# ENERGY EVALUATION

## Town of Brattleboro
## Wastewater Treatment Facility

## Riverside Drive
## Brattleboro, Vermont

PROCESS ENERGY SERVICES, LLC

WATER ♦ WASTEWATER ♦ INDUSTRIAL

# ENERGY EVALUATION

# for the

# TOWN OF BRATTLEBORO

# WASTEWATER TREATMENT FACILITY

**October 2017**

**Riverside Drive**
**Brattleboro, Vermont**

**Performed by:**

Process Energy Services, LLC
2 Lafayette Rd.
Londonderry, New Hampshire 03053
(603) 537-1286

**Supported by:**

Efficiency Vermont

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**APPENDIX A: UTILITY RATE SCHEDULE**

**APPENDIX B: ENERGY BALANCE**

While the recommendations in this report have been reviewed for technical accuracy, Process Energy Services is not liable if the projected savings are not achieved. The recommendations are based on an analysis of conditions observed at the time of the evaluation, information provided by facility staff and estimated costs for equipment and labor based on similar projects. Actual savings and project costs will depend on many factors, including varying process flows and loads, recommendations implemented, seasonal variations in fuel costs and weather, and proper equipment operation. Before implementation of the measures presented in this report, Process Energy Services recommends a more detailed analysis to verify savings and project costs.

# SECTION 1. EXECUTIVE SUMMARY

## 1.1 Overview

This report details energy saving recommendations identified by Process Energy Services for the Brattleboro Wastewater Treatment Plant in Brattleboro, VT. The evaluation included the following tasks:

- Provide an energy-related review of each facility process.
- Assemble energy, flow, and equipment operational information based on plant process and field measurements collected to identify potential cost saving projects.
- Provide preliminary savings and cost data for the identified energy measures.

We would like to thank facility staff for their assistance during the evaluation. Bruce Lawrence, the facility Chief Operator provided us with the plans, specifications and process data needed to evaluate potential energy saving measures. The operations staff also provided assistance for all the field measurements.

## 1.2 Facility Improvements Related to Efficiency

The facility performed a significant upgrade in 2012 that included high efficiency equipment and design features to reduce energy costs. Some of these improvements included the following:

- Low energy preliminary treatment equipment that included a fine screen for solids removal classifier type grit system
- Low energy odor control systems.
- Energy dissipating primary clarifier design that provides high primary BOD removals
- Variable frequency drives (VFDs) included for the majority of pump and blower systems.
- Water source heat pumps and heat recovery ventilation systems installed throughout the plant
- Turbo blowers used for the new MBBR system
- Low energy sludge dewatering system

To supplement these efficiency upgrades, this evaluation benchmarked existing energy use using equipment power measurements taken during site visits and facility process/equipment run time data supplied by staff. This data was used to identify potential additional energy saving opportunities.

## 1.3 Report Organization

As cost savings projects were developed, each measure was prioritized based on ease of implementation, cost effectiveness and ability for each project to support subsequent measures. The projects have been categorized as energy conservation measures (ECMs), for projects that require a capital investment, operational measures (OMs) for fast payback improvements (1 year or less), and energy supply measures (ESMs) for improvements that may reduce energy costs without reducing energy consumption (i.e. alternative energy source and rate schedule changes). We have also included energy management practices (EMPs) that are essential for a successful energy management program.

The report organization includes an Executive Summary to provide an overview of the recommended project savings and costs. Section 2 reviews energy management initiatives and benchmarking facility energy use. Section 3 contains an energy related overview of each process. Section 4 summarizes energy use and costs, and Section 5 includes a detailed review of each proposed measure.

The project evaluation summary table is presented in Table 1.1, and a summary of the qualified measures and their associated savings is presented in Table 1.2.

## Table 1.1: Project Evaluation Summary

**2016 Baseline Annual Electric Energy and Fuel Oil Costs**

| | |
|---|---|
| Wastewater Plant Electric Energy | $ 109,896 |
| Plant Fuel Oil | $ 61,030 |
| **Total** | **$ 170,926** |

**Projected Annual Cost and Savings Summary**

| | Calculated Savings | Percent of Costs |
|---|---|---|
| Electric Cost Savings | $ 8,894 | 8% |
| Fuel Oil Savings | $ 39,575 | 65% |
| **Net Annual Savings/Percent of Energy Costs** | **$ 48,469** | **28%** |

**Project Costs/Payback**

| | |
|---|---|
| Estimated Cost of Projects | **$ 234,440** |
| Simple Payback | **4.8 Years** |

**Electric Energy Reduced Power Plant Emissions**

In addition to the energy cost savings, reducing facility energy use will also provide environmental benefits by reducing greenhouse gas emissions (GHG) that include $CO_2$, $N_2O$ and $CH_4$. The information in this evaluation can be used by the Town to develop a GHG inventory plan in accordance with the EPA's Climate Leadership Program.

| | | |
|---|---|---|
| Carbon Dioxide (1.37 lbs/kWh and 22.2 lbs/gal fuel oil) | 538,657 | lbs/year |
| Sulfur Oxides (0.0035 lbs/kWh and 0.142 lbs/gal fuel oil) | 2,982 | lbs/year |
| Nitrous Oxides (0.0010 lbs/kWh and .02 lbs/gal fuel oil) | 465 | lbs/year |

Reduced power plant emission is based on 87,809 kWh and 18,845 gallons of fuel oil annual savings. Emission unit source: U.S. EPA eGrid 2007 and U.S. EPA Office of Air Quality Planning & Standards *(www.epa.gov/cleanenergy/energy-resources/egrid/faq.html).*

**Table 1.2: Recommended Cost Saving Projects**

| No | Cost Saving Measures | Annual Energy Savings (kWh) | First Year Annual Savings ($) | Initial Cost ($) | Simple Payback (yrs) |
|---|---|---|---|---|---|
| | | | | | |
| | **ENERGY MANAGEMENT PRACTICES** | | | | |
| EMP 1 | Energy Benchmarking Data Collection | -- | -- | -- | -- |
| | **Total for EMPs** | -- | -- | **--** | -- |
| | | | | | |
| | **ENERGY SUPPLY MEASURES** | | | | |
| ESM 1 | Power Factor Correction | -- | $ 2,221 | $ 4,440 | 2.0 |
| | **Total for ESMs** | **--** | **$ 2,221** | **$ 4,440** | **2.0** |
| | | | | | |
| | **OPERATIONAL MEASURES** | | | | |
| OM 1 | Reduce Grit Pump Cycle | 6,812 | $518 | -- | -- |
| OM 2 | Reduce Septage Blower On Cycle | 5,031 | $382 | -- | -- |
| OM 3 | Extend Offline Time for RBC Trains | 30,170 | $2,293 | -- | -- |
| OM 4 | Cycle Sludge Holding Tank Mixer | 36,160 | $2,748 | -- | -- |
| OM 5 | Reduce Plant Water Setpoint | 9,636 | $732 | -- | -- |
| | **Total for OMs** | **87,809** | **$ 6,673** | | |
| | | | | | |
| | **ENERGY CONSERVATION MEASURES** | | | | |
| ECM 1 | Digester System Improvements *(Staff Initiative)* | -- | $39,575 | $230,000 | 5.8 |
| | **Total for ECMs** | **--** | **$39,575** | **$230,000** | **5.8** |
| | | | | | |
| | Total Electric Energy Savings & Cost | 87,809 | $8,894 | $4,440 | < 1 |
| | Total Fuel Oil Energy Savings & Cost | -- | $39,575 | $230,000 | 5.8 |
| | | | | | |
| | **Total** | **87,809** | **$48,469** | **$234,440** | **4.8** |
| | | | | | |

Efficiency Vermont may be able to provide incentives for qualified measures in Table 1.2.

# SECTION 2. ENERGY MANAGEMENT

## 2.1 Energy Management Program

The Brattleboro WWTP staff currently makes an effort to operate the facility as efficiently as possible. During the evaluation, the Town Finance Office began forwarding copies of the WWTF and pump station electric bills to the Chief Operator. All the Town electric accounts are now consolidated into one statement from Green Mountain Power, with the energy use and cost for individual facilities broken down by meter. With this information now available to the facility, the Chief Operator can track monthly usage and verify savings. This initiative is discussed in EMP #1 in Section 5.

The EPA 2008 Energy Management Guidebook for Water and Wastewater Utilities (*www.epa.gov/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf)* presents a management system approach for water and wastewater utilities for energy conservation. Based on the successful Plan-Do-Check-Act process, the guidebook provides information on establishing and prioritizing energy conservation targets (Plan), implementing specific practices to meet these targets (Do), monitoring and measuring energy performance improvements and cost savings (Check), and periodically reviewing progress and making adjustments to energy programs (Act).

## 2.2 Benchmarking Facility Energy Use

Energy benchmarking can be accomplished using internal or external comparisons. Internal benchmarking allows an organization to evaluate facility energy use year to year to monitor facility efficiency changes. The results can be used within an organization to track performance over time, identify best practices, and to increase management's understanding of how to analyze and interpret energy data.

For external benchmarking, a wastewater treatment facility can be compared to other facilities with similar process systems. When process and energy use data is assembled, the information can be used to assess performance and motivate a facility to investigate why facility performance is lower than expected or to confirm efficiency efforts by receiving a high performance rating relative to other facilities. As indicated for internal benchmarking efforts, this data can also be used to identify new best practices for improving facility performance, and to increase understanding of how to analyze and evaluate energy performance.

Whether using the internal or external approach, benchmarking can also be divided into either quantitative or qualitative comparisons. In a quantitative benchmarking process, numerical measures of performance are compared. In a qualitative process, management and operational practices are examined to identify areas for improvement.

Using average monthly flow and energy use, we benchmarked energy use for the Brattleboro Wastewater Treatment Facility with several similar sized wastewater treatment facilities. The performance indicator (kWh/mg) used in Table 2.1 provides a general comparison between facilities, however each facility has unique process systems that make benchmarking comparisons challenging.

**Table 2.1: Benchmarking Data Compared to Similar Facilities**

| NH Plant | Total Annual Energy Use (kWh) | Total Annual Flow (MG) | Annual Average Daily BOD Loading, lb/day | Annual Average kWh/lb BOD removed | Annual Average kWh/MG Treated |
|---|---|---|---|---|---|
| Claremont, NH | 899,304 | 490 | 2,599 | 0.96 | 1,863 |
| Hanover, NH | 911,700 | 461 | 2,896 | 0.86 | 1,978 |
| Airport Parkway South Burlington, VT | 1,582,523 | 732 | 3,647 | 1.2 | 2,162 |
| **Brattleboro, VT** | **881,937** | **403** | **2,570** | **0.96** | **2,188** |
| Berlin, NH | 1,051,883 | 680 | 2,066 | 1.97 | 2,252 |
| Somersworth, NH | 1,241,949 | 525 | 4,731 | 0.73 | 2,412 |
| Montpelier WWTF, VT (2013 data) | 1,652,441 | 679 | -- | -- | 2,434 |
| Milford, NH | 1,298,816 | 486 | 2,297 | 1.59 | 2,756 |

The Brattleboro WWTF is very efficient compared to similar sized facilities. These values are a starting point to begin the process of benchmarking since it does not consider specific systems or levels of treatment for each facility.

