A Thesis

entitled

# The Energy, Greenhouse Gas Emissions, and Cost Implications of Municipal Water Supply & Wastewater Treatment

by

Thelma Rodriguez-Winter

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in Civil Engineering

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An Abstract of

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All man-made structures and materials have a design life. Across the United States there is a common theme for our water and wastewater treatment facilities and infrastructure. The design life of many of our mid 20$^{th}$ century water and wastewater infrastructures in the United States have reached or are reaching life expectancy limits (ASCE, 2010). To compound the financial crisis of keeping up with the degradation, meeting and exceeding quality standards has never been more important in order to protect local fresh water supplies. This thesis analyzes the energy consumption of a municipal water and wastewater treatment system from a Lake Erie intake through potable treatment and back through wastewater treatment then discharge. The system boundary for this thesis includes onsite energy consumed by the treatment system and distribution/reclamation system as well as the energy consumed by the manufacturing of treatment chemicals applied during the study periods. By analyzing energy consumption, subsequent implications from greenhouse gas emissions and financial expenditures were quantified. Through the segregation of treatment and distribution processes from non-process energy consumption, such as heating, lighting, and air handling, this study

identified that the potable water treatment system consumed an annual average of 2.42E+08 kBtu, spent $5,812,144 for treatment and distribution, and emitted 28,793 metric tons of $CO_2$ equivalent emissions. Likewise, the wastewater treatment system consumed an annual average of 2.45E+08 kBtu, spent $3,331,961 for reclamation and treatment, and emitted 43,780 metric tons of $CO_2$ equivalent emissions.

The area with the highest energy usage, financial expenditure, and greenhouse gas emissions for the potable treatment facility and distribution system was from the manufacturing of the treatment chemicals, 1.10E+08 kBtu, $3.7 million, and 17,844 metric tons of $CO_2$ equivalent, respectively. Of the onsite energy (1.4E-03 kWh per gallon treated) 74% is process energy and 26% is non-process energy. Sixty-six percent of the process energy is consumed by the main treatment facility and high service distribution. When analyzing seasonal variations, the highest amount of process energy treated the largest amount of potable water with the maximum revealing four Btu used per gallon treated while utilizing 54% of the design capacity. Compared to the periods when the lowest amount of the design capacity was utilized, 32 – 33%, the facility consumed the seasonal high in energy, approximately 6.7 Btu per gallon treated.

For the wastewater treatment and reclamation side, secondary treatment dominates all 3 categories by consuming 81,701,764 kBtu, $1.1 million, and 32,395 metric tons of $CO_2$ equivalent. The total onsite energy was 2.79E-03 kWh per gallon treated, of which 43% was process energy, and the remainder was consumed by natural gas heating and 'other non-process and process' energy, 34% and 23%, respectively. Most significantly during the months of April and May, when the influent flow of wastewater doubles and is diluted due to the addition of seasonal rain water, the amount of energy spent per gallon of treated wastewater decreases by 48% and 34% from the maximum (5.03E-03 kWh/gallon).

By functioning closer to a forecasted design capacity, the efficiency of the potable water treatment facility could be dramatically improved. This can be achieved by implementing additional storage of ready-to-use potable water and/or by expanding the customer base and collaborating with other regional potable water utilities. For example, a county-wide approach to potable water planning falls into agreement with sustainable planning methods, providing regions of the county that have maximized treatment capacity of potable water and giving this region the opportunity to operate closer to the intended design capacity. On the wastewater treatment side, it is apparent that the more dense the BOD concentration in influent waters the more energy is spent in secondary treatment trying to remove it. Exploring more effective screening and pre-precipitation methods could also prove to save a significant amount in energy spent in the secondary treatment step, reducing the organic load prior to aeration. Coupling this with aeration blower and diffuser improvements can offer significant energy savings. Further water quality data and energy use data needs to be collected and analyzed on the individual wastewater treatment processes, especially regarding the impact and effectiveness of the preliminary and primary treatment steps on secondary treatment.

This thesis is dedicated to my mother, who passed while I was in graduate school working to produce this thesis. Her strong will and legacy lives on through me. This thesis is also dedicated to my best friend and husband, Javier. With love we can do anything.

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# Preface

The contents of this thesis represent a full case study of the energy use consumed, financial expenditures exhausted, and greenhouse gases emitted by a City of Toledo water and wastewater treatment and distribution/reclamation system. Two separate analyses were conducted. One analysis focused on the Collins Park Water Treatment Plant and distribution processes. The other analysis focused on the Bay View Park Wastewater Treatment Plant and reclamation processes.

For both analyses energy consumption data and the financial expenditures spent on energy and chemical purchases were obtained. From these datasets, the greenhouse gas emissions were calculated. Data sets for 2009 – 2011 were obtained for the potable water treatment system. These datasets include electricity usage, natural gas usage, lighting counts, nameplate information from air-handling equipment, and treatment chemical amounts. Data sets obtained for 2010 for the wastewater treatment system include electricity usage, natural gas usage, biogas generation amounts, influent and effluent quality, and treatment chemical amounts. Obtaining data sets for different years was one obvious reason for analyzing the system separately but also because these two systems are experiencing different issues when addressing a sustainability plan.

Both facilities have either looked into or are looking into minimizing non-process related energy through energy efficiency programs but process energy requires a more specific focus. This study separates the potable water treatment & distribution processes from the wastewater treatment & reclamation process then analyzes the energy, greenhouse gas emission, and cost implications of each using the indicated years of analysis.

# Chapter 1

# The Energy, Greenhouse Gas Emissions and Cost Implications of Municipal Water Supply

## 1.1 Introduction

Historically energy use at potable water treatment facilities has been viewed as a static usage that fluctuates with season and is contingent with demand needs. The more potable water needed, the more energy is consumed resulting in higher costs. In many areas of the United States, communities have responded to high water demand by increasing the cost to consumers and/or by implementing demand-reduction programs to reduce customer usage then in turn this reduces treatment costs (Olmstead et al., 2007). The Great Lakes region provides the greater Northwest Ohio area with an abundant amount of fresh surface water. For 2008, the Great Lakes Commission (GLC, 2011) reported approximately 46 billion gallons was withdrawn daily from the Great Lakes (excludes self-supply hydroelectric use). For Lake Erie alone, 172 million gallons a day are withdrawn for consumptive use and all of Ohio withdraws 528 million gallons per day for our public water supply alone (GLC, 2011). Freshwater is abundant for our region while other areas of the United States are experiencing shortages. To date, research regarding the sustainable use and treatment of the Great Lakes water supply is limited.

Infrastructure maintenance/replacement, urban sprawl, and improving the water quality of our Great Lakes region have left local governments to deal with the high cost of supplying potable water. Concentrating on one water treatment facility in the Great Lakes region, the Collins Park Water Treatment Plant is experiencing this issue. Up until recently the main focus for this water treatment facility has been to comply with United States Environmental Protection Agency (US EPA) standards. In 2010 as a response to the President's budget request, the US EPA established a statement of policy on EPA's Clean Water and Drinking Water Infrastructure Sustainability Policy (US EPA, 2011). The US EPA now encourages water utilities to incorporate sustainability into their planning process and to "optimize environmental, economic, and social benefits" (US EPA, 2012). One of the objectives in the EPA Planning for Sustainability, A Handbook for Water and Wastewater Utilities, is to reduce energy consumption by 25% within five years of starting the planning for sustainability process (US EPA, 2012). There are many US EPA case studies that look at the energy efficiency of the treatment and supply processes. The majority of these studies seek to alleviate supply shortage problems and/or relate energy efficiency to financial implications. Taking the sustainability analysis a step farther by incorporating a life cycle approach also reveals the global impact of energy use and administrative supply chain decisions.

Energy analyses on potable water treatment facilities have been conducted but to collect detailed data on site-specific treatment processes, non-treatment process energy consumption, and the distribution process for any one facility has proven to be difficult for the research community. Most life cycle analyses conducted on potable water treatment facilities are only able to analyze the facilities entire energy consumption as a whole such as Friedrich & Buckley (2002), Lassaux et al. (2007), and Tripathi (2007). Stokes & Horvath (2006, 2009, 2011) were either able to combine data segments from various treatment facilities or are generalized from industry case studies to provide a base case scenario then analyzing new technologies to help with supply issues or a changing infrastructure. Brent (2006) found that comprehensive data was not available.

In order for treatment facilities to utilize and to implement published life cycle assessment findings, submetered energy use must be diligently recorded and shared. With the intention of helping one facility move into this direction, this study analyzed the Collins Park Water Treatment Plant's energy consumption of different processes while in tandem analyzing the cost energy and emissions.

# 1.2 Objectives and Scope

## 12.1 Objectives

The goal of this portion of the study was to provide a case study analysis utilizing the primary energy consumption data maintaining a Northwest Ohio urban potable water system and evaluating the impact it has on our global environment. By analyzing the following, we were able to determine the energy, greenhouse gas emissions, and cost associated with the water treatment facility and distribution system as well the system's upstream energy use and greenhouse gas emissions. This analysis can be used as a tool and will help to relate and incorporate life cycle assessment research on potable water systems to a municipal system's main focus: compliance and energy efficiency.

### 1.2.2 Scope

The scope of this portion of the analysis includes the direct amounts of energy consumed by the treatment facility from intake/low service through distribution for the years 2009 – 2011. All raw data can be found in appendix A. This data-capture also allows quantification of the facility's greenhouse gases (GHG) emissions. Onsite energy use was divided into process and non-process energy. Non-process energy includes lighting, air handling, and the natural gas used for air and water heating. Process energy includes all energy going into the equipment used for potable water treatment and conveyance. The potable water utilized within each building for personnel use was excluded from this study because it is a miniscule quantity. The analysis includes upstream emissions produced by the facility's chemical needs. This comprises the total amount of chemicals applied during the study not the total amount of chemicals purchased.

## 1.3 Methods

### 1.3.1 Site Description

This urban water system has an intake capacity of 198 MGD and serves approximately 500,000 people. An average treated daily flow is approximately 70 MGD. The system consists of: an intake crib three miles off the Lake Erie shore, a Low Service Pump Station (LSPS), a High Service Pump Station (HSPS), water treatment and sludge dewatering facilities, and distribution pump stations and pipes between stations and to points of service. The construction and decommissioning of all equipment, including the distribution pipes, were not included in the energy, emissions, and cost calculations due to lack of data but also because Stokes & Horvath (2006) and Friedrich & Buckley (2002) found these portions of their life cycle analysis to be insignificant to the overall environmental impact compared to the operation phase. All other system components were included in the analysis.

#### 1.3.1.1 Process Train

Figure 1-1 gives an overview of the potable water treatment process. Starting with point 1, water flows from the intake crib through 16 inlets, 24 feet below water surface. The intake crib is a total of 83 feet in diameter and is located three miles off shore of the lower Western Lake Erie basin.

The start of the treatment process begins shortly after the intake crib. On an as needed basis, potassium permanganate is added to the lake water to control iron and manganese, taste and odor, disinfection byproducts (DBPs), as well as to control nuisance organisms such as zebra mussels and asiatic clams.

The water then flows three miles by gravity to the Low Service Pump Station (LSPS) through a nine-foot diameter pipe. Before the water enters low service, screens remove debris and powdered activated carbon (PAC) is added to the raw water to continue in the aid of adsorbing organic compounds that cause taste and odor. Typically, two of the four pumps at the LSPS are used to provide most of the head needed in transporting water to the main treatment facility (SSOE, 2011).

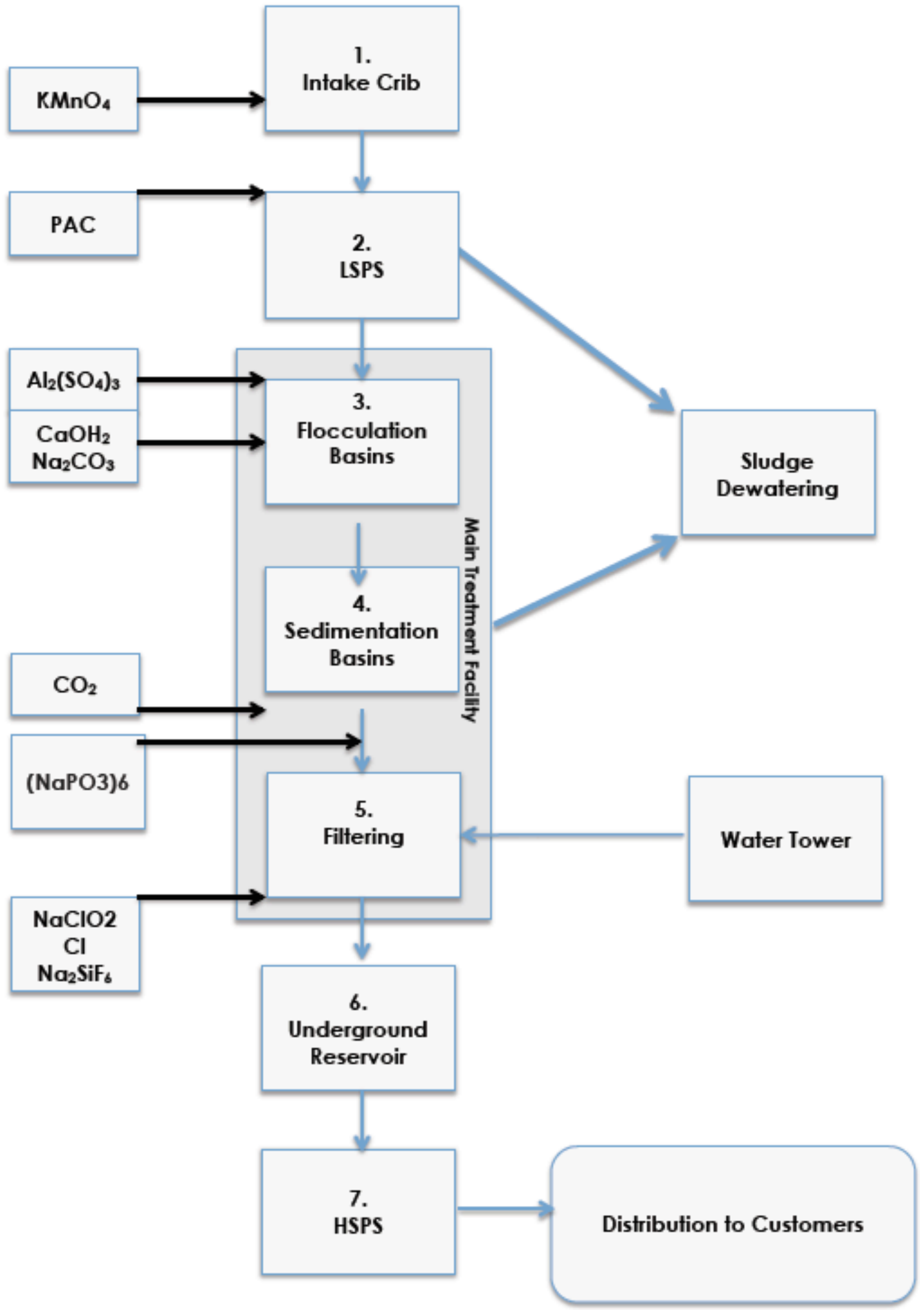



**Figure 1-1: Overview of the potable water treatment process train. Raw Lake Erie surface water flows through the intake crib to the low service pump station, steps 1 &2. The main facility treats raw water in steps 3 – 5. The high service pump station moves potable water from reservoir storage through the distribution system. The water tower is used to backwash the filter beds.**

Water reaches the main treatment facility approximately 10 miles from the LSPS and enters through twin channels or flumes. Prior to reaching the flocculation basins, liquid alum (aluminum sulfate, $Al_2(SO_4)_3$) is added to the incoming waters to help form floc. In the flocculation basins, lime (calcium hydroxide, $CaOH_2$) and soda ash (sodium carbonate, $Na_2CO_3$) are added for softening as well as to prevent scale buildup within the distribution pipes. After a significant amount of floc forms, the water moves to the sedimentation basins. Floc is removed and carbon dioxide ($CO_2$) is added to the water to lower the pH. Polyphosphate, a stabilizer, is added between sedimentation and the filtering processes, which is also to help prevent scaling within the distribution network. After sedimentation, the water enters the filter beds removing all remaining particles. A drainage system beneath the filter beds provide a means for filtered water to flow out as well as a means to clean the filters beds with backwash water. After this point, sodium chlorite ($NaClO_2$), chlorine gas (Cl), and fluoride in the form of sodium silicofluoride, ($Na_2SiF_6$) are added to the water. Sodium chlorite is used in a reaction with a chlorine solution to create chlorine dioxide, which is a disinfectant but is primarily used for taste and odor control.

Potable water intended for distribution fills the underground reservoirs and ensures potable water is readily available for consistent distribution by the HSPS. An additional three pumps are available to fill the backwash water tower used to backwash the carbon-sand filter beds every 24 – 48 hours. Although disregarded in this study, generally, 2 – 3% of the total potable water processed is used for backwashing (Hammer & Hammer, 2008).

Floc and debris from the flocculation basins, sedimentation basins, and backwashed filter beds are processed for sludge dewatering. The sludge dewatering facility is also located on the facility grounds. The dewatering process consists of two clarifier-thickening tanks followed by two mechanical filter presses. Sludge resulting from the treatment process is immediately sent to the clarifier–thickening tanks. The sludge slurry is then sent to the filter press for further dewatering and compression into sludge cakes. The solid sludge cakes are then sold to a fertilizer company intended for land application. The potable water facility also utilizes five lagoons for sludge settling. The lagoons are used when the dewatering facility is to be cleaned or repaired. These cleaning chemicals are not quantified or analyzed in this study. The lagoons are also used for spent backwash water and for settled sludge containing large amounts of clay. There are various small motor driven equipment throughout the treatment facility to help move water through the treatment process including the flocculation basin equipment, sludge collection/pumping equipment, sludge dewatering pumps and equipment, backwash pumps, and chemical feed equipment and conveyance systems.

#### 1.3.1.2 Water Distribution System

The six pumps located at the HSPS provide the head needed to distribute potable water to customers within city limits. Two municipality-owned pump stations are used to transport potable water to the suburban areas: The Flanders Pump Station (FPS) and The Heatherdowns Pump Station (HPS). The FPS does not run regularly but only on an as needed basis. A third pump station, the Berkey Pump Station, provides service to the Northwestern portion of the county. This station is not included in this study.

#### 1.3.1.3 Energy Audits

The facility had an energy assessment conducted in September of 2011, which suggested five energy conservation measures (ECMs) but the facility will plan to implement six ECMs (Table 1.1) as of the time of this study. All ECMs, except the last, are non-process related energy improvements. These conservation measures are to be implemented in 2013 and 2014 and the energy savings are estimated at an approximate total of 3 million kBtu per year (SSOE, 2011). Prior to these planned ECMs, various improvements related to the treatment process had been implemented bringing the treatment train up to current state. A treatment capacity expansion was applied in the mid 1950s.

**Table 1.1: Energy conservation measures found by a professional energy assessment and the projected energy savings. Implementation is planned for 2013 and 2014.**

| Energy Conservation Measure | Energy Savings Projection (kBtu/year) |
|---|---|
| Insulate Steam Valves | 175,900 |
| Insulate Steam Lines | 95,100 |
| Replace Air Handling Units | 10,113 |
| Install Boiler Economizers | 802,000 |
| Flocculation Tank VFDs | 430,403 |
| Lighting Improvements | 1,554,739 |
| **Total Energy Savings** | **3,068,256** |

### 1.3.2 Data Collection

Onsite energy and indirect energy use were analyzed in this study. Onsite energy use was that which was utilized directly at the treatment facilities and at the pump stations. The indirect energy use or upstream energy use was energy used to manufacture treatment chemicals.

#### 1.3.2.1 Onsite Energy Use Data

The lighting and air handling data sets as well as the chemical usage amounts were obtained directly from treatment facility personnel. The 2009 – 2011 electricity and natural gas consumption amounts were taken directly from utility bills. One discrepancy seen at the time this article was written was that personnel at the treatment facility do not view or analyze the utility bills. One would assume that this means the day-to-day operation of the facility proceeds without knowledge of how much energy is being used and whether or not it is necessary to control it.

1.3.2.1.1 Separating Process and Non-Process Onsite Energy Use

The direct energy use for all of the water treatment facilities were aggregated and then separated into process and non-process energy. The total non-process energy consumption equals the summation of energy used for air handling and lighting as well as heating via natural gas. This total was subtracted from the average annual energy use to obtain the process energy consumption (Table 1.2).

**Table 1.2: Non-Process and Process Energy Separated**

| Non-Process Energy | Process Energy |
|---|---|
| Lighting<br><br>11,238,014 kBtu | Pump Motors |
| Air Handling<br><br>903,157 kBtu | Sludge Belt Press (2) |
| Natural Gas (Heating)<br><br>21,670,064 kBtu | Chemical Mix/Feed |
| **TOTAL: 33,811,235 kBtu** | **TOTAL: 98,691,891 kBtu** |

### 1.3.2.2 Upstream Energy Data

The energy values used to manufacture treatment chemicals came from four sources and all energy values were converted to electricity units (kWh). The amount of energy required to manufacture each chemical was taken from Tripathi (2007), SPINE LCI data set (2003), Kim & Overcash (2003), and Saffarian (2009). The quantity (lbm) was converted to metric ton (MT) then multiplied by the amount of energy in mega joules (MJ) required to manufacture 1 MT of corresponding chemical. These amounts are given in table 1.3 in mega joules per metric ton of chemical manufactured. The emission factors for the U.S. electricity mix was then used to estimate the greenhouse gas emissions for the chemical quantities used at the treatment facility.

