestion and electrical generating facilities, the electrical production potential was calculated as 31 MW.

6.5. Electrical Generation at NYS WWTPs

6.5.1. Installed Capacity

Approximately 29 MW of biogas-fueled generation capacity is currently installed at NYS WWTPs. An additional 13 MW of on-site generation capacity with the capability to use biogas as fuel is installed at two facilities (for a total of 42 MW). However, the equipment was installed knowing that insufficient biogas is available to fire the units, and it is currently operated using natural gas. Based on biogas production potential, the estimated electrical production potential of the facilities reporting biogas fired on-site electrical generation is approximately 9 MW. The cause of the discrepancy between installed capacity (29 MW) and electrical production potential (9 MW) is unclear but is likely due to a number of factors including: the reporting of redundant equipment or equipment purchased to address potential growth as "installed biogas-fueled generation capacity"; treatment of atypically high strength wastes, hauled wastes, or regional wastes that would result in greater than expected biogas production relative to the estimating methodology used (as described in Section 1.2.1); or the inherent conservativeness of our assumptions.

6.5.2. Electrical Generation and Biogas Clean-up Equipment

The majority of facilities reported having internal combustion engines with a generator set; fuel cells were reported at five WWTPs, and microturbines were reported at one WWTP. These systems ranged in size from 60 kW to 8,000 kW. Several of the facilities reported having biogas cleanup systems installed in the form of moisture traps and particulate filters. One of these also reported an iron sponge used for the removal of hydrogen sulfide. Another, the WWTP with the microturbines, reported using an activated carbon filter for the removal of siloxanes.

6.5.3. Existing Electrical Generation

Approximately 45,000 megawatt-hours per year (MWh/yr) of biogas-fueled electricity is currently generated by New York State WWTPs. However, avoided electricity purchases are greater than this, as several WWTPs use biogas-fired engines to directly drive pumps and blowers, rather than converting the biogas to electricity to power electric motors.

6.6. Assessment of Market Potential

Use of anaerobic digester gas offers significant opportunities for the municipal wastewater sector to generate renewable electricity. These opportunities are described in the following sub-sections. [Note: for most WWTPs the on-site electrical use will exceed the biogas-fired electrical generation potential (i.e., all electricity will be used behind the meter)].

6.6.1. Facilities that Under-Produce Electricity Compared to Estimated Biogas Production

Although many WWTPs do employ biogas recovery and use, it appears that most are not capitalizing fully on their electrical production potential based on their estimated biogas production. Typically at larger WWTPs (greater than 40 MGD), electrical production is limited by the capacity of installed generating equipment (i.e., the generation equipment is undersized compared to the estimated volume of biogas that is produced). For example, of the 14 WWTPs reporting both installed generation capacity and the actual amount of biogas-fueled electricity being generated, seven produce between 35% and 75% of their electrical production potential based on their estimated biogas production, and three produce less than 20%.

6.6.2. Facilities with Excess Generation Capacity Installed

At several WWTPs, installed electrical generating capacity exceeds the estimated biogas production. Based on correspondence with industry personnel, WWTPs may not be capitalizing on the full potential of their installed biogas-fueled generation capacity for a variety of reasons including labor pressures, unit costs to produce electricity being greater than the unit costs to purchase electricity, operational problems with the electrical generation equipment, air permitting problems, and/or other constraints. Additionally, it may only appear that these facilities are not capitalizing on their full biogas potential due

to the fact that they are actually using some fraction of the biogas for direct firing of boilers to heat the digesters or WWTP buildings or for shaft power.

6.6.3. Summary of Opportunities for WWTPs with Existing Digestion Facilities

The greatest near-term opportunities in the sector for biogas-fired distributed electrical generation are at WWTPs with existing digestion facilities, particularly those that are greater than 4.5 MGD. These WWTPs represent nearly 90 percent of the estimated biogas production at WWTPs with existing digesters. [Note: installations at smaller facilities, particularly those with a strong local champion or those that treat high-strength wastes, are also feasible.] In particular, efforts should be focused on:

- Improving performance at WWTPs where existing electrical generating equipment is adequately sized for the quantity of biogas produced but electrical output of the equipment is not optimized.
- Increasing biogas production at WWTPs where electricity production by installed generating equipment is currently limited by insufficient biogas. Biogas production may be increased through process improvements or by treating high-strength or hauled wastes, assuming adequate anaerobic digester treatment capacity is available and local laws allow treatment of hauled or high-strength wastes. At WWTPs with significantly more generating capacity than biogas and excess treatment capacity, centralized waste treatment facilities could be established.
- Installing additional electrical generating capacity at WWTPs where ample biogas is produced but the capacity of existing electrical generating equipment is insufficient.
- Installing electrical generating equipment at WWTPs where no generating capacity currently exists.

6.6.4. Summary of Opportunities for WWTPs without Existing Digestion Facilities

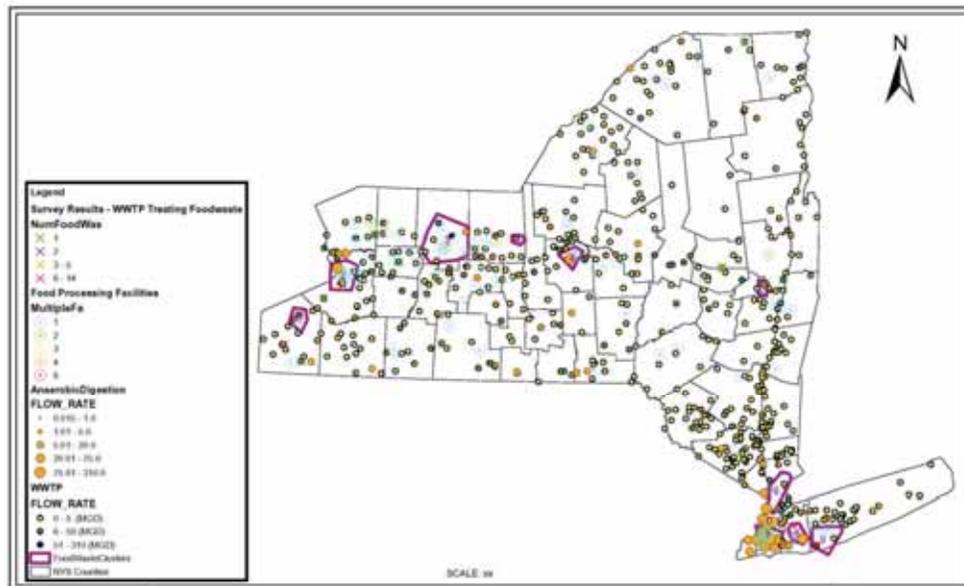
The construction of new anaerobic digesters and installation of electrical generating equipment at the 445 WWTPs that currently do not have anaerobic digestion facilities offers significant longer-term opportunities in the sector. These 445 WWTPs represent approximately one-third (nearly 1 billion gallons per day) of the statewide WWTP design capacity. As infrastructure continues to age and sludge disposal regulations become more stringent, WWTPs will be forced to consider alternative methods of sludge treatment and disposal. Given the increased funding that is available for renewable energy projects, as well as anticipated increases in electricity costs, the use of anaerobic digesters with biogas recovery may prove the most economical alternative for some municipalities.

7. Pretreatment of High-Strength Industrial Wastes from the Food and Beverage Manufacturing Sector at Municipal WWTPs

A dataset of food and beverage manufacturing facilities across New York State, developed by Cornell University under a NYSERDA-funded study titled, “A Web-Based Spatial Decision Support System for Utilizing Organic Wastes as Renewable Energy Resources in New York State”, was used for this evaluation. Food and beverage manufacturing facilities typically generate high-strength wastes, and if a municipal WWTP is not designed to address these discharges, or is nearing its design capacity, the high-strength waste streams can be very difficult and expensive to accommodate. Anaerobic treatment is particularly well suited for treating high-strength waste streams, and anaerobic pre-treatment systems typically can be located within the confines of most municipal WWTPs.

To assess the potential for increasing biogas generation at municipal WWTPs by receiving and treating high-strength waste from industrial facilities, the dataset developed under the Cornell University project was overlain on the map of WWTPs. The overlay provided a tool to identify “clusters” of manufacturing facilities in close proximity to municipal WWTPs. The overlay is shown in Figure 3.

Figure 3: Overlay of Food and Beverage Manufacturing Facilities and WWTPs in NY



The WWTPs were contacted to ascertain information on the wastes received from the manufacturing clusters including volumes, chemical characteristics, whether or not pretreatment or additional treatment was required, and if so, the cost associated with the additional treatment. While each of the WWTPs acknowledged operational challenges associated with treating high-strength wastes, all of the facilities were equipped to monitor, control, and treat the industrial loadings received, and many of the WWTPs relied on the revenues generated from the high-strength wastes.

Food and beverage manufacturers were also contacted to ascertain whether or not they pretreated their wastewater prior to discharge. Of the 75 facilities providing information, 41 facilities reported discharging their wastewater to a municipal WWTP, 18 of which provided some level of pretreatment prior to discharging.

Based on the assumptions that 1) 70% of the influent waste stream chemical oxygen demand (COD) is converted to biogas during the anaerobic process, 2) 6.4 cubic feet of methane are produced per pound of COD converted, 3) the methane content of the biogas is 60%, 4) the COD of a food and beverage manufacturing waste is 1.5 times its biochemical oxygen demand (BOD), and 5) the thermal value of biogas is 550 BTU/cf, it was estimated that the 128 food and beverage manufacturing facilities have a biogas production potential of 3.8 billion cf per year, with a corresponding theoretical heating value of 2,106 billion British Thermal Units (2,106,000 MMBTU). Using a further assumption that an average electrical conversion efficiency of 25% will be achieved, the electrical production potential of these 128 facilities is approximately 154,000 megawatt-hours per year, which corresponds to an electrical generation potential of 17.5 MW. If conveyance and anaerobic treatment of high-strength industrial wastes were practiced on a more widespread basis at municipal WWTPs, the biogas generated by these facilities could be increased substantially.

8. Peak Load Reduction/Shifting Using Backup Generators

8.1. Load Shape for Water and Wastewater Sector

Because of the wide range of variability in system designs and operating schedules, as well as the unique characteristics of each service area, it is difficult to develop a single, representative load profile for the water and wastewater sector. In general, both the daily and peak electrical demands occur, coincidentally, with the periods of highest electrical demand realized by the New York Independent System Operator (NYISO).

The daily peak electrical demand is directly influenced by the hydraulic or organic loading experienced by the facility, which follows a diurnal pattern. However, because of differences in drinking water distribution systems and wastewater collection systems (e.g., pipe size and length, pumping rates, available storage), the exact timing and magnitude of the diurnal variation varies. Another significant influence on the peak electrical demand is the number and types of processes that are operated concurrently. Additionally, because most water and wastewater facilities have the greatest number of staff present during the first shift, the largest number of processes are typically operated during this timeframe, which further exacerbates the already high electrical demand due to the morning high use period.

On a seasonal basis, the peak electrical demand for the sector typically occurs during the summer months. For wastewater systems, effluent limits (e.g., nitrification and disinfection requirements) are frequently more stringent during the summer months and it is at these times the oxygen transfer within the activated sludge process is less efficient - requiring greater aeration and energy input to achieve the same level of treatment. In drinking water systems, peak electrical demand is typically during the summer as well, as this is the time when lawn sprinkler systems, which significantly affect water demand, are in use.

8.2. Peak Demand Reduction/Load Flattening Opportunities

There are a number of peak demand reduction programs administered by the NYISO to improve the reliability of New York's electric grid. Specific programs include:

- **Emergency Demand Response Program (EDRP)** - A short-notice program that provides payments to electric customers who reduce load during specific times in response to NYISO concerns over the availability or reliability of the grid.

- **Day-Ahead Demand Reduction Program (DADRP)** – A program that allows large energy users to bid their load-reduction capability into New York's wholesale electricity market on a day-to-day basis. These load reduction bids compete with generators' offers to meet the State's electricity demands.
- **Installed Capacity Special Case Resources** – A reserve capacity program that contracts resources to meet supply requirements over a specified contract period.

In addition to programs administered by the NYISO, water and wastewater utilities may choose to use backup generators to offload peak demand in an effort to reduce demand charges associated with operation of their facility. However, in many cases the backup generating equipment is aging and may not meet current environmental standards. Additionally, water and wastewater utilities may be able to stagger or delay the operation of large equipment or specific treatment processes to flatten electrical demands during peak periods. However, due to the tendency to staff primarily during the first shift, it is difficult to shift operations to evening or nighttime hours. Specific details on the potential for peak load reduction and current participation in these programs is provided below.

8.2.1. Drinking Water Systems

Diesel generators provide the majority of on-site generation capacity in the drinking water sector. Nearly 120 survey respondents, representing approximately 20% of the total treatment capacity in New York, reported having backup electrical generation capacity totaling approximately 100 MW. Fourteen respondents, with a combined backup electrical generating capacity of 33 MW, participate in Demand Response Programs; their backup generators range in size from 250 kW to 22,500 kW. The largest participant is a correctional facility, and the reported backup generator capacity is for the entire facility, not just the water system.

The reasons cited for not participating in Demand Response Programs include lack of electric service provider participation, inadequate process flexibility, noise and emissions concerns and other municipal departments being responsible for electricity purchases. Extrapolating the survey responses statewide, based on the ratio of installed backup electrical generation capacity to population served (KW/population), it is estimated that over 300 MW of installed backup electrical generation capacity is associated with the drinking water sector.

8.2.2. Wastewater Sector

Approximately 80 percent of on-site backup generators in the wastewater sector are diesel fueled. Over 150 survey respondents, representing approximately two-thirds of total treatment capacity in New York, reported having backup electrical generation capacity totaling approximately 140 MW. One in five respondents reported participating in Demand Response Programs, with a combined capacity of 34.5 MW. Program participants have backup generators ranging in size from 80 kW to 6,750 kW.