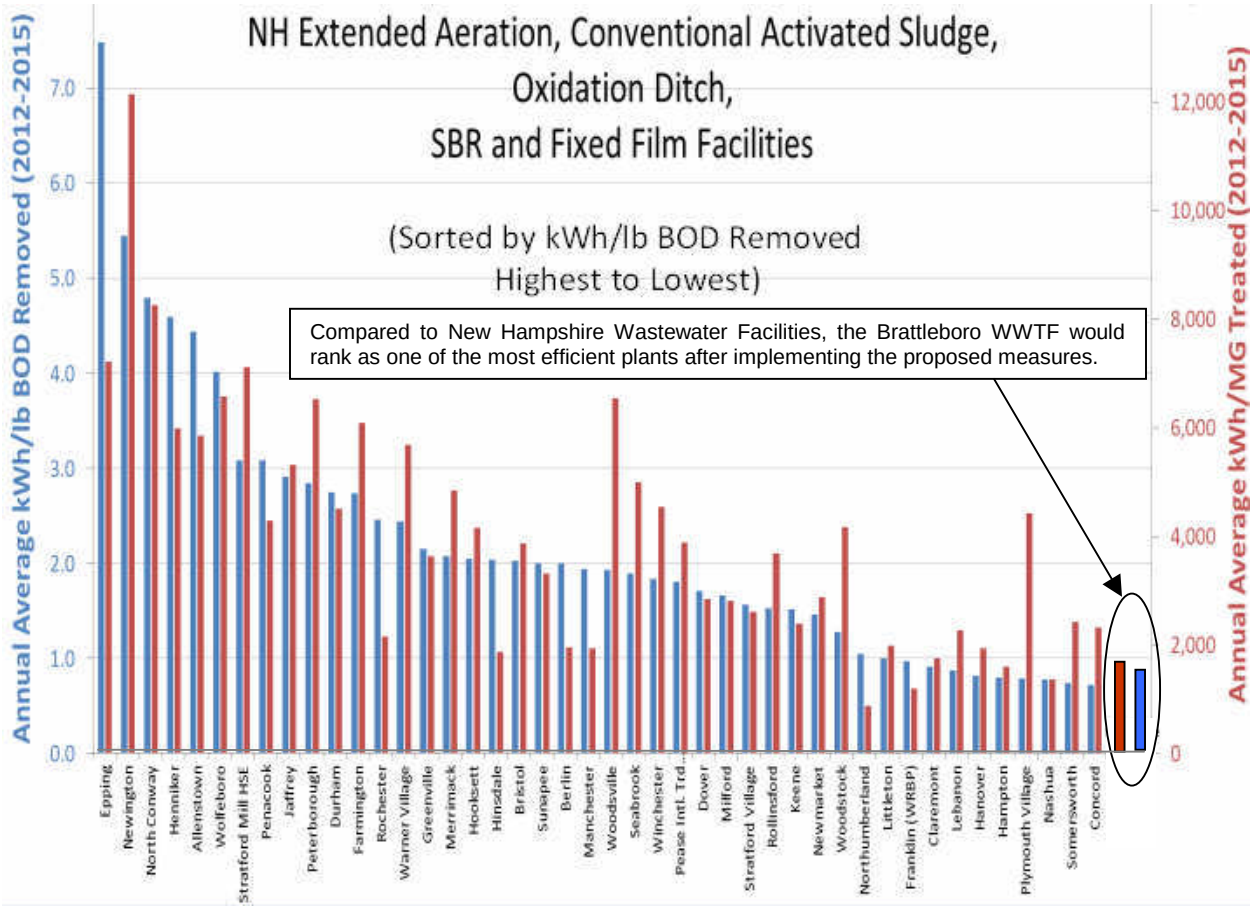
We believe the Brattleboro facility can reach an even higher efficiency level through the recommendations presented in this report. If the identified measures can be implemented, annual facility energy use would be reduced to approximately 794,128 kWh which would make it one of the most efficient wastewater plants in Vermont and New Hampshire. The new benchmark values after making the proposed projects in this report are summarized below.

**Table 2.2: New Benchmark Values after Energy Project Implementation**

| Plant | Total Annual Energy Use (kWh) | Annual Average Daily Effluent Flow (MG) | Annual Average BOD Loading (lb/day) | Annual Average kWh/lb BOD removed | Annual Average kWh/MG Treated |
|---|---|---|---|---|---|
| **Brattleboro, VT** | **794,128** | **403** | **2,570** | **0.85** | **1,970** |

In Figure 2.1, Process Energy Services included the Brattleboro data with facility data collected by the New Hampshire Department of Environmental Services (this data was not available for Vermont facilities) to illustrate how the facility compares to other New England wastewater plants.

**Figure 2.1: New Hampshire Wastewater Facility Efficiency Comparison**



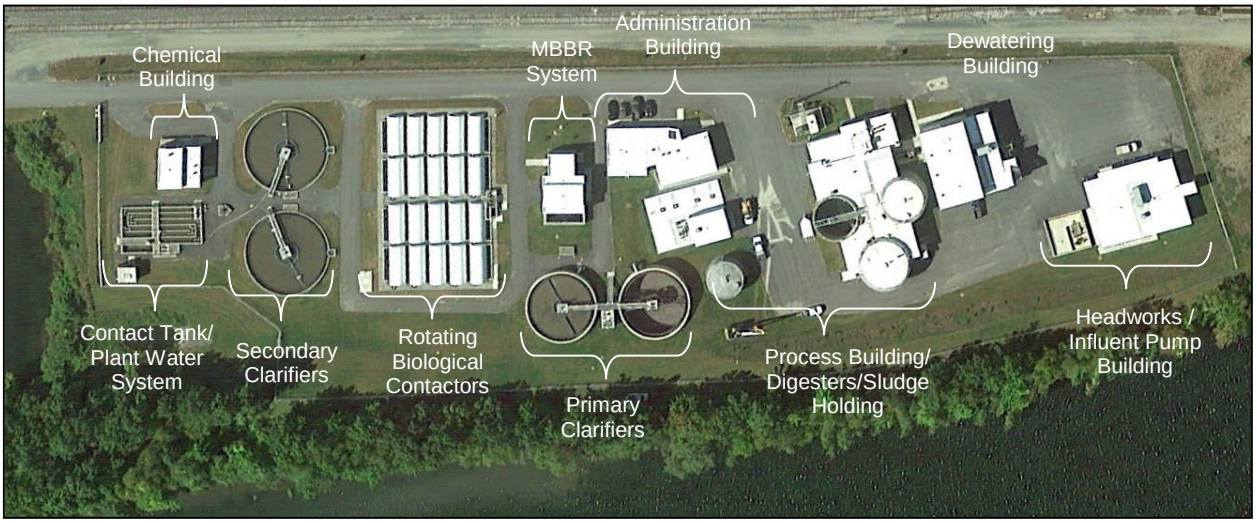

A review of the facility process and pumping systems along with supporting data for the recommended improvements identified by Process Energy Services has been presented for each of the plant systems in Section 3.

# SECTION 3. FACILITY SYSTEMS

## 3.1 General

The Brattleboro Wastewater Treatment Facility (WWTF) is located on Riverside Drive in Brattleboro, Vermont. The facility is designed to treat an average flow of 3.0 million gallons per day (MGD). The facility collection system includes four pump stations and the Riverside Pump Station, which is just outside the fenced treatment plant.

As flow enters the plant site, it is first directed to the Headworks Building where it flows through a mechanical fine screen and grit collection system for preliminary treatment to remove large solids and grit. The flow is then conveyed to the influent pump system wetwell where it is pumped to two primary clarifiers to remove settleable solids before the flow is directed to the MBBR system, and then to the RBCs for biological treatment. After the RBCs, the effluent flows to the secondary clarifiers for final treatment before being disinfected in the chlorine contact tank and discharged to the Connecticut River.




Secondary Sludge is wasted to the influent of the primary clarifiers for co-settling. The primary/secondary sludge is periodically pumped to the pre-feed sequencing tank where it is blended with septage prior to digestion. The sludge stabilization process is a two-phase anaerobic digestion process utilizing mesophilic and thermophilic digesters. Following digestion, sludge is pumped to a sludge storage tank prior to being dewatered with two rotary sludge presses.

The facility is equipped with a biogas-fueled microturbine capable of generating 65kW of electric power, however, the unit is not currently in service due to low gas production.

## 3.2 Facility Energy Balance

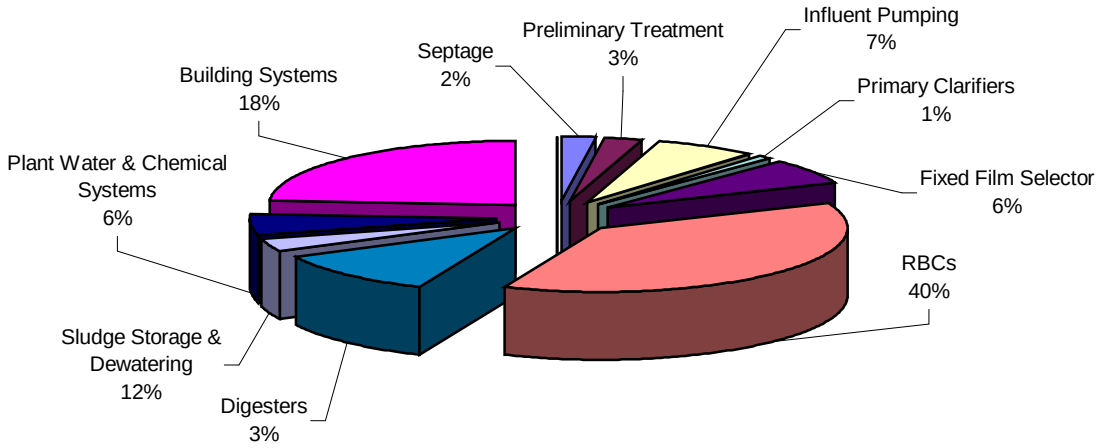
Using plant SCADA data, kW measurements and discussions with plant staff, we developed a breakdown of electrical energy use for the facility in Table 3.1.

**Table 3.1: Facility Energy Use Breakdown**

| Plant System | 2016 Baseline Annual Use (kWh) | Percent of Total |
|---|---|---|
| Septage | 20,120 | 2% |
| Preliminary Treatment | 20,941 | 3% |
| Influent Pumping | 57,606 | 7% |
| Primary Clarifiers | 5,852 | 1% |
| Fixed Film Selector | 49,880 | 6% |
| RBCs | 333,875 | 40% |
| Secondary Clarifiers and Waste Pumps | 13,059 | 2% |
| Digesters | 24,757 | 3% |
| Sludge Storage & Dewatering | 103,589 | 12% |
| Plant Water & Chemical Systems | 46,273 | 6% |
| Building Systems | 153,278 | 18% |
| **Annual Total** | **829,231** | **100%** |
| **Annual Electric Use 2015 Bills** | **881,937** | **--** |

The energy use breakdown is illustrated below.