**Table 1.3: Amount of energy required to manufacture the chemicals used in the potable water treatment process. * Taken from Tripathi, (2007); ** Average taken between Kim & Overcash, (2003)(3020 MJ/MT) and SPINE LCI (2003) (710 MJ/MT) dataset; ***Saffarian, (2009). Values for sodium chlorite and potassium permanganate could not be found.**

| | Energy Needed to Manufacture the Chemical (MJ/MT) |
|---|---|
| Activated Carbon *** | 5838 |
| Aluminum Sulfate (Alum) * | 6290 |
| Lime * | 6500 |
| Carbon Dioxide * | 12900 |
| Sodium Carbonate (Soda Ash) ** | 1865 |
| Sodium Hexametaphosphate * | 12800 |
| Chlorine Gas * | 20130 |
| Sodium Chlorite (Chlorine Dioxide) | 0 |
| Sodium Silicofluoride* | 12800 |
| Potassium Permanganate | 0 |

The amount of energy (MJ/MT) needed to manufacture aluminum sulfate (Alum), lime, carbon dioxide, chlorine gas, sodium silicofluoride, and the polyphosphate was found in Tripathi (2007). This source used Simapro 6.0 (BUWAL 250 inventory, Eco-indicator 99 method) to quantify the production energy of alum, lime and carbon dioxide. For the production of chlorine, the Association of Plastic Manufacturers in Europe (APME), Eco-profiles of the European plastic industry, July 2006 was used. The energy requirements for polymer manufacturing were taken from William F. Owens, Energy in Wastewater Treatment. Sodium Silicofluoride energy requirements were taken from the National Renewable Energy Laboratory (NREL), U.S. Life Cycle Inventory Database.

The energy needed to produce activated carbon was taken from Saffarian (2009). The amounts given by Saffarian (2009) were 1600 kWh for production and 2.59 MJ/ton/km for transportation of 1 ton of activated carbon. The source of the hard coal in Saffarian's analysis was Datong, China and energy calculations included transport by Truck (semi-trailer & medium sized truck) and ship. Because the coal utilized at the local electric utility is from the Black Thunder coal mine in Wright, WY and from the Bull Mountains Coal Mine No. 1 in Musselshell County, MT, the average distances between these two mines and Northwest Ohio was used and only the energy (MJ/ton/km) for the trucks was used, disregarding travel by ship. The distance estimated is 4,538 km. It should also be noted that 3 tons of hard coal is required to produce 1 ton of activated carbon (Saffarian, 2009).

The energy requirement listed in table 1.3 for sodium carbonate is an average from two gate-to-gate sources: The SPINE LCI dataset (2003)and Kim & Overcash (2003). It should be noted that the SPINE dataset used a German electricity mix to determine energy requirements for the Solvay production process. The German electricity mix used for the LCI dataset includes 36% nuclear, 28% coal, 13% natural gas, 13% hydro, 7% crude oil, 2.1% biomass, 0.6% geothermal, 0.3% wind. The U.S. electricity mix in 2011 was approximately 42% coal, 25% natural gas, 19% nuclear, 8% hydro, 5% other renewables (biomass, geothermal, solar, & wind), 1% oil and other fuel sources. Kim & Overcash (2003) take into consideration the energy mix needed for the most common design in the production process. The energy values for potassium permanganate and sodium chlorite were not accounted for in this study due to lack of information on the life cycle energy needed to manufacture these chemicals.

**1.3.2.3 Emissions Data**

In order to provide this case study with an accurate local perspective, emission rates take all generation sources into consideration. The water treatment facility received electricity from the First Energy Corporation's Toledo Edison Company, which operates three power plants (Bay Shore, Richland, and Stryker) and one nuclear power plant (Davis Besse) with 74% of the Toledo Edison's total energy generated from the nuclear power plant. The primary fuel sources for Bay Shore, Richland, and Stryker were coal, natural gas, and distillate fuel oil respectively. Since the nuclear power plant does not emit GHG, the emission rates for Toledo Edison are lower than the RFCW subregion (RFCW) that the water treatment facility is located in (Table 1.4). Toledo Edison's emission rates were used for the onsite electricity use and national emission rates were used to quantify the emissions resulting from the manufacturing of treatment chemicals.

The natural gas emission rates are also listed in table 1.4. The Local Government Operations Protocol uses average heat content to determine which default emission factor to use for the $CO_2$ emissions resulting from natural gas use. The average heat content for Ohio natural gas for the years 2009 – 2011 was used. The commercial default rates in the LGOP (2010) were used for $CH_4$ and $N_2O$.

**Table 1.4: Greenhouse gas emission rates used for electricity and natural gas usage. The natural gas rates were taken from the Local Government Operations Protocol (LGOP, 2010). The LGOP obtained the $CO_2$ rates from the U.S. EPA Final Mandatory Reporting of Greenhouse Gases Rule Table C1 (2010). The LGOP $CH_4$ & $N_2O$ rates were taken from Inventory of Greenhouse Gas Emissions and Sinks: 1990 – 2005 (LGOP, 2010). The electricity rates are 2009 U.S. EPA eGRID rates for the Toledo Edison Co., the RFCW eGRID subregion, and the U.S., respectively.**

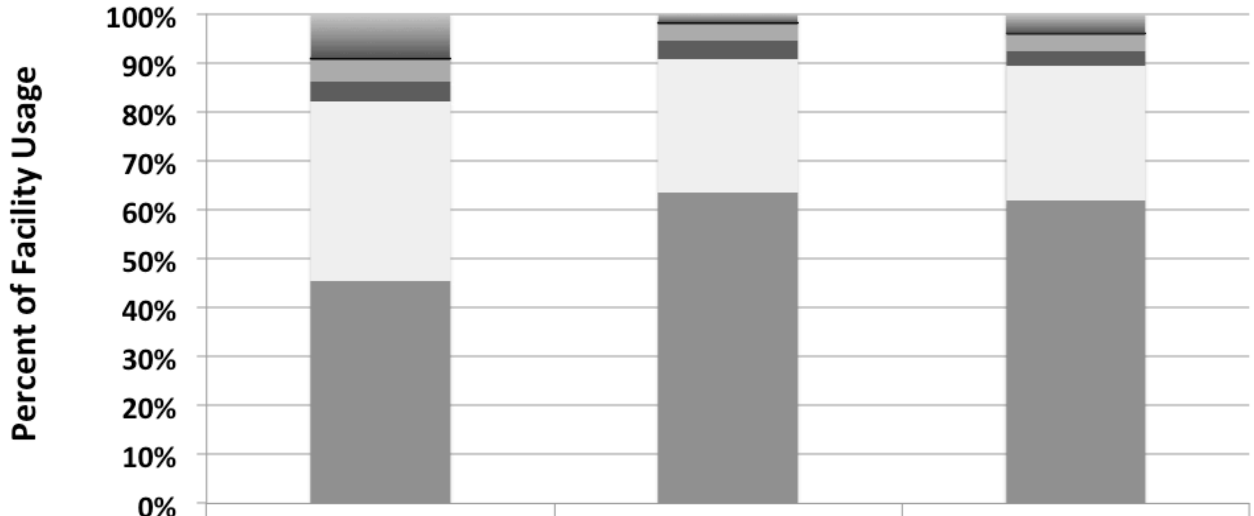
| | Natural Gas Emission Rates: LGOP | Electricity Emission Rates: Toledo Edison | Electricity Emission Rates: eGRID RFC West | Electricity Emission Rates: eGRID U.S. |
|---|---|---|---|---|
| **CO2** | 53.06 kg/MMBtu | 660.85 lb/MWh | 1,520.59 lb/MWh | 1,216.18 lb/MWh |
| **CH4** | 0.005 kg/MMBtu | 7.32 lb/GWh | 18.12 lb/GWh | 24.03 lb/GWh |
| **N2O** | 0.0001 kg/MMBtu | 10.95 lb/GWh | 25.13 lb/GWh | 18.08 lb/GWh |

# 1.4 Results and Discussion

## 1.4.1 Energy Analysis

### 1.4.1.1 Chemical Energy Use

The total energy used by the potable water system is shown in the first bar of figure 1-2. The single most contribution to energy use comes not from onsite energy use but from the upstream process of chemical manufacturing (45% of total). We compiled data from the literature to compare our results to other studies (Table 1.5). However, system types, system boundaries, and data reporting vary considerably in the literature all of which make it difficult to make direct comparisons. Of the 19 reviewed studies only five studies (Tripathi (2007), Stokes & Horvath (2009, 2011), Racoviceanu et al. (2007), and Kyung et al. (2013) analyzed the energy from chemical manufacturing & transport. The Ann Arbor, Michigan water treatment facility study (Tripathi, 2007) found 36% of the total energy use was due to chemical manufacturing. The City of Toronto found 6% of total energy was by consumed chemical manufacturing and transport (Racoviceanu et al., 2007). Stokes & Horvath (2009, 2011) found that material production was the second largest contributor, which includes chemical manufacturing along with the manufacturing of construction and equipment materials. Kyung et al. (2013) was the only study to find that chemical production (95% of total energy) was greater than the Northwest Ohio Water Treatment (NWOWT) facility.




| | | Total Energy Use 242,353,984 kBtu | | Total Cost $5,812,144 | | Total GHG Emissions 28,793 MT CO2E | |
|---|---|---|---|---|---|---|---|
| Non-Process | Natural Gas | 21,670,064 | 9% | $104,238 | 2% | 1,153 | 4% |
| | Air Handling/ HVAC | 903,160 | 0.4% | $15,286 | 0.3% | 80 | 0.3% |
| | Lighting | 11,335,047 | 5% | $208,580 | 4% | 1,002 | 3% |
| Process | Water Distribution | 9,804,125 | 4% | $219,439 | 4% | 867 | 3% |
| | Treatment Process | 88,791,150 | 37% | $1,573,343 | 27% | 7,848 | 27% |
| Upstream | Chemical Production | 109,850,438 | 45% | $3,691,256 | 64% | 17,844 | 62% |

**Figure 1-2: Annual average energy use consumed, financial expenditure, and greenhouse gases emitted from potable water treatment and distribution**

**Table 1.5: Conventional surface water treatment studies and the amount of energy used per gallon of treated potable water. If applicable, values apply to base case only. *Energy required to obtain raw water supply is included in operations/treatment; **60% of the stated supply is surface water, 30% ground, & 10% desalted & recycled. ***Turbidity 10 NTU.**

| Author, Year | kWh / gallons | Unit Processes Included | Comments on the Inclusion of Energy Attributed to Non-process Functions &/Or Chemical Manufacturing |
|---|---|---|---|
| **Stokes & Horvath, 2009** | 7.9E-03 | Onsite/Direct Energy<br>Supply 81%<br>Treatment 8%<br>Distribution 11% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included in the life cycle energy (LCE) of which chemical manufacturing is a subcategory of material production (13%). Other LCE categories: Energy production (81%), Equipment use (4%), & Material delivery (2%). Specific values not given for chemical manufacturing. |
| ****CEC, 2005 (State of CA)** | 7.9E-03 | North<br>Supply 10%<br>Treatment 7%<br>Distribution 83%<br><br>South<br>Supply 87%<br>Treatment 1%<br>Distribution 12% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| ***Tripathi, 2007** | 6.7E-03 | Operation & Pumping 36%<br>Chemical Manuf. 36%<br>NG heating 28% | Non-process Energy<br>Not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included |
| ***Lundie et al., 2004** | 5.5E-03 | Treatment 30%<br>Distribution 70% | Non-process Energy<br>6% of total WTP and WWTP energy is attributed to non-process energy, which includes office buildings and vehicle fleets<br><br>Energy for Chemical Manufacturing<br>Not included |
| ***Brent, 2006** | 4.1E-03 | Treatment, Pumping, & Disposal 24%<br>Distribution 76% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| ***Racovicean u et al, 2007** | 2.7E-03 | Treatment 94%<br>Chemical Manuf 5%<br>Chemical Trans 1% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included |

| | | | |
|---|---|---|---|
| ***Friedrich & Buckely, 2002** | 2.2E-03 | Operational Stage (Supply & Treatment) 96%<br>Construction & Decommissioning 4% | <u>Non-process Energy</u><br>Not included or not separated from total onsite energy<br><br><u>Energy for Chemical Manufacturing</u><br>96% operational stage includes chemicals production as well as energy production |
| ***Venkatesh & Brattebo, 2011** | 1.6E-03 | Water treatment 63%<br>Distribution 37% | <u>Non-process Energy</u><br>63% Water treatment includes space heating, lighting, & general maintenance although this non-process energy is not separated out into subcategories.<br><br><u>Energy for Chemical Manufacturing</u><br>Not included |
| **Stokes & Horvath, 2011** | 1.5E-03 | Supply 30%<br>Water treatment 22%<br>Distribution 48% | <u>Non-process Energy</u><br>Not included or not separated from total onsite energy<br><br><u>Energy for Chemical Manufacturing</u><br>Included in the life cycle energy (LCE) of which chemical manufacturing is a subcategory of material production (36%). Other LCE categories: Energy production (50%), Equipment use (12%), & Material delivery in combination with sludge disposal (< 2%). Specific values not given for chemical manufacturing. |
| ***Cheng, 2002** | 1.5E-03 | Water treatment 56%<br>Distribution 44% | <u>Non-process Energy</u><br>Not included or not separated from total onsite energy<br><br><u>Energy for Chemical Manufacturing</u><br>Not included |
| **Lassaux et al., 2007** | 1.5E-03 | Catchment/Supply 45%<br>Treatment 10%<br>Distribution 45% | <u>Non-process Energy</u><br>Not included or not separated from total onsite energy<br><br><u>Energy for Chemical Manufacturing</u><br>Not included |
| **ECW, 2003 (State of WI: Class AB Facilities)** | 1.4E-03 | Supply 9%<br>Treatment 91%<br>(Does not include distribution) | <u>Non-process Energy</u><br>Lighting can consume 2% or more<br>HVAC consumes an insignificant amount<br><br><u>Energy for Chemical Manufacturing</u><br>Not included |
| **EPRI, 2002** | 1.4E-03 | High service 80 - 85% (Surface Water Treatment Only; Onsite energy with no distribution energy accounted for; Indifferent of facility size) | <u>Non-process Energy</u><br>Not included or not separated from total onsite energy<br><br><u>Energy for Chemical Manufacturing</u><br>Not included |

| | | | |
|---|---|---|---|
| **Bonton et al., 2012** | 6.1E-04 | Treatment 23%<br>Distribution 18%<br>(supply not considered) | Non-process Energy<br>55% attributed to heating buildings<br>4% attributed to lighting.<br>Ventilation not considered<br><br>Energy for Chemical Manufacturing<br>Not included |
| **NYSERDA, 2008 (State of NY: 100 MGD & larger)** | 4.7E-04 | Energy consumed by different processes was not separated from total energy consumed | Non-process Energy<br>Total energy consumed includes lights & HVAC but these components are not separated from total onsite energy.<br><br>Energy for Chemical Manufacturing<br>Not included |
| ***Friedrich et al., 2009** | 3.8E-04 | Water treatment 43%<br>Water distribution 56% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| *****Kyung et al., 2013** | 1.2E-04 | Treatment 5%<br>Supply & Distribution not included in system boundary. | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>95% of the total energy consumed was found to be from chemical manufacturing and transport. |
| **Stokes & Horvath, 2006 (Marin County)** | 6.4E-05 | Supply 9%<br>Treatment 1%<br>Distribution 90% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included in the life cycle energy (LCE) of which chemical manufacturing is a subcategory of the operational phase (64%). Specific values not given for chemical manufacturing. |
| **Stokes & Horvath, 2006 (OWD)** | 2.2E-05 | Supply 42%<br>Treatment 35%<br>Distribution 23% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included in the life cycle energy (LCE) of which chemical manufacturing is a subcategory of the operational phase (89%). Specific values not given for chemical manufacturing. |

A more detailed analysis of chemical usage at the potable water treatment facility is shown in figure 1-3. Manufacturing energy for the chemicals vary from 0.08 to 8.67 kBtu/lbm (Figure 1-3a and 1-3c). Chlorine gas manufacturing requires the highest energy on a per ton basis because the gas is extracted from a highly purified brine solution via electrolysis, requiring a constant DC power supply (ECVM & PlasticsEurope, 2006). The capture, retention, and separation of the chlorine gas from the other byproduct, hydrogen, is said to be difficult. Soda ash has the least energy per metric ton because the Solvay production process requires only three major inputs: salt, limestone, and thermal energy. Carbon dioxide and ammonia are recovered and reused in the process (Swiss Centre for Life Cycle Inventories, 2007). The chemical of highest quantity added to the treatment train was lime, because of which results in the highest energy use (Figure 1-3b). Carbon dioxide and aluminum sulfate are also used in high amounts and results in the second and third highest energy use due to this. Other chemicals do not contribute much to chemical energy use because the quantities used at the treatment facility are very low. Even though chlorine's embedded energy is highest, chlorine also does not add much to the energy footprint because it was used in small quantities in comparison to other chemicals.

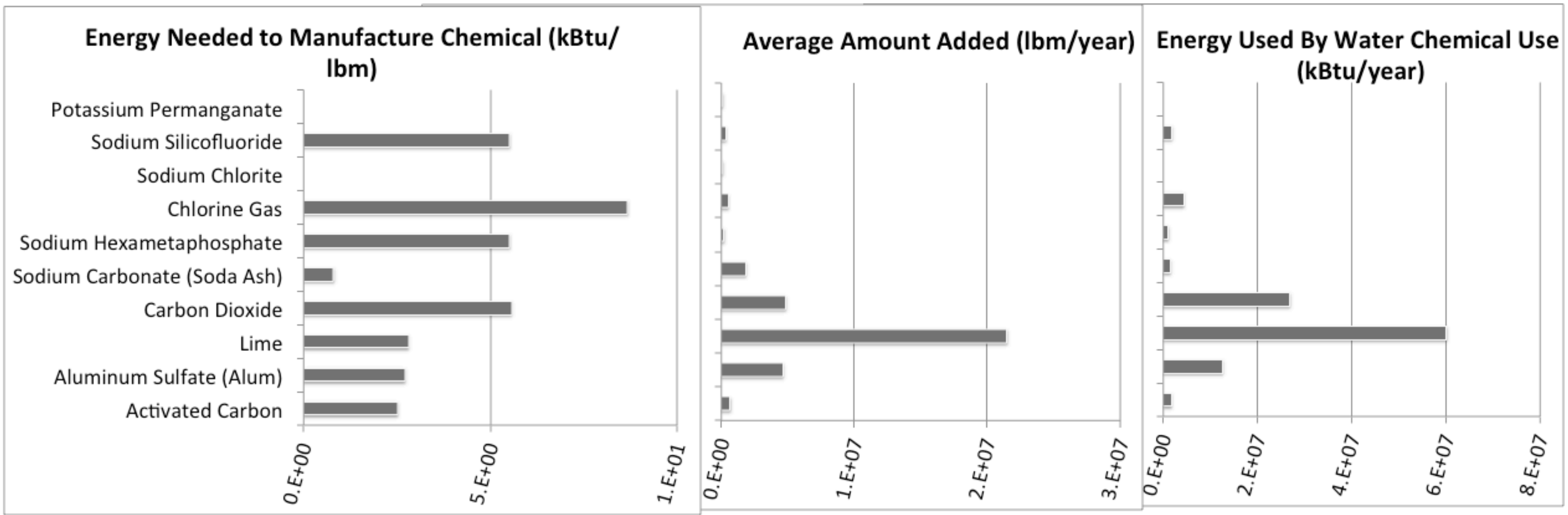



**Figure 1-3a – 3c: Energy requirements and usage amounts of treatment chemicals**

### 1.4.1.2 Onsite Energy Use

Onsite energy use includes low service (intake), treatment & high service, distribution, and non-process energy. This comprises 55% of the total energy use (Figure 1-2). Of the onsite energy, the largest portion of the energy was consumed by the water treatment process, which includes high service (67% of onsite energy), followed by natural gas/heating (16% of onsite energy). Energy required for lighting (9% of onsite energy) and water distribution (7% of onsite energy) were similar. The HVAC system contributed only 0.7% to onsite energy use.

#### 1.4.1.2.1 Process versus Non-Process Energy

Of the onsite energy use lighting, HVAC, and natural gas are considered non-process energy. Their sum contribution to onsite energy (26%) was lower than the process energy (74%). In Sydney, Australia (Lundie et al, 2004), only 6% of total water and wastewater treatment facility energy was attributed to non-process energy. The non-process energy used at the potable water facility was higher than what Lundie et al. (2004) found. Although, the Lundie et al. study did not include energy utilized for HVAC/ventilation. Bonton et al. (2012) found non-process energy to be much greater than the non-process energy at the potable water facility (63%, table 1.5). In most studies found, non-process energy either was not accounted for or not separated from process energy. This suggests that a more detailed analysis on what processes consume exactly how much energy is needed.