Reasons cited for not participating include insufficient knowledge of the programs, lack of electric service provider participation, outdated generating equipment, noise and emissions concerns, and an incongruity among the facility and alternate departments responsible for electricity purchases. Considering both emergency generators and biogas/dual fuel-fired generators, it is estimated that the wastewater sector has over 250 MW of installed electrical generation capacity statewide.

9. Other Opportunities for Energy Efficiency Improvement

9.1. Energy Conservation Measures

A number of other demand-side opportunities with energy implications also are available within the sector. However, the applicability and economic feasibility of each opportunity is dependent upon the specific characteristics of a particular system. The *Wastewater Treatment and Sludge Management Energy Reference Guide*, a study of energy conservation measures for the wastewater sector, was completed by NYSERDA in 1995. While construction and operating costs have increased since 1995, due to escalating electricity prices, all of the measures identified at that time remain viable options, and for many, the payback period has actually improved. In addition, in 2008, NYSERDA undertook development of a compilation of previous energy efficiency studies for the wastewater sector entitled *A Guide to Energy Efficiency for the New York State Wastewater Sector*. A copy of the draft document is included in Appendix C.

A number of the most relevant opportunities identified in both documents are listed below:

9.1.1. Wastewater Sector

- Aeration Improvements
- Solids Handling Improvements
- Waste Heat Recovery
- Inflow and Infiltration Reduction
- Flow Equalization
- Variable Speed Drives on Large Motors
- Operational Changes to Reduce Peak Loads
- Building Improvements (lighting, HVAC)
- Building Code Improvements to Reduce Leaking Laterals and Sewers
- Advanced Process Control Systems
- Influent or Effluent Hydroelectric Generation
- Recovery and Use of Anaerobic Digester Gas

9.1.2. Drinking Water Systems

- Variable Speed Drives on Large Motors
- Increased Storage
- Operational Changes to Reduce Peak Loads
- Optimization of Emerging Technologies
- Distribution Improvements (accurate metering, reduce leakage)
- Water Reuse
- Raw Water for Non-Potable Applications
- Building Code Updates for Water Conserving Fixtures
- Building System Improvements (lighting, HVAC)
- Hydroelectric Generation on Gravity Raw Water or Finished Water Transmission Mains or in Lieu of Pressure Reducing Valves

9.2. Water Conservation Opportunities

While energy conservation measures can reduce the amount of electricity consumed to meet a utility's water and wastewater treatment requirements, water conservation programs can significantly impact electricity use by reducing the amount of potable water that must be produced and distributed and the amount of wastewater that must be collected and treated. Water conservation opportunities can be broadly broken down between supply-side and demand-side conservation opportunities. Supply-side measures are more readily controllable by the water system and include:

- Metering of all customers to aid in identification of unaccounted for water
- Leak detection and repair
- Rate structure to promote water conservation
- Rebates to support replacement of standard plumbing fixtures with water conserving fixtures
- Audits to identify opportunities for water savings
- Codes and regulations to require use of water conserving fixtures and promote water conservation

Demand-side conservation measures rely on the water system customers "buying in" to the conservation program that the system is advocating. Public education is a key component to any water conservation program and should be a part of every water system's routine expenditures, either through widespread dissemination of information or simply by including conservation tips with customer's bills. While there are countless techniques to save water, such as collecting rain water for garden or house plants, there

are a relatively finite number of measures that most customers encounter on a routine basis and to which they can easily adapt their lifestyle. Table 14 summarizes some of these measures as well as the potential water savings associated with each measure.

**Table 14
Demand-Side Water Conservation Measures**

Activity	No. of Times	Detail	Water Used	Total
Toilet	4 flushes per day	Conventional	3.5 to 7 gpf	14 to 28 gpd
		Low-flow	1.6 gpf	6 gpd
Shower	5 min. per day	Conventional	3 to 8 gpm	14 to 40 gpd
		Low-flow	2.5 gpm	12 gpd
Shaving	1 per day	Tap running	5 to 10 gals	5 to 10 gpd
		One full basin	1 gallon	1 gpd
Brushing teeth	2 per day	Tap running	2 to 5 gals	4 to 10 gpd
		Tap off	¼ to ½ gal	½ to 1 gpd
Dishwashing by hand	1 per day	Tap running	30 gals	30 gpd
		Full basin	5 gals	5 gpd
Laundry	1 per 3 days	Top loader	35 to 50 gals	70 to 100 gal/week
		Front loader	18 to 20 gals	36 to 40 gal/week
Car washing	2 per month	Hose with shutoff	50 gals	100 gal/month
		5 full buckets	10 gals	20 gal/month
TOTAL (Conventional)			29,250 to 49,500 gals/year	
TOTAL (Water Conserving)			11,250 gals/year	

Based on the 2000 Census, the average household size in New York State is 2.61 people. Using the unit flow rates shown above, it is estimated that the average household can reduce water consumption by 35,000 to 85,000 gallons per year by converting conventional plumbing fixtures and water use practices to water conserving fixtures and practices. Based on the average per unit electricity use of New York's water and wastewater sector, the conversion of 500,000 households (less than 7.5%) to water conserving fixtures and practices would reduce electricity use in the sector by 45,000,000 to 100,000,000 kWh/year.

10. Sector-Specific Barriers and Opportunities

10.1. Barriers to Energy Efficiency

The water and wastewater sector has a number of sector-specific barriers that may inhibit widespread implementation of energy efficiency measures. The following barriers were identified through the survey and subsequent interviews:

- **Operational Barriers** – Municipal treatment plant staff typically have distinct roles in the operation of the facility. Crossover of responsibility is limited, and only in a few instances, mainly at medium to large facilities, is there a designated energy manager. In fact, for many facilities, operations staff may have little to no experience or training in the identification and implementation of energy efficiency measures and are not directly involved in purchase of electricity. This segregation of job responsibilities and lack of training does not encourage the development of facility-wide energy awareness.

Additionally, in most instances, WWTP plant staff are trained to address wet stream and solids processes; relatively few wastewater plant operators have experience and training in the recovery and use of biogas and the operations and maintenance of biogas-fired electrical generating equipment. The technical knowledge that is needed to successfully operate a distributed electrical generation facility may necessitate hiring an individual specifically for that purpose, which may not be possible. In a number of instances, situations were observed where significant annual savings could be achieved, but because additional costs would need to be incurred to achieve those savings, the projects were not implemented. For example, while electrical generation using biogas increases both operating complexity and costs, if the annual savings through avoided electricity purchases exceed the annual cost of operating the system it is still a project that should be implemented and maintained.

Finally, many municipal facilities are facing budget challenges and labor shortages, which make operating personnel less likely to take on additional responsibilities outside of the water quality realm.

- **Institutional Barriers** – Of paramount concern to this sector is the protection of public health. As a result, water and wastewater utilities tend to err to the side of conservativeness when balancing energy efficiency and process performance. This is particularly evident at smaller facilities, where the potential dollar savings through energy efficiency improvement is fairly small, and resources, in terms of labor and control systems, are typically fewer.

Another frequently cited institutional barrier is the distribution of responsibility for energy procurement and operations efficiency across multiple municipal departments, which significantly complicates holistic implementation of energy efficiency measures. In many instances, the operating personnel do not see utility bills and have no responsibility for reducing energy use.

- **Political Barriers** – The two political barriers that were most frequently cited include a lack of understanding by political officials of the technical and economic aspects of implementing energy efficiency improvements and an unwillingness to invest in energy efficiency improvements that fail to result in savings within an individual’s term of office.
- **Regulatory Barriers** – Energy efficiency is not currently regulated at water and wastewater utilities. Compliance with effluent limits and drinking water standards are the criteria by which a municipal water or wastewater system is evaluated. Inherent in this philosophy is a resistance to decreasing the “public safety buffer” in an attempt to improve energy efficiency. Because of this conservative nature, oversized equipment is often designed and installed, which results in less energy efficient operations.

Pending emissions regulations were cited by a number of facilities as the reason biogas is not recovered and used for electricity generation and also as a reason why distributed electrical generation to reduce peak electrical loads is not more commonly used. Most water and wastewater operators are less familiar with the controls that are available and the regulatory process that is followed for air emissions; consequently, operators are resistant to employing distributed electrical generation at their facilities.

A final regulatory barrier cited was the conservative nature of regulators and their lack of willingness to accept new treatment technologies or to revise design standards to be more reflective of these newer technologies.

- **Financial Barriers** – One of the biggest concerns cited was an inability to obtain short term funding to finance projects without creating rate volatility.

Another financial barrier cited was the thought that cost savings obtained through energy efficiency improvements would be returned to the municipality’s general operating fund and would result in a smaller operating budget the following year. A culture of energy efficiency is more likely to take root if some of the savings are returned to the treatment plant for reinvestment in equipment and training.

Low-cost electricity was identified as another financial barrier; low rates inhibit investment in energy efficiency improvements because of the longer period of time it takes to achieve project payback.

10.2. Opportunities for Energy Efficiency

As highlighted above, there are a number of sector-specific barriers that may inhibit widespread implementation of energy efficiency measures. However, there are also a number of unique opportunities that support increased energy efficiency in the sector. The following opportunities were identified through the survey and interviews:

- **Public Sentiment** – Public sentiment is demanding that municipalities and businesses operate efficiently and in a manner that is both protective of the environment and sustainable. The concept of a municipal carbon footprint is growing

and for many municipalities, water and wastewater systems may offer one of the greatest opportunities for reducing their carbon footprint.

- **Government Support** –The government is responding to public sentiment by fostering inter-agency collaboration and by making energy efficiency a consideration for State Revolving Loan funding.
- **Tools and Guidance** – To support improved energy efficiency in the sector, local, State, and federal agencies and non-governmental organizations are developing and making available tools and guidance to aid utilities and municipal decision-makers in the identification, implementation, and long-term operation of energy efficiency measures.
- **Research and Development** – Given the ever-increasing importance of energy efficiency to the municipal water and wastewater sector, a broad range of institutional, academic, governmental, and professional organizations are investing substantial resources into the research and development of new, more energy efficient technologies and the development and implementation of programs to improve energy efficiency awareness and performance.

11. Conclusions

With systems ranging in size from less than 10 gpm to over 2 billion gallons per day and treatment technologies ranging from some of the simplest to some of the more complicated in the industry, New York's municipal water and wastewater sector is one of the most diverse in the United States. As highlighted in this report, the sector as a whole is approximately 10% more efficient than the national average, consuming less than 2,400 kWh/MG (versus the national average of 2,600 kWh/MG). However, with an average retail price for electricity that is 40 to 60% higher than the national average, New York's water and wastewater sector is spending 35% more on electricity than their national counterparts on a per unit basis (\$/MG).

There remains significant opportunity for energy efficiency improvements at utilities of all sizes and types through supply-side and demand-side energy efficiency improvements. Regulatory, infrastructure, and technological trends are likely to result in increased electrical energy use by the sector, making energy efficiency an even greater concern as municipalities continue to face budget constraints.

While there are a number of sector-specific barriers, the combination of public and governmental support, funding, and knowledge transfer should help overcome these barriers, keeping New York's water and wastewater infrastructure – the backbone of our communities – operating efficiently.

APPENDIX

A

**Assessment Methodology
and Survey Instruments**

A. Assessment Methodology

A.1. PROMOTIONAL MATERIAL AND SURVEY DEVELOPMENT

Malcolm Pirnie developed promotional material for distribution at conferences within the water and wastewater sector. This material introduced the program and the individuals who are involved in its development and implementation. The promotional materials were distributed at several sector-focused conferences. Promotional material was also developed and provided with each survey in the form of a cover letter, to assure the survey recipients that this survey is legitimate and supported by an advisory group consisting of respected state and national professional organizations in the water, wastewater and energy sectors, as well as, regulatory agencies. The cover letter outlined the objectives of the energy study, provided instructions for completing the survey, and provided contact information for questions and/or to find out more about the project. Detailed documentation also was developed for NYSERDA's website to provide recipients of the survey with a greater understanding of the purpose and benefits of the study and importance of their participation.

Surveys were used to collect information about municipal water and wastewater systems and their energy use. Malcolm Pirnie developed three different surveys including a water system survey, a wastewater treatment system survey, and a survey for municipal collection systems that do not have their own wastewater treatment facility. A sample of these surveys is included as Attachment A1. The survey questions focused on the age of facilities and systems, treatment processes, types of equipment, quantity and characteristics of flow, and energy use. These draft surveys were submitted to representatives of the New York State Energy Research and Development Authority (NYSERDA) and the Advisory Group (AG) for a detailed review. The diverse perspectives represented by the members of the AG were beneficial in finalizing the survey instruments and facilitating their implementation. Two of the group members are administrators at treatment facilities and also hold prominent positions in professional water and wastewater organizations that helped to promote this program. Their input on the types of information that should be readily available to survey recipients within the sector and their assistance in identifying the types of incentives that would encourage recipients to complete the survey were of tremendous value. The AG consisted of the following organizations:

Organization
Iowa Energy Center
Albany County Sewer District and Water Environment Association (WEA)
New York Power Authority (NYPA)
American Council for an Energy Efficient Economy (ACEEE)
EPA Combined Heat and Power Partnership
Council for Environmental Education (CEE)
New York City Department of Environmental Protection (NYCDEP)
Latham Water District and American Water Works Association (AWWA)
New York State Department of Environmental Conservation (NYSDEC)
New York State Department of Health (NYSDOH)
New York Public Service Commission (PSC)

A national energy benchmarking initiative for water and wastewater treatment facilities was being conducted concurrently with this program. This initiative was sponsored by the American Water Works Association Research Foundation (AwwaRF), the California Energy Commission, and NYSERDA. Malcolm Pirnie met with NYSERDA and the firms that were responsible for the development of this program to discuss the goals and similarities of the two programs. To reduce the level of effort associated with data collection within New York for the national benchmarking initiative, it was agreed that the wastewater survey used for this study would be modified to include additional questions that were needed for the national assessment and that relevant data from this study would be transmitted to the firms completing the national initiative. Data were transmitted in a manner that protected the anonymity of the survey respondents.