**Figure 3.1: Facility Energy Use**



## 3.3 Preliminary Treatment

As raw wastewater flows into the treatment plant site, it is directed to a rotary fine screen unit to remove debris from the influent. The fine screen unit is equipped with a three horsepower motor and operates intermittently based on differential level across the screen. The collected solids are washed, compacted and deposited in a bin for disposal. Plant water is periodically used for the washing process.

The bar screen controls include an option to operate the unit based on a timer. However, the differential level control has been very effective and has minimized run time to less than one hour/day according to 2016 run time data.

After screening, the influent flow enters a grit removal basin where the velocity of the flow is reduced and solids are allowed to settle. A peristaltic hose-type grit pump is activated 8 minutes every hour to remove the settled grit by directing it through a low energy classifier/cyclone where the grit is separated from the flow and conveyed to a bin for disposal. The remaining flow stream is redirected back to the treatment process. System energy use is summarized below.

**Table 3.2: Preliminary System Energy Use Estimate**

| Equipment | Motor Hp | Power Draw (kW) | Annual Hours | Energy Use (kWh) |
|---|---|---|---|---|
| Fine Screen | 3.00 | 1.79 | 321 | 575 |
| Grit Chamber Drive | 1.00 | 0.60 | 8742 | 5,217 |
| Grit Classifier | 1.00 | 0.60 | 1303 | 778 |
| Grit Pump | 15.00 | 8.95 | 1196 | 10,707 |
| Screenings/Grit Conveyor | 3.00 | 1.79 | 2047 | 3,665 |
| **Total** | | | | **20,941** |

Although the preliminary system is a low energy process, many facilities have found that they can extend grit pump run times without adversely impacting the process. In OM #1 we have recommended investigating the feasibility of operating the grit pump approximately 4 minutes every hour instead of 8 minutes per hour. The savings for this operational adjustment is expected to be approximately 6,000 kWh annually (including reduced classifier and conveyor hours).

## 3.4 Septage Receiving

The facility is equipped with a septage receiving station in the Headworks Building. Septage and dairy waste haulers discharge waste through a fine screen unit before it is stored in three below grade tanks (one tank is typically used). The screenings are washed, compacted and dewatered before being conveyed to a hopper. Spray water for the unit is supplied by the plant water system.

The septage/dairy waste is aerated with one of two 5 hp Aerzen Blowers equipped with VFDs. The facility typically uses one blower on a timer that operates approximately 50% of the time based on 2016 run time hours. The septage is introduced to the pre-feed sequencing tank using one of the two available 5 hp septage pumps equipped with variable speed drives.

A duplex carbon adsorption odor control system is provided in the Headworks Building to treat air discharged from the wet wells and septage holding tanks. The system consists of a carbon adsorption canister, activated carbon media and a ducted exhaust fan. The two odor control systems are connected in series and in parallel, so that each unit can function in tandem or as individual units. As shown in Table 3.3, the staff operates one unit at a time, and energy use for this type of system is much lower than other headworks odor control systems that Process Energy has reviewed.

System annual energy use is estimated in Table 3.3 based on field power measurements, kW estimates for low horsepower equipment and run time hours recorded by staff in 2016.

**Table 3.3: Septage Equipment Energy Use Estimate**

| Equipment | Motor Hp | Power Draw (kW) | Annual Hours | Energy Use (kWh) |
|---|---|---|---|---|
| Septage Receiving Station | 2.0 | 1.19 | 196 | 234 |
| Septage Grinder | 3.0 | 1.79 | 196 | 351 |
| Septage Pump #1 | 5.0 | 2.98 | 50 | 149 |
| Septage Pump #2 | 5.0 | 2.98 | 50 | 149 |
| Septage Blower #1 | 5.0 | 1.87 | 2584 | 4,819 |
| Septage Blower #2 | 5.0 | 1.87 | 2825 | 5,269 |
| Septage Odor Control Fan #1 | 2.0 | 1.04 | 4380 | 4,574 |
| Septage Odor Control Fan #2 | 2.0 | 1.04 | 4380 | 4,574 |
| **Total** | | | | **20,120** |

Based on discussions with staff, there may be opportunity to reduce the cycle time of the septage blowers. If the activation time could be reduced, over 5,000 kWh annually could be saved. The cost savings for this operational adjustment is reviewed in OM #2.

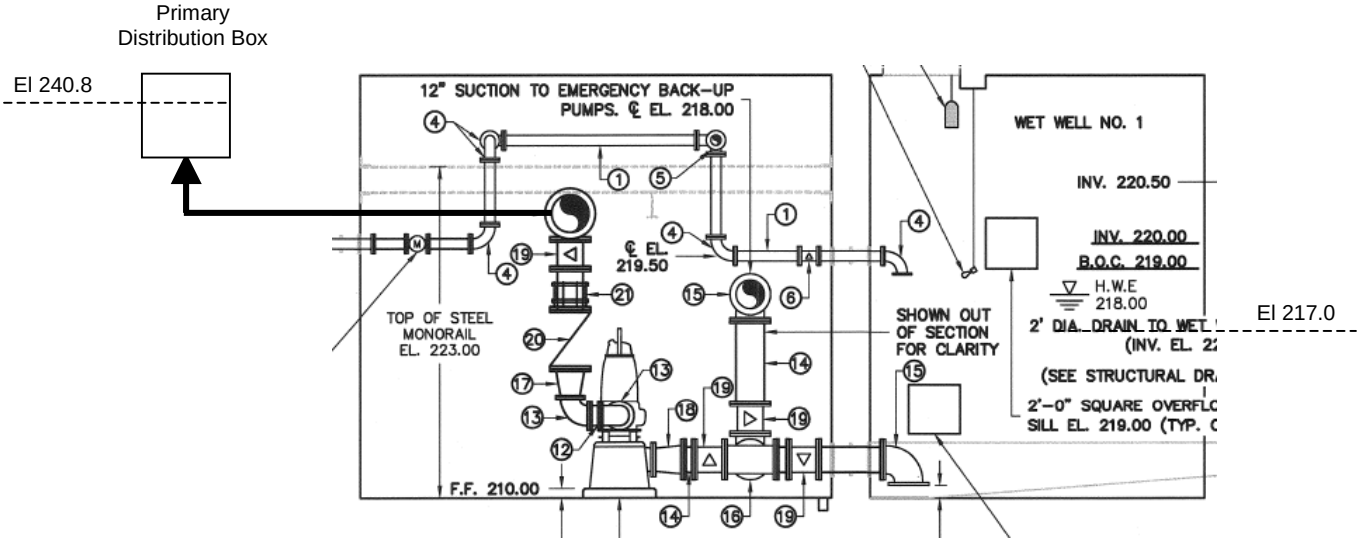
## 3.5 Influent Pump System

After the grit removal system, raw wastewater is collected in two influent wetwells before pumping with one of four influent pumps to the primary clarifier distribution box where it flows by gravity through the remaining treatment plant processes.

The influent pumps are Flygt Model 3202 dry pit submersible pump units equipped with 35 hp motors and VFDs. Each pump has a design rating of 2,350 gpm @ 46' TDH. As shown in Figure 3.2, pump wetwell level is typically close to 7' (testing was performed at approximately 6.7'). At the design flow, the overall curve efficiency (motor/pump) is 69%.

As the wetwell increases or decreases with incoming flow, the lead pump VFD adjusts speed as needed to match the wetwell setpoint level. As is the case for many wastewater pump systems equipped with VFDs, the pumps are set at a low VFD speed to prevent the pumps from shutting off. This can result in low pump efficiency during the early morning hours when plant flow can be lower than 100 gpm according to staff.

**Figure 3.2: Influent Pump System Elevations**




To evaluate existing pump efficiency, power and flow data was collected for Pump #3 at various flow rates. A summary of the data is provided in Table 3.4.

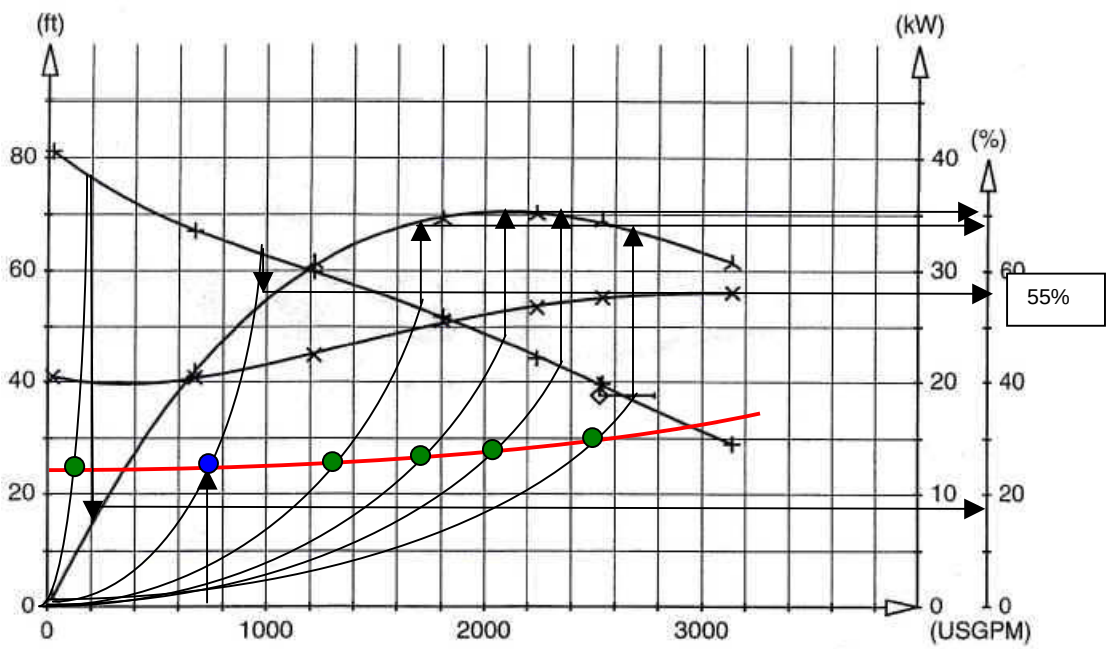
**Table 3.4 Influent Pump #3 System Test Data**

| VFD Speed Hz | Recorded Flow (gpm) | Wetwell Level (ft) | Discharge Pressure (psi) | Estimated TDH (ft)* | Power (kW) | Calculated Pump/Motor Efficiency** | Estimated Curve Efficiency |
|---|---|---|---|---|---|---|---|
| 35 | 100 | 6.9 | N/A | 23 | 4.4 | 10% | 15% |
| 45 | 1380 | 6.9 | N/A | 26 | 10.6 | 61% | 68% |
| 48 | 1670 | 6.9 | N/A | 28 | 13.9 | 68% | 70% |
| 53 | 2050 | 6.9 | N/A | 30 | 17.9 | 69% | 70% |
| 60 | 2570 | 6.9 | N/A | 33 | 25.3 | 67% | 68% |

*The pump TDH was estimated based on the static head elevation difference + estimated frictional head since there was no pressure tap available to measure discharge pressure
**The pump/motor efficiency was calculated using a VFD efficiency of 96%

The curve efficiency data at the tested flow rates is shown below. The green data points represent the test data in Table 3.4.