The majority of the process energy was consumed by the main facility (66% of process energy, table 1.6). The unit processes that typically require higher energy than others are low service and high service pumping (EPRI, 2002). EPRI reports that 80 – 85% of a potable water utility's electricity consumption is attributed to pumping water to the distribution network (high service). The Collins Park system fits the EPRI scenario in that low service (LSPS) consumes 24% of the process energy requirements, pumping water from Lake Erie to the treatment facility. The two water distribution pump stations (FSP & HPS) consumed approximately 10% of the process energy. To differentiate, potable water at this facility is distributed outside the municipality to the surrounding suburbs. These out-of-bounds suburbs purchase potable water from the municipality. The 10% energy estimated in this study does not include the distribution to these other communities that purchase water from municipality own water utility. Sludge dewatering required less than 1% of the process energy. This process consists of a filter press turning the sludge slurry into dried sludge cakes. A private fertilizer company then purchases these cakes.

The 10% energy consumed by the water facility for distribution was low compared to Brent (2006). Brent found the majority of the electrical needs were for the boosting requirements within the water distribution system (76%). Similarly, the Lassaux et al. (2007) life cycle assessment of a Belgium system shows supplying & distributing water equally consumed 45% of total energy and treatment consumed only 10%.

**Table 1.6: Process and non-process energy use in different facilities of the potable water system. The sludge dewatering facility and the LSPS are not provided with natural gas heating during the winter months. The HPS is the only other facility other than the main treatment facility that is provided with natural gas heating.**

| | | Total Energy (kBtu) | Main Facility | Sludge Dewatering | Low Service Pump Station (LSPS) | Outlying Pump Stations (FPS & HPS) |
|---|---|---|---|---|---|---|
| Process Energy | **Electricity** | **98,595,275 (100%)** | 64,666,274 (65.6%) | 932,503 (0.9%) | 23,192,373 (23.5%) | 9,804,125 (9.9%) |
| Non-Process Energy | **Lighting** | **11,335,047 (100%)** ***(33%)*** | 8,094,037 (71%) | 572,789 (5%) | 1,755,221 (15%) | 913,001 (8%) |
| | **Air Handling/ HVAC** | **903,160 (100%)** ***(3%)*** | 871,509 (96%) | 31,651 (4%) | - | - |
| | **Natural Gas** | **21,670,064 (100%)** ***(64%)*** | 21,445,517 (99%) | - | - | 224,547 (1%) |

Of the non-process energy, most of it (64%) was used for heating the buildings (natural gas, table 1.6). The buildings at the main facility consume the majority of this energy. Although there was some natural gas usage at the Heatherdowns Pump Station (HPS), all of which was used for heating. At the time of this study, HPS was the only pump station that was heated due to personnel working there all year long. A third of the non-process energy was used for lighting with 71% of lighting used at the main facility. Air handling used only 3% of non-process energy with 96% of it being used at the main facility and 4% used at the sludge dewatering facility.

1.4.1.2.2 Seasonal Variation and Energy Per Gallon Treated

There was a consistent usage of total electricity per gallon treated for the entire scope of the system, which includes treatment, all distribution, non-process electricity, and natural gas (Figure 1-4). This maintains the range of 3.4 – 4.6 Btu per gallon. Total energy use per gallon treated fluctuates with seasonal variation due to heating. The maximum total energy used per gallon treated was 6.8 Btu in February 2010. The minimum total energy used was 3.7 Btu in July 2010. Consistent with the system's historical trends the potable water system experiences the peak water demand, the highest electricity use, and the lowest natural gas use during summer months. The opposite is observed during the winter months in that the system experiences the lowest water demand and the lowest electricity use, while consuming the largest amount of natural gas for heating.

When looking how efficiently the design capacity was utilized, a seasonal trend can also be observed. With an intake capacity of 198 MGD, the maximum capacity utilized was in July of 2011 (54%). Comparing this to the system's total energy use per gallon treated, July 2011 was also the month that total energy per gallon treated was at it's lowest and the facility was producing the largest amount of potable water. The system's design capacity was utilized the least in December of each year in the study period (32%). With the exception of December 2011, these periods of lesser efficient capacity utilization also coincide with periods of the highest amount of total energy consumed per gallon treated and the lowest amount of potable water produced.

Narrowing down the scope, a correlation between process electricity and flow in million gallons per month offers a $R^2$ value of 0.8, showing the greater the flow the greater the amount of process energy needed (Figure 1-5). The highest amount of process electricity used and the largest amount of potable water processed during the study period reveals itself as the highest plotted point on figure 1-5. Again, this plotted point was July of 2011 and utilized approximately four Btu per gallon treated, which is the median of the range mentioned above and occurred during the maximum amount design capacity used (54%). One obvious observation is this helps to emphasize the impact of non-process energy on the total amount of energy used per gallon treated. In regards to design capacity, this is similar to a Young & Koopman study (1991) in which the more of the design capacity utilized the less electricity used per gallon treated.

Looking at this issue from an operations standpoint, 89% of the system's process energy is utilized at the low service pump station and main treatment facility, which includes high service. Optimization can be achieved by focusing on this 89% separately from the energy efficiency measures relating to non-process energy.

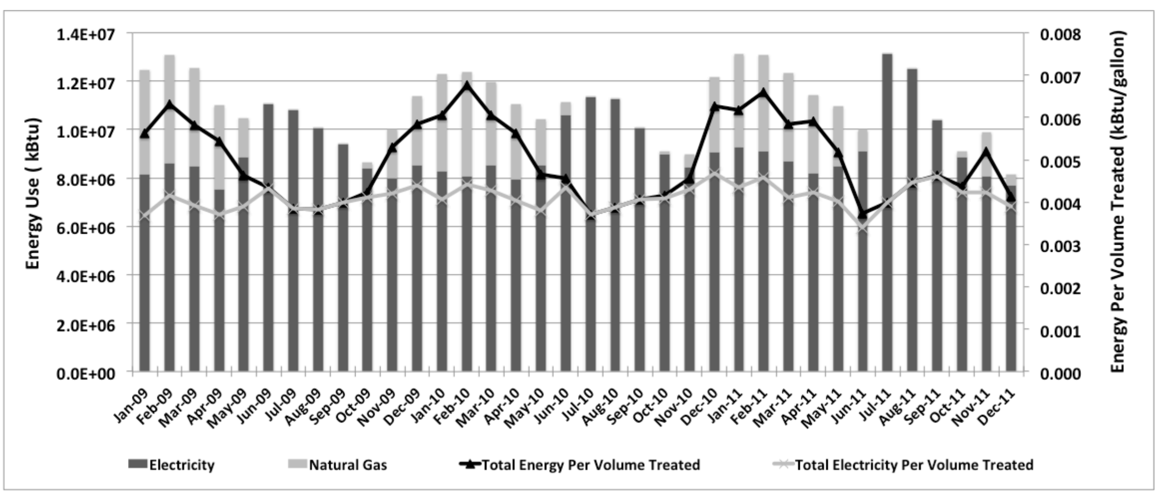



**Figure 1-4: System's total energy use 2009 - 2011. The annual average is 132,504 MMBtu and includes energy used from water acquisition/supply through distribution as well as non-electricity and natural gas for heating.**

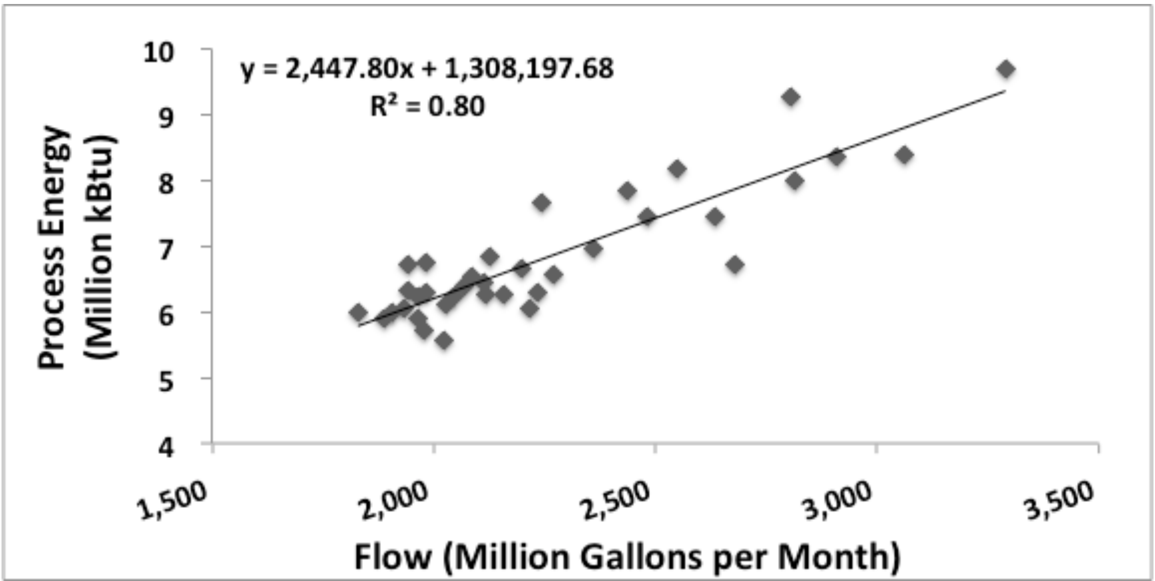



**Figure 1-5: Correlation between process electricity and the flow of water treated. The highest amount of energy consumed for the greatest amount of water produced is July 2011, the highest plotted point on the most right hand side.**

1.4.1.2.3 Comparison of Energy Usage per Gallon Treated

Table 1.5 lists 16 papers and three statewide studies that analyze conventional surface water treatment facilities, using a life cycle approach. The energy consumption range is 7.9E-03 to 2.2E-05 kWh/gallon treated. The Collins Park system consumes 1.4E-03 kWh per gallon treated. This kWh per gallon value includes total onsite energy consumed (electricity and natural gas). Also to be noted, some facilities discussed below may apply more energy consuming treatment technologies and/or are required to accommodate complicated supply acquisitions. System boundaries may also vary. For example some studies include distribution energy and others do not. These variations, when applicable and clearly stated in the corresponding work are noted.

Of the 17 papers, the two facilities with the highest energy use are Stokes & Horvath (2009) and Tripathi (2007). For their base case, the Stokes & Horvath study used a conglomerate of data from several Southern California water treatment facilities to equate what the region/authors consider 1 typical sized system. This base system imports surface water, serves 175,000 residents, and requires 7.9E-03 kWh/gallon treated. The Tripathi (2007) study regards an Ann Arbor, Michigan water treatment facility. This facility is the most geographically similar to the Collins Park Water Treatment facility, sharing similar heating and cooling days. Tripathi's (2007) study shows 6.7E-03 kWh/gallon treated for one system that utilizes two separate treatment plants with a combined 50 MGD capacity. This facility utilizes 80% river water and 20% pumped well water. Ann Arbor also utilizes ozonation as the disinfection treatment, which is a high-energy consumer.

Three states have issued reports focusing on the energy consumption of all statewide public potable water systems: New York (NYSERDA, 2008), Wisconsin (ECW, 2003), & California (CEC, 2005). The state of New York collected energy usage information surveys. Surface water systems serving greater than 100,000 people used an average of 4.7E-04 kWh per gallon treated. The state average of all systems (ground and surface water supplies) was found to be 7.1E-04 kWh per gallon treated, all of which consume less then the NW Ohio system.

In terms of kWh per gallon, the state of Wisconsin is most comparable to the Collins Park facility. Wisconsin's analysis classified treatment systems according to the amount of water treated in 1 year. Class AB facilities are the largest, pumping more than five billion gallons of potable water per year. The Collins Park facility pumped approximately 27 billion gallons per year for the given study period. Although all of the Wisconsin facilities are significantly smaller than Collins Park, it is worth noting that all Wisconsin Class AB facilities consumed the most total energy but the least energy per gallon treated, giving another argument for a more efficient use of design capacity. Also the largest class AB Wisconsin facilities had a smallest range in energy consumption (1.16 – 2.03E-03 kWh/gallon) compared to all other facilities (38% smaller). The median energy consumed for surface water Class AB facilities was 1.4E-03 kWh per gallon treated.

Lastly California's report indicates the energy intensity for potable water treatment facilities was dependent on region. Those facilities with the highest energy intensity were in the southern region requiring 1.0E-02 kWh per gallon treated, because this region has the highest demand and a limited supply. The northern region has the lowest energy intensity at 1.5E-03 kWh per gallon treated. This lower energy intensity is because 70% of the stream runoff is located in this upper part of the state and 40% of these systems are gravity fed, elevating pumping. Treatment and distribution was estimated to be 1.0E-04 per gallon treated for the Northern region and 1.2E-03 kWh per gallon treated for both the Southern region. Similar to the Northern region, the NWOWT system is gravity fed from the Lake Erie intake to the shore but is pumped from shore to the treatment facility.

Taking on the perspective of the three state reports, the municipality would benefit from evaluating and comparing the Collins Park Water Treatment system to other regional water treatment facilities that utilize Lake Erie water supply. This can offer best practices in treatment methods and energy efficiency efforts.

### 1.4.2 Energy, Cost, and Emission Comparison

Figure 1-2 shows that the relative impacts from different system components are similar but not exactly the same across cost, energy, and climate impacts. For example, chemical production had the highest contribution and the electricity had the second highest contribution to all three categories. However, the exact percentages of contributions were not the same. The percent contribution of chemical production is lower for energy (45%) than for cost (64% of total financial cost), and climate (62% of total GHG emissions). For electricity, the opposite is observed. The percent contribution of electricity was higher in energy (37% of total energy use) than in cost (27% of total financial cost) and climate (27% of total GHG emissions) impact categories.

This trend is observed because of the distance or locality in which the energy consumed by each of these categories is calculated. A national energy mix was used to calculate the chemical energy contribution, which combines coal, oil, gas, biomass, hydropower, nuclear, wind, solar, and geothermal (US EPA, 2012). Collins Park facility obtains electricity directly from the local electric utility, which utilizes 74% nuclear and only 26% coal. This in turn, results in less greenhouse gas emissions from their direct electricity consumption and more greenhouse gas emissions for their chemical use. Most life cycle assessments on potable water facilities, for example Stokes & Horvath (2009) and Lundie et al. (2004), show climate impacts correlate in tandem with energy consumption. It is assumed this is because the same energy mix is used for all aspects of these studies. As life cycle information on chemical processes, various industrial processes, and companies become more readily available, analyses, such as these, will become more specific. It will also become easier for water utilities to make better supply chain decisions not only in regards to the direct financial cost but also in terms of the global impact from the chemical manufacturing process.

Table 1.7 shows that the Collins Park Water Treatment facility pays less for both natural gas and electricity then the average Ohio industrial user or the average United States industrial user. Natural gas has the lowest cost intensity and the lowest emissions intensity between the two fossil fuel sources. Natural gas cost $0.015/kBtu less than electricity and produces 3.5E-05 MT $CO_2$ E per kBtu less than electricity (Table 1.7). The average annual energy needed for processing & distributing potable water was 9.9E+07 Btu and the average annual energy needed to maintain non-process operations was 3.4E+07 Btu.

**Table 1.7: Cost and Emission Comparison between the Northwest Ohio water treatment facility, State of Ohio, United States, & Emissions. (*U.S. Energy Information Administration)**

| | Cost Intensity NW OH's Water System ($/kBtu) | Cost Intensity Ohio* ($/kBtu) | Cost Intensity U.S.* ($/kBtu) | Emission Intensity NW OH's Water System (MT $CO_2$ E/kBtu) |
|---|---|---|---|---|
| **Natural Gas** | 0.005 *($0.498/Ccf)* | 0.009 *($9.41/ Mcf)* | 0.009 *($9.48/ Mcf)* | 5.3E-05 |
| **Electricity** | 0.018 *($0.062/kWh)* | 0.028 *($0.0967/ kWh)* | 0.029 *($0.102/ kWh)* | 8.8E-05 |
| **Chemicals** | 0.034 *($0.034/kWh)* | | | 1.6E-04 |

When looking at the climate impact of the water treatment facility and distribution system alone, the main facility produces 70% of the onsite GHG emissions and LSPS produces 20% of the onsite GHG emissions (Figure 1-6). This result is low compared to

Racoviceani et al. (2010) and Lundie et al. (2004). It is assumed the Racoviceani et al. and Lundie et al. studies include low service and high service. When compared to the NWOWT facility, these studies contributed 16,137 MT of $CO_2E$ and 69,447 MT of $CO_2E$ more to climate change than the Collins Park facility, respectively.

The solar field at the Collins Park main treatment facility is currently generating an average of 1.3E+03 MWh a year but as of the time of this study all of this energy is transmitted directly to the electric utility and will continue to do so through 2021. After contractual obligations are met, this solar generation will be used directly by the Collins Park facility, lowering the climate impact by 378 MT of $CO_2E$ per year.

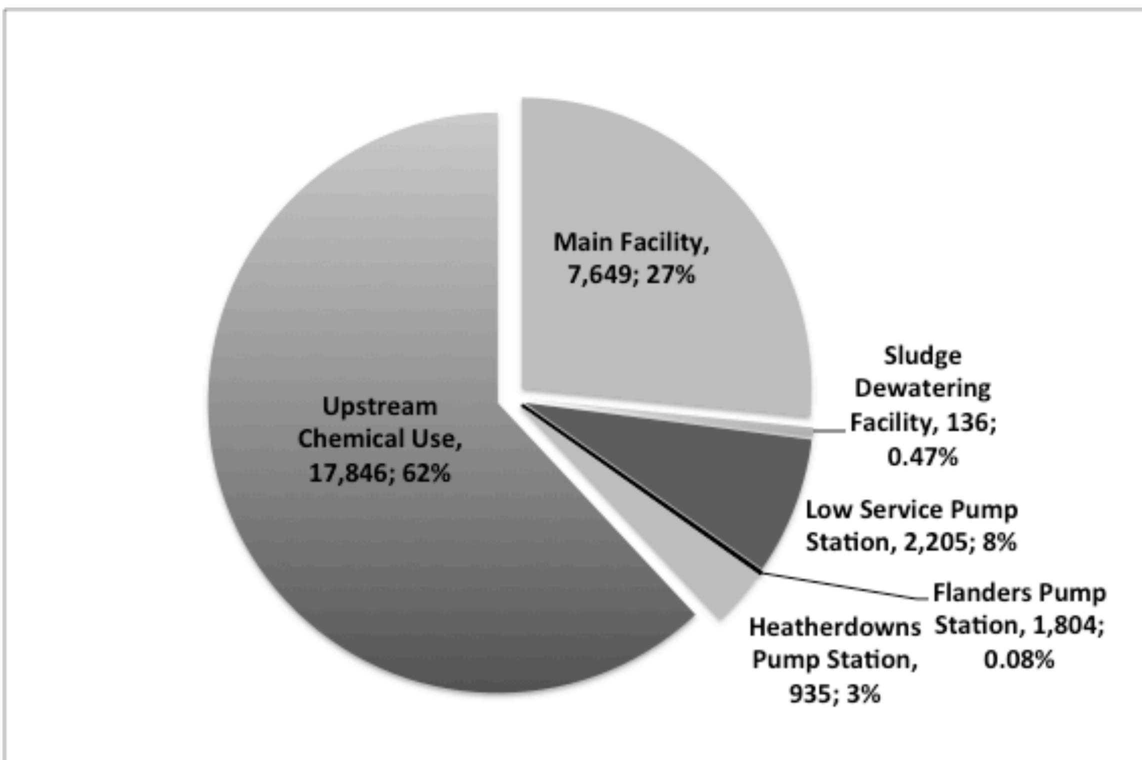



**Figure 1-6: Greenhouse gases (MT $CO_2E$) by emitted by upstream chemical usage as well as each treatment and distribution system**

## 1.5 Conclusions and Recommendations

### 1.5.1 Recommendations

The results of this study suggests that in order to reduce energy, costs, and greenhouse gas emissions, the Collins Park Water Treatment facility needs to focus on their chemical usage, efficiency of processing energy, and efficient use of the design capacity. It is typical for chemical suppliers to be chosen by the cost offered per pound purchased. By focusing on life cycle costs and by applying green supply chain procedures, water utilities could significantly reduce costs and global climate impacts. Green supply techniques include applying a scorecard system for choosing the chemical supplier with the least climate and environmental impact while obtaining the best face value cost for the facility. Another green supply chain technique is extending a requirement for responsible resource allocation, energy efficiency processes, and greenhouse gas accounting to chemical suppliers &/or supplier for all material acquisitions.

Because there is already a focus on supplementing fossil fuel energy with alternatives through the 1 MW solar field (1.3E+03 MWh per year), it would be fitting for the facility to continue this focus but increase alternatives to a quantity that will make a significant impact on a portion of process energy or all of non-process energy. For example, 1 year of non-process energy is approximately 3.4E+05 Btu, which is 3.3E+03 MWh per year electricity or 2.1E+04 MCF. Eliminating or reducing the fossil fuel energy used for non-process energy would make it easier to identify treatment processes that require optimization. For example utilizing VFD pumping for high and low service as well as filling reservoirs during the time of electricity lowest cost/rates (Biehl & Inman, 2010).

It is also apparent that design capacity utilization affects the efficiency and cost effectiveness of the potable water treatment facility. If the water treatment facility were able to operate closer to the intended design capacity, the amount of potable water produced would increase and the amount energy needed per gallon would decrease. In order to achieve this, the Collins Park facility would have to address the issue of water storage and/or usage. One viable solution could be collaborating with other water treatment utilities within the county or remaining Northwest Ohio region. This solution could be especially attractive if other regional water treatment utilities have reached their design capacity limits. Regional water supply planning has been implemented in many other regions of the United States such as in Southwest and Northwest Florida and areas of Wisconsin as well.