Publicly available datasets were used to identify the facilities that should be contacted and to fill in the data gaps for surveys that were incomplete or never returned. The New York State Department of Environmental Conservation (NYSDEC) developed and maintains a database, titled Descriptive Data of Municipal Wastewater Treatment Plants in New York State (Descriptive Data). This database contains information on municipal wastewater treatment plants across the state including plant contact information and treatment processes and technologies. The New York State Department of Health (NYSDOH) maintains information on the water supply facilities across the state in a database called SDWIS (Safe Drinking Water Information System). Due to heightened security concerns, much of these data are not available to the public. A modified version of this database, containing contact information and population served, was provided by the NYSDOH to identify and select water systems for inclusion in this study. In addition to the Descriptive Data and SDWIS datasets, EPA Discharge Monitoring Reports (DMRs) were used to fill in the gaps for treatment plant flow, solids, and biochemical oxygen demand (BOD) parameters. While this information is publicly available, a more

usable dataset containing the discharge information was obtained from the Environmental Protection Agency through the assistance of the Advisory Group.

A.2. METHODOLOGY FOR SELECTION OF SURVEY PARTICIPANTS

A.2.1. Selection of Wastewater Treatment Facilities

The NYSDEC Descriptive Data was used for the selection of municipal wastewater treatment facilities for this study. As previously mentioned, this database contains information on municipal wastewater treatment plants across the state including plant contact information and treatment processes and technologies. In addition to municipal wastewater treatment plants, this database also contains records of sanitary sewer overflows, combined sewer overflows, facilities not yet built, and small non-municipal treatment plants. These additional records were filtered from the 701 records in this database. The remaining 585 wastewater treatment facilities were sent surveys. The largest 50 wastewater treatment facilities were contacted prior to the survey mailing to verify the proper individual received the survey and to personally request their participation in the study.

A.2.2. Selection of Water Systems

The NYSDOH SDWIS database was used to select water systems for this project. Water systems are categorized by the NYSDOH as community and non-community. It was assumed that the majority of the electric energy use by the sector is represented by systems that serve greater than 1,000 persons, and these systems were targeted during implementation of the survey instrument. All community water systems serving more than 1,000 persons were mailed a survey. There are 683 community systems that fall into this category (446 of them produce their own water and 237 purchase their water from another water system). In addition, 40 community systems that serve populations of less than 1,000 persons were also mailed surveys to gather information about electric energy use and the types of processes being used. The chosen systems were a mix of those that purchase water and those that produce their own water.

Non-community water systems were not surveyed as part of this study. The vast majority of non-community systems are small (serve less than 1,000 people). Non-community systems that serve over 1,000 people generally fall into three categories including schools, NYS Thruway service areas, and camping/RV type summer areas. Because of the nature of these non-community systems (i.e., seasonal use or transient populations) it is unlikely that they would be prime targets for energy reduction strategies. In many instances, data provided by the NYSDOH included multiple administrative and operator contacts for each drinking water system. The administrative contact was chosen as the contact person for the survey mailing. The largest 50 water supply systems and a number of the smaller systems were contacted prior to the survey mailing to verify the proper individual received the survey and to request their participation.

A.3. SURVEY IMPLEMENTATION AND FOLLOW-UP

Survey instruments were mailed out between May 6 and May 20, 2005. As the completed survey instruments were received, they were reviewed for completeness and entered into a Microsoft Access database. From the 585 WWTPs surveyed, 174 completed survey instruments were received; of the 723 survey instruments that were mailed to water systems, 179 were completed and returned. Thirty-one of the 81 surveys mailed to satellite collection systems were completed and returned.

A.3.1. Data Collection

Data collection was the most difficult and time consuming task in this project. Malcolm Pirnie took the following efforts to maximize survey participation:

- Reduced the number of questions in the survey to include only the basic information required to complete the project.
- Reviewed and edited the survey carefully to make the questions as clear as possible.
- Provided a draft copy of the surveys to the Advisory Group for a final review.
- Solicited the support and cover letter endorsements of the New York Chapters of the Water Environment Association, American Water Works Association, and Rural Water Association.
- Populated portions of the individual survey instruments using publicly available data, so respondents would need only to verify the correctness of some portions of the survey.

After the first wave of survey responses subsided, Malcolm Pirnie began contacting the facilities to remind them to complete the survey. Two sets of postcard reminders were sent to facilities that had not yet responded. The first reminder proved to be very effective and resulted in a large influx of additional completed surveys. The second reminder was reasonably effective, but it was evident that any subsequent efforts would have limited benefit. Concurrent with the postcard reminders, we contacted the 50 largest non-respondent water systems and wastewater treatment facilities (many of them multiple times) to request that they complete and return their survey. Follow-up efforts focused on the larger systems because they have the greatest impact on the baseline energy use and represent the greatest opportunity for noticeable improvement in the electric energy use of the sector through reduction efforts.

Significant time was spent contacting small systems to ensure a representative sample for the report. All 40 non-respondent small water systems were contacted to request that they complete the survey. Since smaller water and wastewater systems often have only one or two part time operators, many did not have time or did not want to complete the survey. Additionally, direct communication with small system operators was difficult, and in a number of instances, these systems did not have an answering machine at the facility, which further complicated follow-up communication.

Approximately 70 additional faxes were sent to facilities that, when contacted by phone, could not locate the survey we had mailed to them. Some of the facilities/systems were part of a county or regional authority or other agency and were not allowed to complete the survey without authorization from the larger organization. After we identified the organizations and the appropriate contacts, we were able to go through the proper channels to receive the authorization. During data review and population of the database, it was determined that many of the surveys were incomplete. Nearly every survey had one or more questions that were not answered, most likely because they did not have that data readily available. If a large number of questions or critical data fields were left unanswered, the facility was given a follow-up call to answer the questions verbally.

A.4. DATABASE AND GIS DEVELOPMENT

A Microsoft Access database was developed to compile and evaluate the large amount of data collected and generated during this project. Public datasets including Descriptive Data, SDWIS, and DMR data were added to the database. These datasets were used to populate some of the fields in the survey with facility specific data prior to mailing the surveys. This reduced the amount of time required to complete the survey and allowed the facility operators the opportunity to verify the accuracy of the publicly available datasets. Once completed surveys were received they were scanned into a pdf format, logged, and entered into the database through a data input form. A sample data input form is provided in Figure A1.

Figure A1 – Data Input Form

SPDES: 0037117 Contact:

CONTACT INFORMATION
 Mailing Address: TOWN HALL, 20 MIDDLEBUSH RD
 City: WAPPINGERS FALL State: NY Zip: 12590
 Phone: _____ Fax: _____

GENERAL INFORMATION
 Design Flow (MGD): 0.1 Population Served: 0.00
 Year Built: 1964 Collection (comb/separate): Separate
 Year Updated: _____ Collection System Age: _____

OPERATING INFORMATION
 1) Level of treatment (Primary/Secondary/Tertiary/Other) _____ Secondary
 2) Secondary treatment technology Activated Sludge Trickling Filter RBC SBR Lagoon
 3) Disinfection: (Yes/No/Seasonal) Yes
 4) Flow and Load Data: Please verify the data provided and fill in any blanks.

SPDES	Parameter	Units	Month	Avg	Max	Avg Q	Max Q	Comment
0037117	FLOW (INFLUENT)	MGD	1/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	2/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	3/1/2003	0.200000003				
0037117	FLOW (INFLUENT)	MGD	4/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	5/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	6/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	7/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	8/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	9/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	10/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	11/1/2003	0.100000001				
0037117	FLOW (INFLUENT)	MGD	12/1/2003	0.200000003				
0037117	FLOW (EFFLUENT)	MGD	1/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	2/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	3/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	4/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	5/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	6/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	7/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	8/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	9/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	10/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	11/1/2003					Not included in survey results
0037117	FLOW (EFFLUENT)	MGD	12/1/2003					Not included in survey results
0037117	BOD (INFLUENT)	LB/DAY	1/1/2003	154.3999939	219.94			
0037117	BOD (INFLUENT)	LB/DAY	2/1/2003	129.3000031	99.973			
0037117	BOD (INFLUENT)	LB/DAY	3/1/2003	317.1000061	449.061			

Record: 14 of 14

OPERATING INFORMATION CONTINUED
 Record: 14 of 14

A.4.1. Quality Assurance and Quality Control

Drop-down menus and check boxes were used on the input forms where appropriate to standardize the data values that were entered into the database and to reduce the amount of time required for data entry. The date of entry, initials of individual entering data, and a comments column were added to keep track of entries and additional data received with the surveys and to provide accountability for individuals entering the data. Each survey was reviewed by a manager and/or a project leader to identify errors in the data entry and discrepancies in the way survey recipients interpreted the survey and responded to the questions. In many instances, survey respondents used different units or changed the meaning of the question to reflect the format in which they recorded the data (e.g., BOD in mg/l instead of lbs/day). As situations like this were identified, they were addressed, and the data was corrected to ensure the correct units or format. In addition, to spot check reviews, the final database was reviewed, sorted, and filtered numerous times to identify additional discrepancies in survey and publicly available data.

A.4.1.1. Methodology Used to Bridge Data Gaps and Rectify Anomalous Data

Given the tremendous amount of data that were managed as part of this study and the number and variety of data gaps that were identified, it is impossible to discuss each data gap and the specific methodology used to compensate for the missing data. Professional judgment was continuously used to determine the most appropriate method of filling each identified data gap. In general, data gaps and anomalous data identified during quality assurance and quality control activities were addressed using information from the publicly available datasets or through extrapolation of data from other completed fields. Where extrapolation was used, efforts were first made to extrapolate available data for the same system and then to extrapolate data from other, similarly sized facilities.

Additional discussion about the methodology used to address several of the most common data gaps is provided below:

- Permit Compliance System (PCS) data were used to fill in the data gaps for flow and BOD for WWTP facilities that did not respond to the survey or provided only partial information. There were a limited number of facilities for which flow data were not available through PCS. In those instances, design flow values from Descriptive Data were used. Where BOD data were unavailable through PCS, the data gaps were addressed using data from similarly sized plants.
- Anomalous energy use data were eliminated and substituted, where appropriate, with “typical” data. For example, if the entry had a decimal that appeared to be off by an order of magnitude based on other monthly data for that specific account or data for other, similar accounts, the entry was changed to reflect the “correct” decimal point location.
- Missing energy use data for survey respondents, where possible, were interpolated based on the totality of the data set. For example, if May 2004 was missing, then

the relationship of May 2003 data to April and June 2003 data were used to estimate May 2004. If the facility supplied only the latest 24 months of data and efforts to obtain the earlier 2003 data proved unsuccessful, then the most recent data were substituted for the unavailable data. For example, if the facility provided data from August 2003 through August 2005, then the January 2005 through July 2005 was substituted for the missing 2003 data.

- Energy use for facilities that did not respond to the survey was estimated based on actual energy use data acquired for similar facilities within the same size category. For wastewater facilities, energy use was estimated based on influent BOD and the unit energy use for respondent facilities within the same size category. For water systems, energy use for non-respondents was estimated based on population served and the unit energy use for respondent systems within the same size category.

A.4.1.2. Aggregation and Normalization of WWTP and Water System Data

Once all survey data were input and critical data gaps were addressed, data aggregation and analysis was undertaken. In addition to categorization by treatment capacity, wastewater treatment data were aggregated based on the type of secondary treatment technology that is used (activated sludge, fixed film and lagoons) and the level of treatment provided (primary, secondary and tertiary/advanced). Water systems were aggregated by population served and also by source (surface water, groundwater or purchased water).

To facilitate comparison of the energy use of different facilities, annual energy use was normalized to the operating characteristics that are considered most directly correlated to energy use. Energy use for wastewater treatment plants was normalized to volume of wastewater treated (kWh/MG), mass of BOD removed (kWh/lb), and mass of biosolids produced (kWh/lb). Energy use for water systems was normalized to population served (kWh/capita) and volume of water produced (kWh/MG).

A.4.2. GIS Development

The locations for the WWTPs and WTPs across the state were mapped using geographic information system (GIS) software. The WWTP facility dataset was developed from the USEPA Permit and Compliance System Facilities (PCS) GIS file. The PCS dataset contains data on the National Pollution Discharge Elimination Systems (NPDES) permit-holding facilities. The New York State wastewater treatment facilities were filtered from this master PCS dataset. There is not a publicly available dataset for the water treatment facilities. Instead, a map layer of the general location of water treatment plants across the state was generated using the address zip code attribute of the SDWIS data.