**Figure 3.3: Manufacturer's Pump Curve with Test Data**




Based on an average 2016 flow of 1.1 MGD or 764 gpm (represented by blue data point in Figure 3.3), the 55% pump efficiency shown on the pump curve is reasonable. Even though the pump may operate at lower flow rates (<200 gpm) occasionally during the evening hours, it does not appear that the pumps operate enough hours at these flow rates to generate the energy savings needed to justify installing a smaller pump.

Estimated pump system annual energy use based on facility run time data is shown in Table 3.5. The average pump power draw of 6.5 kW was estimated based on the average annual flow of 764 gpm.

**Table 3.5: Influent Pump System Equipment Energy Use Estimate**

| Equipment | Motor Hp | Power Draw (kW) | Annual Hours | Energy Use (kWh) |
|---|---|---|---|---|
| Influent Pump 1 | 35.0 | 6.53 | 2214 | 14,452 |
| Influent Pump 2 | 35.0 | 6.53 | 2148 | 14,021 |
| Influent Pump 3 | 35.0 | 6.53 | 2123 | 13,858 |
| Influent Pump 4 | 35.0 | 6.53 | 2151 | 14,041 |
| Riverside PS Pump #1 | 5.0 | 1.87 | 379 | 707 |
| Riverside PS Pump #2 | 5.0 | 1.87 | 283 | 528 |
| **Total** | | | | **57,606** |

## 3.6 Primary Treatment

The influent pumps direct flow to a primary clarifier distribution box where it splits the flow to two 56’ diameter primary clarifiers with a sidewater depth of 11’-6”. Each clarifier has a 0.50 hp collector drive that operates continuously. Co-settled primary and secondary solids are collected on the bottom of the tank and pumped out with the primary sludge pumps. The floating solids are collected on the surface and deposited into the scum tank where it is pumped out periodically.

From an energy perspective, the primary treatment process is one of the most important systems in the plant. The higher the BOD removal efficiency of the primary clarifiers, the lower the energy needed for the higher-energy MBBR and RBC systems. The higher BOD levels also increase the primary to secondary sludge ratio, which can improve digester performance and dewatering solids. Primary clarifier BOD removals at New England Facilities are typically 25 to 30%.

Although primary effluent BOD readings are not typically recorded, staff indicated that BOD removals are typically in the 30 to 40% range. One of the reasons for the higher BOD removals is the energy dissipating inlet design and tangential gates at the water surface of the clarifier. These design features improve settling and help reduce short-circuiting through the clarifiers.

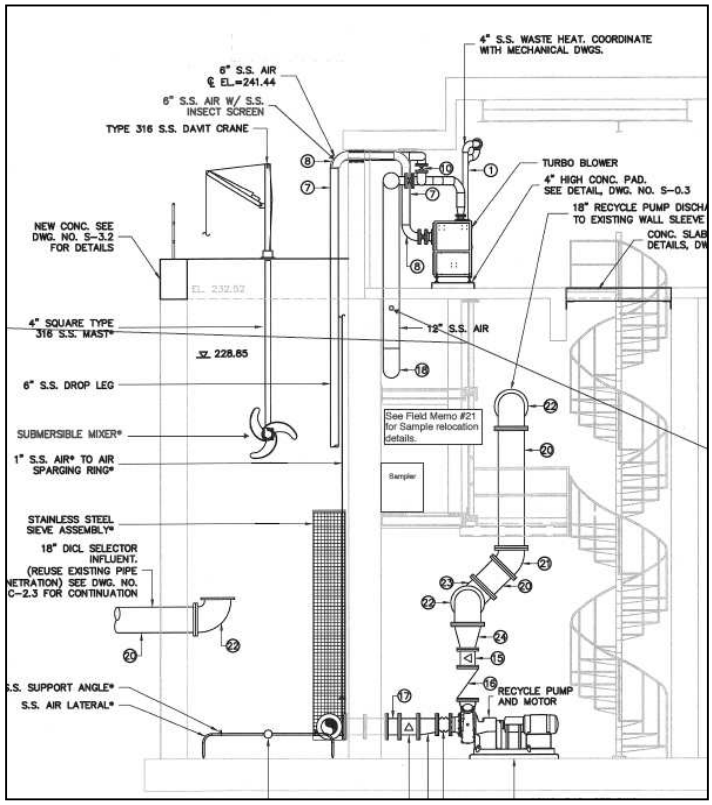
The effluent from the clarifiers flows to the RBC’s and/or to the moving bed biological reactor (MBBR) in the selector building. The primary clarifier effluent/selector influent line passes through the pump gallery, where there is a magnetic flow meter and pinch valve that can be used to control the selector influent flow.

The clarifiers are equipped with sludge level sensors to help determine the sludge pumping flow rate. Settled primary sludge is pumped from the clarifiers to the sludge pre-feed sequence tank (PFST) using one of the two available sludge pumps. Each pump is rated for 40 gpm @ 30’ TDH and equipped with 5 hp motors. As shown in Table 3.6, the hours of operation in 2016 show that the pumps averaged 1.3 hours of total pumping each day. This system represents less than 1% of total facility energy use.

**Table 3.6: Primary System Equipment Energy Use Estimate**

| Equipment | Motor Hp | Power Draw (kW) | Annual Hours | Energy Use (kWh) |
|---|---|---|---|---|
| Primary Clarifier Drive #1 | 0.50 | 0.30 | 8760 | 2,614 |
| Primary Clarifier Drive #2 | 0.50 | 0.30 | 6000 | 1,790 |
| Primary Sludge/Scum Pump #1 | 5.0 | 2.98 | 238 | 710 |
| Primary Sludge/Scum Pump #2 | 5.0 | 2.98 | 247 | 737 |
| Primary Sludge Grinder | 3.0 | 1.79 | 995 | 1,781 |
| **Total** | | | | **5,852** |

## 3.7 Moving Bed Biofilm Reactor




A side stream portion of the effluent flow from the primary clarifiers is directed to a moving bed biofilm reactor (MBBR). The reactor is used to supplement BOD removal before the RBC process using an aerobic or anoxic process. For the aerobic process, oxygen is supplied by a diffused aeration/blower system, and the reactor functions as a flow through process for the primary clarifier effluent. If the anoxic process is selected, two submersible mixers and return pumps provide an oxygen free environment. For this anoxic mode, the flow is a combination of primary clarifier effluent and recycled RBC effluent.

The MBBR has a treatment capacity of 6 MGD. The system includes plastic media that moves within the reactor to provide a surface aerator for biological growth. Screens are used to prevent the media from entering the suction piping of the recycle pumps. The diffused air system is fed from three turbo blowers rated for 330 scfm @ 11.4 psig. Each blower is equipped with a 25 hp motor and VFD. A dissolved oxygen (DO) probe automatically controls the blower airflow rate.

The operator can divert 0 to 100% of the flow (up to 6 MGD) to the reactor by opening a pinch valve on the primary effluent in the pump gallery. The primary effluent flow rate can be automatically controlled by setting the flow rate as a percentage of the influent plant flow, or as a constant flow rate. Based on the system flow meter value, the pinch valve is modulated to get the desired flow rate.

When the system is operating in the anoxic mode, two constant speed 6.1 hp submersible mixers are operated continuously to keep solids suspended in each tank. The recycle pumps are 20 hp screw centrifugal pumps equipped with VFDs that are adjusted based on the MBBR wetwell level. The RBC recycle flow rate to the MBBR is automatically controlled by modulating a pinch valve, based on a percentage of the influent plant flow, or as a constant flow rate. The MBBR has a maximum flow capacity based on the number of available pumps. With one recycle pump running, the maximum permitted flow is 4.5 MGD.

Using 2016 run time hours recorded by staff and power measurements taken on site, the annual system energy use was estimated in Table 3.7

**Table 3.7: MBBR Equipment Energy Use Estimate**

| Equipment | Motor Hp | Power Draw (kW) | Annual Hours | Energy Use (kWh) |
|---|---|---|---|---|
| Blower #1 | 25.00 | 11.19 | 252 | 2,820 |
| Blower #2 | 25.00 | 11.19 | 967 | 10,821 |
| Blower #3 | 25.00 | 11.19 | 1593 | 17,826 |
| Recycle Pump #1 | 20.00 | 5.97 | 866 | 5,168 |
| Recycle Pump #2 | 20.00 | 5.97 | 1982 | 11,829 |
| Mixer #1 | 6.10 | 3.19 | 193 | 615 |
| Mixer #2 | 6.10 | 3.19 | 6 | 19 |
| Air Sparger Compressor | 5.00 | 2.61 | 300 | 783 |
| **Total** | | | | **49,880** |

The staff has done a good job minimizing equipment use to maintain low system energy use.

## 3.8 Rotating Biological Contactors

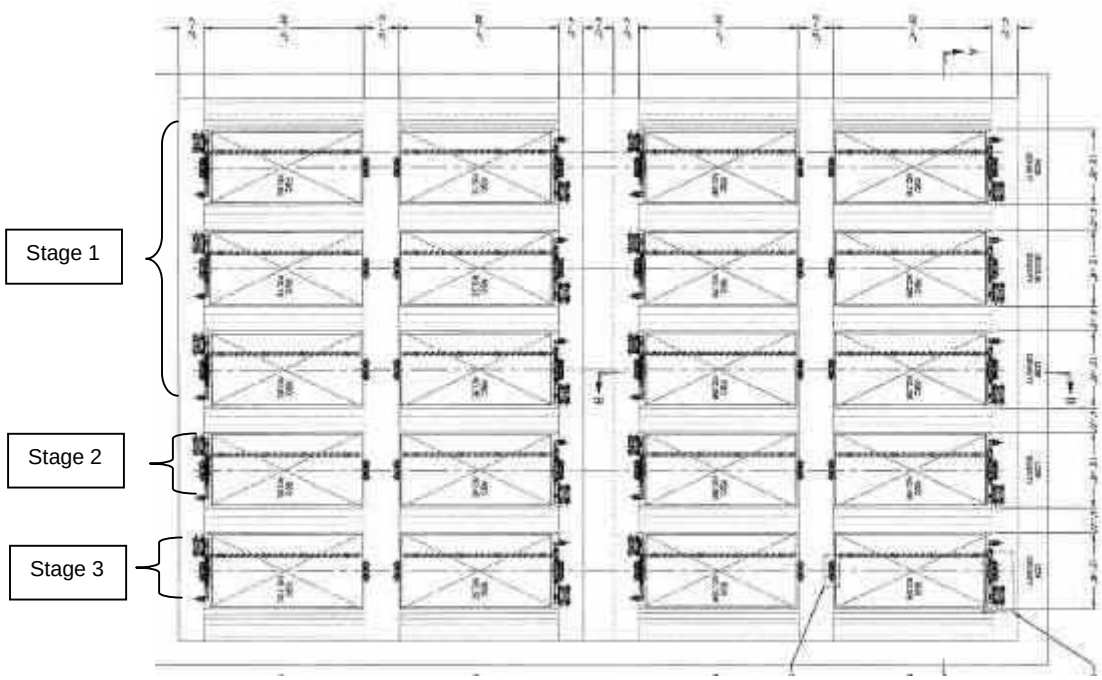
Wastewater flows from the discharge of the primaries to a flow splitter structure, which distributes flow to either the MBBR system or the rotating biological contactors (RBCs) for secondary treatment. As discussed in the MBBR section, approximately 20% of the flow is diverted to the MBBR system before being combined with the primary effluent flow to the RBCs.