### 1.5.2 Conclusions

Chemical use is the highest contributor in all categories analyzed, consuming 45% of the water treatment facility's energy use (1.1E+08 kBtu), 64% of the water treatment facility's financial cost ($3 million), and 62% of the water treatment facility's climate impact (17,846 of MT $CO_2E$). When regarding onsite energy use only, the water treatment facility consumes 1.4E-02 kWh per gallon of treated potable water (total electricity and natural gas onsite energy use). This usage is an average value compared to the other 19 studies cited with the range of 7.9E-03 to 2.2E-05 kWh per gallon of treated potable water. The highest being Stokes & Horvath (2009) and the lowest was another

Stokes & Horvath (2006) study. Given that information, the most significant & most controllable aspect of the onsite treatment process is the energy used at low service and high service as well as the efficiency of design capacity utilization. If the treatment facility were able to produce a larger quantity of water while operating closer to the intended design capacity, less energy would be spent per gallon treated resulting in lower energy usage and cost. Achieving this could mean the facility would have to collaborate with other potable water utilities in region. Surprisingly, the Collins Park Water Treatment facility has one of the lowest cost intensities in Ohio and the United States, paying only $0.49 per CCF of natural gas and $0.06 per kWh of electricity. Because of the local energy mix, onsite energy of the treatment process and the distribution system reveals low greenhouse gas emissions (28,796 MT of $CO_2E$) compared to other studies found. For example, Racoviceani et al. (2010) and Lundie et al. (2004) were found to contribute 16,137 MT of CO2E and 69,447 MT of CO2E more in greenhouse gas emissions than the NWOWT facility, respectively. Although natural gas produces less greenhouse gas emissions and cost less then electricity, it contributes to a significant fluctuation in amount of energy spent per gallon of treated potable water during the winter months.

# Chapter 2

# The Energy, Greenhouse Gas Emissions, and Cost Implications of Municipal Wastewater Reclamation and Treatment System

## 2.1 Introduction

Because wastewater infrastructure and treatment facilities are becoming antiquated in the United States (ASCE, 2011), more energy is needed keep up with treatment needs. As reclaimed wastewater is lost through leaking pipes and the mechanical, electrical, and structural degradation of different aspects of the treatment system compound, more money and energy is needed to alleviate these issues while keeping up with treatment and effluent quality standards. When a wastewater treatment facility focuses on energy and operational efficiency measures of individual processes, a facility will reveal areas potential for improvement as well as reduce its global warming impact (Rosso & Stenstrom, 2008).

Cradle-to-grave life cycle assessments (LCAs) of wastewater treatment facilities offer a broad perspective of a treatment facility's environmental impact. Although there is a considerable amount of variation between studies in terms of system boundaries, most studies show that the operational phase of the LCA has the most significant impact. Zhang et al. (2010) found 75% of the total life cycle energy was attributed to treatment processes and Zhang & Wilson (2000) attributed 68% to onsite operations. Both studies include chemical production/transport (11% & 6%, respectively) and commissioning (12% & 33%, respectively). The later study also includes decommissioning, which was negligible. Dixon (2003), Del Borghi et al. (2008), and Emmerson (1995) also report a small amount of energy going into commissioning, 11%, 8%, and 4%, respectively. There is an apparent need to focus on the operational phase of wastewater treatment systems.

This study focuses on one wastewater treatment facility in the Northwest Ohio area, the Bay View Park Wastewater Treatment facility. At the time of this study, this system was undergoing improvement to the water reclamation and treatment system. While many studies looked into energy use or energy coupled with greenhouse gas emissions or in many cases just greenhouse gas emissions, none have been found that analyze energy (onsite/offsite and process/non-process), greenhouse gas emissions and cost. By analyzing how all-3 parameters effect one another, additional information will extend the sustainability efforts already in place at the Bay View facility.

## 2.2 Objective and Scope

The goal of this portion of the study was to provide a case study analysis utilizing the primary energy consumption data maintaining the Bay View Park Wastewater Treatment system and evaluate the impact it has on our global environment. By analyzing the primary data, we were able to determine the energy, greenhouse gas emissions, and cost associated with the Bay View system's wastewater reclamation and treatment as well as the system's upstream energy use and greenhouse gas emissions. This analysis can be used as a tool to help relate life cycle assessment research on wastewater treatment systems to a municipal system's main focus: compliance and energy efficiency.

The scope of this study focused on the 2010 direct energy consumption by the Bay View Park system from reclamation through treatment and discharge. Because wastewater treatment demands a large quantity of chemical usage, the scope included the energy required to manufacture the chemical quantities applied to the process train in 2010. The onsite direct energy was divided into process energy and non-process energy, differentiating energy utilized for treatment and that used for building operation/comfort. Greenhouse gas emissions for onsite energy use and chemical production were quantified as well as how these aspects are relevant to the Bay View Park facility's financial expenditures.

## 2.3 Methods

### 2.3.1 Site Description

#### 2.3.1.1 The Northwest Ohio Wastewater Treatment Facility

The Bay View Park Wastewater Treatment facility is a 165 million gallons per day (MGD) sewage treatment facility and serves approximately 398,000 residents. The facility sits on 50 acres of land and began as a discharge pump station in 1922. Sewage treatment began in 1932. Currently dry weather flows are approximately 50 – 60 MGD. The facility personnel have expressed that this dry flow rate is 25 – 30% lower than pre-2008 flows, which is when the national recession hit the Midwest. The maximum peak flow experienced to date was 405 MGD. Peaks flows occur due to the additional storm water entering the combined reclamation sewers. As a result of a 2005 U.S. EPA requirement to add 195 MGD to the treatment capacity, a wet weather facility was constructed in 2006 – 2009, accommodating these extra wet weather flows.

Wastewater enters the Bay View facility through the onsite pump station (Figure 2.1). At this point, preliminarily treatment is accomplished via fine bar screens, removing large debris. Primary treatment continues with the grit removal tanks and the skim tanks, removing oil and grease. Ferrous chloride ($FeCl_2$) is added to the wastewater stream prior to water entering the grit removal tanks. The wastewater then moves to the primary clarifiers, removing floc and settled solids. In the clarifier, the solid floc settles while oil and grease float and are skimmed off.

In secondary treatment, organic matter in the sewage stream is biologically treated and degraded by aerobic heterotrophic bacteria in the aeration tanks. Wastewater then enters the secondary clarifiers where flocs of organic material and activated sludge settle to the bottom. Afterwards, the treated wastewater then enters the chlorine contact tank to kill pathogens. Then an opposing dechlorination process takes place by adding sodium bisulfite to protect receiving waters before treated wastewater is discharged into the Maumee River.

The wet weather facility (WWF) is able to complete primary and secondary chemical treatment via ferric chloride ($FeCl_3$) and polymer but does not biologically treat waste. The excess flows during these heavy rain episodes are mostly comprised of stormwater. In 2010 the WWF provided treatment services on four occasions. The WWF begins operation when the main treatment facility reaches approximately 165 MGD. This is also the approximate point in which the grit removal and skim tanks (oil &

grease tanks) reach their capacity. The amount of flow diverted to the WWF averages 45 MGD with a maximum of 115 MGD and a minimum of 30 MGD.

The majority of the sludge residuals undergo onsite-dewatering then a private firm treats the solids. A small portion is landfill disposed. Before dewatering, the solids are then sent to the equalization tank followed by the fixed covered digesters. The dewatering process also utilizes a polymer to develop the dried sludge cakes.

Most of the biologically activated sludge from the secondary treatment process is recycled back to the aeration tanks to help maintain the microorganism activity. The waste activated sludge is handled through a dissolved air floatation process, adding a polymer and mixing the activated sludge with pressurized water. This process also removes debris consisting of oils and solid floatables. The removed debris is then processed with the sludge residuals. The excess water is returned to the aeration tanks.

The Bay View facility also has an onsite cogeneration facility that has been operating since January 2010. The cogeneration facility was designed to utilize the biogas from the onsite anaerobic digesters and methane from a nearby landfill. This scrubbed methane gas is piped two miles from the Hoffman Road Landfill. The facility was shut down mid-July 2012 through late March 2013 due to lack of quantity and quality of landfill gas. During this time the integrity of the landfill cells were improved and 22 new landfill wells were installed. This improvement increased landfill gas quantities from approximately 550 cubic feet per minute (cfm) to 1000 cfm and the quality from 35% methane to 48 – 52% methane. The cogeneration facility also receives approximately 100 – 200 cubic feet per minute (cfm) of methane gas from the anaerobic digesters. This study focuses on 2010 data only, which is prior to the landfill upgrade.

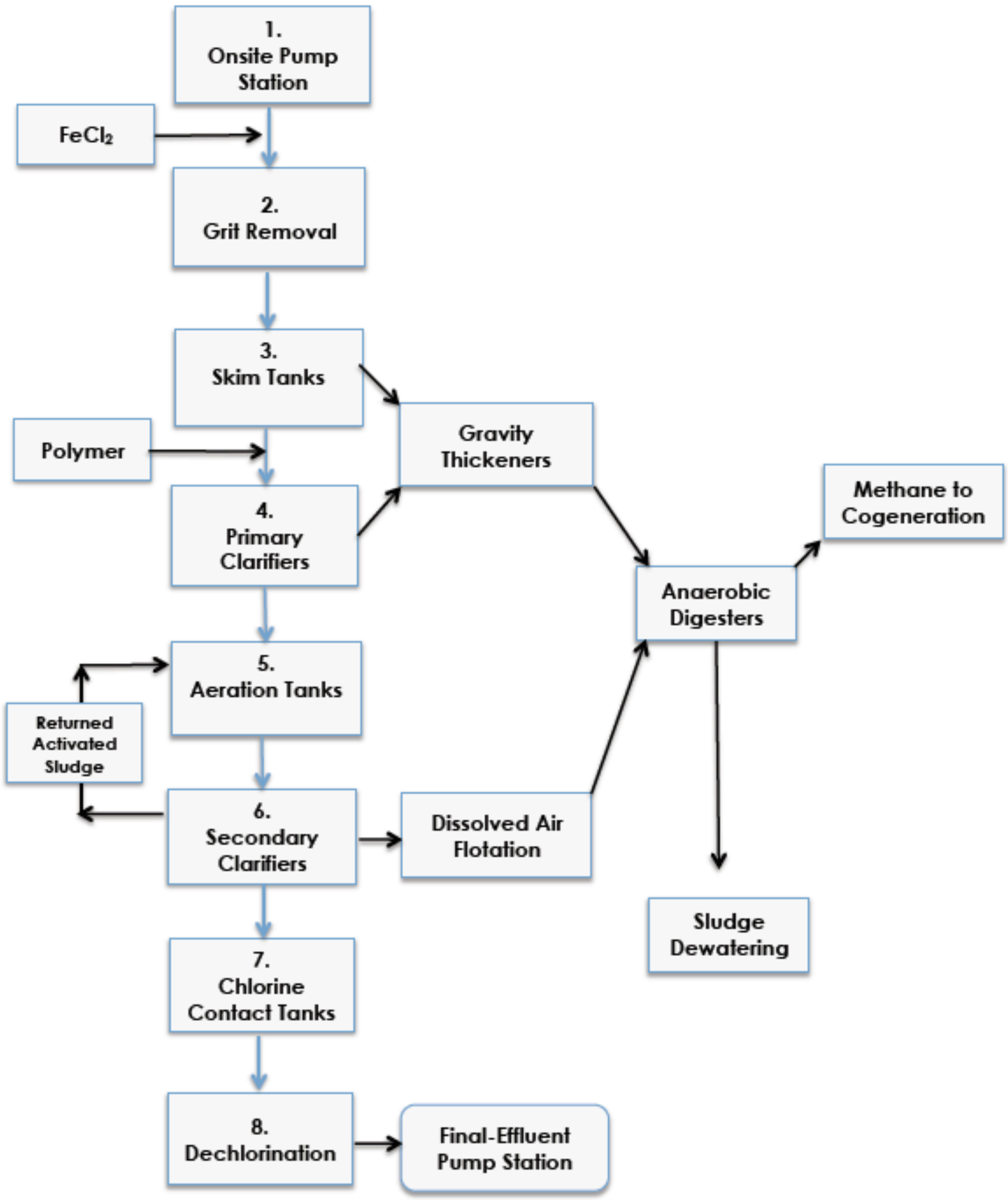



**Figure 2-1: Wastewater treatment and sludge processing. The sludge residuals from the skim tanks and primary clarifiers are sent to the gravity thickeners before processed in the anaerobic digesters. The sludge residuals from the secondary clarifiers are sent to dissolved air floatation tanks prior to the anaerobic digesters. Methane from the digesters is sent to the cogeneration facility. The final-effluent pimp station is only used during rain episodes, when the river water levels are high.**

### 2.3.1.2 Water Reclamation

The water reclamation system consists of a series of storm and sewer pipes that return sewage back to the Bay View Park facility and/or displace rainwater back to area waterways. Water is reclaimed from approximately 100 square miles. Industrial wastewater also discharges into the sewer system. Up until recently, the majority of the area sewers were combined sewers. These types of combined sewers collect sewage, stormwater, and industrial wastewater. During extreme wet-weather episodes, the combined sewers discharge rainwater and sewage into the area waterways. There are also seven main combined sewer overflow (CSO) stations or large flumes designed to store the slurry of sewage, rainwater, and industrial wastewater during episodes of wet weather. These large storage flumes are designed to slow down the combination of wastewater and stormwater flow going to the Bay View Park facility, giving the facility adequate time to process these larger quantities. Historically during these extreme wet-weather events, the facility would be forced to discharge raw sewage into the mouth of the Lake Erie basin due to lack of treatment capacity. Mandated by the Ohio EPA, the Toledo Waterways Initiative was created. The 20-year plan was designed to address 3 main issues:

1. To eliminate all raw sewage discharges from the NWOWWT facility.
2. To eliminate all discharges from sanitary sewer overflows.
3. To reduce the amount of discharge from combined sewer overflow (CSO) stations.

The initiative began in 2002 with the renovation of the 3 major pump stations and the installation of a back up power facility followed by the completion of the WWF in 2009. This added a 195 MGD processing capacity to the Bay View facility elevating the need for raw sewage discharge. Also included in the ongoing strategic plan is the separation of combined sewers, the installation of new sewers and storage basins, and the installation of new pump stations located throughout the city.

### 2.3.2 Data Collection

From reclamation through wastewater treatment, data was analyzed for 2010 only (with the exception of the 2011 submetering data) because only certain years/fragments of data for certain parts of the treatment system could be obtained. Also the cogeneration facility did not start operation until January 2010. In order to incorporate all energy consuming aspects of the treatment process, 2010 was the chosen study period. The onsite energy use consists of both process and non-process energy. Process energy is all energy utilized for reclamation and treatment of wastewater. Non-process energy is all energy utilized for maintaining building operational needs and comforts, representing lighting and heating/air handling. Upstream energy use is the energy needed to manufacture and transport the chemicals used during the treatment process.

All onsite energy data for the treatment facility and the reclamation pump stations, chemical quantities and cost ($/unit), and cogeneration gas consumption were obtained from facility personnel. Although the cogeneration facility was not operating at optimal capacity during the study period, it did have an impact on energy use and greenhouse gas emissions. All primary data mentioned below can be obtained in appendix B.

#### 2.3.2.1 Onsite Energy Use Data

Pump stations or lift stations throughout the city maintain the head needed to transport sewage back to the treatment facility. Electricity consumption information was obtained for four large pump stations, 39 small lift stations (13 storm water and 26 sanitary/sewage), and seven combined sewer overflow (CSO) interceptor sewers, including sluice gates that control the flow of sewage to the treatment facility. Rain gauges also consume a minimal amount of electricity during rain episodes for monitoring purposes. Because of this minimal energy consumption, these rain gauges have been left out of this study.

The daily power requirement for the main Bay View Park facility is approximately 4.5 MW or less on dry days. Electricity is supplied to the main facility via one direct 69 kV line/substation. Electricity consumed for reclamation service is purchased off the electricity grid network. Monthly kWh's consumed as well as the associated cost were taken from electricity bills. In addition to the purchased grid electricity, electricity is generated by the onsite cogeneration facility. This is used directly by the facility as it is created.

When addressing the separation and analysis of process and non-process electricity, we were only able to obtain an 11-month sample from the submetering system. A full year of energy use was determined by adding the monthly average between the prior and post months of the vacant value. Because obtaining this information proved to be difficult, it was assumed that this 2011 submetered sample was applicable and comparable to 2010 energy consumption. The submetering system provided daily average kW values for the 4160-volt AC pumps, providing flow for preliminary and primary treatment, as well as for the 4160-volt AC blowers and return activated sludge (RAS) pumps used in secondary treatment. The remaining electricity was assumed for the facility's sludge handling, effluent pumping, other process energy requirements (residuals removal from treatment tanks and digester function), and all other non-process needs (lighting and air handling). At the time of this study, it was not possible to accurately separate these electricity-consuming functions.

Natural gas is used only for building heat. Monthly CCF's used and cost was collected for the 2010 study period. Only three pump stations utilize natural gas for heating of which monthly usage in CCF and cost was also collected. No natural gas was consumed by the cogeneration facility in 2010.

#### 2.3.2.2 Upstream Energy Data

Chemical amounts used for treatment and the cost per chemical unit was collected. The source for the life cycle energy necessary to manufacture the chemicals is listed in table 2.1 in mega joules per metric ton. With the exception of sodium bisulfite, which values could not be found, all values were obtained from Tripathi (2007), who compiled original data from other sources.

**Table 2.1: Life cycle energy requirements in mega joules to manufacture one metric ton of wastewater treatment chemical (*Tripathi, 2007).**

| Treatment Chemical | Energy Requirement (MJ/Metric Ton) | Original Source |
|---|---|---|
| ***Polymer** | 44,682 | Owen, 1982 |
| ***Ferrous Chloride** | 1,200 | Owen, 1982 |
| ***Ferric Chloride** | 1,200 | Owen, 1982 |
| **Sodium Bisulfite** | | |
| ***Chlorine** | 20,130 | ECVM & PlasticsEurope, 2006 |

### 2.3.3 Emissions Data

Guidance from the Local Governments Operating Protocol (LGOP, 2010) and the Intergovernmental Panel on Climate Change guidelines for National Greenhouse Gas Inventories (IPCC, 2006) was used for the emissions analysis. Because this was a site-specific analysis, it was important to be as specific as possible with Scope 1, biogenic, and Scope 2 emissions calculations. The IPCC was able to provide a site-specific calculation for methane ($CH_4$) but not for the site-specific combustion of digester gas, which in this case was used for an emission reduction. For nitrous oxide ($N_2O$), the LGOP was able to provide site-specific calculations. In regards to biogenic emissions from the cogeneration facility, carbon dioxide as well as methane and nitrous oxide were calculated and included in the Scope 1 calculations using the LGOP because the cogeneration is essentially an onsite power plant. Scope 1 emissions include Methane ($CH_4$) and nitrous oxide ($N_2O$) emissions resulting from the treatment process for a wastewater treatment facility without nitrification/denitrification as well as $N_2O$ emissions from effluent discharge/outfall. Scope 2 emissions are a result from purchased electricity, natural gas, and the emissions related to manufacturing the portion of treatment chemicals used at the Bay View Park facility.

Regarding Scope 1 emissions, Equation 1 was used to identify $CH_4$ emissions. The $CH_4$ quantities were converted to metric tons of carbon dioxide equivalent emissions (MT $CO_2$ E) using the global warming potential value of 25. Two emission factors were calculated for the NWOWWT facility. $EF_{j1}$ for an overloaded aerobic centralized treatment plant with a methane correction factor of 0.3 (IPCC, 2006) and $EF_{j2}$ for an anaerobic digester used to treat sludge with a methane correction factor of 0.8 (IPCC, 2006). The reason for utilizing the methane correction factor for an overloaded aerobic treatment system is because of the recent EPA mandate and the 20-year remediation plan that overlaps with this study. Equation 1 takes into account the amount of $CH_4$ that is recovered for electricity production, value R. This value was calculated using a LGOP (2010) equation because it is a site-specific calculation for the amount of methane produced by the digesters at the Bay View Park facility. Also taken into account for $CH_4$ emissions (Equation 1) is each income group and their fraction of the total population served by the treatment facility. IPCC (2006) identifies income groups by rural, urban high-income, and urban low-income for various counties. The United States identifies as having no urban low-income groups.

The summation of the results of Equations 2 and 3 were used to identify the nitrous oxide ($N_2O$) emissions (LGOP, 2010). Equation 2 results in the $N_2O$ emissions from the secondary treatment process. Equation 3 results in the $N_2O$ emissions from the effluent discharge into the mouth of Lake Erie.