APPENDIX

B

Market Characterization Report:

*Anaerobic Digester Gas-to-Electricity
for the Municipal Wastewater Sector in New York*

Market Characterization Report:

Anaerobic Digester Gas-to-Electricity for the Municipal Wastewater Sector in New York

November 2007

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1. Market Characterization

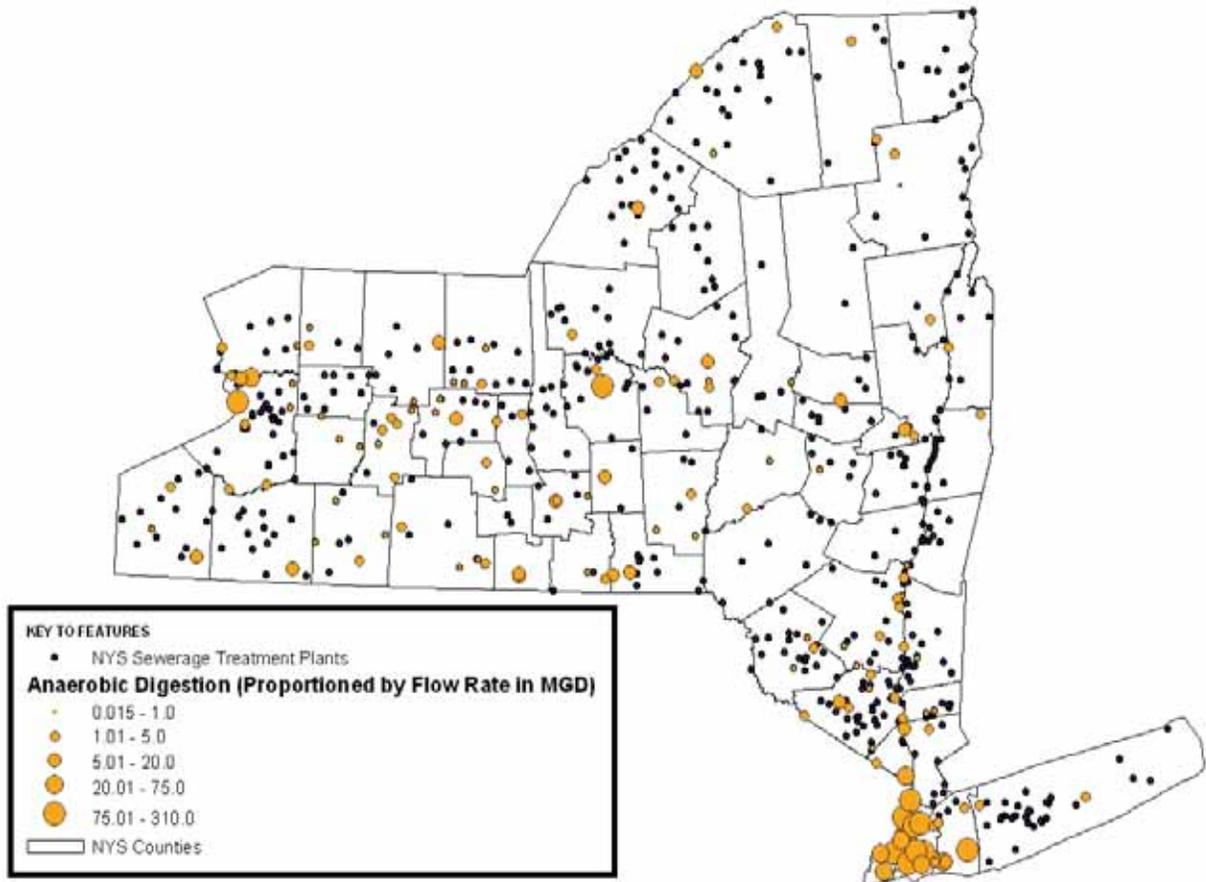
1.1. Description of New York's Wastewater Sector

Based on the New York State Department of Environmental Conservation's Descriptive Data of Municipal Wastewater Treatment Plants in New York State (Descriptive Data), there are 610 permitted municipal wastewater discharges in New York. Of those, 20 permitted discharges in the database are combined sewer overflows or sanitary sewer overflows, leaving a total of 590 municipal wastewater treatment plants (WWTPs). The combined design flow of the 590 WWTPs is approximately 3.7 billion gallons per day (BGD), or roughly 10% of the total national wastewater treatment design capacity reported during a national evaluation conducted by ICF Consulting, in 2004, using data provided by the United States Environmental Protection Agency (USEPA). In addition to the 590 municipal WWTPs in New York, there are approximately 95 other non-industrial WWTPs in New York that treat wastewater from camps, schools, and similar properties. The combined capacity of these 95 facilities represents less than 0.2% of the total design capacity in the state. Given the negligible impact on the findings and the municipal focus of this market characterization, these facilities were not included in this evaluation.

Surveys were sent to the 590 municipal WWTPs as part of a Statewide Energy Assessment (conducted under a separate contract). 145 of the 590 WWTPs (roughly 20%) have anaerobic digestion facilities in place. As part of this Market Characterization, significant follow-up efforts were focused on these 145 WWTPs, as they represent approximately 75% of the overall wastewater treatment capacity within the State.

Figure 1-1 illustrates the geographic distribution of WWTPs in New York and highlights those that currently have anaerobic digestion facilities. The relative size (design capacity) of the WWTPs is indicated by the size of the symbol on the map. It should be noted that several of the WWTPs with anaerobic digestion facilities do not currently operate their digesters, or they operate their digesters at reduced rates.

Figure 1-1: Distribution of Wastewater Treatment Plant in NYS



1.2. Biogas and Electrical Production Potential

1.2.1. Biogas Production Potential

As mentioned previously, significant follow-up efforts were made to maximize the response rate from the 145 WWTPs with existing anaerobic digestion facilities, particularly from the larger facilities that represent the greatest biogas production potential due to the larger organic loads they receive. 67 of these WWTPs responded to the survey. Using the assumptions that 1) 70% of the total solids generated at a facility are volatile solids, 2) a volatile solids destruction rate of 50% is achieved through anaerobic digestion, and 3) 15 cubic feet of biogas is generated for every one pound of volatile solids that is destroyed, the estimated biogas production of the 67 survey respondents is approximately 4.7 billion cubic feet per year (cf/yr).

Extrapolating the data received from the 67 respondents, it is estimated that the biogas production at these 145 WWTPs is 5.2 billion cf/yr. (Note: Over 90% of the estimated biogas production associated with existing digestion facilities is represented by the 67

survey respondents.) Further extrapolating the data received from the 67 respondents, it is estimated that the State’s 590 WWTPs have a biogas production of 6.7 billion cf/yr (were they all to install anaerobic digestion facilities).

1.2.2. Electrical Production Potential

Based on an average heating value of 550 British thermal units per cubic foot (BTU/cf) of biogas and an electrical conversion efficiency of 25%, the electrical production potential of the 145 WWTPs with existing anaerobic digestion facilities is 24 megawatts (MW). The electrical production potential of the State’s 590 WWTPs, if they all were to install digestion and electrical generating facilities, is approximately 31 MW. (Note: The 145 WWTPs with existing digester facilities represent nearly 78% of the State’s electrical production potential.)

As distributed electrical generation technologies continue to advance and equipment efficiencies improve, electrical production will increase. Additionally, the overall energy efficiency of biogas-fueled electricity systems can be maximized through recovery of waste heat, which can be used to meet digester heating requirements without sacrificing electrical production potential. Finally, during the summer months, when the electricity demand is typically greatest, facility and digester heating requirements are typically lowest. This would allow biogas-fueled electricity production to be of the greatest benefit as most, if not all, of the biogas produced could be used for electricity generation.

**Table 1-1
Biogas and Electrical Production Potential of NYS WWTPs**

Category (Number of WWTPs)	Estimated Biogas Production (cf/year)	Theoretical Heating Value (MMBTU)	Electrical Production Potential ¹ (kwh/yr)
Survey Respondents (67)	4,734,000,000	2.59 million	189,000,000
All WWTPs w/Existing Anaerobic Digestion Facilities (145)	5,191,501,000	2.86 million	209,000,000
All WWTPs (590)	6,672,065,000	3.7 million	268,600,000

¹Based on an electrical conversion efficiency of 25%.

1.3. Existing Biogas Use

At least 40 of the 67 respondents reported that they flare or vent some portion of the biogas produced by their facility. Unfortunately, similar to an assessment recently completed by the USEPA, insufficient data were provided by the respondents to determine the fate of the total volume of biogas produced by these facilities, due in part to the fact that very few facilities have accurate gas metering. However, it is assumed that all WWTPs waste some portion of the biogas that is produced due to limited gas storage and typical fluctuations in gas production. Unless the electrical generating equipment is sized for the maximum rate of biogas production (i.e., maximum biogas flow rate), then biogas in excess of the design throughput of the generating equipment is typically wasted. While WWTPs often have some biogas storage either within the digesters or in separate gas storage facilities, in most instances the storage is insufficient to prevent wasted biogas during periods of peak biogas production. A breakdown of the biogas use as reported by the 67 respondents is shown in Table 1-2.

**Table 1-2
Summary of Biogas Use of Survey Respondents**

Biogas Use	Number of Facilities	Theoretical Volume of Gas Produced¹	Percentage of Total NYS Theoretical Gas Production
Digester Mixing Only	1	2,064,302 cf/yr	0.03 %
Electric Generation Only	3	114,807,935 cf/yr	1.7 %
Facility Heating Only	3	124,695,416 cf/yr	1.9 %
Other Use	4	535,843,537 cf/yr	8.0 %
Flare/Vent Only	9	627,959,856 cf/yr	9.4 %
Combined Electric Generation and Heating	14	1,653,550,694 cf/yr	24.8 %
Digester/Facility Heating	33	1,745,872,035 cf/yr	26.2 %

¹ The value shown is the calculated or reported biogas produced at those survey respondents included in each category. The actual amount of biogas that is recovered and used cannot be determined from the data provided.

1.4. Existing Electrical Generation

1.4.1. Installed Capacity

Seventeen (17) of the 67 respondents reported their installed biogas-fueled generation capacity. The estimated biogas production of these 17 facilities is approximately 1.9 billion cf/yr, or 36% of the estimated biogas production of the 145 WWTPs with existing digestion facilities.

The installed biogas-fueled generation capacity of these 17 facilities, which is used to generate electricity for on-site use or for sale to the commercial grid, is approximately 29 MW. An additional 13 MW of on-site generating capacity is installed at two of the facilities (for a total of 42 MW). While this additional 13 MW of electrical generating equipment has the capability to use biogas as fuel, the equipment was installed knowing

that insufficient biogas is available to fire the units, and they are currently operated using natural gas.

Based on the estimated biogas production, the electrical production potential of these 17 facilities is approximately 9 MW. The cause of the discrepancy between installed capacity (29 MW) and electrical production potential (9 MW) is unclear, but is likely due to a number of factors including: the reporting of redundant equipment or equipment purchased to address potential growth as “installed biogas-fueled generation capacity”; treatment of atypically high-strength wastes, hauled wastes, or regional wastes that would result in greater than expected biogas production relative to the estimating methodology used (as described in Section 1.2.1); or the inherent conservativeness of our assumptions.

1.4.2. Electrical Generating and Biogas Clean-up Equipment

The 17 facilities reported having the following biogas-fueled technologies installed: internal combustion engines with generator sets, microturbines, and fuel cells. The reported capacity of these technologies ranges in size from 60 kW to 8,000 kW. The majority of facilities reported having internal combustion engines with a generator set; fuel cells were reported at five WWTPs, and microturbines were reported at one WWTP.

To reduce engine wear and tear and to control emissions, 6 of the 17 facilities reported having biogas cleanup systems installed in the form of moisture traps and particulate filters. One of these also reported an iron sponge, used for the removal of hydrogen sulfide. Another, the WWTP with the microturbines, reported an activated carbon filter for the removal of siloxanes.

1.4.3. Existing Electrical Generation

Fourteen of the 17 WWTPs reported both their installed generation capacity and the actual amount of biogas-fueled electricity they generate. The estimated biogas production of these 14 facilities is approximately 1.5 billion cf/yr, or 30% of the estimated biogas production of the 145 WWTPs with existing digestion facilities. These facilities reported a total installed biogas-fueled generation capacity of approximately 28 MW, although, based on their estimated biogas production, their electrical production potential is only 7 MW. These facilities also reported generating a total of 27 million kilowatt-hours per year (kWh/yr) of biogas-fueled electricity. This indicates they are, on average, operating at approximately 45% of their electrical production potential and less than 10% of their installed generation capacity.

Extrapolating the results from the survey (i.e., approximately 21% of the 145 WWTPs with digesters produce electricity) and applying the electrical production characteristics of the 14 facilities that reported the actual amount of electricity generated (i.e., approximately 45% of their electrical production potential is achieved), it is estimated that approximately 45,000 megawatt-hours per year (MWh/yr) of electricity is currently generated by WWTPs in New York State. [Note: avoided electricity purchases are

greater than this, as several WWTPs use biogas, rather than electricity, to directly drive pumps and blowers.]

1.5. Assessment of Funding Used for Existing Facilities

Most of the internal combustion engines with a generator set were installed in the late 1980s to early 1990s as part of facility upgrades. More recently, microturbines and fuel cells were installed. Since 2000, NYSERDA has contributed a total of \$1 million in funding for fuel cells at four DEP facilities (26th Ward, Oakwood Beach, Red Hook, Hunts Point). NYSERDA also contributed funding for a fuel cell project at Westchester County's Yonkers Joint WWTP, which went online in 1997, and for a microturbine facility at the Town of Lewiston WWTP. Additionally, NYSERDA funding is pending for projects at the Village of Fredonia WWTP and the City of Schenectady WWTP. Survey respondents reported that the New York Power Authority (NYPA), the Clean Water Act revolving loan fund, and a Petroleum Overcharge Restitution fund have also provided funding for existing cogeneration facilities.

The receipt of outside funding does not appear to have directly influenced the performance, efficiency, or capacity of systems that were installed. However, for many projects, particularly those involving the use of fuel cells or microturbines (that offer benefits when compared to traditional internal combustion engines but are typically more expensive), outside funding was the only reason projects were able to move forward and become successful. With the increased interest in renewable energy, new sources of project funding may be available through carbon credits, renewable energy credits, and Clean Renewable Energy Bonds.

1.6. Installation Costs for Existing Facilities

In many instances, the biogas-fueled cogeneration facilities were constructed as part of a larger project, making identification of the specific costs for the equipment difficult to determine. Based on a very limited number of installations that were able to break out these costs, the average installation cost for the biogas-fueled facilities was \$1,700 per kilowatt (kW) of installed capacity, with costs adjusted to 2007 dollars using the construction cost index published by the Engineering News Record.

1.7. Assessment of Market Potential

Use of anaerobic digester gas offers significant opportunities for the municipal wastewater sector to generate renewable electricity. Based on this market characterization, the majority of near-term opportunities are at facilities that underproduce electricity compared to their estimated biogas production and at facilities with excess installed electrical generation capacity.