The RBC system is an efficient fixed film wastewater treatment process that is an alternative to a conventional high-energy use activated sludge system that uses aeration and return activated sludge pumps for the biological process. RBC systems also generate less sludge resulting in lower sludge disposal costs.

Each RBC consists of a rotating shaft with multiple sheets of high-density polyethylene media used for biological growth to oxidize waste material. The shafts are slowly rotated with 5 hp drive units coupled with gear reducers.

The RBC system at the Brattleboro facility consists of twenty units, which include low density, medium density, and high-density units. The RBC units are arranged in three treatment stages in four parallel trains. The first stage of each train consists of three low density RBCs, the second stage is one medium density RBC, and the third stage consists of one high density RBC.

**Figure 3.4: RBC Layout**



Air can be provided to the RBC periodically with the MBBR Blowers to provide aeration or help remove excessive media biological growth. For this operation the Operator must connect hoses to one of the three air stand-pipes, set manual valves and operate the VFD manually. According to the O&M manual, the minimum recommended airflow rate is 150 CFM, and the maximum is 1350 CFM.

The Brattleboro WWTF is one of the few RBC facilities in New England with load cells under each RBC. The staff tracks shaft weight on a regular basis to be sure each RBC is operating in the optimal range. When the shaft weight in the final stage is in the 20,000 to 25,000 lb range, the staff takes a train off line. An example of the weight-tracking sheet for May 2017 is shown below.

**Table 3.8: RBC Shaft Weight Data Sheet**

| | RBC Shaft Weight Sheet | | | | |
|---|---|---|---|---|---|
| | May 2017 | | | | |
| | 5/2 | 5/10 | 5/16 | 5/23 | 5/31 |
| RBC 1-1 | 38,450 | 36,760 | 34,500 | 33,930 | 35,060 |
| RBC 1-2 | 36,190 | 35,060 | 33,930 | 33,930 | 34,500 |
| RBC 1-3 | 38,450 | 36,760 | 35,060 | 34,500 | 34,500 |
| Stage 1 avg. | 37,697 | 36,193 | 34,497 | 34,120 | 34,687 |
| RBC 1-4 | 42,970 | 44,670 | 44,670 | 44,100 | 42,970 |
| Stage 2 avg. | 42,970 | 44,670 | 44,670 | 44,100 | 42,970 |
| RBC 1-5 | 44,100 | 46,930 | 46,360 | 46,360 | 46,360 |
| Stage 3 avg. | 44,100 | 46,930 | 46,360 | 46,360 | 46,360 |
| | | | | | |
| RBC 2-1 | 36,190 | 39,020 | 40,710 | 40,150 | 39,580 |
| RBC 2-2 | 34,500 | 36,760 | 38,450 | 37,890 | 37,890 |
| RBC 2-3 | 35,630 | 37,890 | 40,150 | 39,580 | 39,020 |
| Stage 1 avg. | 35,440 | 37,890 | 39,770 | 39,207 | 38,830 |
| RBC 2-4 | 35,627 | 35,060 | 34,500 | 33,930 | 33,930 |
| Stage 2 avg. | 35,627 | 35,060 | 34,500 | 33,930 | 33,930 |
| RBC 2-5 | 34,500 | 35,060 | 34,500 | 33,930 | 33,370 |
| Stage 3 avg. | 34,500 | 35,060 | 34,500 | 33,930 | 33,370 |
| | | | | | |
| RBC 3-1 | Off-Line | Off-Line | 23,760 | 29,410 | 30,540 |
| RBC 3-2 | Off-Line | Off-Line | 24,330 | 29,410 | 29,980 |
| RBC 3-3 | Off-Line | Off-Line | 25,460 | 28,850 | 29,410 |
| Stage 1 avg. | Off-Line | Off-Line | 24,517 | 29,223 | 29,977 |
| RBC 3-4 | Off-Line | Off-Line | 24,890 | 28,280 | 30,540 |
| Stage 2 avg. | Off-Line | Off-Line | 24,890 | 28,280 | 30,540 |
| RBC 3-5 | Off-Line | Off-Line | 26,590 | 28,280 | 29,410 |
| Stage 3 avg. | Off-Line | Off-Line | 26,590 | 28,280 | 29,410 |
| | | | | | |
| RBC 4-1 | 35,630 | 36,760 | 35,060 | 34,500 | 33,930 |
| RBC 4-2 | 35,630 | 36,760 | 35,060 | 34,500 | 33,930 |
| RBC 4-3 | 37,890 | 36,190 | 35,630 | 34,500 | 34,500 |
| Stage 1 avg. | 36,383 | 36,570 | 35,250 | 34,500 | 34,120 |
| RBC 4-4 | 40,710 | 43,540 | 45,800 | 42,410 | 40,150 |
| Stage 2 avg. | 40,710 | 43,540 | 45,800 | 42,410 | 40,150 |
| RBC 4-5 | 40,710 | 41,280 | 42,970 | 41,280 | 40,710 |
| Stage 3 avg. | 40,710 | 41,280 | 42,970 | 41,280 | 40,710 |
| Flow direction ↑ | ME | CS | CS | ME | ME |

Process Energy Services summarized RBC data from three other wastewater facilities and benchmarked the data based on flow and influent BOD load in Table 3.9. Although the Brattleboro kWh/MG was slightly higher than the other facilities, the kWh/lb of BOD was excellent with only the Plymouth, NH WWTF at a lower value. The BOD process load provides a better benchmarking indicator for RBC system energy use.

**Table 3.9: RBC Benchmarking (RBC Energy Use Only)**

| NH Plant with RBCs | RBC System Annual Energy Use (kWh) | Total Annual Flow (MG) | Annual Average kWh/MG Treated | Average Influent BOD Load (lbs/day) | Annual Average kWh/lbs BOD |
|---|---|---|---|---|---|
| Bennington, VT (2013) | 675,143 | 1084 | 622 | 2,665 | 0.69 |
| St. Johnsbury, VT (2013) | 211,715 | 336 | 630 | 1,731 | 0.34 |
| **Brattleboro, VT (2016)** | **329,471** | **403** | **817** | **2,710** | **0.33** |
| Plymouth, NH (2016) | 104,244 | 131 | 795 | 1,411 | 0.20 |

The above table shows that the staff has done an excellent job optimizing RBC system operation. A summary of annual system energy use shown in Table 3.10 using the average power draw from sample RBC unit measurements.

**Table 3.10: RBC System Equipment Energy Use Estimate**

| Equipment | Motor Hp | Power Draw (kW) | Annual Hours | Energy Use (kWh) |
|---|---|---|---|---|
| RBC 1E | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 2E | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 3E | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 4E | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 5E | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 6E | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 7E | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 8E | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 9E | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 10E | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 1W | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 2W | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 3W | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 4W | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 5W | 5.0 | 2.05 | 8760 | 17,971 |
| RBC 6W | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 7W | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 8W | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 9W | 5.0 | 2.05 | 7300 | 14,976 |
| RBC 10W | 5.0 | 2.05 | 7300 | 14,976 |
| **Total** | | | | **329,471** |

The staff is already tracking RBC unit weights and taking the initiative to take trains off line as shown in Table 3.6. To build on this effort, we have outlined the potential savings if the off time for the selected trains can be extended by another 20%. This will require additional monitoring of the load cell data to

insure that the on-line unit weights are in the ideal range for optimal biomass thickness (0.30” to 0.50”). The savings for this measure is reviewed in OM #3.

## 3.9 Secondary Clarifiers

After the aeration system, flow is directed to two 68’ diameter secondary clarifiers with a side water depth of 11’. The secondary clarifiers remove suspended solids from the effluent prior to discharging to the disinfection system. Each secondary clarifier uses a 0.5 hp collector drive to collect the settled sludge and operates continuously.

The secondary sludge pumps are operated as required to pump secondary sludge to the primary clarifiers for co-settling with the primary sludge. This low energy system does not contribute significantly to overall facility energy use.

Annual system energy use is estimated below.

**Table 3.11: Secondary Clarifier Energy Use Baseline**

| Equipment | Motor Hp | Power Draw (kW) | Annual Hours | Energy Use (kWh) |
|---|---|---|---|---|
| East Secondary Clarifier Drive | 0.50 | 0.30 | 8760 | 2,614 |
| West Secondary Clarifier Drive | 0.50 | 0.30 | 6000 | 1,790 |
| Secondary Sludge Pump #1 | 3.00 | 1.34 | 3120 | 4,190 |
| Secondary Sludge Pump #2 | 3.00 | 1.34 | 3325 | 4,465 |
| **Total** | | | | **13,059** |

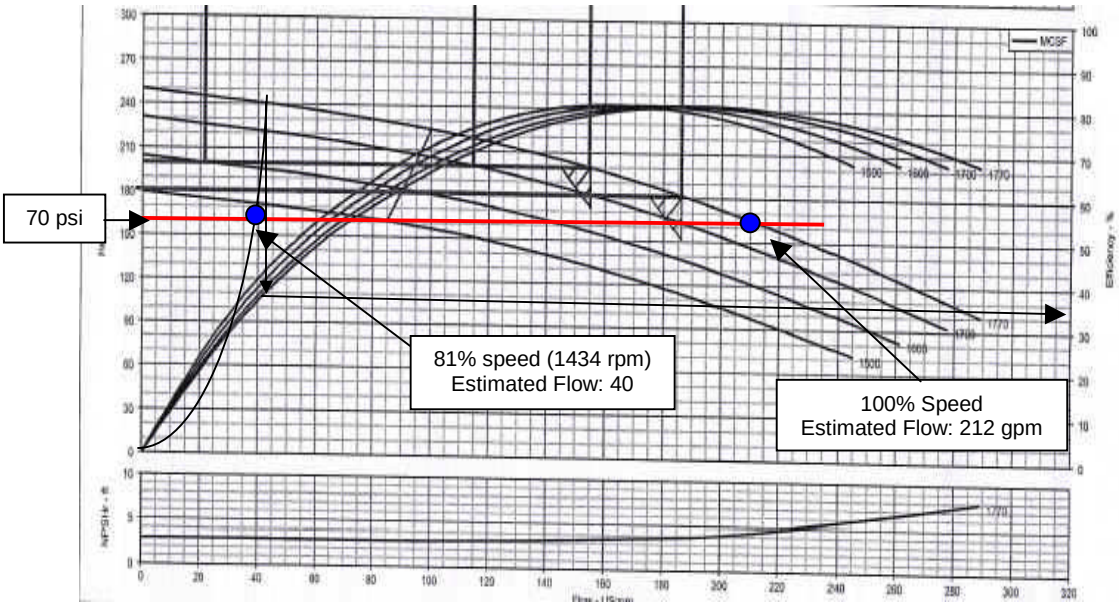
## 3.10 Plant Water System

The plant water system consists of three ITT pumps and pressure based control system located in a concrete building at the south side of the site.