**Equation 1. Total methane ($CH_4$) emissions from domestic wastewater (IPCC, 2006). The value R was calculated using LGOP (2010)**

$$CH_4\ Emissions = \left[\sum_{i,j}\left(U_i \cdot T_{i,j} \cdot EF_j\right)\right](TOW - S) - R$$

Where:

| | |
|---|---|
| $CH_4$ Emissions = | kg $CH_4$/year |
| TOW = | Total organics in wastewater, kg BOD/year |
| S = | Organic component removed as sludge, kg BOD/year |
| $U_i$ = | Fraction of population in income group i |
| $T_{i,j}$ = | Degree of utilization of treatment/discharge pathway or system, j, for each income group fraction |
| $EF_j$ = | Emission factor, kg $CH_4$ / kg BOD |
| R = | Amount of $CH_4$ recovered, kg CH4/year |

**Equation 2. Total Nitrous oxide Emissions produced from the treatment process for a wastewater treatment plant without nitrification/denitrification (LGOP, 2010)**

$$N_2O = \left((P_{total} \cdot F_{ind-com}) \cdot EF\ w/o\ \ nit/denit\ \cdot 10^{-6}\right) \cdot GWP$$

Where:

| | |
|---|---|
| $N_2O$ = | MT $CO_2$ E |
| $P_{total}$ = | Population served by WWTP adjusted for industrial discharge (# of people) |
| $F_{ind\text{-}com}$ = | Factor for industrial and commercial co-discharge wastewater into the sewer system |
| EF w/o nit/denit = | Emission factor for WWTP without nitrification/denitrification (g N2O/person/year) |
| $10^{-6}$ = | Conversion from g to metric ton (metric ton/g) |
| GWP = | Global warming potential of $N_2O$ |

**Equation 3. Total nitrous oxide emissions produced from discharging effluent to rivers and estuaries, using site-specific n-load data (LGOP, 2010)**

$$N_2O = \left(N\ Load\ \cdot EF\ effluent \cdot 365.25 \cdot 10^{-3} \cdot {}^{44}/_{28}\right) \cdot GWP$$

Where:

| | |
|---|---|
| N Load = | Total nitrogen load, kg N/day |
| EF Effluent = | Emissions factor, kg $N_2O$-N/kg sewage – N Produced |
| 365.25 = | Conversion factor, day/year |
| $10^{-3}$ = | Conversion from kg to metric ton, metric ton/kg |
| 44/28 = | Molecular weight ratio of $N_2O$ to N |

Site-specific emissions were calculated using Equations 1 – 3 then these quantities were compared to emissions calculated using the default values for methane and nitrous oxide. These default equations utilize general textbook values for nutrient loads and are population based (LGOP, 2010). The default calculation for methane is identical to Equation 1 (IPCC, 2006) with the exception of digester gas recovery ($CH_4$), which is given in Equation 4. Also, the default calculation for nitrous oxide is also the summation of $N_2O$ emissions resulting from a treatment process without nitrification/denitrification and the emissions resulting from effluent discharge. For this default calculation, the site-specific value from Equation 2 (LGOP, 2010) was used and added to default calculation for the $N_2O$ effluent discharge emissions (Equation 5).

**Equation 4. Default equation used to calculate $CH_4$ emissions from anaerobic digesters.**

$$CH_4\,Emissions = (P \cdot Digester\ Gas \cdot F_{CH4} \cdot \rho(CH_4) \cdot (1 - DE) \cdot 0.0283 \cdot 365.5 \cdot 10^{-6}\ ) \cdot GWP$$

Where:

| | |
|---|---|
| $CH_4$ Emissions = | MT $CH_4$/year |
| P= | Population served by WWTP, # of people |
| Digester Gas = | Volume of digester gas produced, 1 $ft^3$/person/day |
| $F_{CH4}$ = | Fraction of CH4 in biogas, 0.65 |
| ρ(CH4) = | Density of methane, 662 $g/m^3$ |
| DE = | CH4 destruction efficiency, 0.99 |
| 0.0283 = | Conversion from $ft^3$ to $m^3$ |

**Equation 5. Default equation used to calculate N2O emissions resulting from effluent discharge using default n load data.**

$$N_2O\ Emissions = \left((P_{total} \cdot F_{ind-com}) \cdot (Total\ N\ Load - N\ uptake \cdot BOD_5 load) \cdot EF\ effluent \cdot \frac{44}{28} \cdot \left(1 - F\ plant \frac{nit}{denit}\right) \cdot 365.25 \cdot 10^{-3}\right) GWP$$

Where:

| | |
|---|---|
| Total N Load = | 0.026 kg/person/day |
| N uptake = | N uptake for cell growth in aerobic system, 0.05 kg/kg $BOD_5$ |
| BOD5 load = | Amount of BOD5 produced, 0.09 kg/person/day |
| EF effluent = | 0.005 kg/kg sewage-N produced |
| F plant nit/denit = | Fraction of nitrogen removed, 0 |

Regarding biogenic emissions, electricity is generated at the onsite cogeneration facility utilizing scrubbed methane from the Hoffman Road Landfill and from the facility's anaerobic digesters. Emissions for this electricity generation were quantified using the 'fuel use-based methodology for a stationary power generation facility' in the LGOP (2010). Facility personnel provided annual quantities of each gas.

Regarding Scope 2 emissions, the electricity emission rates used were from the local electric supplier, First Energy Corporation's, Toledo Edison Company (Table 2.2). The national electricity emission rates were used for the emissions resulting from chemical manufacturing. Both the local emission rate as well as the national average came from the U.S. EPA, eGRID data (US EPA, 2012). Natural gas emission rates were taken from the LGOP (2010).

**Table 2.2: Emission rates used to quantify greenhouse gas emissions from treatment operations from the reclamation and wastewater treatment processes**

| | Natural Gas (LGOP) | Local Grid Electricity (eGRID) | U.S. National Average Electricity (eGRID) | Landfill/Biogas Combustion (LGOP) |
|---|---|---|---|---|
| **$CO_2$** | 53.06 kg/MMBtu | 661 lb/MWh | 1216 lb/MWh | 0.0262 kg/scf |
| **$CH_4$** | 0.005 Kg/MMBtu | 7 lb/GWh | 24 lb/GWh | 0.0032 kg/MMBtu |
| **$N_2O$** | 0.0001 kg/MMBtu | 11 lb/GWh | 18 lb/GWh | 0.00063 kg/MMBtu |

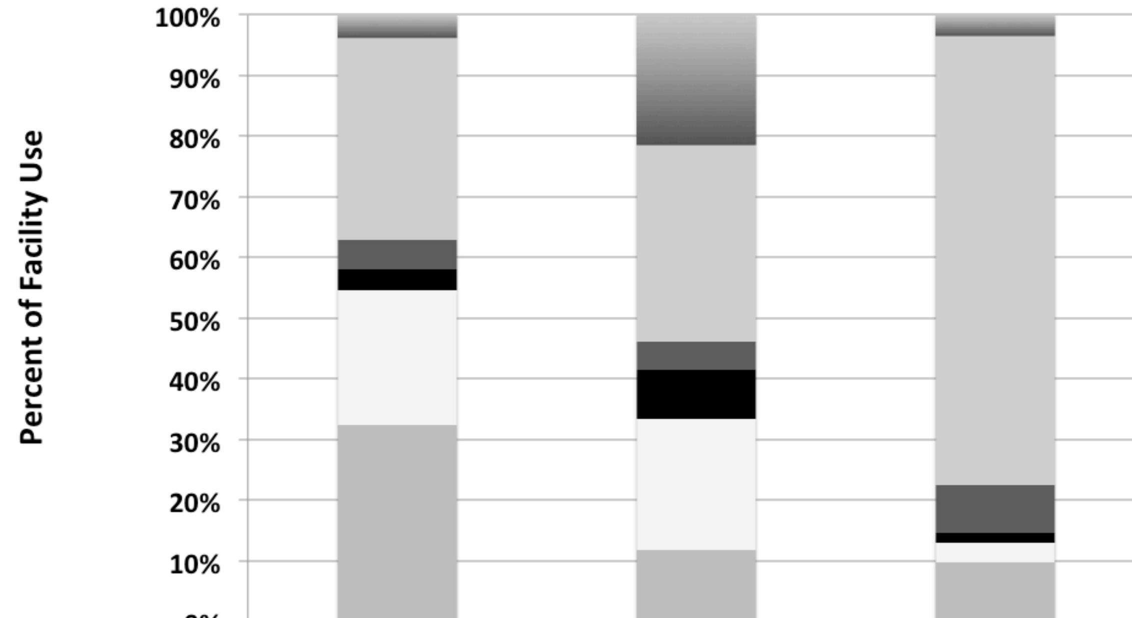
# 2.4 Results and Discussion

## 2.4.1 Energy Analysis

### 2.4.1.1 Onsite Energy Use

Total energy use for Bay View Park Wastewater Treatment facility is given in the first bar of figure 2-2. The majority of the energy consumed was onsite energy (96%)

with only 4% of the total energy consumption attributed to upstream chemical production. Onsite energy use includes all processes involved with the reclamation of wastewater to the Bay View Park facility and the treatment train (Figure 2-1). The facility's onsite energy use was 2.79E-03 kWh per gallon of treated water in 2010. Twenty-two studies were reviewed (Table 2.3) and because the differences in system boundaries, only two studies (Tripathi, 2007 & Stokes & Horvath, 2010) are comparable to the Bay View Park facility. These studies include upstream and/or downstream parameters as well as characterize the majority of their life cycle energy for onsite energy use. Tripathi (2007) analyzed three wastewater treatment facilities: The Ann Arbor Wastewater Treatment Plant (AAWWTP) in Michigan, The Laguna Treatment Plant (LWWTP) in California, and The Ypsilanti Community Utility Authority (YCUA) in Michigan. All three facilities found onsite energy consumption to be much higher than chemical production and transport. The AAWWTP and the LWWTP facility found 91% and 92% of the total life cycle energy was attributed to onsite energy use (4.04E-03 kWh/gallon & 2.81E-03 kWh/gallon, respectively) and the remainder of the energy for upstream chemical production and transport. At the YCUAWWTP, 72 % of the total life cycle energy (4.21E-03 kWh/gallon) was consumed for onsite operations. Stokes & Horvath's (2010) life cycle analysis concludes the operational phase to be most significant in terms of energy consumption. This same study also analyzed the base case in terms of life cycle activity in which material production is most significant. Of the energy going into material production (2.9 GJ), chemical production was 78% of this total. The Remy & Jekel (2008) study also analyzes chemical production and transport but offers only one number in terms of energy consumption (Table 2.3), which also includes treatment and commissioning. Similarly, the Sahely et al. (2006) analysis offers one number for energy consumption includes treatment and energy production but excludes chemical production/ transport.




| | | Total Energy Use 244,956,803 kBtu | | Total Cost $3,331,961 | | Total GHG Emissions 43,780 MT CO2 E | |
|---|---|---|---|---|---|---|---|
| Upstream | Chemical Production | 9,355,855 | 4% | $715,447 | 21% | 1,520 | 3% |
| Process | Secondary Treatment | 81,701,764 | 33% | $1,081,393 | 32% | 32,395 | 74% |
| Process | Preliminary & Primary Treatment | 11,774,652 | 5% | $155,848 | 5% | 3,483 | 8% |
| Process | Reclamation | 8,214,808 | 4% | $267,686 | 8% | 725 | 2% |
| | Other Process and Non-Process Energy | 54,665,996 | 22% | $723,551 | 22% | 1,435 | 3% |
| | Natural Gas (Non-Process) | 79,243,727 | 32% | $388,036 | 12% | 4,222 | 10% |

**Figure 2-2: Annual energy use, financial expenditure, and greenhouse gases emitted from the Northwest Ohio's wastewater reclamation system and treatment facility**

**Table 2.3: WWTP studies and the amount of total energy used to treat one gallon of wastewater as well as amount of greenhouse (GHG) emissions produced. If applicable, values apply to the base case only. *Reclamation included**

| | Total energy kWh/gallon | GHG Metric Ton $CO_2E$ | Comments on the Inclusion of Energy Attributed to Non-process Functions &/Or Chemical Manufacturing |
|---|---|---|---|
| *Friedrich, 2009 | **4.47E-02**<br>Reclamation 30%<br>1° treatment 19%<br>2° treatment 51% | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included but not separated from total |
| Vidal et al., 2002 | **3.43E-02**<br>Treatment 3%<br>Energy Production 95%<br>Transport (For energy production) 2% | **0.14**<br>Total sum only | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| Emmerson et al., 1995 | **1.60E-02**<br>Commissioning 4%<br>Treatment 96%<br>Demolition negligible | **2,455** | Non-process Energy<br>Natural gas is used for heating; lighting not accounted for<br><br>Energy for Chemical Manufacturing<br>Included |
| *Del Borghi et al., 2008 | **1.36E-02**<br>Production Phase 8%<br>Use Phase 92% | **$0.82/m^3$**<br>Total treatment quantity not given. | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| *Lassaux et al., 2007 | **1.21E-02**<br>Includes commissioning phase. | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| Tripathi, 2007 (YCUA WWTP) | **5.84E-03**<br>Electricity use 47%<br>Natural gas & diesel use 26%<br>Chem. Production 28% | **21,575**<br>Total sum only | Non-process Energy<br>Not included or not separated from total onsite energy. Natural gas is used for sludge incineration.<br><br>Energy for Chemical Manufacturing<br>Included |

| | | | |
|---|---|---|---|
| CEC, 2005 (State of CA) | **4.61E-03**<br>Total sum only<br>Energy consumption range is 1100 - 4600 kWh/MG | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| Tripathi, 2007 (AAW WTP) | **4.44E-03**<br>Electricity 50%<br>Natural Gas 26%<br>Chem. Production 9%<br>Sludge Disposal 15% | **13,772**<br>Electricity 87%<br>Diesel 9%<br>Chemicals 5%<br>Natural gas 0.1% | Non-process Energy<br>Natural gas is used for heating; lighting not accounted for<br><br>Energy for Chemical Manufacturing<br>Included |
| Pasqualino et al., 2011 | **3.66E-03**<br>Reclamation 25%<br>Treatment 75%<br>(Includes 1° - 3° & UV; 3° is 12% of the 75%) | **625**<br>1° & 2° = 83%<br>3° = 17% | Non-process Energy<br>Natural gas is used for heating; lighting not accounted for<br><br>Energy for Chemical Manufacturing<br>Not included |
| Sahely & Kennedy, 2007 | **3.30E-03**<br>Natural gas 40%<br>Treatment 49%<br>Pumping 11% | **465,000**<br>Onsite 65.3%<br>Electricity production 23.3%<br>Chem. production 0.3%<br>Natural gas production 11% | Non-process Energy<br>Natural gas is used for heating; lighting not accounted for<br><br>Energy for Chemical Manufacturing<br>Chemicals included in GHG analysis only |
| Venkatesh & Brattebo, 2011 | **3.07E-03**<br>Reclamation 7%<br>Operation 93% | **NA** | Non-process Energy<br>Operational energy includes space heating & lighting<br><br>Energy for Chemical Manufacturing<br>Not included |
| Tripathi, 2007 (LWWTP) | **3.05E-03**<br>Electricity 91%<br>Chemicals 8%<br>Sludge Hauling 1% | **16,652**<br>Electricity 99%<br>Diesel, natural gas combustion, & chemicals 1%, | Non-process Energy<br>No natural gas for heating because this is produced via geyser steam cogeneration, which generates 85 MW/day<br><br>Energy for Chemical Manufacturing<br>Included |
| Young & Koopman, 1991 | **3.00E-03**<br>Treatment only | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| *Remy & Jekel, 2008 | **2.49E-03**<br>Includes commissioning, energy supply, chemicals, & transport | **600** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included but not separated from total |

| | | | |
|---|---|---|---|
| Stokes & Horvath, 2010 | **2.39E-03**<br>Reclamation 11.4%<br>Treatment 88.1%<br>Discharge 0.5% | **5,225**<br>Collection 36%<br>Treatment 64%<br>Discharge 0.01% | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Chemicals are incorporated into the life cycle analysis category, material production (8.06E-04 kWh/L), which is separate from onsite (given in column 2). Material production also includes construction materials. |
| Dixon 2003 (AF) | **2.07E-03**<br>Commissioning 11%<br>Operation 89% | **26** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| Zhang et al., 2010 | **1.98E-03**<br>Treatment 75%<br>Chemicals 11%<br>Demolition 2%<br>Commissioning 12% | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included |
| Mels et al., 1999 | **1.65E-03**<br>Treatment only | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| Cheng, 2002 | **1.57E-03**<br>Treatment only | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |
| Zhang & Wilson, 2000 | **1.56E-03**<br>Commissioning 33%,<br>Operational 61%,<br>Polymer production 6% | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Included |
| Sahely et al., 2006 | **1.14E-03**<br>Treatment & energy production included | **1.05**<br>For most WWTP in Canada<br>Onsite 67%<br>Upstream 33% | Non-process Energy<br>Facility heating is included<br><br>Energy for Chemical Manufacturing<br>Not included |
| EPRI, 2002 (50 MGD) | **1.05E-03**<br>Treatment only | **NA** | Non-process Energy<br>Not included or not separated from total onsite energy<br><br>Energy for Chemical Manufacturing<br>Not included |

Of the Bay View Park facility's total energy use, 54% was attributed to natural gas heating and 'other process and non-process energy'. Again this 'other process and non-process energy' includes the facility's sludge handling, effluent pumping, other process energy requirements (residuals removal from treatment tanks and digester function), and all other non-process needs (lighting and air handling). 42% was attributed to the facility's reclamation, primary treatment, and secondary treatment processes. The largest portion of energy was for secondary treatment (33%) then followed by natural gas/heating, which consumes 32% of the total energy. Other process and non-process energy consumed 22% followed by the least energy consuming processes, preliminary and primary treatment (5%) and reclamation (4%).

2.4.1.1.1 Process versus Non-process energy

Thirty-two percent of onsite energy was attributed to natural gas consumption, which was used exclusively for heating. It should be noted that during the following two years of this study the Bay View Park facility's cogeneration facility needed natural gas to maintain function. Because this analysis focuses on the 2010 operational year, no portion of the facility's natural gas use was attributed to the cogeneration operation in 2010.

Of the 22 studies compiled, six studies addressed non-process energy in some way (Sahely et al., 2006; Venkatesh & Brattebo, 2011; Sahely & Kennedy, 2007; Pasqualino et al., 2011; Tripathi, 2007; and Emmerson, 1995). Three studies include facility heating via natural gas into their analysis (Sahely et al. (2006), Pasqualino et al. (2011), and Emmerson (1995)). The operational energy analyzed in Venkatesh &

Brattebo (2011) includes lighting (electricity) and space heating from heating oil. None of these studies were able separate the non-process energy from the total energy consumed. Sahely & Kennedy (2007) accounted 40% of the total energy use to natural gas heating. Of the three facilities that Tripathi (2007) analyzed, non-process energy was accounted for at the AAWWTP (26% of total energy use). The YCUAWWTP utilizes natural gas for sludge incineration and the LWWTP utilizes heat from a geyser steam cogeneration system, which also generates 85 MW per day for the facility. None of the studies, except for Venkatesh & Brattebo (2011) account for lighting.

Process energy was dominated by secondary treatment (35% of onsite energy). Preliminary and primary treatment as well as reclamation attributes only a minimal amount, 5% and 3% of onsite energy, respectively.

It is apparent that natural gas heating makes a significant impact on the overall energy use at the Bay View Park facility. Figure 3 represents the monthly onsite energy use, emphasizing the impact of natural gas consumption on the total amount of energy needed to treat one gallon of wastewater. When accounting for natural gas during the months of December, January, and February, the amount of energy (kBtu) needed per gallon treated increases by 46%, 58%, and 57%, respectively. In contrast, the total electrical energy (kBtu) per gallon treated is relatively consistent with an average of 2.18E-04 kBtu/gallon.

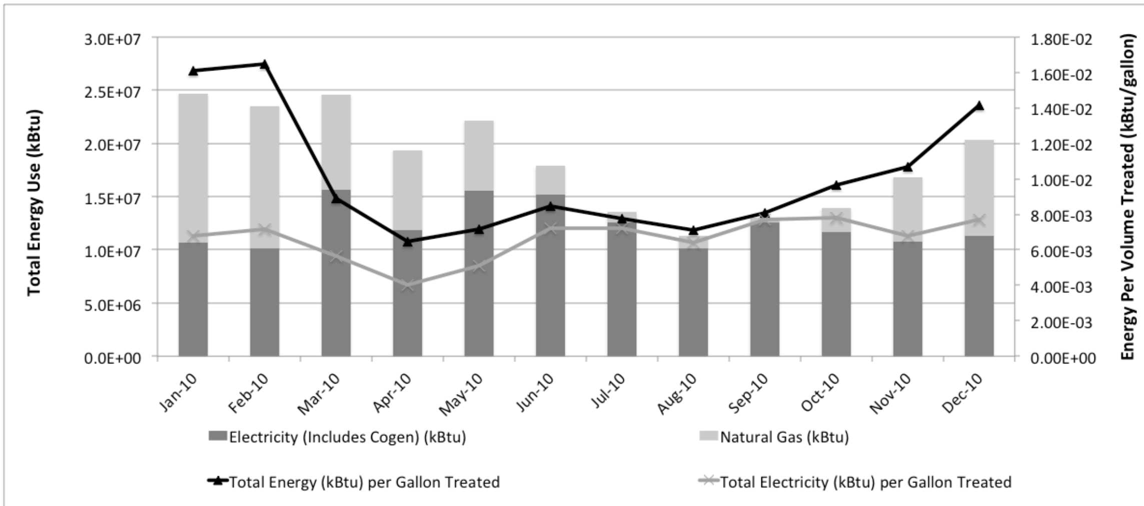



**Figure 2-3: Total 2010 onsite energy use. The annual summation is 235,600,947 kBtu and includes electricity, natural gas, and cogeneration. Processes include citywide reclamation through discharge.**

2.4.1.1.2 Comparison of energy usage per gallon treated

For 2010 the Bay View Park facility utilized 2.79E-03 kWh per gallon of treated wastewater. This includes onsite energy only (electricity and natural gas). The energy consumption range was from 1.90E-03 (April) to 4.83E-03 (February) kWh per gallon of treated wastewater.