1.7.1. Facilities that Underproduce Electricity Compared to Estimated Biogas Production

Although many WWTPs do employ biogas recovery and use, it appears that most are not capitalizing fully on their electrical production potential based on their estimated biogas production. Typically, at larger WWTPs (greater than 40 MGD), electrical production is limited by the capacity of installed generating equipment (i.e., the generation equipment is undersized compared to the estimated volume of biogas that is produced). For example, of the 14 WWTPs reporting both their installed generation capacity and the actual amount of biogas-fueled electricity being generated, seven produce between 35 and 75% of their electrical production potential based on their estimated biogas production, and three produce less than 20%. Underuse of biogas at these 10 facilities represents an additional 38,000 MWh/yr of electrical generation potential.

1.7.2. Facilities with Excess Generation Capacity Installed

At several WWTPs, installed electrical generating capacity exceeds the estimated biogas production. At three of the 14 WWTPs, the installed capacity is significantly greater than the estimated biogas production. It is estimated that nearly 170,000 MWh/yr could be generated by these three facilities if biogas production can be increased to fully use the installed generating capacity. Based on correspondence with WWTP and industry personnel, WWTPs may not be capitalizing on the full potential of their installed biogas-fueled generation capacity for a variety of reasons including labor pressures, unit costs to produce electricity being greater than the unit costs to purchase electricity, operational problems with the electrical generation equipment, air permitting problems, and/or other constraints. Additionally, it may only appear that these facilities are not capitalizing on their full biogas potential due to the fact that they actually are using some fraction of the biogas for direct firing of boilers to heat the digesters or WWTP buildings or for shaft power. However, as noted earlier, as a result of insufficient data provided by the respondents, it is very difficult to determine the exact fate of the total volume of biogas produced by these facilities.

1.7.3. Summary of Opportunities for WWTPs with Existing Digestion Facilities

The greatest near-term opportunities in the sector are at WWTPs with existing digestion facilities, particularly the 44 with design capacities greater than 4.5 MGD. These WWTPs represent nearly 90 percent of the estimated biogas production at WWTPs with existing digesters. Forty-two of the 44 were successfully contacted. Fourteen of the 42 have installed functional electrical-generating equipment. [Note: installations at smaller facilities, particularly those with a strong local champion or those that treat high-strength wastes, are also feasible. However, project feasibility may be limited by the availability of appropriately sized generating equipment or adequate staffing.] In particular, efforts should be focused on:

- Improving performance at seven WWTPs where existing electrical generating equipment is adequately sized for the quantity of biogas produced, but electrical output of the equipment is not optimized.
- Increasing biogas production at three WWTPs where electricity production by installed generating equipment is currently limited by insufficient biogas. Biogas production may be increased through process improvements or by treating high-strength or hauled wastes, assuming adequate anaerobic digester treatment capacity is available and local laws allow treatment of hauled or high-strength wastes. At WWTPs with significantly more generating capacity than biogas and excess treatment capacity, centralized waste treatment facilities could be established.
- Installing additional electrical generating capacity at four WWTPs where ample biogas is produced but the capacity of existing electrical generating equipment is insufficient.

1.7.4. Summary of Opportunities for WWTPs without Existing Digestion Facilities

The construction of new anaerobic digesters and installation of electrical generating equipment at the 445 WWTPs that currently do not have anaerobic digestion facilities offers significant longer-term opportunities in the sector. These 445 WWTPs represent approximately one-third (nearly 1 billion gallons per day) of the statewide WWTP design capacity. As infrastructure continues to age and sludge disposal regulations become more stringent, WWTPs will be forced to consider alternative methods of sludge treatment and disposal. Given the increased funding that is available for renewable energy projects, as well as anticipated increases in electricity costs, the use of anaerobic digesters with biogas recovery may prove the most economical alternative for many municipalities.

APPENDIX

C

**A Guide to Energy Efficiency
for the New York State Wastewater Sector**

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A Guide to Energy Efficiency for the New York State Wastewater Sector

INTRODUCTION

The wastewater treatment sector accounts for approximately 1.5-2% of all electrical energy consumed in New York State. The sector uses substantial amounts of energy for a variety of processes, including pumping, aeration, and sludge treatment. This energy represents a sizeable share—about 25-40%—of operating costs in a wastewater treatment plant (WWTP). A well accepted engineering rule of thumb is that typical energy savings of 15 percent can be achieved in a wastewater system by employing fairly basic energy efficiency measures, and these measures typically are associated with simple paybacks of three to five years.

The bulk of this Guide describes cost-effective energy efficiency measures that can be readily implemented in the wastewater sector to reduce energy use. In general, motors and drives, pumping, aeration, and sludge treatment (dewatering and thickening) offer the best opportunities for energy savings because they typically account for more than 90% of the total energy consumed. Opportunities associated with digestion, UV disinfection, and building systems also offer significant opportunities.

This Guide comprises two sections: the first section describes the steps required to develop a successful Energy Management Program, and the second describes the specific energy efficiency measures. The information provided in this Guide was developed as part of NYSERDA's subscription to the Global Energy Partners' (Global) Water and Wastewater Program. The Global Program focuses on advancing energy efficiency, demand response, and innovative technology applications in the municipal and industrial water and wastewater treatment sectors. Global has extensive background working with both municipal wastewater plants and electric utilities and also uses legacy information developed by the Electric Power Research Institute (EPRI), their parent organization.

SECTION I: ESTABLISHING AN ENERGY MANAGEMENT PROGRAM

Establishing an energy management program is the critical first step in successfully reducing energy consumption and associated costs at a WWTP. A sound energy management program begins with a mission statement that articulates the energy efficiency goals of the WWTP. Once an organization is committed to an energy management program, an energy manager or energy task force should be appointed to establish the framework for implementing the energy management program. The procedure for establishing an energy management program involves six basic steps:

- a. Review historical energy use
- b. Perform energy evaluations
- c. Identify energy efficiency opportunities
- d. Rank, prioritize, and promote these opportunities
- e. Implement changes to save energy
- f. Monitor your progress and refine your goals

The following subsections briefly summarize the steps.

Review Historical Energy Use The first step is to compile utility records that describe past energy use patterns. The data should be analyzed (graphed format is recommended) to identify monthly, seasonal, and

yearly variations and past trends. These data should be used to identify future energy use goals and to verify future energy use reductions.

Perform Energy Evaluations The second step is to conduct an energy evaluation of the WWTP. Evaluations are used to identify the inefficiencies associated with the equipment and with the operation and maintenance procedures of the major energy-using systems at the WWTP. Evaluations also can be used to quantify the specific energy used by each individual piece of equipment. The evaluation results should be compared with the historical energy use data to ensure that the major energy-using systems are accounted for and represented correctly by the historical data.

Depending on the goals of the organization, the evaluation can be detailed and comprehensive enough to pinpoint the bulk of energy efficiency opportunities, or it can consist of a simple walkthrough to identify obvious inefficiencies. The former approach typically requires an evaluation specialist, while the latter can often be conducted by on-site staff. It is best to begin with a simple walkthrough before investing in a more detailed evaluation. Walkthrough evaluations usually uncover a variety of inefficiencies that can be remedied with easy to implement low-cost measures.

Identify Energy Efficiency Opportunities The third step is to identify the range of energy efficiency opportunities. As discussed previously, motors and drives, pumps, aeration equipment, and sludge processing equipment represent the major energy end-use areas in a WWTPs. Disinfection systems, air compression, lighting, heating, and ventilation equipment are typically smaller end-users. Your list of energy efficiency opportunities can be developed by reviewing each system or piece of equipment with the following questions in mind:

- ◆ Is it needed?
- ◆ Is it maintained and operated properly?
- ◆ How can the equipment (as is) be used more efficiently?
- ◆ How can the treatment objective be accomplished with less energy?
- ◆ Can the equipment be modified to use less energy?
- ◆ Would new, more efficient equipment be cost effective?

Rank, Prioritize, and Promote Opportunities Once the relevant energy efficiency opportunities have been identified, a cost-benefit analysis should be performed to determine if the costs associated with each opportunity are justified before recommending implementation of the measure. This analysis must also consider potential positive or adverse effects in wastewater treatment quality. Economic criteria might include a minimum return on investment (e.g., 25%), a minimum payback period (e.g., 3 years) or a minimum cost-benefit ratio (e.g., 2.0). Measures that satisfy the economic criteria of the plant and have no negative impact on treatment quality should be implemented.

Once a set of measures are deemed economically justifiable, they should be ranked and prioritized based on their ease of implementation. It is advisable to begin with low-cost, easy to implement measures. It is important to engage management in the process, including local elected officials, as early as possible, to ensure that necessary resources are made available.

Table 1 summarizes selected results from several studies conducted at North American WWTPs by Global, in collaboration with EPRI. This team has conducted over 50 such studies, which resulted in significant energy savings for the WWTPs.

Table 1: Selected Results from Global/EPRI Energy Analyses of WWTPs*Source: Global Energy Partners, LLC*

Energy Efficiency Measure	Demand savings (kW)	Annual energy savings (kWh)	Annual energy cost savings (\$)	Estimated capital cost (\$)	Simple payback (years)
Lower water pressure	12	105,100	6,000	0	0
Shed load at peak energy use	75	58,500	4,900	0	0
Remove orifice plate and throttle blower intake	40	324,000	14,300	0	0
Install IR heater in grit basin	10	15,000	900	500	0.6
Replace sheaves on sludge silo mixing pumps	41	29,000	1,700	1,000	0.6
Install energy management system	14-200	0	16,900	30,000	1.8
Reduce aeration at night	0	146,000	8,400	15,000	1.8
Install indoor lighting control	0	87,600	5,000	10,000	2
Install VFD control on raw sewage pump	22	355,800	18,200	50,000	2.7
Change discharge to	127	893,500	51,000	150,000	2.9
Replace return activated sludge (RAS) pump	30	262,800	11,000	33,600	3.0
Lower dissolved oxygen (DO) content and install DO control; lower sludge retention time (SRT)	146	1,279,000	54,300	305,000	5.6

Implement Changes After a list of energy efficiency opportunities has been developed and the opportunities ranked and prioritized, the energy efficiency measures must be implemented. Many of the measures may be installed by plant personnel; however, the more complicated measures may require outside expertise.

Monitor Your Progress, Refine Your Goals The final step in the program is monitoring your progress and refining (or re-defining) your goals. Benchmarking can help you develop the metrics by which you evaluate your performance. You can either choose to benchmark your facility against your own past performance or against another WWTP with similar wastewater treatment processes.

The US EPA recently released a tool for benchmarking wastewater and water utilities. The tool is a multi-parameter energy performance metric that allows for comparison of energy use among WWTPs. The tool can be accessed through the US EPA's EnergySTAR Portfolio Manager platform (see link below). Portfolio Manager is an interactive energy management web-based system that allows commercial building managers, as well as water and wastewater treatment plant operators, to track and assess energy consumption and carbon footprint. The Portfolio Manager is appropriate for primary, secondary, and advanced treatment plants with or without nutrient removal. The tool is applicable to WWTPs that have design flows of less than 150 MGD. After inputting the information shown in the list below into the

Portfolio Manager platform, the tool produces an energy use “score” for your facility, which is relative to the scores of a national population of WWTPs. The score is expressed on a scale of 1 to 100.

- ◆ Zip code
- ◆ Average influent flow
- ◆ Average influent biological oxygen demand (BOD5)
- ◆ Average effluent biological oxygen demand (BOD5)
- ◆ Plant design flow rate
- ◆ Presence of fixed film trickle filtration process
- ◆ Presence of nutrient removal process

The tool can be accessed through Portfolio Manager at:

http://www.energystar.gov/index.cfm?c=eligibility.bus_portfoliomanager_eligibility

SECTION II: COST-EFFECTIVE ENERGY EFFICIENCY MEASURES

The measures described in this section are categorized into seven end-use areas: motors and drives, pumping, aeration, sludge treatment, digestion, ultraviolet (UV) disinfection, and building systems. Many of the measures are consistent with good housekeeping or improving operation and maintenance procedures; some require equipment retrofit or replacement. More complicated measures (those requiring high capital expenditures and detailed planning) have been excluded from this guide. The measures are summarized in Tables 2a and 2b. The measures summarized in Table 2a are measures associated with the four end-use areas that consume 90% of the energy in a typical WWTP – motors and drives, pumping, aeration, and sludge treatment. The measures summarized in Table 2b are associated with digestion, UV disinfection, and building systems.

Section II-A: Measures Associated with Motors/Drives, Pumping, Aeration, and Sludge Treatment

Motors and Drive Measures

WWTPs rely extensively on motors for the operation of a variety of equipment, including pumps, blowers, and air compressors. Most motors used in wastewater treatment operations are either single-phase or polyphase AC motors. Typically, single-phase motors are smaller with capacities less than 0.5 horsepower, while polyphase motors generate higher torque and power. Polyphase motors include squirrel cage induction, wound rotor induction, and synchronous motors.

Many motors operating in WWTPs are oversized and, therefore, waste significant amounts of energy. As a result, the primary opportunity for motor energy savings is the correct sizing of motors, or the replacement of old, inefficient motors with high-efficiency or premium efficiency motors.

Using variable frequency drive (VFD) control of motors is another way to save energy. Drives transfer energy from a motor or engine to a pump or blower by converting electricity to mechanical energy. VFDs control speed and flow electronically. It is almost always more efficient to use VFDs to control pump speed and flow than throttling valves for fixed-speed drives.

The range of recommended, cost-effective, energy efficiency measures for motors and drives are described below.

M&D1: Monitor power efficiency and load factors on all motors

Motors and drives require proper and periodical maintenance to ensure they are operating at optimum performance. Periodic monitoring of power efficiency and load factors can provide valuable information, including inefficient motor operation or potential motor failure.

Table 2a: Cost-Effective Energy Efficiency Measures for WWTPs: These measures are associated with the four end-use areas that consume 90% of the energy in a typical WWTP.