Each pump is rated for 155 gpm @ 200’ TDH (86.6 psi). The pumps are equipped with 15 hp motors and VFDs. Staff indicated that the system is set-up to maintain 70 psi (162’ + ~10’ from gauge to water surface = 172’ TDH). The system is not equipped with a flow meter, but based on 81% VFD speed observed during our site visit, the flow was estimated to be 40 gpm using the original pump curve in Figure 3.5. When flow requirements exceed the capacity of one pump and pressure is reduced, a second pump is automatically activated and operated in parallel with the lead pump.

Plant water is used for site hydrants, spray water for the fine screen unit, rotary press wash water and circulated through the water source heat pumps. With the constant use of flow required for the water source heat pumps, there are limited opportunities to reduce plant water system capacity and energy use.

**Figure 3.5: Plant Water Pump Curve**




The power draw measured for one pump operating at 81% speed was 4.5 kW, although pump capacity and power draw will increase during dewatering or when screen spray water is needed. We estimate that system flow averages approximately 40 gpm. At this flow rate, pump efficiency is approximately 35% based on the pump curve.

Many packaged plant water systems include a smaller “pony” pump that can provide lower flows at a higher efficiency than the standard sized pumps. This was considered for the Brattleboro system, but preliminary calculations revealed that more savings would be achieved with a simple pressure reduction compared to replacing one of the 15 hp pumps with a smaller unit.

A fine screen wash system is typically the wastewater process with the highest-pressure requirements (unless a GBT or BFP is used for dewatering). The wash system typically requires a minimum flow of 40 gpm @ 30 psi pressure. The facility O&M manual also indicates that 70 psi is the *maximum* pressure required for the system. In OM #5, we recommend adjusting the plant water pressure setpoint to 50 psi, which should be sufficient for end use requirements.

## 3.11 Disinfection

After the secondary clarifiers, effluent flow is directed to the chlorine contact tank. Sodium hypochlorite is added for effluent disinfection and mixed with a flash mixer equipped with a VFD, before being discharged to the Connecticut River.

The system includes two 1600-gallon chemical storage tanks and metering pumps in the Chemical Building. In addition to effluent chlorination, hypochlorite can also be added to the secondary clarifiers if needed.

The disinfection system is a low energy system with minimal energy use. Staff has optimized the operation of the 5 hp flash mixer VFD by reducing the speed to provide sufficient mixing without excessive energy use.

## 3.12 Sludge Storage & Dewatering

Digested sludge is pumped to the digested sludge storage tank prior to dewatering. The sludge is mixed with a 20 hp hyperbolic mixer equipped with a VFD and timer. Normal operation is for the mixer to operate continuously at a VFD speed of approximately 90%. The day before the sludge is dewatered, the mixer is operated with the timer to activate the mixer 10 minutes every hour to allow the sludge to settle. The run time hours in 2016 show the mixer operating 93% of the time.

The dewatering system includes two sludge feed pumps, polymer system, two rotary sludge presses, and two sludge conveyors. The dewatering system (with both presses operating) is normally operated 20 hours/week. The two sludge feed pumps are equipped with 5 hp motors and VFDs, and pump thickened sludge from the sludge storage tank to the rotary press where polymer is introduced just before the flocculator before being directed to the press. The sludge conveyors transport dewatered sludge from the rotary press to the sludge truck bay where the cake is discharged to a sludge trailer.

Estimated annual energy use for the system shown in Table 3.12 is based on 2016 run time data and site power measurements. The most significant energy use system equipment is for sludge mixing, which accounts for 70% of the system energy use. In OM #4, we have recommended adjusting the VFD to operate to 50% speed, or to cycle the mixer on/off on a regular basis to reduce equipment energy use.

**Table 3.12: Sludge Thickening/Dewatering System Energy Use**

| Equipment | Hp | Power (kW) | Annual Hours | Annual Energy Use (kWh) |
|---|---|---|---|---|
| Sludge Storage Mixer | 20.0 | 8.95 | 8127 | 72,753 |
| Rotary Press Feed Pump #1 | 5.0 | 1.87 | 1153 | 2,150 |
| Grinder #1 | 3.0 | 1.12 | 1153 | 1,290 |
| Rotary Press Feed Pump #2 | 5.0 | 1.87 | 1255 | 2,341 |
| Grinder #2 | 3.0 | 1.12 | 1255 | 1,404 |
| RSP Floc Tank #1 | 2.0 | 0.75 | 1153 | 860 |
| Rotary Press #1 | 15.0 | 5.60 | 1153 | 6,451 |
| RSP Floc Tank #2 | 2.0 | 0.75 | 1255 | 936 |
| Rotary Press #2 | 15.0 | 5.60 | 1255 | 7,022 |
| Dry Polymer Screw | 0.8 | 0.28 | 1255 | 351 |
| Conveyor Blower | 2.5 | 0.93 | 1255 | 1,170 |
| Polymer Pump #1 | 0.5 | 0.19 | 1153 | 215 |
| Polymer Pump #2 | 0.5 | 0.19 | 1255 | 234 |
| Polymer Mixer | 0.8 | 0.30 | 1255 | 374 |
| Sludge Conveyor #1 | 3.0 | 1.12 | 1255 | 1,404 |
| Sludge Conveyor #2 | 3.0 | 1.12 | 1255 | 1,404 |
| Pump Gallery Odor Control Fan #1 | 2.0 | 0.75 | 2000 | 1,492 |
| Pump Gallery Odor Control Fan #2 | 2.0 | 0.75 | 2000 | 1,492 |
| Sidestream Pump #1 | 3.0 | 1.12 | 104 | 116 |
| Sidestream Pump #2 | 3.0 | 1.12 | 114 | 128 |
| **Total** | | | | **103,589** |

## 3.13 Sludge Digesters

The sludge digestion system was originally designed to be a two-phase anaerobic digestion (2PAD) process. The Infilco-Degremont, Inc. (IDI) system includes two mesophilic digesters, a thermophilic digester, pre-feed sequencing tank (PFST), feed sequencing tank (FST) and heating tank (HT). The system also includes heat exchangers and multiple pumping systems, and was designed to process three sludge batches per day at eight-hour intervals to produce Class A biosolid.

The design intent was to first pump ambient temperature raw sludge to the pre feed sequencing tank~~s~~ to provide flow equalization. From there this sludge would be pumped through a “sludge to sludge” heat exchangers that are designed to preheat the raw sludge before being directed to the feed sequence tank while cooling the 55°C thermophilic sludge as it is pumped to the mesophilic digester which is kept at ~37°C. The preheated sludge in the feed sequence tank is then pumped to the sludge heating tank where it is heated to 55°C before being pumped to the thermophilic digester which is also operated at 55°C. The digesters are kept at their respective operating temperatures with heat coils around the cannon bubbler type mixers. These heat coils are supplied hot water from the boiler hot water system.

The feed tank and thermophilic tanks are insulated with foam insulation to minimize heating costs. The mesophilic tanks are also insulated and equipped with floating covers. Gas compressors are used for each of the digesters to keep the contents mixed using cannon bubble type mixers.

The system includes a combined heat and power (CHP) Capstone microturbine system rated to produce 65 kW. The unit was designed to generate power and heat from the digester gas before using the boilers. The system includes digester gas conditioning equipment for removal of contaminates and siloxanes. The gas conditioning equipment is self-controlled and runs concurrently with the microturbine or boiler.

The conditioning process was designed to run concurrently with the microturbine. The gas treatment system blowers are designed for concurrent operation with the generator and gas-fired boiler B-1 or B-2. The gas system includes a boiler feed line point downstream of the blowers, but upstream of moisture and siloxane removal treatment. This avoids the need to operate the gas treatment equipment when using the gas directly in the boilers.

The digester heating system includes two Buderus boilers. One boiler is provided with dual fuel burners (biogas and fuel oil) and one unit is set-up for only fuel oil. The boilers provide heat for the process and also the building hot water circulation loops.

Digester gas is also used to mix the sludge in the digesters. Each digester utilizes a gas compressor and one or more cannon mixers to keep the sludge in the digesters completely mixed. The cannon mixer utilizes the compressed digester gas to create a large digester gas bubble in the mixer draft tube. The mixer generates several bubbles per minute to mix the digester. There is one cannon mixer in the thermophilic digester, one mixer in Mesophilic Digester #1, and three mixers in Mesophilic Digester #2. A list of system equipment with estimated annual electric energy use is provided in Tables 3.13 and 3.14.

**Table 3.13: Digester Gas System Equipment**

| Equipment | Hp | Power (kW) | Annual Hours | Annual Energy Use (kWh) |
|---|---|---|---|---|
| **Pre Feed Sequencing Tank** | | | | |
| Pump 1 A | 7.5 | 3.36 | 500 | 1,679 |
| Pump 1 B | 7.5 | 3.36 | 466 | 1,564 |
| Grinder | 5.0 | 1.12 | 966 | 1,081 |
| Heat Exchanger | -- | -- | -- | -- |
| **Feed Sequencing Tank** | | | | |
| Pump 2 A | 7.5 | 3.36 | 0 | 0 |
| Pump 2 B | 7.5 | 3.36 | 0 | 0 |
| Heat Exchanger | -- | -- | -- | -- |
| **Thermophilic Digester** | | | | |
| Thermophilic Digester Compressor | 10.0 | 3.73 | 1849 | 6,897 |
| Cannon Mixer | -- | -- | -- | -- |
| Heating Jacket | -- | -- | -- | -- |
| Pump 3 A | 7.5 | 3.36 | 481 | 1,615 |
| Pump 3 B | 7.5 | 3.36 | 487 | 1,635 |
| Grinder | 5.0 | 1.12 | 968 | 1,083 |
| Heat Recovery Exchanger | -- | -- | -- | -- |
| Cooling Exchanger (using PW) | -- | -- | -- | -- |

**Table 3.14: Digester Gas System Equipment (continued)**

| Equipment | Hp | Power (kW) | Annual Hours | Annual Energy Use (kWh) |
|---|---|---|---|---|
| **Mesohilic Digester #1** | | | | |
| Mesohilic Digester #1 Compressor | 15.0 | 5.60 | 0 | 0 |
| Cannon Mixer | -- | -- | -- | -- |
| Heating Jacket | -- | -- | -- | -- |
| **Mesohilic Digester #2** | | | | |
| Mesohilic Digester #2 Compressor | 15.0 | 5.60 | 1285 | 7,190 |
| Cannon Mixer#1 | -- | -- | -- | -- |
| Heating Jacket | -- | -- | -- | -- |
| Cannon Mixer#2 | -- | -- | -- | -- |
| Heating Jacket | -- | -- | -- | -- |
| Cannon Mixer#3 | -- | -- | -- | -- |
| Heating Jacket | -- | -- | -- | -- |
| Pump 4 A | 7.5 | 3.36 | 300 | 1,007 |
| Pump 4 B | 7.5 | 3.36 | 300 | 1,007 |
| **Digester Gas/Microturbine System** | | | | |
| Gas Conditioner Skid | 1.5 | 0.78 | 0 | 0 |
| Gas Booster #1 | 1.5 | 0.78 | 0 | 0 |
| Gas Booster #2 | 1.5 | 0.78 | 0 | 0 |
| Gas Treatment Blower | 5.0 | 2.61 | 0 | 0 |
| Gas Treatment Compressor | 10.0 | 5.22 | 0 | 0 |
| Chiller | 10.0 | 5.22 | 0 | 0 |
| **Total** | | | | **24,757** |

Most digester systems use totalizing gas meters to evaluate gas production. Without flow meters we estimated digester gas production using a benchmark rule of thumb figure of 12,000-$ft^3$/digester gas/day (industry standard range 10,000-12,000 $ft^3$) for every million gallons of average flow. This estimate is for standard primary/secondary anaerobic digesters, so the actual gas production for the Brattleboro WWTF should be higher. These values are summarized in Table 3.15.