The facility removed 8.94E+12 mg of BOD in 2010. The amount of process energy spent on removing BOD is 3.33E-06 kWh/mg of BOD and the amount of total onsite energy (electricity and natural gas) spent on removing BOD was 7.72E-06 kWh/mg. In comparison, Zhang et al. (2010) cites the average energy consumption to remove one mg of BOD is 2.86E-06 kWh for a conventional domestic wastewater treatment process, only slightly less than the Bay View Park facility. In an earlier study, Zhang & Wilson (2000) estimated a base-case aeration system of a conventional WWTP required 1.41E-06 kWh to remove one mg of BOD. It is assumed that both of these studies exclude non-process energy. Zhang & Wilson (2000) attribute the decreased aeration energy consumption to the periodic air application practiced at the WWTP. Also, this Chinese study shows the aeration system was operating at 60% less energy than the original design intended, attributing this to good administration practices.

During the months of April and May, the Bay View Park facility's wet weather facility (WWF) was used to accommodate extra flow from seasonal precipitation. When the WWF is activated, the design capacity more than doubles from 165 MGD to 360 MGD and the flow of wastewater into Bay View Park also doubles from the 50 MGD dry weather conditions to over 100 MGD. In analyzing process electricity consumed per gallon of treated wastewater during the months of April and May, there is a 48% and 34% decrease in process energy usage from the maximum used (5.03E-03 kBtu/gallon of treated water). The influent BOD concentrations during these months are also diluted due to the extra stormwater entering the sanitary sewer system. The month of May results in the lowest concentration of influent BOD in 2010, which is 54% less than the highest concentration of BOD (518.97 mg/gallon, also in October). Clearly the more dense/higher concentration of BOD entering the treatment facility, the more energy is spent per gallon. Mels (1999) references this in a Netherlands study and indicates that 70% of wastewater's total COD is in particles greater than 0.45 µm. The study found that by adding a significant pre-precipitation step (screening less than 6mm and significant quantities of chemical pre-precipitation of ferric chloride and polymer) to a treatment process that previously did not have a primary treatment step, energy requirements were reduced from 3,100 MWh/year to 50 MWh/year (Mels, 1999), a 98% decrease in energy usage. It is apparent there energy and financial savings available to the Bay View Park facility. Looking at the Bay View Park's pretreatment step, it may be necessary to reassess the chemical effectiveness of their chemical pre-precipitation step, ferrous chloride, and/or look into more effective screening. A focus in reducing the organic load going into the aeration system will result in less energy needed to remove the dissolved organic waste in secondary treatment. Energy requirements for aeration in secondary treatment increase exponentially as the dissolved oxygen (DO) concentration increases (US EPA, 2010). There are 5 factors affecting the energy efficiency of an aerations system: diffuser flux rate, oxygen transfer rate, oxygen transfer efficiency, alpha (ratio of oxygen transfer efficiency), & the mixed liquor DO concentration (US EPA, 2010). Over-aeration or operating closer to total oxygen saturation both lowers the oxygen transfer efficiency and increases the energy used by the aerators and diffusers that are driving oxygen into the wastewater. Under-aeration can result in underperformance of the activated sludge and poor settling issues (US EPA, 2010). The Water Environment Federation and the American Society of Civil Engineers (2006) estimate that strong DO control in aeration can save a wastewater plant 10 – 30% of total energy costs. Many facilities are doing this via automated DO control.

Energy conservation measures for the aeration tanks, other than automated DO control, include proper blower sizing and turndown, dedicated low-pressure blowers for channel aeration, tapered diffusers, and intermittent aeration (US EPA, 2010). Regarding blower size and turndown, the total blower system should be operating at $1/5^{th}$ of its full capacity in whatever configuration necessary (US EPA, 2010). The Bay View Park facility has 3 new blowers (1450 hp) and 3 older blowers (1750 hp) both sets with soft-start capabilities. Now that Bay View Park is operating with a WWF it may be necessary to reevaluate the blower size and whether or not it is oversized. Sizing down is an option in this case as well as installing variable frequency drives (VFDs). Also it is unclear if the Bay View Park facility uses the main aeration system for channel aeration. If this is the case, channel aeration only requires a significantly lower pressure aeration system. Solutions include reducing pressure of the blower currently used for channel aeration by throttling the air through a flow control valve or by dedicating a smaller blower rated for the necessary pressure (US EPA, 2010).

The configuration of the diffusers can also offer energy savings. By utilizing more diffusers near the inlet where the organic load is highest and decreasing the number of diffusers as the wastewater reaches the end of the plug and flow basins will eliminate unnecessary use and save energy (US EPA, 2010). Bay View Park utilizes nine aeration tanks. The first 6 are newer and contain more diffusers than the last three tanks. Wastewater passes twice through tanks 1 – 6 and twice through tanks 7 – 9 for a total of four passes. Since the diffusers are already in regular rotation for replacement every 5 years, it would be reasonable to try and reconfigure the diffusers in a pattern that allows more tapering.

Intermittent aeration is an operational change that reduces the number of hours the aeration system operates or reduces the capacity to match specific treatment quantity needs. This involves momentarily stopping airflow to a specific aeration zone or cycling air from one zone then another. The length of the cycle is determined by the DO concentration. Air is turned off at a high DO level and then turned back on at a lower DO level (US EPA, 2010).

There are many examples of other U.S. wastewater facilities that have significantly reduced energy consumption by implementing one or more of the above mentioned strategies. The Big Gulch Wastewater treatment Plant in Washington State saved 148,900 kWh and $10,076 annually by installing fine bubble diffusers, an automatic blower operation system, and controls for their tertiary treatment. The City of O'Fallon, Missouri set out to reduce energy use by 10% as well as reduce cost and greenhouse gas emissions (US EPA, 2013). This was achieved by implementing administrative education via workshops and Energy Star Portfolio Manager trainings but also through aeration equipment upgrades. The diffusers were upgraded and the blowers used for aeration were upgraded to turbo blowers (10 – 20% more efficient), saving approximately $53,000 per year (US EPA, 2013). The Narragansett Bay Commission's Bucking Point Wastewater Treatment Facility, Rhode Island realized a 12% reduction in annual energy usage by modifying the aeration process control system to optimize the DO levels (US EPA, 2013). The Waco Metropolitan Area Regional Sew System, Texas is saving $423,226 annually by upgrading the aeration system with more fine bubble diffusers and a new automatic control system (US EPA, 2013). Other facilities realizing similar upgrades are the Greater Lawrence Sanitary District, North Andover Massachusetts, Kent County Department of Public Works, Delaware, and the City of Cleburne, Texas.

Currently, the Bay View Park facility has a BOD removal efficiency of 96%, phosphorous removal efficiency of 78%, and total nitrogen removal efficiency of 53% for the year 2010. By focusing on reducing the organic load as much as possible prior to secondary treatment and then implementing energy saving measures in the secondary process, the facility can reduce energy, financial expenditures, and emits the less greenhouse gas emissions over all. Because the documentation for the energy efficiency of a wastewater facility's preliminary and primary treatment is not well documented, it is suggested that further water quality and energy use data be collected for each individual treatment process in order to further analyze the benefits of improving the preliminary and primary treatment options.

**2.4.1.2 Greenhouse Gas Emissions**

The global warming analysis reveals the secondary treatment process was the top producer of greenhouse gas (GHG) emissions (74% of total emissions, figure 2-2). The biogenic and Scope 1 emissions created from the cogeneration facility were split between preliminary/primary treatment (8% of total emissions) and secondary treatment. The emissions resulting from non-process, natural gas consumption and other process and non-process energy was 10% and 3%, respectively. When equated to electricity, the emissions rate for natural gas heating was 82% lower than electricity (Table 2.2). The GHG emissions calculated for reclamation and other process and non-process energy used the local grid electricity emissions rates. Reclamation and chemical production did not contribute significant amounts of greenhouse gas emissions, 2% and 3%, respectively. The biogenic and Scope 1 emissions resulted from the combustion of approximately 1.86E+8 standard cubic feet (scf) of landfill and digester gas methane. The mixed gas was estimated to have a 550 Btu/scf heat value.

When comparing the Bay View Park facility's emissions to the LGOP (2010) default calculations for digester gas ($CH_4$) and the default calculation for effluent discharge ($N_2O$), the Bay View Park facility was comparable in both areas. Bay View Park's onsite specific $CH_4$ emissions are 19,591 metric ton of $CO_2$ equivalent emissions and the default calculation, which is based on population (US Census, 2010), is 19,549 metric ton of $CO_2$ equivalent emissions. Also based on population, the $N_2O$ resulting from the default calculation for effluent discharge was also comparable to the actual site-specific $N_2O$ emissions, 9,148 and 8,962 metric ton of $CO_2$ equivalent, respectively.

Of all studies listed in table 2.3, only 12 modeled greenhouse gas emissions and most report significantly lower GHG emissions then the Bay View Park facility, ranging 0.14 – 21,570 metric ton of $CO_2E$. Only one resulted in higher greenhouse gas emissions than Bay View Park. Sahely & Kennedy (2007) give a Toronto, Canada a total of 465,000 metric ton of $CO_2E$ for both emissions produced onsite (53%) as well as emissions produced upstream (47%) from energy and chemical production/ transport.

### 2.4.2 Energy, Cost, and Greenhouse Gas Emissions Comparison

The energy (33% of total energy) and cost (32% of total cost) needed to operate the secondary treatment process expectedly equates (Figure 2-2) but not for greenhouse gas emissions (72% of GHG emissions). This is because the secondary treatment $CH_4$ and $N_2O$ emissions are not only generated from the treatment process itself but also from the nitrous oxide emissions generated by discharging wastewater into the mouth of Lake Erie as well as the emissions from the electricity consumed by operating the treatment equipment. With the cost intensity of electricity at a low $0.05/kWh and the 2010 national average cost intensity being $0.10/kWh (Table 2.4), it can be expected that the Bay View Park facility's electricity intensity will increase due to price increases alone.

Therefore by conducting operations in the same manner as this 2010 analysis, administrators of Bay View Park can expect a significant increase in financial expenditures as well as the climate impact.

Reclamation has relatively low energy needs and results in low GHG emissions due to the utilization of grid electricity. The local grid electricity utilizes 74% nuclear and only 26% coal giving electricity utilization a low GHG emissions intensity (Table 2.4). Similarly, the 'other process and non-process' category was affected in the same manner. Also, the GHG emissions from the onsite cogeneration operation gave the 'other process and non-process energy' category slightly higher emissions.

Because of the low amount of energy necessary to manufacture the chemical products in context of the entire facility's energy use, it was unanticipated that the financial cost of the treatment chemicals was excessive. Also surprising, the national electricity rate, which was 46% higher than the local electricity mix, was used to estimate the chemical emissions. Yet emissions were lower than expected. The cost intensity for treatment chemicals is higher than the cost intensities of natural gas and electricity at the Bay View Park facility (Table 2.4). This can only be improved by adjusting supply chain operations, especially if the pre-precipitation chemicals are not providing enough solids removal.

**Table 2.4: Comparison of cost and emissions intensity to the Northwest Ohio WWT system**

| | Cost Intensity NW OH's Wastewater System ($/kBtu) | Cost Intensity Ohio* ($/kBtu) | Cost Intensity U.S.* ($/kBtu) | Emission Intensity NW OH's Wastewater System (MT $CO_2$ E/kBtu) |
|---|---|---|---|---|
| **Natural Gas** | 0.005 *($0.506/Ccf)* | 0.009 *($9.41/ Mcf)* | 0.009 *($9.48/ Mcf)* | 1.20E-04 |
| **Electricity** | 0.014 *($0.049/kWh)* | 0.028 *($0.0967/ kWh)* | 0.029 *($0.102/ kWh)* | 5.33E-05 |
| **Chemicals** | 0.064 *($0.218/kWh)* | | | 1.62E-04 |

# 2.5 Conclusions

Total annual energy consumed by the Bay View Park Wastewater Treatment facility is 244,956,803 kBtu. Of this energy, 54% is from non-process related activities including heating, lighting, air handling, and small amounts of process energy (other process and non-process energy) and 42% is from the main treatment processes. The aeration/oxidation process in secondary treatment alone consumes 81,701,764 kBtu (35% of the total process energy) and produces 29,388 metric ton of $CO_2$ equivalent emissions (72% of the total GHG emissions). Natural gas heating makes a significant impact on the overall energy use at the Bay View Park facility. As a result the amount of energy (kBtu) needed per gallon treated increases during the months of December, January, and February, by 46%, 58%, and 57%, respectively. In regards to the energy required for secondary treatment, the facility removed 8.94E+12 mg of BOD in 2010. The amount of process energy spent on removing BOD is 3.33E-06 kWh/mg of BOD and the amount of total onsite energy (electricity and natural gas) spent on removing BOD was 7.72E-06 kWh/mg.

By differentiating the months of the year that require use of the wet weather facility, the design capacity more than doubles from 165 MGD to 360 MGD and the flow of wastewater into the Bay View Park facility also doubles from the 50 MGD to over 100 MGD. In analyzing process energy consumed per gallon of treated during the wet months, there is a 48% and 34% decrease from the maximum used, 5.03E-03 kBtu/gallon of treated water. The influent BOD concentrations during these months are also diluted due to the extra stormwater entering the sanitary sewer system, causing a significant decrease in process energy needed, 2.62E-03 kBtu/gallon, compared to the dry months when BOD is most concentrated.

In regards to energy and financial savings available to the facility's treatment process, it may be necessary to look into the chemical effectiveness of their chemical pre-precipitation step, ferrous chloride, and/or look into more effective screening. A focus in reducing the organic load going into the aeration system will result in less energy needed to remove the dissolved organic waste in secondary treatment. Energy requirements for aeration in secondary treatment increase exponentially as the dissolved oxygen (DO) concentration increases (US EPA, 2010). Energy conservation measures for the aeration tanks, other than automated DO control, include proper blower sizing and turndown, dedicated low-pressure blowers for channel aeration, tapered diffusers, and intermittent aeration (US EPA, 2010).

The lifecycle energy needed to sustain the chemical needs at the Bay View Park facility is relatively low but the financial expenditures were higher than expected. Also surprising, the national electricity rate, which was 46% higher than the local electricity mix, was used to estimate the chemical emissions. This can only be improved by adjusting supply chain operations, especially if further analysis shows that the pre-precipitation chemicals are not providing enough solids removal.

Because the cost intensity for electricity is low for the facility in comparison to the national average, it should be expected that the facility's electric intensity would increase due to national market price increases alone, causing significant increase in financial expenditures as well as increases in the WWTP's climate impact. With the implementation of the cogeneration facility and non-process energy efficiency measures already underway, the Bay View Park facility has the opportunity to save money, energy, and produce less greenhouse gas emissions by fine-tuning each step the treatment process. The secondary treatment process requires the most energy. The suggested energy efficiency measures here have shown documented energy saving. While improving preliminary and primary treatment could provide additional savings and provide significant operational efficiency, it is suggested that further water quality data and energy use data be collected for each individual treatment process in order to further analyze the benefits as well as the relationship to secondary treatment.

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# Appendix A

# Municipal Water Supply Data

Tables A.1 – A.6 provide full primary datasets for the Collins Park Water Treatment system obtained from facility personnel. Table A.1 displays electricity data. The information obtained for each month in the study period was: meter identification, total monthly kWh, max kW, and total monthly cost.

The Collins Park system has 5 electricity meters. It was assumed that no other electricity meters exist for the treatment or distribution system. The meters represent energy usage for:

1. The Main Treatment facility (include the HSPS),
2. The Sludge Dewatering facility (SDF),
3. Low Service Pump Station (LSPS),
4. Flanders Pump Station (FPS), and
5. Heatherdowns Pump Station (HPS).

Meter 1 for the main treatment facility is a 69 kV transmission line, direct from First Energy's Toledo Edison and includes all buildings shown in figure 1.2 with the exception of the sludge dewatering facility (SDF). The SDF has a separate service line that is connected to the local 12.5 kV electricity grid. The SDF pays an approximate rate of $0.12 per kWh (consumption and transmission) and main facility pays an approximate $0.06 per kWh (consumption and transmission).

**Table A.1: Electricity consumption 2009 - 2011; Monthly summation for kWh and Cost; Maximum monthly value for kW**

| **2009** | **Jan** | | | **Feb** | | | **Mar** | | | **Apr** | | | **May** | | | **Jun** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Meter #** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** |
| 1 | 1,809,633 | - | $71,161 | 1,666,462 | - | $55,099 | 1,717,488 | - | $59,466 | 1,444,889 | - | $50,428 | 1,798,070 | 3,888 | $92,516 | 2,259,029 | 4,147 | $169,291 |
| 2 | 43,400 | 174 | $5,927 | 43,000 | 158 | $5,629 | 40,800 | 153 | $5,635 | 22,800 | 85 | $3,155 | 33,100 | 130 | $4,271 | 44,800 | 175 | $5,680 |
| 3 | 533,561 | 986 | $39,272 | 600,454 | - | $25,222 | 536,547 | - | $19,178 | 517,472 | - | $19,858 | 488,029 | - | $19,511 | 600,138 | 1,510 | $37,084 |
| 4 | 7,000 | 14 | $456 | 6,080 | 59 | $924 | 5,680 | 29 | $427 | 5,840 | 29 | $417 | 7,480 | 29 | $641 | 8,000 | 14 | $823 |
| 5 | - | - | $0 | 208,200 | - | $7,328 | 180,000 | - | $6,352 | 214,800 | - | $8,532 | 270,000 | 924 | $11,038 | 324,000 | 921 | $30,496 |
| **2009** | **Jul** | | | **Aug** | | | **Sep** | | | **Oct** | | | **Nov** | | | **Dec** | | |
| **Meter #** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** |
| 1 | 1,952,900 | 4,176 | $151,608 | 1,883,988 | - | $105,296 | 1,808,864 | - | $101,765 | 1,623,628 | - | $92,646 | 1,596,578 | - | $90,363 | 1,752,206 | - | $96,466 |
| 2 | 48,600 | 189 | $6,176 | 51,700 | 174 | $5,983 | 36,500 | 152 | $4,179 | 39,800 | 160 | $4,499 | 43,400 | 178 | $4,935 | 42,200 | 174 | $4,755 |
| 3 | 830,128 | 1,830 | $76,752 | 710,029 | 1,894 | $67,002 | 643,546 | 1,600 | $58,081 | 589,593 | 1,600 | $45,052 | 485,818 | 960 | $36,091 | 457,284 | 819 | $33,751 |
| 4 | 7,160 | 13 | $748 | 7,640 | 13 | $757 | 5,880 | 13 | $577 | 5,200 | 11 | $504 | 6,520 | 13 | $634 | 6,520 | 11 | $605 |
| 5 | 332,400 | 925 | $31,603 | 295,200 | 944 | $28,448 | 263,400 | 922 | $20,682 | 208,800 | 915 | $16,799 | 202,200 | 845 | $16,159 | 246,000 | 910 | $19,322 |
| **2010** | **Jan** | | | **Feb** | | | **Mar** | | | **Apr** | | | **May** | | | **Jun** | | |
| **Meter #** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** |
| 1 | 1,616,818 | - | $90,447 | 1,583,388 | - | $88,285 | 1,730,938 | - | $93,524 | 1,580,162 | - | $88,287 | 1,768,313 | - | $104,114 | 2,182,968 | - | $128,580 |
| 2 | 37,500 | 196 | $4,577 | 40,000 | 180 | $4,616 | 39,700 | 183 | $4,660 | 40,000 | 183 | $4,696 | 43,700 | 196 | $5,070 | 46,500 | 184 | $5,114 |
| 3 | 533, | 986 | $39 | 505, | 998 | $36 | 490, | 1,1 | $36 | 508, | 973 | $37 | 467, | 1,3 | $35 | 581, | 1,2 | $43 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 561 | | ,272 | 767 | | ,818 | 205 | 14 | ,018 | 419 | | ,184 | 724 | 83 | ,693 | 984 | 67 | ,275 |
| 4 | 6,040 | 10 | $559 | 6,480 | 10 | $595 | 5,560 | 10 | $518 | 5,480 | 11 | $520 | 7,080 | 13 | $695 | 7,920 | 25 | $919 |
| 5 | 225,600 | 850 | $17,322 | 232,200 | 868 | $17,790 | 226,200 | 920 | $17,509 | 198,600 | 931 | $15,916 | 211,800 | 919 | $16,811 | 282,000 | 926 | $21,530 |
| **2010** | **Jul** | | | **Aug** | | | **Sep** | | | **Oct** | | | **Nov** | | | **Dec** | | |
| **Meter #** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** |
| 1 | 2,136,067 | - | $125,285 | 2,088,065 | - | $118,947 | 1,781,172 | - | $105,267 | 1,732,291 | - | $92,692 | 1,650,348 | - | $90,727 | 1,760,781 | - | $94,127 |
| 2 | 37,200 | 151 | $4,104 | 37,700 | 151 | $4,185 | 37,400 | 118 | $3,902 | 31,400 | 105 | $3,321 | 26,600 | 96 | $2,874 | 34,400 | 111 | $3,568 |
| 3 | 806,909 | 1,958 | $59,911 | 833,789 | 1,779 | $60,916 | 781,495 | 1,664 | $57,168 | 611,482 | 1,293 | $45,257 | 588,835 | 1,152 | $43,038 | 576,531 | 1,190 | $42,313 |
| 4 | 7,160 | 13 | $737 | 8,760 | 13 | $851 | 6,640 | 13 | $635 | 5,760 | 12 | $556 | 5,880 | 11 | $555 | 6,320 | 11 | $590 |
| 5 | 333,600 | 917 | $24,737 | 337,800 | 927 | $25,021 | 346,800 | 956 | $26,041 | 253,800 | 940 | $19,725 | 202,200 | 845 | $15,989 | 283,200 | 902 | $21,574 |
| **2011** | **Jan** | | | **Feb** | | | **Mar** | | | **Apr** | | | **May** | | | **Jun** | | |
| **Meter #** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** |
| 1 | 1,760,781 | - | $94,127 | 1,807,229 | - | $92,519 | 1,658,966 | - | $87,109 | 1,610,208 | - | $86,106 | 1,658,498 | - | $86,428 | 1,767,103 | - | $107,787 |
| 2 | 34,400 | 111 | $3,568 | 26,000 | 111 | $2,922 | 25,300 | 111 | $2,871 | 30,500 | 90 | $3,050 | 32,400 | 100 | $3,295 | 37,500 | 117 | $3,908 |
| 3 | 628,825 | 1,114 | $45,598 | 665,264 | 1,152 | $47,266 | 620,864 | 1,165 | $44,341 | 562,084 | 1,088 | $40,226 | 515,875 | 934 | $36,747 | 574,941 | 1,664 | $42,856 |
| 4 | 6,320 | 11 | $590 | 6,600 | 12 | $613 | 6,480 | 12 | $602 | 7,000 | 11 | $641 | 6,600 | 13 | $628 | 7,120 | 13 | $705 |
| 5 | 283,200 | 902 | $21,574 | 167,400 | 899 | $13,504 | 240,000 | 868 | $18,148 | 186,600 | 922 | $14,762 | 273,600 | 905 | $20,443 | 277,800 | 908 | $20,749 |
| **2011** | **Jul** | | | **Aug** | | | **Sep** | | | **Oct** | | | **Nov** | | | **Dec** | | |
| **Meter #** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** | **Total KWH** | **Max KW** | **Total Bill** |
| 1 | 2,488,587 | - | $147,105 | 2,321,272 | - | $141,675 | 1,888,106 | - | $119,112 | 1,704,614 | - | $98,940 | 1,596,104 | - | $94,937 | 1,551,564 | - | $89,959 |
| 2 | 38,700 | 118 | $4,047 | 35,700 | 111 | $3,763 | 32,900 | 125 | $3,823 | 32,000 | 141 | $3,992 | 40,000 | 150 | $4,700 | 43,700 | 154 | $5,028 |
| 3 | 908,160 | 1,933 | $66,126 | 876,080 | 1,946 | $64,998 | 796,272 | 1,664 | $59,120 | 527,033 | 1,715 | $41,828 | 522,903 | 1,075 | $37,019 | 456,656 | 922 | $32,275 |
| 4 | 8,040 | 13 | $845 | 7,680 | 14 | $824 | 7,960 | 13 | $835 | 6,080 | 13 | $561 | 5,760 | 12 | $528 | 5,320 | 12 | $496 |
| 5 | 403,200 | 914 | $30,454 | 430,800 | 919 | $33,413 | 315,000 | 919 | $25,410 | 319,800 | 914 | $26,268 | 205,200 | 914 | $17,611 | 202,200 | 845 | $16,991 |