Source: Global Energy Partners, LLC

Motor & Drives Measures	Pumping Measures	Aeration Measures	Sludge Dewatering and Thickening Measures
<ul style="list-style-type: none"> ● M&D1. Monitor power efficiency and load factors on all motors ● M&D2. Install power factor correction ● M&D3. Proper sizing of motor ● M&D4. Replace inefficient or oversized motors with correctly sized, high-efficiency or premium-efficiency motors ● M&D5. Replace hydraulic drives with electrical drives ○ M&D6. Replace older VFDs with more efficient drives 	<ul style="list-style-type: none"> ● P1. Perform pump efficiency test on all pumps periodically ● P2. Correctly size and operate pumps ● P3. Replace check valves associated with higher head loss with low head loss valves ● P4. Replace or adjust inefficient pump impeller ● P5. Install VFD on pumps with variable loads ● P6. Replace inefficient or oversized pumps with correctly sized, high-efficiency pumps ● P7. Replace pneumatic pumps with electrical-driven pumps 	<ul style="list-style-type: none"> ● A1. Monitor blower pressure, maintain blower operation within recommended speeds, and clean filters regularly ○ A2. Install inlet guide vanes on centrifugal blowers for throttling airflow ● A3. Replace multi-stage or inlet guide-controlled centrifugal blower with single-stage centrifugal blower with VFD control ● A4. Install VFD control on mechanical aerators ○ A5. Replace older blowers with high-efficiency blowers ● A6. Install dissolved oxygen (DO) control ● A7. Replace coarse bubble diffusers with fine bubble diffusers 	<ul style="list-style-type: none"> ● S1. Improve solids capture and dewatering in the dissolved air flotation thickening process ● S2. Replace centrifuge with screw press for improved sludge dewatering ● S3. Replace centrifuge with gravity belt for improved sludge thickening

Legend:

- Typically provides high operational cost savings
- Typically provides medium operational cost savings
- Typically provides low operational cost savings

Most motors are designed to operate at 50-100% of rated load. Maximum efficiency typically is near 75% of rated load. Since a motor's efficiency tends to decrease significantly below 50% of rated load, and power factor also tends to drop off at partial load, it is important to know the power efficiency and load factors on all motors, or at least on all motors operating in excess of 1,000 hours, annually. Motors that are significantly oversized should be replaced with more efficient, properly sized motors (see M&D3 and M&D4). Overloaded motors also should be replaced because they can operate at lower efficiency due to overheating.

The Department of Energy has developed a popular motor selection and management tool: MotorMaster+ software. This free software includes a catalog of more than 25,000 AC motors and features motor inventory management tools, maintenance log tracking, predictive maintenance testing, energy efficiency analysis,

savings evaluation capabilities, and environmental reporting. The motor load and efficiency values are determined automatically when measured values are entered into the software. MotorMaster+ can help WWTPs quickly identify inefficient or oversized motors and, subsequently, calculate the savings that can be achieved with more energy-efficient models.

To download MotorMaster+ visit:

<http://www1.eere.energy.gov/industry/bestpractices/software.html>

Frequency: Periodically.

M&D2: Install power factor correction. Low power factor is caused by inductive loads, such as motors, transformers, and high-intensive discharge lighting. Low power factor is expensive and inefficient. Many electric utilities charge a facility if the power factor is less than 0.95. Low power factor also can cause voltage drops, which, in turn, can result in overheating and premature failure of motors and other inductive equipment. As a result, WWTPs can reduce energy costs, as well as O&M costs, by improving the power factor. Strategies for improving the power factor include: minimizing the operation of idling or lightly loaded motors, avoiding operation of equipment above its rated voltage, replacing inefficient motors with energy-efficient motors that operate near their rated capacity, and installing power factor correction capacitors. The installation of either single or banks of power factor capacitors is especially beneficial in facilities with larger motors, such as WWTPs.

Frequency: One-time activity.

M&D3: Proper sizing of motors. Motors are frequently oversized, which cause them to operate at part-load conditions below their optimum efficiency. This, in turn, results in significant amounts of wasted energy. As a result, it is critical to size motors properly for the specific application. Properly sized motors also help manage demand. Motors should be sized to run primarily in the 65% to 100% load range. In applications that require oversizing for peak loads, alternative strategies, such as the use of a correctly sized motor backed up with a smaller motor that only operates during peak demand, should be considered.

Frequency: One-time activity.

M&D4: Replace oversized or inefficient motors with correctly sized, high-efficiency or premium-efficiency motors. Many motors are oversized for their application, thereby wasting energy. Oversized motors also can result in a lower power factor. Motors that are oversized by more than 50% should be replaced with correctly sized, high-efficiency or premium-efficiency motors.

High-efficiency motors comply with standards set forth in the Energy Policy Act (EPA) of 1992. Premium-efficiency motors meet the Consortium for Energy Efficiency's (CEE) standards, which exceed EPA requirements. High-efficiency motors are 2 to 6% more efficient than standard motors, while premium-efficiency motors are 0.8 to 4% more efficient than high-efficiency motors. It is often cost-effective to replace an existing inefficient motor with a high-efficiency or premium efficiency motor. Indeed, in some applications, the annual cost of operating a motor can be many times greater than the initial purchase price of the motor. Standard motors that are older than five years and run at least 75% of the time are usually good candidates for motor replacement. Typically, it also is cost-effective to install a high-efficiency or premium-efficiency motor in a new system or to replace a failed motor with a high-efficiency or premium-efficiency motor because the incremental cost for the more energy-efficient motor can be quickly recovered from energy savings.

Premium-efficiency motors with copper rotors recently have become commercially available. These motors are comparable in prices to standard motors but are 0.5-1 % more efficient than the National Electric Manufacturers Association (NEMA) premium-efficiency motors. The CEE recognizes NEMA premium-efficiency motors up to 200 hp as meeting its criteria for premium-efficiency motors.

Frequency: One-time activity.

M&D5: Replace hydraulic drives with electrical drives. Hydraulic systems (water or hydraulic-oil driven equipment) consume more energy than electrically-driven systems. Hydraulic systems convert energy from electric to mechanical to hydraulic and then back to mechanical. Electric-driven systems only convert energy from electric to mechanical. Since a portion of the energy is lost in each conversion, hydraulic systems are less efficient than electrically-driven systems. Replacing hydraulic drives with electric drives can result in energy savings of 20% or more.

Another major benefit of electrical drives that is relative to hydraulic drives is the reduced maintenance associated with direct drive system and the elimination of hydraulic leaks. The improved performance of electrical drives also provides enhanced motor control and easier set-up. Variable frequency drives (VFDs) are especially beneficial (see ***M&D6***).

Frequency: One-time activity.

M&D6: Replace older VFDs with more efficient drives. A VFD is an electronic controller that varies the speed of the motor to match the desired operational load. This allows the motor to be continually adjusted relative to the power required, which, in turn, translates into energy and maintenance cost savings. VFDs can be used in a wide array of WWTP applications and are particularly beneficial for pumping and aeration, but they are also valuable for air compression.

Frequency: One-time activity.

Pumping Measures

Pumps are an integral part of the wastewater treatment process and convey wastewater to, within, and from the WWTP. Pumps also are used for pumping sludge. Pumping accounts for a significant share of the total energy associated with WWTPs. In trickling filter systems, pumping accounts for 50-55% of total energy used in the plant. In activated sludge systems, pumping accounts for 15-20% of total energy use.

The most commonly used pumps in WWTPs include centrifugal and positive displacement pumps. However, some WWTPs also use progressive cavity pumps. Centrifugal pumps are used for pumping of raw wastewater, primary sludge, secondary sludge, effluent wastewater, flush water, spray water, and seal water. Progressive cavity pumps are used in primary sludge, thickened sludge, digested sludge, slurries, and chemical feed applications. Positive displacement pumps are used for all types of sludge and slurries.

Since flow requirements in WWTPs often vary, plants must either throttle, use bypass valves, operate multiple pumps in parallel, use on/off control, or rely on VFD control to accommodate the fluctuating pump demand. Centrifugal pumps can use any of these control strategies, but positive displacement pumps cannot be throttled because they are constant torque systems. Some cost-effective energy efficiency measures for pumping are presented below.

P1: Perform periodic pump efficiency testing. Periodic pump efficiency testing to determine pump performance, as well as the need for repair and replacement, is highly recommended and allows for timely and cost-effective maintenance before pump failure. Additionally, preventive pump maintenance can

identify opportunities for energy cost savings. Efficiency testing is performed by comparing the operating point of the pump to the manufacturer's pump curve. The operating point of the pump is determined by measuring either flow or the differential head across a pump (inlet vs. outlet pressure).

Frequency: Periodically.

P2: Correctly size and operate pumps. Pumps are often oversized, which results in wasted energy. Selecting a pump (or more specifically, a combination of pump, drive, and motor) for an application based on existing flows, and with the ability to increase impeller size to handle higher flow, can significantly reduce pumping energy use relative to the use of oversized pumps. Additionally, selecting pumps to match base or average flow and using supplemental pumps for peak flow further reduces energy use. The most efficient pumps should be operated first. Matching the pump flow also helps manage demand better, as it avoids the use of additional pumps. Another way to reduce demand is to turn one pump off before starting another.

Frequency: One-time activity for sizing of pumps, and ongoing activity for pump demand management.

P3: Replace check valves associated with higher head loss with low head loss valves. The basic purpose of a valve is to permit flow in one direction while preventing flow in the opposite direction and to do so automatically and with a minimum of maintenance and pressure drop (head loss) across the valve. Valves can produce significant head loss in pumping applications, which results in increased energy requirements. Consequently, valves with high head loss should be replaced with low head loss valves to reduce energy costs. There are three commonly used types of valves in WWTPs: swing check valves, ball check valves, and flapper check valves. Swing check valves have higher head loss but have adjustable closing speeds. Ball check valves have lower head loss and slow closing speeds. Flapper check valves have the lowest head loss, but they have non-adjustable closing speed.

Frequency: One-time activity.

P4: Adjust or replace inefficient impellers. Pumps can be modified to operate more efficiently. For example, inefficient pump impellers can be adjusted or replaced to generate energy savings. Instead of operating with partially closed valves, which is highly inefficient, impeller size can be reduced. Alternatively, impeller size can be increased to reduce peak demand.

Frequency: One-time activity.

P5: Install VFD control on pumps with variable loads. Pumps with variable loads benefit from VFD control because adjusting the flow rate to match the load reduces the amount of energy wasted in relation to other methods used for accommodating fluctuating flow demand (e.g. throttling or bypassing.) Centrifugal pumps (variable torque) are appropriate for VFD control, while VFD control of positive displacement pumps requires careful selection due to the constant torque required. Unlike centrifugal pumps, where power varies with the cube of the speed, in constant torque pumps power varies in direct proportion to speed. As a result, VFD control of positive displacement pumps generates lower energy savings compared to VFD control of centrifugal pumps. The energy savings, although lower, still can be significant in some applications of positive displacement pumps.

Frequency: One-time activity.

P6: Replace inefficient or oversized pumps with high-efficiency pumps. Replacing inefficient or oversized pumps with high-efficiency pumps reduces energy costs. High-efficiency pumps are especially appropriate for applications with long operating hours.

The Department of Energy (DOE) has developed a tool—the Pump System Assessment Tool (PSAT)—that can be used together with the Hydraulic Institute’s Achievable Efficiency Estimate Curves to determine the achievable and optimum efficiencies for the selected pump type, as well as correction factors, at the specified operating conditions. This method can be used to calculate the energy savings based on the difference between the anticipated energy use of a high-efficiency pump and the baseline energy use associated with the inefficient or oversized pump.

Frequency: One-time activity.

P7: Replace pneumatic pumps with electrical-driven pumps. Some WWTPs use air pumps, called pneumatic pumps, which use compressed air to drive pneumatic pumps. However, compressed air is expensive to produce. Centrifugal (or other electrical-driven) pumps can achieve the same pumping capacity as an air pump but are much more energy-efficient. As a result, replacing pneumatic pumps with electrical-driven pumps generate energy cost savings. Other merits of electrical-driven pumps include a reduction in air leaks associated with the use of air equipment. Since air leaks represent lost compressor horsepower, replacing pneumatic pumps with electrical-driven pumps translates into additional energy cost savings.

Frequency: One-time activity.

Aeration Measures

In New York State, activated sludge systems are the most commonly used secondary treatment systems. Activated sludge systems rely on aeration to supply oxygen to the metabolizing microorganisms and to provide sufficient mixing within the system. There are two primary methods of aeration. The first uses subsurface diffusers (or blowers) to introduce air into the wastewater. The second uses mechanical systems to agitate the wastewater to introduce air from the atmosphere.

Most subsurface diffuser systems rely on positive displacement type blowers and centrifugal blowers (single-stage and multi-stage centrifugal blowers.) Positive displacement blowers typically are used in applications where a high discharge pressure is required and for capacities less than 15,000 cfm, while centrifugal blowers are widely used in applications with capacities exceeding 15,000 cfm. Blowers must meet a wide range of airflows and pressures at a WWTP.

In the past, blowers often were controlled by discharge throttling. Today, typical methods of regulating blower airflow include bypassing, inlet throttling, adjustable discharge diffuser, parallel operation of multiple units, timed on/off operation, and VFD control. Inlet throttling and adjustable discharge diffuser are applicable only to centrifugal blowers because positive displacement blowers operate at constant capacity with variable flow and as a result cannot be throttled. However, positive displacement blowers can be controlled through the use of multiple units operating in parallel, timed on/off operation, or VFD control.

Aeration is a highly energy-intensive process, and aeration typically accounts for as much as 50-60% of the total electricity used in WWTPs that have activated sludge systems. As a result, improvements in aeration system energy efficiency can have a profound impact on total energy use and operating costs in a WWTP. There are numerous energy efficiency measures associated with aeration, and some of the most cost-effective measures are presented below.