**Table 3.15: Digester Gas Flow Estimated Based on Flow**

| Month | Average 2016 Plant Flow (MGD) | Digester Gas Production using 12,000 ft3/MG/day |
|---|---|---|
| Jan | 1.17 | 426,816 |
| Feb | 1.32 | 481,536 |
| Mar | 1.39 | 507,072 |
| Apr | 1.21 | 441,408 |
| May | 1.11 | 404,928 |
| Jun | 1.05 | 383,040 |
| Jul | 1.02 | 372,096 |
| Aug | 1.08 | 393,984 |
| Sep | 1.00 | 364,800 |
| Oct | 1.00 | 364,800 |
| Nov | 0.92 | 335,616 |
| Dec | 0.98 | 357,504 |
| **Avg/Total** | **1.10** | **4,833,600** |

Digester gas production can vary between facilities with similar average daily flows. Process Energy Services collected gas production data from the Vermont facilities summarized in Table 3.16 for comparison purposes.

**Table 3.16: Facility Digester Gas Flow Comparison**

| Facility | Average Daily Flow (MGD) | Supplemental Fuel Cost (fuel oil and propane) | Annual Gas Production ($ft^3$) | Utilization of Digester Gas |
|---|---|---|---|---|
| Essex Junction, VT WWTF (2012) | 1.84 | <$1000 | 14,091,000 | CHP, Digester Heating, Space Heating |
| Hanover, NH WRF (2016) | 1.26 | $6,500 | 9,610,000 | Digester Heating and Space Heating |
| Montpelier, VT WWTF (2013) | 1.86 | $11,737 | 9,127,072 (est) | Digester Heating and Space Heating |
| Bennington, VT WWTF (2012) | 3.06 | $650 | 7,447,190 | Digester Heating and Space Heating |
| St Johnsbury, VT WWTF (2014) | 0.92 | $7,170 | 4,696,000 | Digester Heating |
| South Burlington, VT (2013) | 2.01 | $35,961 | 8,788,032 (est) | CHP, Digester Heating, Space Heating |
| **Brattleboro, VT WWTF (2016)** | **1.10** | ***$61,000*** | **4,833,600 (est)** | **CHP, Digester Heating, Space Heating** |
| Barre WWTF (2013) | 2.80 | $67,574 | 9,989,683 | Digester Heating |
| Springfield, VT WWTF (2014) | 0.94 | $61,393 | 4,102,906 (est) | Digester Heating and Space Heating |
| Newport VT WWTF (2013) | 1.00 | $49,489 | 2,882,665 | Digester Heating & Space Heating |

One of the primary reasons for the high gas production at the Essex Junction Facility in Table 3.16 is the significant amount of fats, oils and grease (FOG) accepted at the plant.

Brattleboro Digester System Operational Issues

Operating the system as originally designed has been challenging for staff due to the following issues:

- The flow has been less than anticipated, which has resulted in lower sludge/digester gas production.
- The SCADA system and automatic controls are not fully functional, and the system must be operated in manual. Without all systems working as designed, the process cannot meet Class A sludge requirements.
- The digester seal on one of the digesters is not seating properly and needs to be replaced.
- The cannon mixer system has had issues providing adequate mixing
- The system does not produce enough gas to operate the Capstone microturbine consistently.
- The control system needs to be modified to allow the boiler to use digester gas directly.

The facility staff has been able to manually operate one of the mesophilic digesters and the thermophilic digester, with both units maintained at a mesophilic temperature value (the tanks averaged 35 deg C in 2016). This has reduced fuel oil costs and provided a method to keep most of the system on-line until equipment repairs are completed.

From a practical standpoint, operating the Capstone microturbine does not make economic sense unless the facility process loads increase significantly. After the equipment repairs have been completed, the unit could be cycled on and off as gas accumulates in the digester, but based on the summary data in Table 3.17, it does not appear to provide an annual positive cash flow when the Capstone long-term maintenance contract is included.

**Table 3.17: Microturbine Evaluation Cost Benefit Summary**

| Project Parameters | Annual Estimated Data |
|---|---|
| Estimated Gas Production (ft3) | 4,833,600 |
| Equivalent Gas Heat Value (Btu/hr) | 331,075 |
| Gas Production Required for Full Utilization of 65 kW Microturbine | 760,500 |
| Annual Microturbine Projected kWh Energy Savings (44% uptime/65 kW) | 250,536 |
| Annual kWh Parasitic Energy Use (8 kW for 3,850 hours) | (30,800) |
| Net Annual Energy Savings (kWh) | 219,736 |
| Total Electric Cost Savings (using 0.12/kWh) | $26,368 |
| Annual Capstone Maintenance Contract (9 year contract required) | ($30,000) |
| **Net Annual Savings (negative savings)** | **($3,631)** |

We have not accounted for the potential savings of using the microturbine waste heat. However, it would actually create more negative savings since the gas would be redirected to the microturbine (which typically provides 50% of the available BTUs into waste heat), instead of using the boilers exclusively, which would convert approximately 85% of the available BTUs into useable digester heat (without the negative savings).

To operate the system cost effectively, we recommend the following improvements discussed in ECM #1.

- Repair the digester cover seal to prevent digester gas from escaping.
- Change the control system programming to allow the boiler to operate using digester gas independently of the Capstone microturbine. This measure is a high priority project that is already being pursued by facility staff and provides the greatest benefit to reduce facility energy costs.
- Install digester gas flow meters for the waste gas flare and the boiler. This is another high priority project to maintain system efficiency and monitor gas flows. It will also help the Town evaluate future gas production (if process loads increase) to determine when the microturbine may be cost effective to operate.

We also recommend that the Town consider maintaining the existing operation of the digesters to produce Class B sludge instead of operating in the mesophilic/thermophilic mode to produce Class A sludge. Based on an estimated 1,000 tons of sludge generated annually at the Brattleboro WWTF, the $57,000 annual cost ($57/ton) for a Class B sludge compared to the $40,000 annual cost ($40/ton) for a Class A sludge would only provide $17,000 in annual sludge disposal savings. This does not include hauling costs, which would be similar for either option.

If the mesophilic/thermophilic process were pursued, the supplemental fuel oil that would be required to maintain the digester at the higher thermophilic temperature could offset any sludge disposal savings.

Past Recommendations Suggested to the Town

Since the plant upgrade was completed, other Engineers and Architects have offered recommendations to the Town to improve facility efficiency. As part of our system review, we have included one of these

digester related recommendations and offered a response to explain if we thought the recommendation should be pursued.

***Engineer's Recommendation**:*

*There are currently three insulated digesters, which require significant amounts of heat energy to maintain the units at their respective temperatures of ~140°F and 98°F. This is likely the largest energy consumption within the wastewater plant. Two energy and environmental impact reduction solutions come to mind. First, reduce the tank heat losses by adding an even greater R-Value insulation envelope than has already been added around the tanks. Second, change the fuel used to provide heat to the tanks- A new low-emission, site-located, large pellet-wood chip-biomass boiler system could replace current propane usage while reducing cost and GHG emissions. Additionally, new building or tank-mounted solar hot water collector arrays could also supplement and reduce fossil or biomass fuel usage.*

PES Response: All digester walls have 12" of foam insulation. Although adding more insulation may provide a long-term benefit, the current effort by staff to take advantage of underutilized digester gas is expected to provide a significant amount of the required digester heating and minimize fuel oil use. The propane available for the system is only used for boiler pilot gas use before they are operated with digester gas.

## 3.14 Building Heating & Ventilation Systems

The Headworks, Dewatering and Digester Buildings are heated with hydronic unit heaters using the boilers located in the Digester Building. The Control Building, Chlorine Building and Pump Gallery are heated with multiple effluent source heat pumps that are supplied with the plant water system. The system was designed to be controlled with a central Energy Management Control System, however, the communication system has not functioned since it was originally installed, and the control systems for the heat pumps and unit heaters are limited to local controls. The site buildings with the corresponding HVAC equipment are listed below.

**Table 3.18: HVAC Equipment for Site Buildings Heated with the Boiler System**

| Headworks Building | Dewatering Building | Digester Building |
|---|---|---|
| HRU-1 Supply | Dewater Bldg FCU-1 | Digester Bldg CAF-1 Boiler Room |
| HRU-1 Exhaust | Dewater Bldg FCU-2 | Digester Bldg CAF-2 Cogen Room |
| ERU-1 Supply | Dewater Bldg EF-6 | Digester Bldg EF-11 Cogen Room |
| ERU-1 Exhaust | Dewater Bldg EF-7 | Digester Bldg EF-12 Boiler Room |
| EX Fan #1 | Dewater Bldg EF-8 | Digester Bldg Elect Room FCU-3 |
| Multiple Hydronic Heaters | Dewater Bldg AHU-1 | Digester Bldg Elect Room EF-10 |
| Odor Control System | Dewater Bldg HRU-2 Supply | Digester Bldg Fan SF-3 through SF-6 |
| | Dewater Bldg HRU-2 Exaust | Digester Bldg Fan EF-16 |
| | Multiple Hydronic Unit Heaters | Digester Bldg Fan EF-17 |
| | | Multiple Hydronic Unit Heaters |

**Table 3.19: HVAC Equipment for Site Buildings with Heat Pumps**

| Control Building | Chlorine Building | Pump Gallery |
|---|---|---|
| Heat Pump HP-4 | EF-3 | ERU-3 Supply |
| Heat Pump HP-5 | EF-4 | ERU-3 Exhaust |
| Heat Pump HP-6 | EF-5 | SF-7 |
| Heat Pump HP-7 | Heat Pump HP-1 | Heat Pump HP-13 |
| Heat Pump HP-8 | Heat Pump HP-2 | ERU-3 Supply |
| Heat Pump HP-9 | Heat Pump HP-3 | Pump Gallery |
| Heat Pump HP-10 | | |
| Heat Pump HP-11 | | |
| Heat Pump HP-12 | | |
| ERU-2 Supply/Exhaust | | |

Facility staff has done an excellent job minimizing the use of ventilation equipment and maintaining temperatures at low levels in process areas. Instead of investing in system improvements to get the energy management system working, we recommend simple low temperature thermostats in all the buildings to give staff the ability to fine-tune the room temperatures. For the Control Building and other occupied office/administration areas, we recommend individual setback thermostats with occupied/unoccupied settings. The staff has already made progress pursuing this improvement.

Building/Heating Related Recommendations Suggested to the Town

As discussed, Engineers and Architects have offered recommendations to the Town to improve facility efficiency. As part of our system review, we have included some of the building related recommendations and offered a response to explain if we thought the recommendation should be pursued.