Table A.2 displays natural gas data obtained. The natural gas supply for the analytical period was from GTS, Inc. (Gas Transport Services) and distributed by Columbia Gas of Ohio. Only 2 buildings were metered for natural gas: the main treatment facility (meter 1) and the Heatherdowns pump station (meter 2). All the natural gas was considered to be non-process energy and was used only for heating buildings. The Heatherdowns pump station was heated only because personnel work at this facility. The other pump station, Flanders pump station, is located underground and does not require heating. It has been indicated by facility personnel that some natural gas was utilized for the pumps that heats up and disperse sodium carbonate (soda ash). These amounts are not known and because the amount was assumed to be minute, it has been not been considered as process energy.

Natural gas consumption quantities were given in hundred cubic feet (Ccf) and converted to kBtu with conversion rates set by the United States Department Energy Information Administration (US EIA). The heat content of natural gas (Btu) is different according to geographical area and time extracted. For Ohio, the amount of Btu per cubic foot (CF) of natural gas in 2009 was 1041 Btu, in 2010 it was 1034 Btu, and in 2011 it was 1031 Btu. Amounts for all states in the U.S. can be found at this URL: http://www.eia.gov/dnav/ng/ng_cons_heat_a_EPG0_VGTH_btucf_a.htm. The price per CCF for the main facility is approximately $0.49 as opposed to the Heatherdown Pump Station which cost the facility $0.94/CCF.

## Table A.2: Natural gas consumption 2009 – 2011; Monthly summation for cost, Mcf, & Ccf

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | |
| Meter # | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** |
| 1 | $27,137 | 4,076 | 40,760 | $22,222 | 4,277 | 42,770 | $18,459 | 3,884 | 38,840 | $14,244 | 3,312 | 33,120 | $6,307 | 1,563 | 15,630 | $160 | 37 | 370 |
| 2 | $763 | 68.3 | 683 | $349 | 30 | 300 | $291 | 32.4 | 324 | $313 | 35.2 | 352 | $67 | 6.2 | 62 | $50 | 4.1 | 41 |
| 2009 | **Jul** | | | **Aug** | | | **Sep** | | | **Oct** | | | **Nov** | | | **Dec** | | |
| Meter # | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** |
| 1 | $42 | 8 | 80 | $- | 0 | 0 | $- | 0 | 0 | $904 | 204 | 2,040 | $9,445 | 1,953 | 19,530 | $14,229 | 2,697 | 26970 |
| 2 | $32 | 2.1 | 21 | $20 | 0.7 | 7 | $41 | 1.4 | 14 | $115 | 8.8 | 88 | $302 | 27 | 270 | $237 | 18.8 | 188 |
| 2010 | **Jan-10** | | | **Feb** | | | **Mar** | | | **Apr** | | | **May** | | | **Jun** | | |
| Meter # | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** |
| 1 | $12,522 | 3,852 | 38,520 | $24,850 | 4,141 | 41,410 | $18,615 | 3,346 | 33,460 | $13,546 | 2,979 | 29,790 | $9,180 | 1,846 | 18,460 | $2,595 | 534 | 5,340 |
| 2 | $486 | 42.5 | 425 | $188 | 14.9 | 149 | $189 | 20 | 200 | $101 | 9.2 | 92 | $59 | 3.7 | 37 | $110 | 8.5 | 85 |
| 2010 | **Jul** | | | **Aug** | | | **Sep** | | | **Oct** | | | **Nov** | | | **Dec** | | |
| Meter # | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** |
| 1 | $- | 0 | 0 | $- | 0 | 0 | $- | 0 | 0 | $619 | 126 | 1,260 | $1,839 | 505.3 | 5,053.0 | $13,732 | 2,945.3 | 29,453 |
| 2 | $41 | 1.4 | 14 | $41 | 1.4 | 14 | $45 | 3.7 | 37 | $33 | 2 | 20 | $148 | 19.9 | 199.0 | $329 | 46.9 | 469 |
| 2011 | **Jan** | | | **Feb** | | | **Mar** | | | **Apr** | | | **May** | | | **Jun** | | |
| Meter # | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** |
| 1 | $17,848 | 3,691 | 36,910 | $18,404 | 3,806 | 38,060 | $16,755 | 3,465 | 34,650 | $15,198 | 3,143 | 31,430 | $11,692 | 2,418 | 24,180 | $4,255 | 880 | 8,800 |
| 2 | $486 | 70 | 703 | $294 | 43 | 426 | $419 | 64 | 640 | $219 | 30 | 302 | $51 | 5 | 46 | $30 | 1 | 14 |
| 2011 | **Jul** | | | **Aug** | | | **Sep** | | | **Oct** | | | **Nov** | | | **Dec** | | |
| Meter # | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** | **Total Bill** | **Total Mcf** | **Total Ccf** |
| 1 | $- | - | - | $- | - | - | $- | - | - | $1,209 | 250 | 2,500 | $8,457 | 1,749 | 17,490 | $2,137 | 442 | 4,420 |
| 2 | $31 | 2 | 17 | $29 | 1 | 14 | $41 | 3 | 34 | $49 | 5 | 50 | $112 | 16 | 162 | $- | - | - |

Table A.3 shows the quantity (lbm) of treatment chemicals applied during study period, 2009 – 2011. Only those chemicals that have been added to the treatment train are represented here, not total purchases. The contracted price per pound was also obtained for each chemical. It was assumed that if additional chlorine was added anywhere throughout the distribution system, it was included in the amount listed in table A.3 or not included in the analysis of this study.

**Table A.3: Chemicals and the quantities applied to the Collins Park treatment train 2009 – 2011**

| | CARBON ($0.83/lb) | ALUM ($0.18/lb) | LIME ($0.06/lb) | SODA ASH ($0.12/lb) | CO-2 ($0.03/lb) | POLYPHOSPHATE ($0.65/lb) | CHLORINE ($0.14/lb) | SODIUM CHLORITE ($1.32/lb) | SODIUM SILICOFLUORIDE ($0.42/lb) | POTASSIUM PERMANGANATE ($1.81/lb) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2009 | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** |
| **JAN** | 44,096 | 553,277 | 2,023,778 | 342,204 | 541,495 | 20,334 | 48,698 | 4,322 | 24,422 | |
| **FEB** | 53,691 | 955,342 | 2,091,357 | 606,363 | 535,303 | 19,429 | 47,802 | 4,354 | 22,970 | |
| **MAR** | 78,564 | 1,177,319 | 2,318,830 | 866,970 | 544,514 | 21,598 | 53,540 | 3,640 | 23,851 | |
| **APRIL** | 51,649 | 483,301 | 1,819,922 | 209,513 | 399,388 | 15,949 | 40,297 | 3,231 | 21,794 | |
| **MAY** | 29,088 | 225,252 | 1,896,996 | 3,292 | 411,492 | 16,832 | 37,107 | 3,625 | 24,899 | |
| **JUNE** | 16,818 | 173,403 | 1,961,831 | 0 | 443,807 | 17,772 | 44,531 | 4,103 | 26,654 | |
| **JULY** | 50,830 | 161,807 | 1,934,118 | 0 | 442,544 | 16,957 | 50,562 | 4,405 | 31,079 | |
| **AUG** | 82,231 | 210,992 | 1,665,413 | 0 | 398,879 | 12,911 | 41,488 | 4,125 | 31,297 | |
| **SEPT** | 73,215 | 364,793 | 1,690,133 | 0 | 327,447 | 11,155 | 31,709 | 3,677 | 26,859 | |
| **OCT** | 71,738 | 216,852 | 1,470,779 | 0 | 361,457 | 11,246 | 25,984 | 3,437 | 25,137 | |
| **NOV** | 37,408 | 173,726 | 1,337,018 | 0 | 372,585 | 12,377 | 22,725 | 3,108 | 21,763 | |
| **DEC** | 41,846 | 201,577 | 1,379,331 | 0 | 371,405 | 13,749 | 27,450 | 3,211 | 23,884 | |
| | **CARBON** | **ALUM** | **LIME** | **SODA ASH** | **CO-2** | **POLYPHOSPHATE** | **CHLORINE** | **SODIUM CHLORITE** | **SODIUM SILICOFLUORI** | **POTASSIUM PERMANGANA** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **DE** | **TE** |
| 2010 | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** |
| **JAN** | 39,641 | 225,728 | 1,690,960 | 104,560 | 380,695 | 14,784 | 37,488 | 3,327 | 24,397 | |
| **FEB** | 53,691 | 955,342 | 2,091,357 | 606,363 | 535,303 | 19,429 | 47,802 | 4,354 | 22,970 | |
| **MAR** | 78,564 | 1,177,319 | 2,318,830 | 866,970 | 544,514 | 21,598 | 53,540 | 3,640 | 23,851 | |
| **APRIL** | 51,649 | 483,301 | 1,819,922 | 209,513 | 399,388 | 15,949 | 40,297 | 3,231 | 21,794 | |
| **MAY** | 29,088 | 225,252 | 1,896,996 | 3,292 | 411,492 | 16,832 | 37,107 | 3,625 | 24,899 | |
| **JUNE** | 16,818 | 173,403 | 1,961,831 | 0 | 443,807 | 17,772 | 44,531 | 4,103 | 26,654 | |
| **JULY** | 50,830 | 161,807 | 1,934,118 | 0 | 442,544 | 16,957 | 50,562 | 4,405 | 31,079 | |
| **AUG** | 82,231 | 210,992 | 1,665,413 | 0 | 398,879 | 12,911 | 41,488 | 4,125 | 31,297 | |
| **SEPT** | 73,215 | 364,793 | 1,690,133 | 0 | 327,447 | 11,155 | 31,709 | 3,677 | 26,859 | |
| **OCT** | 71,738 | 216,852 | 1,470,779 | 0 | 361,457 | 11,246 | 25,984 | 3,437 | 25,137 | |
| **NOV** | 37,408 | 173,726 | 1,337,018 | 0 | 372,585 | 12,377 | 22,725 | 3,108 | 21,763 | |
| **DEC** | 41,846 | 201,577 | 1,379,331 | 0 | 371,405 | 13,749 | 27,450 | 3,211 | 23,884 | |
| | **CARBON** | **ALUM** | **LIME** | **SODA ASH** | **CO-2** | **POLYPHOSPHATE** | **CHLORINE** | **SODIUM CHLORITE** | **SODIUM SILICOFLUORIDE** | **POTASSIUM PERMANGANATE** |
| 2011 | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** | **TOTAL POUNDS** |
| **JAN** | 42,519 | 151,755 | 1,620,917 | 27,366 | 405,558 | 18,931 | 41,309 | 3,518 | 25,779 | 5,208 |
| **FEB** | 29,931 | 199,112 | 1,622,931 | 164,023 | 392,693 | 20,556 | 36,580 | 3,281 | 23,084 | 4,992 |
| **MAR** | 61,398 | 1,055,708 | 2,196,786 | 797,545 | 462,861 | 23,103 | 58,961 | 5,432 | 33,484 | 10,056 |
| **APRIL** | 59,868 | 509,069 | 1,783,476 | 336,666 | 308,600 | 19,964 | 44,019 | 4,920 | 23,583 | 1,728 |
| **MAY** | 72,715 | 708,468 | 2,157,161 | 348,832 | 326,523 | 17,194 | 51,086 | 5,180 | 26,128 | 2,520 |
| **JUNE** | 56,989 | 326,550 | 2,173,136 | 0 | 346,611 | 14,572 | 65,480 | 5,820 | 30,563 | 30,960 |
| **JULY** | 85,995 | 193,005 | 2,085,067 | 0 | 449,499 | 13,180 | 67,387 | 7,143 | 44,677 | 35,760 |
| **AUG** | 122,567 | 392,384 | 2,134,902 | 0 | 403,159 | 9,693 | 56,351 | 6,854 | 34,338 | 36,720 |
| **SEPT** | 143,094 | 394,976 | 1,743,479 | 0 | 358,585 | 7,987 | 46,253 | 6,086 | 30,670 | 31,680 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **OCT** | 62,966 | 175,317 | 1,394,194 | 12,273 | 267,226 | 11,045 | 35,352 | 5,046 | 26,689 | 20,040 |
| **NOV** | 0 | 143,405 | 1,264,040 | 0 | 297,474 | 13,031 | 28,106 | 3,163 | 25,925 | 17,544 |
| **DEC** | 18,750 | 187,129 | 1,422,211 | 0 | 347,358 | 20,619 | 37,569 | 3,465 | 25,460 | 18,240 |

Table A.4 represents a list of all lighting fixtures in the main treatment facility. Lighting counts were not obtained from the low service pump station or the Heatherdowns pump station. The nameplate information from all equipment was used for calculating typical energy use per year. It was assumed that all fixtures listed here were utilized 8,760 hours per year. A commercial lighting calculator, provided by the First Energy Corporation, was used to determine the energy use for each type of fixture and bulb combination.

**Table A.4: Lighting counts**

| Building Name | Interior or Exterior Fixture | Description | Pre Fixture Qty | Pre Fixture Code | Pre Watts / Fixture (W) |
|---|---|---|---|---|---|
| **SDF** | Interior | Tubes 4ft T8 - Two | 55 | F42ILL | 59 |
| **SDF** | Interior | Tubes 4ft T8 - Three | 39 | F43LE | 110 |
| **SDF** | Interior | U Lighting FOB31/835 - Two | 6 | FU1ILL | 31 |
| **SDF** | Interior | Multivapor 250W - Single | 15 | MH250/1 | 295 |
| **SDF** | Interior | Multivapor 400W Single | 9 | MH400/1 | 458 |
| **SDF** | Interior | Emergency Exit Sign - Single | 12 | ECF5/2 | 20 |
| **SDF** | Interior | Emergency Flood Lights - Two | 9 | | |
| **SDF** | Exterior | High Pressure 250W - Single | 9 | HPS250/1 | 295 |
| **HSPS** | Interior | Incandescent 100W - Single | 73 | I100/1 | 100 |
| **HSPS** | Interior | Incandescent 300W - Single | 26 | I300/1 | 300 |
| **HSPS** | Interior | Multivapor 250W -Single | 37 | MH250/1 | 295 |
| **HSPS** | Interior | Tubes 4ft T8 - Four | 8 | F44SS | 188 |
| **HSPS** | Interior | Tubes 4ft T12 - Two | 7 | F42SS | 94 |
| **HSPS** | Interior | Tubes 4ft T12 - Four | 24 | F44SS | 484 |
| **HSPS** | Interior | Tubes 8ft T12 - Two | 27 | F82SS | 173 |
| **HSPS** | Interior | Emergency Flood Lights - Two | 4 | | |
| **HSPS** | Exterior | High Pressure 250W - Single | 12 | HPS250/1 | 295 |
| **HSPS** | Exterior | Incandescent 100W - Two | 2 | I100/2 | 200 |
| **CHEMICAL BUILDING** | Interior | U Lighting 26W 2 Pin - Two | 16 | FU2ILL | 59 |
| **CHEMICAL BUILDING** | Interior | Incandescent 100W - Single | 49 | I100/1 | 100 |
| **CHEMICAL BUILDING** | Interior | Flood Lights - Single | 4 | | |
| **CHEMICAL BUILDING** | Interior | Tubes 4ft T8 - Single | 4 | F41ILL | 31 |
| **CHEMICAL BUILDING** | Interior | Tubes 4ft T8 - Two | 47 | F42ILL | 59 |