A1: Monitor blower pressure, maintain blower operation within recommended speeds, and clean filters regularly. Blowers produce high volumes of air at about 6-10 psi above atmospheric pressure. Good preventive maintenance practices, such as monitoring pressure and cleaning filters regularly, will help reduce energy use associated with blower operation. Maintaining blower operation within the speed

recommended by the manufacturer is important, as energy efficiency quickly worsens when equipment is operated outside its optimum conditions. For example, centrifugal blowers should always be operated at >50% of rated capacity.

Frequency: Monthly for preventive maintenance, daily for load monitoring.

A2: Install inlet guide vanes on centrifugal blowers for throttling airflow. Inlet guide vanes reduce the amount of airflow (“throttle”) through the centrifugal blower. This, in turn, slightly reduces the power draw of the motor. As a result, installing inlet guide vanes on centrifugal blowers reduces the amount of energy wasted in relation to discharge throttling. However, VFD control of the centrifugal blower provides even greater energy savings because it significantly reduces the power draw of the motor by controlling the airflow through speed control instead of inlet vanes. VFD control of aeration equipment is discussed in Measures A3 and A4.

Frequency: One-time activity

A3: Replace multi-stage or inlet guide-controlled multi-stage centrifugal blowers with single-stage centrifugal blowers with VFD control. Older WWTPs often use multi-stage centrifugal blowers to produce variable flows at a constant pressure. Unfortunately, multi-stage centrifugal blowers have limited turndown capacity (~70%). As a result, multi-stage centrifugal blowers produce excess air that is wasted when the blowers operate at part load. Single-stage centrifugal blowers operate more efficiently than multi-stage centrifugal blowers at various loads. Indeed, they are capable of maintaining a high level of efficiency from full load to about 40% load. Although single-stage centrifugal blowers equipped with variable inlet guide vanes and variable discharge diffusers allow for airflow adjustments while maintaining constant impeller speed, VFD control of single-stage centrifugal blowers is a more energy-efficient method to control the airflow while maintaining a constant pressure.

Single-stage blowers are more costly and have higher noise levels than multi-stage blowers, but those drawbacks are often acceptable when the energy cost savings associated with single-stage centrifugal blowers are considered.

Frequency: One-time activity

A4: Install two-speed or VFD control on mechanical aerator. Mechanical aerators are typically operated at constant speeds independent of the need for oxygen in the aeration basin. This is a highly inefficient mode of operation, as energy is wasted due to over-aeration. Installing two-speed control, or more preferably VFD control, on the mechanical aerator can generate significant energy savings, especially if the control is based on the dissolved oxygen (DO) level of the wastewater. (DO control is discussed in A6.) VFD control also ensures that the minimum amount of oxygen is supplied at any given time, thereby improving the biodegradation process.

Frequency: One-time activity.

A5: Replace older blowers with high-efficiency blowers. Replacing inefficient blowers with high-efficiency blowers can save about 35% of aeration energy, or ~20% of total energy used in a WWTP having an activated sludge system. The Department of Energy (DOE) has developed a tool—the Fan System Assessment Tool (FSAT)—that can be used to determine the achievable and optimum efficiencies for the selected blower type at the specified operating conditions. This tool can be used to calculate the energy savings based on the difference between the anticipated energy use of a high-efficiency blower and the baseline energy use.

Frequency: One-time activity.

A6: Install dissolved oxygen (DO) control. It is extremely hard to manually maintain desirable DO levels in an activated sludge treatment process, especially given large daily variation in flow and wastewater strength. Frequently, operators provide too much oxygen, which results in wasted energy and unstable biological conditions. Automatic monitoring and control of DO can provide significant energy savings and ensure stable biological operation by closely matching the amount of oxygen delivered to the oxygen demand, which eliminates over-aeration. Indeed, data suggests 15-40% of aeration energy can be saved by installing DO control equipment.

Since aeration energy accounts for such a large share of total energy use in WWTPs with activated sludge systems, automatic and continuous monitoring and control of DO levels often translates into total plant energy savings of 10-25%. Automatic aeration control requires the use of a continuous online DO monitors and VFDs on the aerator blowers.

Frequency: One-time activity for installation and monthly for sensor calibration.

A7: Replace coarse pore diffuser with fine pore diffuser. Surface mechanical aerators or coarse pore submerged diffusers are often used in WWTPs to transfer oxygen to the wastewater because they have lower implementation costs and require less maintenance than fine pore diffusers. However, replacing inefficient submerged coarse pore diffusers with energy-efficient submerged fine pore diffusers can generate aeration energy savings of as much as 40-50%, or 20-25% of total plant energy use. The energy savings are even greater if ultra-fine pore diffusers are installed, which sometimes generates savings of up to 50% in aeration energy.

Oxygen transfer efficiency (OTE) is highly dependent upon the surface area of the dispersed bubbles; the more total surface area, the higher the OTE. As a result, the OTE of fine pore diffuser systems, such as disks, domes, and membranes, is typically two to four times better than that of coarse bubble systems.

Frequency: One-time activity.

Sludge Thickening and Dewatering

Sludge treatment accounts for 40-45% of total electricity use in a typical WWTP that has trickling filters. In WWTPs that have activated sludge systems, sludge treatment accounts for a somewhat lower electricity share of 25-30%. Sludge treatment includes sludge thickening, sludge stabilization, sludge dewatering, and disposal by landfill, composting, land application, or incineration.

Thickening is used to reduce the volume of sludge, typically from 1% total solids content to 4-6% total solids content, prior to further treatment. Sludge dewatering increases the total solids contents further, to 15-30%. There are a variety of processes used to thicken and dewater sludge, including gravity thickeners, dissolved air flotation thickeners, centrifuge dewatering systems, and mechanical dewatering equipments such as belt filter press. There are few energy savings opportunities within gravity thickeners and

mechanical dewatering equipment because of their low energy consumption, but optimization of these processes can save energy later in the process.

The primary sludge dewatering and thickening energy users include dissolved air flotation thickeners (which account for 60% of the electricity used for sludge processing) and centrifuges.

S1: Improve solids capture and dewatering in the dissolved air flotation thickening process. Dissolved air flotation thickeners use energy for motorized skimmers, bottom scrapers, air compressors, and recalculation pumps. Air is introduced into liquid sludge that is held at elevated pressure. When the sludge is depressurized, dissolved air is released as finely divided bubbles that carry solids to the top where they are removed. Dissolved air flotation thickeners have high operating costs because they require a significant amount of energy for air pressurization. However, the energy use can be reduced by optimizing the solids capture and dewatering. For example, it is possible to optimize the air-to-solids ratio by adjusting the supply air and/or feeding the highest possible solids content. Additionally, energy use can be reduced by operating the dissolved air flotation thickener continuously and adding polymers to the sludge.

Frequency: One-time activity.

S2: Replace centrifuge with screw press for improved sludge dewatering. In a centrifuge, sludge is fed into a rotating drum where it separates into a dense cake (~20-30% total solids content) and a concentrate containing low-density solids (~4-6% total solids content). The centrifuge is a relatively large energy consumer. Replacing the centrifuge with a screw press saves energy. A screw press is a simple, slow-moving, mechanical piece of dewatering equipment that continuously dewateres the sludge by gravity drainage. In addition to lower energy consumption, the screw press also has lower operation and maintenance costs than the centrifuge. Furthermore, the screw press can produce Class A biosolids if modified (by adding heat). The primary disadvantages with a screw press include potential for odor problems and larger installation space.

Frequency: One-time activity.

S3: Replace centrifuge with gravity belt for improved sludge thickening. Replacing a centrifuge with a gravity belt can also provide energy savings. A gravity belt thickener consists of a gravity belt driven by a motor. As the sludge makes its way down the horizontally-moving belt, water drains through the porous belt. The solids are continuously turned to improve the drainage process. To improve the thickening process, the sludge also is conditioned with a polymer. Gravity belts can reduce sludge volume by up to 90%. Other advantages associated with gravity belts include small space requirements and ease of automation and control.

Frequency: One-time activity.

Section II-B: Measures Associated with Digestion, UV Disinfection, and Building Systems

Anaerobic Digestion

WWTPs use digesters to reduce the amount of sludge generated by the primary and secondary wastewater treatment processes. There are two types of digesters: aerobic and anaerobic. In aerobic digestion, oxygen is used to break down the sludge waste product. Since oxygen has to be supplied by aeration equipment, aerobic digestion is a highly energy-intensive process. Additionally, sludge production is high, which, in

turn, requires significant energy use for thickening and dewatering prior to disposal. Energy efficiency measures associated with aeration processes were discussed above.

AD1: Replace aerobic digester with anaerobic digester. Anaerobic digestion is less energy intensive compared to aerobic digestion, and replacing aerobic digesters with anaerobic digesters can save a significant amount of energy. First, anaerobic digestion does not require oxygen. Second, anaerobic digestion produces less sludge, and as a result, less energy is required for sludge dewatering and thickening. Furthermore, anaerobic digestion produces biogas, which is an energy source that may be used onsite to replace purchased fuel. However, anaerobic digestion is a slower process than aerobic digestion and is more sensitive to variations in flow or composition. Additionally, the anaerobic digestion process requires heat; the lower the solids contents, the more heat is required. As a result, improving solids capture and dewatering upstream of the anaerobic digestions typically will reduce the amount of heat required for the process. For examples on how to improve solids capture and dewatering, see the Sludge Treatment Measures section.

Frequency: One-time activity.

Table 2b: Cost-Effective Energy Efficiency Measures for WWTPs

Source: Global Energy Partners, LLC

Digestion Measures	UV Disinfection Measures	Building System Measures (incl. air compressor, lighting, heating, and ventilation systems)
<ul style="list-style-type: none"> ● D 1. Replace aerobic digesters with anaerobic digesters ○ D 2. Optimize digester performance ● D 3. Install combined heat and power system 	<ul style="list-style-type: none"> ● UV1. Clean UV lamps ● UV2. Turn off UV lamps during low-flow periods ○ UV3. Operate medium-pressure UV system in accordance with water quality ○ UV4. Replace medium-pressure high-output UV system with low-pressure high-output UV system 	<ul style="list-style-type: none"> ● B 1. Install VFD control on air compressors ○ B 2. Monitor light operation ○ B 3. Clean lamps and fixtures ○ B 4. Install high-efficiency lighting ○ B 5. Install occupancy sensors ● B 6. Maintain boilers and furnaces ● B 7. Adjust burners on boilers and furnaces ○ B 8. Monitor combustion and boiler equipment continuously ○ B 9. Check outside ventilation air devices, supply/exhaust fans, and clean fan blades ○ B 10. Replace ventilation air filters

Legend:

- Typically provides high operational cost savings
- Typically provides medium operational cost savings
- Typically provides low operational cost savings

AD2: Optimize anaerobic digester performance. Only about 50% of the organic matter in sludge is degraded in today's anaerobic digesters. Since disposal of sludge is becoming increasingly costly, WWTPs are increasingly investigating methods for improved digestion. The primary ways to enhance biogas production in anaerobic digesters include:

- **Optimizing process temperature:** Changing the digester operating temperature from mesophilic (85-105 °F) to thermophilic (125-140 °F) increases the rate of destruction of the volatile solids in the sludge. Two-phased anaerobic digestion and temperature-phased digestion have shown potential benefits in volatile solids reduction and biogas enhancement and are gaining industry interest.
- **Sludge pre-treatment:** The hydrolysis step is often the limiting factor in anaerobic digestion and can be improved by pre-treatment. There are various pre-treatment methods available, including chemical, physical, and biological methods. Three of the most promising methods include thermal treatment, ultrasonic treatment, and enzyme dosing.
- **Co-digestion of other wastes:** It is often beneficial to co-digest sludge with other types of organic waste, such as restaurant grease, vegetable/fruit waste, and municipal organic waste. By doing so, the nutrient and moisture content can be optimized, process stability can be improved, and biogas yield enhanced substantially.

AD3: Use biogas to produce heat and/or power. The installation of biogas-to-electricity systems typically are cost-effective options for WWTPs with an average influent flow greater than 5 mgd that have, or that are planning to install, anaerobic digesters. Electricity can be generated using reciprocating engines, microturbines, turbines, or fuel cells. Alternatively, the biogas can be used directly as boiler fuel for the production of heat. While microturbines, fuel cells, and reciprocating engines are available in smaller capacity sizes appropriate for WWTPs, with influent flow rates less than 50 mgd, combustion turbines, as well as reciprocating engines greater than 1 MW capacity, can be used in WWTPs with influent flow in excess of 50 mgd. The thermal energy generated by such a system often can be used to meet digester heat loads and for space heating. Another advantage of such a system is that it can provide critical back-up power. A commonly used rule-of-thumb states that the biogas generated from each 4.4 mgd of influent generates ~100 kW of electricity and 12.5 MMBtu of thermal energy in a CHP system.

Frequency: Once-time activity.

UV Disinfection

Secondary treatment effluent is often disinfected with chlorine gas or sodium hypochlorite prior to being discharged to receiving waters; chloramine and chlorine dioxide are used as chemical disinfectants in some WWTPs. An increasing number of WWTPs are replacing chlorine disinfection with ultraviolet (UV) disinfection because it eliminates the need to generate, handle, transport, and store hazardous and corrosive chemicals. UV disinfection also eliminates the potential to produce disinfection by-products (DBP), which are associated with the use of chlorine disinfection. It is estimated that approximately 30% of all WWTPs in the U.S. currently use UV disinfection.

UV1: Clean UV lamps regularly. For optimum performance, UV lamps should be cleaned regularly. Some UV systems have automatic cleaning systems, while others require manual cleaning. Redundant units are often incorporated in to the design to ensure that disinfection is not compromised during the lamp cleaning process. Follow the manufacturer's recommendation for UV lamp cleaning.

Frequency: Regularly, depending on wastewater quality and operation conditions.