| | | | | | |
|---|---|---|---|---|---|
| **CHEMICAL BUILDING** | Interior | Tubes 4ft T8 - Four | 40 | F44LL | 112 |
| **CHEMICAL BUILDING** | Exterior | Tubes 4ft T12 - Single | 8 | F41SS | 57 |
| **CHEMICAL BUILDING** | Interior | Tubes 4ft T12 - Two | 35 | F42SS | 94 |
| **CHEMICAL BUILDING** | Interior | Tubes 4ft T12 - Four | 63 | F44SS | 188 |
| **CHEMICAL BUILDING** | Interior | Tubes 8ft T12 - Two | 87 | F82SS | 173 |
| **CHEMICAL BUILDING** | Interior | Emergency Exit Signs - Single | 22 | ECF5/2 | 20 |
| **CHEMICAL BUILDING** | Interior | Emergency Flood Lights - Two | 14 | | |
| **CHEMICAL BUILDING** | Exterior | High Pressure 250W - Single | 2 | HPS250/1 | 295 |
| **CHEMICAL BUILDING** | Exterior | Incandescent 100W - Two | 2 | I100/2 | 200 |
| **CHEMICAL BUILDING** | Exterior | High Pressure 70W - Single | 2 | HPS70/1 | 95 |
| **80 PLANT** | Interior | Incandescent 100W - Single | 47 | I100/1 | 100 |
| **80 PLANT** | Interior | Flood light - Single | 212 | | |
| **80 PLANT** | Interior | Multivapor - Single | 30 | MH250/1 | 295 |
| **80 PLANT** | Interior | Tubes 3ft T12 - Single | 174 | F31SS | 46 |
| **80 PLANT** | Interior | Tubes 4ft T12 - Single | 266 | F41SS | 57 |
| **80 PLANT** | Interior | Tubes 8ft T12 - Two | 51 | F82SS | 173 |
| **80 PLANT** | Exterior | Incandescent 100W - Two | 6 | I100/2 | 200 |
| **40 PLANT** | Interior | Incandescent 100W - Single | 29 | I100/1 | 100 |
| **40 PLANT** | Interior | Flood Light - Single | 155 | | |
| **40 PLANT** | Interior | Multivapor - Single | 20 | MH250/1 | 295 |
| **40 PLANT** | Interior | Tubes 4ft T12 - Single | 258 | F41SS | 57 |
| **40 PLANT** | Interior | Tubes 8ft T12- Two | 25 | F82SS | 173 |
| **40 PLANT** | Exterior | High Pressure 250W - Single | 3 | HPS250/1 | 295 |
| **40 PLANT** | Exterior | Incandescent 100W - Two | 2 | I100/2 | 200 |
| **GENERATOR** | Interior | Multivapor - Single | 36 | MH250/1 | 295 |
| **GENERATOR** | Interior | Tubes 4ft T8 - Two | 1 | F42ILL | 59 |
| **GENERATOR** | Interior | Tubes 4ft T8 - Three | 14 | F43ILL | 89 |
| **GENERATOR** | Interior | Emergency Exit Sign - Single | 5 | ECF5/2 | 20 |
| **GENERATOR** | Interior | Emergency Flood Lights - Two | 9 | | |
| **GENERATOR** | Exterior | High Pressure 250W - Single | 25 | HPS250/1 | 295 |
| **WASHWATER** | Interior | Incandescent 100W - Single | 3 | I100/1 | 100 |
| **WASHWATER** | Interior | Incandescent 300W - Single | 2 | I300/1 | 300 |
| **WASHWATER** | Interior | Multivapor - Single | 1 | MH250/1 | 295 |
| **WASHWATER** | Interior | Tubes 4ft T12 - Two | 4 | F42SS | 94 |
| **WASHWATER** | Exterior | High Pressure 250W - Single | 1 | HPS250/1 | 295 |
| **CHEMICAL STORAGE** | Interior | Incandescent 100W - Single | 30 | I100/1 | 100 |
| **CHEMICAL STORAGE** | Interior | Multivapor - Single | 17 | MH250/1 | 295 |
| **CHEMICAL STORAGE** | Exterior | Incandescent 100W - Two | 2 | I100/2 | 200 |
| **CLORINE** | Interior | Incandescent 100W - Single | 2 | I100/1 | 100 |
| **CLORINE** | Interior | Multivapor - Single | 4 | MH250/1 | 295 |
| **CLORINE** | Interior | Tubes 4ft T12 - Two | 36 | F42SS | 94 |
| **CLORINE** | Exterior | High Pressure 250W - Single | 4 | HPS250/1 | 295 |
| **MAINT/BOILER** | Interior | Tubes 4ft T12 - Two | 8 | F42SS | 94 |
| **MAINT/BOILER** | Interior | Tubes 8ft T8 - Two | 33 | F82ILL | 109 |
| **MAINT/BOILER** | Interior | Tubes 8ft T12 - Two | 12 | F82SS | 173 |
| **HIGH MAST** | Exterior | Luclax Lamp 1000W - Five | 7 | | 5000 |
| **HIGH MAST** | Exterior | High Pressure 1000W - Three | 8 | HPS1000/3 | 3000 |
| **HDPS** | Interior | I1000/2 | 12 | I1000/2 | 2000 |
| **HDPS** | Interior | F42LL | 5 | F42LL | 60 |
| **HDPS** | Interior | MV250/1 | 3 | MH250/1 | 290 |

| | | | | | |
|---|---|---|---|---|---|
| **HDPS** | Interior | MV1000/1 | 5 | MH1000/1 | 1075 |
| **LSPS** | Interior | I100/1 | 22 | I100/1 | 1000 |
| **LSPS** | Interior | I150/1 | 31 | I150/1 | 150 |
| **LSPS** | Exterior | I150/2 | 2 | I150/2 | 300 |
| **LSPS** | Interior | I200/1 | 78 | I200/1 | 200 |
| **LSPS** | Interior | I300/1 | 41 | I300/1 | 300 |
| **LSPS** | Exterior | I300/2 | 2 | I300/2 | 600 |
| **LSPS** | Interior | I500/1 | 4 | I500/1 | 500 |
| **LSPS** | Interior | F41LL | 6 | F41LL | 32 |
| **LSPS** | Interior | F42LL | 3 | F42LL | 60 |

The nameplate information of all air-handling units was also obtained for all buildings at the main treatment facility (Table A.5). The rooftop ventilators and propane-fired boiler at the low service pump station were not taken into consideration for this analysis. It was assumed that units listed in table A.5 operate 8,760 hours per year, and it was also assumed there were no units located at the Heatherdowns pump station.

**Table A.5: Electricity consumption of the air-handling units at the main treatment facility.**

| Location | Type | HP | VAC | RPM |
|---|---|---|---|---|
| **HSPS #1** | Condenser Fan | 0.75 | 460 | 1075 |
| | Condenser Fan | 0.75 | 460 | 1075 |
| | Supply Fan | 5 | 460 | 1170 |
| | Exhaust Fan | 5 | 460 | 1760 |
| **HSPS #2** | Condenser Fan | 0.75 | 460 | 1075 |
| | Condenser Fan | 0.75 | 460 | 1075 |
| | Supply Fan | 5 | 460 | 1760 |
| | Exhaust Fan | 3 | 460 | 1760 |
| **Chemical #1** | Compressor | NA | 460 | NA |
| | Blower | 1 | 460 | NA |
| | Fan | 0.25 | 460 | NA |
| | Comb. Blower | 0.07 | 460 | NA |
| **Chemical #2** | Compressor | NA | 460 | 3500 |
| | Compressor | NA | 460 | 3500 |
| | Condenser MTR | 0.75 | 460 | 1075 |
| | Condenser MTR | 0.75 | 460 | 1075 |
| | Supply Air MTR | 5 | 460 | 1760 |

| | | | | |
|---|---|---|---|---|
| | Combustion MTR | 0.25 | 460 | 3000 |
| **Chemical #3** | Compressor | NA | 460 | NA |
| | Compressor | NA | 460 | NA |
| | Compressor | NA | 460 | NA |
| | Fan MTR | NA | 460 | NA |
| | Fan MTR | NA | 460 | NA |
| | Combustion MTR | NA | 460 | NA |
| **Chemical #4** | Compressor | NA | 208 | NA |
| | Fan MTR | NA | 208 | NA |
| | Fan MTR | NA | 208 | NA |
| | Combustion MTR | NA | 208 | NA |
| **Chemical #5** | Compressor | NA | 460 | 3500 |
| | Condenser | 0.35 | 460 | 1075 |
| | Evaporator | 1 | 460 | 1780 |
| | Combustion MTR | 0.09 | 460 | 3000 |
| **Chemical #6** | Compressor | NA | 460 | 3450 |
| | Condenser | 0.33 | 460 | 1075 |
| | Evaporator | 1 | 460 | 1760 |
| | Combustion MTR | 0.09 | 460 | 3000 |
| **Chemical #7** | Compressor | NA | 460 | 3500 |
| | Condenser | 0.33 | 460 | 1075 |
| | Evaporator | 2 | 460 | 1760 |
| | Combustion MTR | 0.09 | 460 | 3000 |
| **Sludge Dewatering** | Compressor | NA | 230 | 3500 |
| | Condenser | 0.33 | 230 | 1075 |
| | Evaporator | 1 | 230 | 1760 |
| | Combustion Air | 0.09 | 230 | 3000 |
| **Standby Generator Facility** | Exhaust Fan #1 | 1.5 | 480 | 1010 |
| | Exhaust Fan #2 | 1.5 | 480 | 1010 |
| | Exhaust Fan #3 | 1 | 480 | 810 |
| | Force Air Unit | 0.75 | 480 | 1750 |

There is a solar generation field located on the main treatment site, which feeds directly to the electric supplier, First Energy, Inc. as of August 2011, the Collins Park facility buys the green power from First Energy. The facility will continue to purchase the solar electricity generated through December 31, 2021, after which the facility will own the solar field. Generation data was obtained by facility personnel.

**Table A.6: 2 years of solar generation.**

| | Aug 2011 | Sep 2011 | Oct 2011 | Nov 2011 | Dec 2011 | Jan 2012 | Feb 2012 | Mar 2012 | Apr 2012 | May 2012 | Jun 2012 | Jul 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total KWH** | 64,060 | 97,434 | 93,197 | 63,000 | 37,886 | 39,814 | 74,552 | 112,909 | 149,595 | 176,925 | 182,101 | 179,086 |
| | **Aug 2012** | **Sep 2012** | **Oct 2012** | **Nov 2012** | **Dec 2012** | **Jan 2013** | **Feb 2013** | **Mar 2013** | **Apr 2013** | **May 2013** | **Jun 2013** | **Jul 2013** |
| **Total KWH** | 157,414 | 126,063 | 83,152 | 71,213 | 35,660 | 49,840 | 52,545 | 92,504 | 117,024 | 165,485 | 151,462 | 134,131 |

# Appendix B

# Municipal Wastewater Treatment Data

Tables B.1 – 9 primary data for the Bay View Park Wastewater Treatment system obtained from facility personnel. The WWTP obtains grid electricity from a 69 kV line/substation directly from the local electric utility. Table B.1 includes values for total kWh, max kW, & cost. Table B.2 includes the total monthly kWh and total monthly cost for the 47 pump stations located throughout the community. This electricity was purchased from the local grid and the connection configurations are not known. Table B.3 includes values for the 2010 generation amounts for the cogeneration facility onsite at the Bay View Park facility. Generation amounts from landfill methane and digester methane were given separately. No natural gas was consumed in the year 2010 but was in the proceeding 2 years. Table B.4 lists the amount of landfill and digester gas that was provided the electricity in table B.3.

**Table B.1: Monthly summation for the electricity consumption at the Bay View Park facility for the operation year 2010**

| **Jan** | | | **Feb** | | | **Mar** | | | **Apr** | | | **May** | | | **Jun** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** |
| 2,780,27 | 5,266 | $139,4 | 2,649,47 | 5,894 | $137,4 | 4,151,93 | 8,034 | $213,2 | 3,028,92 | 7,559 | $171,3 | 2,715,45 | 7,237 | $156,3 | 2,444,70 | 6,026 | $135,9 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | | 72 | 0 | | 47 | 9 | | 91 | 7 | | 58 | 2 | | 21 | 3 | | 06 |
| **Jul** | | | **Aug** | | | **Sep** | | | **Oct** | | | **Nov** | | | **Dec** | | |
| **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** | **Total kWh** | **Max kW** | **Total Bill** |
| 3,358,623 | 7,304 | $170,270 | 1,949,269 | 6,477 | $120,939 | 2,110,886 | 5,782 | $122,396 | 2,028,005 | 5,128 | $112,496 | 2,138,002 | 6,513 | $123,178 | 2,801,875 | 5,279 | $132,536 |

**Table B.2: Monthly summation for the electricity consumption for the 47 reclamation pump stations**

| | **Jan** | | **Feb** | | **Mar** | | **Apr** | | **May** | | **Jun** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** |
| 30 Sanitary Sewer | 61,021 | $8,332 | 225,210 | $20,452 | 264,123 | $26,609 | 215,476 | $23,189 | 229,869 | $19,822 | 177,501 | $16,081 |
| 13 Storm Sewer | 7,824 | $1,133 | 13,987 | $2,447 | 15,540 | $3,535 | 12,134 | $2,631 | 11,537 | $3,435 | 4,176 | $2,616 |
| Sluice Gate | - | $- | - | $- | 183 | $37 | 190 | $38 | 170 | $36 | 169 | $38 |
| CSO 1 & 2 | 680 | $194 | 640 | $226 | 880 | $247 | 1,440 | $312 | 1,400 | $193 | 1,080 | $169 |
| CSO 3, 4 & 5 | 500 | $914 | 1,800 | $1,017 | 4,000 | $1,275 | 4,600 | $1,397 | 2,400 | $1,281 | 5,000 | $1,308 |
| CSO 6&7 | 2,600 | $500 | 1,800 | $409 | 3,600 | $600 | 4,000 | $633 | 3,600 | $854 | 5,600 | $1,105 |
| | **Jul** | | **Aug** | | **Sep** | | **Oct** | | **Nov** | | **Dec** | |
| | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** | **Total KWH** | **Total Bill** |
| 30 Sanitary Sewer | 190,887 | $17,799 | 128,935 | $12,957 | 118,203 | $10,893 | 105,411 | $11,813 | 221,040 | $21,059 | 195,083 | $17,642 |
| 13 Storm Sewer | 3,249 | $2,647 | 5,913 | $2,687 | 2,395 | $1,445 | 3,439 | $1,787 | 6,669 | $2,165 | 13,979 | $2,780 |
| Sluice Gate | 164 | $37 | 157 | $37 | 128 | $34 | 187 | $39 | 95 | $32 | 253 | $45 |
| CSO 1 & 2 | 1,56 | $214 | 480 | $188 | 560 | $198 | 560 | $198 | 1,52 | $300 | 520 | $205 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | | 0 | | | |
| CSO 3, 4 & 5 | 4,100 | $1,506 | 5,300 | $872 | 1,400 | $494 | 300 | $383 | 400 | $540 | 600 | $491 |
| CSO 6&7 | 2,000 | $748 | 1,000 | $649 | 2,400 | $780 | 2,100 | $719 | 2,100 | $719 | 2,000 | $717 |

**Table B.3: kWh produced by the onsite cogeneration facility for the year 2010**

| Operation Time | 6 - 8 hours a day | | | | 16 hours a day | | 8 hours a day | 24 hours a day | | | | Testing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Landfill Gas Generation (kWh) | 275,000 | 257,000 | 343,000 | 343,000 | 1,441,000 | 1,572,000 | 260,000 | 796,000 | 1,221,000 | 1,076,000 | 803,000 | 392,000 |
| Digester Gas Generation (kWh) | 77,000 | 73,000 | 97,000 | 97,000 | 407,000 | 444,000 | 74,000 | 225,000 | 345,000 | 304,000 | 227,000 | 110,000 |

**Table B.4: Amount of landfill and methane gas fed to the cogeneration facility.**

| Year | Cogen Landfill + Digester Gas (million scf) | Cogen Landfill + Digester Gas (scf) | Landfill + Digester Gas Average Heat Value (Btu/scf) | Cogen Natural Gas (million scf) |
|---|---|---|---|---|
| 2010 | 185.5 | 185,500,000 | 550 | - |

Table B.5 lists the electricity requirement obtained from the submetering system at the Bay View Park facility. Because only 11 months of electricity usage was obtained, the average usage between the months of September and July were used for the month of August.

**Table B.5: kWh used by the equipment within the main equipment building, blower building, and onsite pump station**

| | Main Equipment Building (kWh) | Blower Building (kWh) | B.V. Pump Station (kWh) | Total kWh |
|---|---|---|---|---|
| September | 1,218,423 | 819,903 | 274,211 | 2,312,537 |
| October | 1,282,929 | 776,202 | 306,346 | 2,365,477 |
| November | 1,298,181 | 790,560 | 379,260 | 2,468,001 |
| December | 877,014 | 1,022,664 | 476,574 | 2,376,252 |
| January | 763,018 | 983,422 | 315,572 | 2,062,012 |
| February | 721,495 | 923,516 | 245,614 | 1,890,625 |
| March | 809,236 | 1,051,566 | 397,060 | 2,257,862 |
| April | 1,216,607 | 834,768 | 205,008 | 2,256,384 |
| May | 1,403,135 | 807,667 | 227,946 | 2,438,748 |
| June | 1,338,015 | 762,447 | 180,428 | 2,280,889 |
| July | 1,357,899 | 791,826 | 203,799 | 2,353,524 |

Table B.6 is the natural gas consumption for the Bay View Park facility. Natural gas was only used for heating the buildings. Table B.6 is the natural gas consumption for 4 reclamation pump stations. These natural gas amounts are also used for heating.

**Table B.6: 2010 natural gas consumption for the wastewater treatment facility**

| **Jan** | | **Feb** | | **Mar** | | **Apr** | | **May** | | **Jun** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** |
| $52,248 | 135,390 | $77,527 | 129,190 | $47,968 | 86,220 | $33,139 | 72,880 | $31,687 | 63,720 | $12,508 | 25,740 |
| **Jul-10** | | **Aug-10** | | **Sep-10** | | **Oct-10** | | **Nov-10** | | **Dec-10** | |
| **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** | **Total Bill** | **Total Ccf** |
| $6,014 | 9,550 | $6,808 | 11,230 | $2,420 | 5,010 | $10,861 | 22,110 | $21,207 | 58,261 | $40,937 | 87,803 |

**Table B.7: 2010 natural gas consumption for four reclamation sanitary sewer pump stations**

| | Jan | | Feb | | Mar | | Apr | | May | | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meter | Cost | CCF | Cost | CCF | Cost | CCF | Cost | CCF | Cost | CCF | Cost | CCF |
| 1 | $135 | 216 | $123 | 186 | $74 | 81 | $46 | 36 | $20 | 0 | $20 | 0 |
| 2 | $10,496 | 9,706 | $5,118 | 4,787 | $2,609 | 3,306 | $1,112 | 1,408 | $267 | 282 | $129 | 101 |
| 3 | $2,638 | 4,980 | $2,905 | 4,840 | $2,403 | 4,320 | $459 | 1,010 | $398 | 800 | $131 | 270 |
| 4 | $13,269 | 14,902 | $8,145 | 9,813 | $5,087 | 7,707 | $1,618 | 2,454 | $685 | 1,082 | $281 | 371 |
| | $40,360 | | $40,391 | | $40,422 | | $40,452 | | $40,483 | | $40,513 | |
| | July | | Aug | | Sept | | Oct | | Nov | | Dec | |
| Meter | Cost | CCF | Cost | CCF | Cost | CCF | Cost | CCF | Cost | CCF | Cost | CCF |
| 1 | $20 | 0 | $20 | 0 | $20 | 0 | $20 | 0 | $344 | 496 | $328 | 481 |
| 2 | $109 | 88 | $114 | 93 | $665 | 736 | $2,513 | 3,249 | $3,014 | 3,767 | $5,106 | 6,293 |
| 3 | $6 | 10 | $6 | 10 | $5 | 10 | $909 | 1,850 | $979 | 2,690 | $1,444 | 3,098 |
| 4 | $136 | 98 | $141 | 103 | 690.48 | 746 | $3,442 | 5,099 | $4,337 | 6,953 | $6,879 | 9,872 |

Table B.8 provides the chemical usage amounts and cost information for the Bay View Park facility for the year 2010.

**Table B.8: Chemicals used at the WWTP**

| **CHEMICAL** | **Process In Which Used** | **AMOUNT** | **$/Unit** |
|---|---|---|---|
| **Polymer** | Dissolved air flotation | 45,620 lbm | 0.90/lb |
| **Polymer** | Belt filter press | 209,640 lbm | 1.015/lb |
| **Polymer** | Wet weather ballasted floc | 3,300 lbm | 1.49/lb |
| **Ferrous Chloride** | Primary | 4,554,720 lbm | 0.64/lb Fe |
| **Ferric Chloride** | Wet weather | 230,280 lbm | 0.81/lb Fe |
| **Sodium Bisulfite** | Dechlorination | 473,363 lbm | 0.1413/lb |
| **Chlorine** | Disinfection/chlorination | 220,065 lbm | 0.1695/lb |

Table B.9 represents amount of BOD, suspended solids, phosphorous, ammonium, nitrate, nitrogen dioxide in the influent (RAW) and effluent (FINAL) as well as the incoming flow in million gallons per month for 2010.

**Table B.9: Influent and effluent nutrient levels as well as the in coming flow of wastewater treated at Bay View**

| | CBOD RAW mg/L | CBOD FINAL mg/L | S.S. RAW mg/L | S.S. FINAL mg/L | PHOS RAW mg/L | PHOS FINAL mg/L | NH3 SETTLED mg/L | NH3 FINAL mg/L | NO3+NO2 FINAL mg/L | Flow Million Gallon/Month |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 125 | 4.26 | 209 | 8.06 | 4.74 | 0.79 | 17 | 0.04 | 16 | 1,665 |
| Feb | 116 | 4.46 | 183 | 10.29 | 3.60 | 0.71 | 18 | 0.15 | 15 | 1,540 |
| Mar | 72 | 6.07 | 138 | 12.23 | 2.42 | 0.63 | 11 | 0.15 | 8 | 2,955 |
| Apr | 71 | 4.41 | 150 | 9.10 | 2.28 | 0.56 | 10 | 0.05 | 8 | 3,159 |
| May | 64 | 4.03 | 134 | 7.71 | 1.86 | 0.61 | 9 | 0.04 | 8 | 3,221 |
| Jun | 86 | 3.37 | 201 | 5.87 | 2.98 | 0.79 | 12 | 0.04 | 8 | 2,200 |
| Jul | 115 | 3.24 | 215 | 4.87 | 3.44 | 0.79 | 16 | 0.10 | 11 | 1,843 |
| Aug | 120 | 3.84 | 223 | 6.10 | 3.24 | 0.84 | 16 | 0.08 | 10 | 1,661 |
| Sep | 133 | 3.79 | 239 | 10.63 | 3.80 | 0.70 | 18 | 0.05 | 18 | 1,681 |
| Oct | 137 | 3.93 | 240 | 8.48 | 4.14 | 0.82 | 20 | 0.23 | 18 | 1,534 |
| Nov | 133 | 6.86 | 231 | 16.53 | 3.90 | 0.74 | 19 | 0.98 | 17 | 1,713 |
| Dec | 117 | 4.34 | 187 | 9.39 | 3.40 | 0.89 | 17 | 0.14 | 21 | 1,560 |