UV2: Turn off UV lamps during low-flow periods. Turning off UV lamps during low-flow periods can save energy. Additional savings can be achieved by using vertical systems that use several series of lamps. In such vertical systems, one series of lamps can be turned off while the remaining rows are active. A small amount of electricity is run through the inactive lamps to keep them warm and prevent excessive lamp cycling.

Frequency: Daily

UV3: Replace medium-pressure UV system with low-pressure UV system. UV systems use either low-pressure or medium-pressure mercury lamps. The energy required for sufficient inactivation of microorganisms is a function of water quality, transmittance, flow rate, and disinfection limits. Medium-pressure lamps are often used in larger WWTPs because they have a smaller footprint than low-pressure systems. However, medium-pressure lamps use significantly more energy compared to low-pressure lamps. Low-pressure, high output UV lamps use about 50% less energy than medium-pressure lamps. Typical energy requirements for low-pressure, high output systems range from 3.2 to 4.8 kWh/mgd, while medium-pressure systems use about 6.8 kWh/mgd.

Depending on the application, it may be feasible to replace medium-pressure lamps with low-pressure, high output lamps. Low-pressure UV lamps are used for flows not exceeding 38 mgd. For higher wastewater flows, or when space is limited, medium-pressure UV lamps are required.

Frequency: One-time activity

UV4: Operate medium-pressure UV system in accordance with water quality. Medium-pressure UV systems can be operated in response to water quality (transmittance); about 13.4 to 15.0 kW/mgd is required for 50% transmittance, but only 10 kW/mgd is required for 65% transmittance. As a result, energy can be saved by reducing the number of UV lamps operating during times of higher water quality.

Frequency: Daily

Building Systems

Although building systems account for only about 2-3% of a WWTP's total energy use, there are a variety of low-cost energy efficiency measures associated with air compression, lighting, heating, and ventilation that can yield immediate savings. For example, WWTPs can change how lighting is used or can install high-efficiency lighting systems. Furthermore, WWTPs can lower the amount of energy required for the operation of boilers and ventilation fans by following well-designed O&M and preventive maintenance strategies. Such strategies also will help extend equipment life to avoid premature replacement.

B1: Install VFD Control on Air Compressors. Compressors produce low volumes of air at 80 to 140 psi. Air compressors often are found in machine shops where they are used for various maintenance functions. They also are used to feed aeration basins and operate hydraulic drives and pumps. Most air compressors are rotary screw-type compressors and are operated in an inlet modulation with unloading mode. In this control scheme, the air compressor produces compressed air until a desired value is reached, at which point it begins modulating and then unloads. When it unloads, the air compressor continues rotating until the maximum pressure value is reached. The unload mode is highly inefficient because it still requires about 20% of its full electrical load. Replacing the inlet modulation with unload mode control scheme with a VFD-controlled rotary-screw air compressor saves energy, especially in part-load operation.

Frequency: One-time activity.

B2: Monitor Light Operation. Manually switching off lights is one of the best no-cost methods of saving lighting energy. With the exception of security lights and exit signs, turn off all lights and signage when daylight is sufficient or whenever they are not needed.

Frequency: Daily.

B3: Clean Lamps and Fixtures. Dirt can accumulate on lamps and fixtures, resulting in a decrease in light output ranging from 5-50%. Fixtures and lamps must be washed on a regular schedule using the proper cleaning solution. The frequency of cleaning depends on the amount and type of dirt in the air, whether the fixture is of the ventilated or non-ventilated type, and the location of the lighting. Older style fluorescent lamps last as little as three years; therefore, it may not be necessary to clean between lamp replacements. Newer fluorescent lamps can last up to 10 years and, therefore, must be cleaned regularly. Most normal maintenance procedures call for lamps and fixtures to be cleaned on an annual basis, but that may be difficult to accomplish with limited staff. Frequent cleaning may be required if the room is exposed to large amounts of dust and grease, if the lamps are directed upward without protection from falling dust, or if the lighting is outside. Many luminaries initially provide the same illumination level, but their ability to be economically maintained and to continue their maximum effectiveness is dependant on quality and appropriateness. Properly selected fixtures can reduce the need for cleaning or can simplify the cleaning process.

Frequency: All lamps and fixtures must be cleaned every three years. Some fixtures and locations require annual cleaning.

B4: Install Energy-Efficient Lighting. Incandescent lighting is no longer necessary for most applications. Incandescent lamps can be replaced with compact fluorescent lamps (CFLs), which come in all shapes and sizes and can replace most incandescent lamps in most fixtures. In addition, fluorescent dimming is now available for both linear fluorescent T-8 and compact fluorescent lamps. Existing incandescent dimmers can sometimes be used to dim fluorescent lighting (check with manufacturers).

Outdoor lighting, warehouse lighting, and indoor lighting with ceilings exceeding 15 feet is usually provided by some type of high-intensity discharge (HID) lamp, such as mercury vapor lamps, highpressure sodium lamps, or metal halide lamps. Mercury vapor lamps are an old and inefficient technology that should be replaced. If the color of the light is not an issue, then high-pressure sodium lamps can provide a very efficient source of light. Otherwise, replacing mercury vapor lamps with pulse-start metal halide lamps is often the best option where white light is desirable. Furthermore, fluorescent lights are now able to work at 20°F or colder and are a viable option for low-wattage outdoor lighting. Look for the ENERGY STAR label on replacement lighting.

Frequency: One-time activity.

B5: Install Occupancy Sensors. Occupancy sensors use motion-detection technologies to turn off lights in unoccupied rooms. Occupancy sensors can be installed in conference rooms, restrooms, storage areas, and other spaces prone to intermittent occupancy. Typical energy savings from occupancy sensors range from 15 to 90%, depending on type and use of space. For example, occupancy sensors integrated with bi-level fluorescent lighting can provide substantial energy savings in hallways, stairways, and warehouses. Occupancy sensors are relatively inexpensive, with installation costs ranging from \$50 to \$150 per sensor.

Frequency: One-time activity.

B6: Maintain Boilers and Furnaces. WWTPs use boilers and furnaces for space heating and for some process heat. Boilers burn fuels to generate hot water or steam, which is subsequently circulated for space heating to the air handling units or coils located in the various building spaces. In the case of a furnace, hot air is circulated throughout the buildings. Natural gas is the main source of energy for the operation of boilers and furnaces. Turning off boilers and furnaces during periods of no use will save fuel.

Burners should be inspected several times per year. Replacing damaged burner tips, and removing soot and other deposits from the burners will improve heat transfer and burner efficiency and will ensure smooth ignition and proper flame color. It is also necessary to clean the heat transfer surfaces within boilers and furnaces annually to eliminate fouling and scale and to maximize heat transfer efficiency.

In addition to maintaining the burners, adjusting the air-to-fuel ratio, and monitoring emission levels, boilers need to be inspected for leaks and damaged insulation. Repairing leaks in pipes, connections, and ducting, as well as repairing or replacing poor insulation on boiler jackets, condensate and feedwater tanks, hot water pipes, and air ducts, will reduce heat loss and energy consumption. A malfunctioning steam trap can waste a large amount of energy. It also is important to clean the boiler tubes and monitor the temperature of stack gases. Tune-ups can achieve boiler energy savings of 2-20%.

Frequency: Quarterly.

B7: Adjust Burners on Furnaces and Boilers. Adjusting burners to yield the correct air-to-fuel ratio will optimize combustion efficiency. Generally, a small amount of excess air is necessary, but the optimal ratio is dependent on the particular system and fuel type. For example, a forced draft gas boiler may operate well with 5-10% excess air (which relates to 1-2% excess oxygen). In some instances, replacing older burners with new efficient burners can be cost-effective.

Frequency: Quarterly.

B8: Monitor Combustion and Boiler Equipment Continuously. Continual monitoring of combustion parameters and boiler operation will help detect problems with the air-to-fuel ratio. Monitoring equipment should be capable of measuring the excess air and carbon monoxide levels. High carbon monoxide levels indicate incomplete combustion, which could be due to a poor air-to-fuel ratio or fouled burners. The U.S. Department of Energy's Federal Energy Management Program (FEMP) recommends that a boiler's combustion efficiency be measured and recorded at least once a month during the heating season. If the combustion efficiency is found to be lower than that of the previous year, a boiler tune-up by a qualified technician may be required.

Frequency: Monthly.

B9: Check Outside Air Ventilation Devices, Ventilation/Supply Fans & Clean Fan Blades. The main purpose of a ventilation system in a WWTP is to supply sufficient outside ventilation air for the dilution of odor-causing contaminants, such as hydrogen sulfide and ammonia. The discharge from the ventilation system is often treated by vapor-phase systems, including wet air scrubbing and carbon adsorption. If a large amount of air is ventilated, vapor-phase systems can also be effective at providing adequate ventilation for occupancy. The ventilation system also plays an important role in conditioning the interior space.

Many ventilation systems use "economizer" dampers that automatically modulate the amount of outside airflow used to condition the space. These economizers allow up to 100% outside air for "free-cooling" during moderate outdoor conditions but restrict the outside airflow to a minimum setting when it is too cold or hot outside for beneficial use. Economizers can have reliability problems. If the outside air damper

becomes stuck open, too much outside air may enter the system, and the cooling coils can be overloaded. If it is stuck closed, then the opportunity for “free cooling” is lost. It is necessary to clean and lubricate the movable parts and check the actuator movement periodically to ensure proper operation and to maintain maximum system efficiency.

Fixed-size outside air openings may not provide adequate outside air to meet prevailing requirements. The amount of outside air intake can usually be modified by adjusting outside air dampers or providing larger fixed openings. In some cases a plate with a fixed hole is screwed to a larger opening and this plate can be removed during mild weather to improve indoor air quality. Additionally, ventilation/supply fans require routine maintenance for optimal operation. It is necessary to lubricate bearings, adjust or change fan belts, and clean fan blades on an annual basis to maximize fan efficiency.

Frequency: Seasonally.

B10: Replace Ventilation Air Filters. The ventilation system removes particulates contained in outside air by way of air filters. Particulate accumulation on air filters reduces airflow and increases fan energy consumption. Air filter technology has been significantly improved; the use of modern air filters improves indoor air quality while reducing the total cost of operation. The cost of the filter is typically 20% of the cost of fan energy required to push air through the filter. The most common improvement is to replace 2” pleated filters with 4” extended service pleated filters.

Frequency: Quarterly or at 0.8” of pressure drop.

SUMMARY

The equipment that uses the greatest amount of energy in WWTPs typically offers the greatest potential for energy savings. Motors and drives, pumps, aeration equipment, and sludge processing systems represent the major energy end-use areas in WWTPs. It is often beneficial to replace standard equipment with high-efficiency equipment upon failure, or when substantial and costly repair or maintenance is required. There are also ample opportunities to reduce energy costs in WWTPS through various other energy-efficiency measures.

Before investing in any energy-efficiency measure it is valuable to conduct an economic analysis to determine the payback of the measure. It is typically recommended to first implement low-cost, easy to implement measures with short payback periods (like those included in this guide). Thereafter, more costly and technically challenging measures can be implemented to yield additional energy savings. Following implementation, energy-efficiency measures must be monitored to ensure that projected energy savings are realized on an on-going basis. A continuous monitoring program also provides a way for energy management personal to gauge the overall performance of the plant.

REFERENCES

1. *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. EPRI, St. Lois, MO: 1996. CR-106941.
2. Energy Center of Wisconsin, *Energy-Saving Opportunities for Wastewater Facilities: A Review*, June 2003.
3. Pacific Gas and Electric Company, *Energy Baseline Study for Municipal Wastewater Treatment Plants*, September 2006.
4. EPRI, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*, CR-106941, September 1996.
5. U.S. Environmental Protection Agency, *Wastewater Management Fact Sheet, Energy Conservation*, EPA 832-F-06-024, July 2006.
6. Smith, C.B., and K.E. Parmenter, "Electrical Energy Management in Buildings," in *Handbook of Energy Conservation and Renewable Energy*, edited by F. Keith and D.Y. Goswami, CRC Press/Taylor & Francis: 2007.
7. Environmental Protection Agency, *Combined Heat and Power, Energy Savings and Energy Reliability for Wastewater Treatment Facilities*, September 25, 2007.
8. Phillips, David, and Michael Fan, University of California, Davis, *Aeration Control Using Continuous Dissolved Oxygen Monitoring in an Activated Sludge Wastewater Treatment Process*, 2005.
9. U.S. Department of Energy, Motor Challenge, *Determining Electric Motor Load and Efficiency*, Fact Sheet, DOE/GO-100097-517.
10. U.S. Department of Energy, Motor Challenge, *Replacing an Oversized and Underloaded Electric Motor*, Fact Sheet, DOE/GO-10096-287.
11. U.S. Department of Energy, Motor Challenge, *Reducing Power Factor Costs* Fact Sheet, DOE/GO-10096-286.
12. U.S. Department of Energy, Motor Challenge, *Optimizing Your Motor-Driven System*, Fact Sheet, DOE/GO-10096-313.
13. U.S. Department of Energy, Motor Challenge, *Buying and Energy-Efficient Electric Motor*, Fact Sheet, DOE/GO-10096-314.
14. U.S. Department of Energy, *Improve Motor System Efficiency with MotorMaster+*, October 2005.
15. U.S. Environmental Protection Agency, *Wastewater Technology Fact Sheet, Fine Bubble Aeration*, EPA 832-F-99-065, September 1999.
16. National Small Flows Clearinghouse, *Fine Bubble Aeration*, Fact Sheet, WWFSOM23.
17. *Enhancing Digester Operation*, Tech Review, Global Energy Partners, LLC, Lafayette, CA: 2007.
18. *Occupancy Sensors for Lighting Control in Commercial Spaces*, Fact Sheet, Global Energy Partners, LLC, Lafayette, CA: 2006.
19. *Advanced Lighting Controls: Marketing Tools for Utility Representatives*, Global Energy Partners, LLC, Lafayette, CA: 2006. 1481-6-06.

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