***Engineer's Recommendation:***

*For the Dewatering Building, the existing (somewhat) insulated overhead doors in the main level truck service bays were reused in order to reduce renovation costs. These doors could be replaced with new heavily insulated overhead doors without major building changes. Payback on this investment may take many years, however, retractable fire-rated interior insulation door curtains might be a possible design solution, which might be less costly.*

PES Response: As is the case for most WWTF process buildings, the most cost effective approach to reduce heat loss for a dewatering building is to maintain the inside temperature at a low level during the winter months (typically 50 degrees) and maintain ventilation at minimal levels while still complying with NFPA 820. Facility staff has already taken the initiative to minimize use of ventilation equipment and maintain building temperature at ~50 degrees. Building envelope improvements, such as new insulated garage doors, do not provide a reasonable payback that justifies the investment.

***Engineer's Recommendation:***

*All of the site roof assemblies utilize new membrane systems over new tapered rigid insulation. Increasing the composite R-Values to with thicker insulation levels was rejected due to project budget concerns. To now add more roof insulation would not be a practical expense. Adding roof insulation on the interior side of these roof assemblies would also be impractical in terms of cost and fire-rating requirements.*

PES Response: This potential improvement appears to be addressed above and would not be cost effective to pursue at this time.

## 3.15 Emergency Generator

The facility is equipped with a 400 kW Cat diesel fired emergency generator. The generator is exercised periodically with minimal annual fuel use.

To activate the generator during cold weather, a 2000-watt block heater is used to maintain the block temperature. The block heater temperature was measured to be approximately 98 degrees, which is ideal (90 to 100 degrees is an efficient range) to maintain the generator without wasting energy.

## 3.16 Renewable Energy

The focus of this evaluation is to identify process related energy efficiency measures. However, when we have identified site-specific opportunities to apply renewable energy projects cost effectively, Process Energy has included these measures in the report recommendations. For the Brattleboro facility, besides effectively using the digester bio-gas, we did not identify any unique facility characteristics for renewable energy projects.

***Engineer's Recommendation:***

*There are seven flat-roofed buildings and additional peripheral lands on the site. This offers a fair amount of real estate which could host a considerable number of solar PV arrays that could be used to supply the wastewater plant and the Town of Brattleboro a great deal of green electrical energy in an industrial-zoned area where there should be no aesthetic objection and no negative impact on the operation of the plant. Following a dutiful structural support analysis of each roof, the roof-mounted solar rack could easily be ballasted on additional membrane padding and without membrane penetration.*

PES Response: Installing solar PV arrays could be pursued after the Town has fully optimized digester bio-gas use. However, a solar PV project is not expected to be cost effective unless it is heavily subsidized. Based on reviewing other PV projects at wastewater facilities in New England, if the Town is able to secure grants or incentives, we recommend a larger capacity ground-mounted system instead of a roof-mounted installation. A comparison of several ground PV arrays compared to roof mounted system is shown below. The Montpelier WWTF system includes roof-mounted panels on three buildings.

**Table 3.20: Comparison of WWTF Solar PV Systems**

| Wastewater Facility | Type of Solar PV Array | Size of System | Annual Energy Generated |
|---|---|---|---|
| Montpelier, VT (2013) | Roof Mounted | 62 kW | 45,214 kWh |
| North Conway, NH (2016) | Ground Mounted | 167 kW | 238,218 kWh |
| Plymouth, NH (2016) | Ground Mounted | 121 kW | 181,405 kWh |

# SECTION 4. ENERGY USE

## 4.1 Electrical Energy

Electric Power for the facility is supplied by Green Mountain Power in the G-63/65PF Rate Schedule from the legacy CVPS Rate 10. A summary of the energy use, demand and facility power factor is shown in Table 4.1 (values in italics estimated).

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**Table 4.1: 2016 Electric Energy Use**

| Month | Energy Use (kWh) | Peak Demand (kW) | Off Peak Demand | Power Factor |
|---|---|---|---|---|
| Jan | 88,607 | *155.0* | *168.0* | *0.86* |
| Feb | 80,619 | *155.0* | *168.0* | *0.86* |
| Mar | 78,065 | 155.0 | 168.0 | 0.86 |
| Apr | 68,116 | 134.0 | 110.0 | 0.87 |
| May | 61,314 | 125.0 | 110.0 | 0.84 |
| Jun | 72,096 | 144.0 | 119.0 | 0.80 |
| Jul | 71,813 | *144.0* | *119.0* | *0.80* |
| Aug | 77,906 | 149.0 | 127.0 | 0.84 |
| Sep | 72,906 | 137.0 | 125.0 | 0.87 |
| Oct | 56,897 | 125.0 | 110.0 | 0.82 |
| Nov | 66,140 | 137.0 | 122.0 | 0.86 |
| Dec | 87,458 | 153.0 | 137.0 | 0.87 |
| **Totals** | **881,937** | **1,713** | **1,583** | **0.84** |

Summaries of the facility unit costs are provided in Table 4.2 (values in italics estimated).

**Table 4.2: 2016 Electric Energy Costs**

| 2016 Month | Energy (kWh) Cost | On Peak Demand Cost | Off Peak Demand Cost | Power Factor Penalty | Monthly Fee | Efficiency Charge | Other Fees | Primary Transformer Discount | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| Jan | *$6,500* | *$2,693* | *$0* | *$185* | *$431* | *$723* | *$53* | *$0* | *$10,633* |
| Feb | *$5,580* | *$2,693* | *$0* | *$185* | *$431* | *$723* | *$53* | *$0* | *$9,666* |
| Mar | $5,580 | $2,693 | $0 | $185 | $431 | $723 | $53 | $0 | $9,666 |
| Apr | $5,803 | $2,390 | $611 | $80 | $378 | $629 | $2 | ($1,408) | $8,486 |
| May | $5,210 | $2,229 | $611 | $177 | $354 | $571 | $2 | ($1,288) | $7,866 |
| Jun | $6,074 | $2,568 | $661 | $318 | $378 | $669 | $2 | ($1,488) | $9,183 |
| Jul | *$6,074* | *$2,568* | *$661* | *$318* | *$378* | *$669* | *$2* | *($1,488)* | $9,071 |
| Aug | $6,579 | $2,658 | $706 | $197 | $391 | $715 | $2 | ($1,590) | $9,658 |
| Sep | $6,212 | $2,443 | $695 | $94 | $378 | $666 | $2 | ($1,494) | $8,996 |
| Oct | $4,823 | $2,229 | $611 | $232 | $342 | $540 | $53 | ($1,226) | $7,608 |
| Nov | $5,594 | $2,443 | $678 | $124 | $329 | $618 | $93 | ($1,394) | $8,489 |
| Dec | $7,380 | $2,729 | $761 | $126 | $402 | $786 | $123 | ($1,737) | $10,575 |
| **Totals** | **$71,409** | **$30,338** | **$5,996** | **$2,221** | **$4,623** | **$8,032** | **$440** | **-$13,113** | **$109,896** |
| Unit Costs | | $17.71 | $3.79 | | | | | $0.076 | |

The demand charges are based on the highest average kW value over a 15-minute period during the month and represent 33% of the total energy cost. Besides reducing demand by investing in more energy efficient equipment, another strategy used by some facilities is to alternate the operation of intermittent high-energy equipment (demand shedding). However, after reviewing each system in detail, we were not able to identify any opportunities for consistent demand shedding at the plant.

The decision by the Town to invest in a primary transformer has provided significant savings. As shown in Table 4.2 in 2016, the primary voltage discount reduced facility annual power costs by $13,113 in 2016.

The power factor penalty charge is calculated by the utility when the power factor is below a 0.90 value. In 2016, this charge amounted to $2,221 for the facility. After April of 2020, this cost is expected to double when the power factor requirement will be increased to 0.95. This provides an even greater incentive for the Town to pursue the power factor correction capacitors recommended in ESM #1.

## 4.2 Fuel Oil Use and Cost

The actual fuel oil bills were not available, but in 2016/2017 facility staff started tracking fuel oil use per day (noted below). This data was used to estimate annual fuel use and costs in Table 4.3 based on an estimated unit cost of $2.10/gallon. Reducing fuel oil use by fully utilizing digester gas for the facility boilers is reviewed in ECM #1.

**Table 4.3: Facility Fuel Use & Cost**

| 2016/ 2017 Month | Fuel Oil Use Average Gallons/Day | Monthly Gallons | Estimated Cost ($2.10/gal) | Equivalent Heating Value (Btu/hr) |
|---|---|---|---|---|
| Jan | 119 | 3,689 | $7,747 | 699,899 |
| Feb | 128 | 3,584 | $7,526 | 679,978 |
| Mar | 121 | 3,751 | $7,877 | 711,662 |
| Apr | 97 | 291 | $611 | 55,210 |
| May | 80 | 2,480 | $5,208 | 470,521 |
| Jun | 83 | 2,490 | $5,229 | 472,418 |
| Jul | 66 | 2,046 | $4,297 | 388,179 |
| Aug | 75 | 2,325 | $4,883 | 441,113 |
| Sep | 52 | 156 | $328 | 29,597 |
| Oct | 69 | 2,139 | $4,492 | 405,824 |
| Nov | 89 | 2,670 | $5,607 | 506,568 |
| Dec | 111 | 3,441 | $7,226 | 652,847 |
| **Avg/Total** | **--** | **29,062** | **$61,030** | **5,513,818** |

A 125-gallon propane tank is located outside the Digester building. Propane gas use in 2016/2017 was minimal since it was only required for boiler pilot gas when operating on digester gas.

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# SECTION 5. RECOMMENDED MEASURES

This section describes the proposed energy management practices (EMPs), operational measures (OMs), energy conservation measures (ECMs) and energy supply measures (ESMs) discussed in the report. The measures are interactive in the order they are listed. All project costs and savings figures are preliminary and should be verified before proceeding with each project.

## 5.1 Energy Management Practices

Energy management practices cannot be justified based on quantifiable energy savings, but can be considered to be good energy efficient practices that will provide long-term benefits.

### *5.1.1 EMP #1 Benchmark Energy Use with Process Data*

***Description***

The Town Finance Office currently forwards copies of the WWTF and pump station electric bills to the Chief Operator. All the Town electric accounts are now consolidated into one statement from Green Mountain Power, with the energy use and cost for individual facilities broken down by meter. With this information the Chief Operator is tracking monthly plant electric energy use.

To build on this effort, we recommend collecting additional data to enhance the existing staff efforts. This includes benchmarking energy use with flow and process data to verify plant efficiency on a regular basis and collect additional energy bill data to document savings for energy saving projects.

- Benchmark the monthly energy use/costs with flow and plant process loads as shown in Section 2.
- In addition to the billed energy use, record the power factor and demand use/costs each month. The power factor value/cost can be used to verify the savings after ESM #1 is implemented.
- Staff currently tracks fuel oil, but having cost data (from the actual bills) will help them also update the cost effectiveness of ongoing digester improvements.

***Calculations***

This measure is an important part of a successful efficiency program to insure savings for the energy projects are realized

***Preliminary Cost Estimate***

Cost is expected to be minimal.

## 5.2 Energy Supply Measures

Energy supply measures are recommended improvements such as fuel switching, power factor improvements and demand savings that reduce energy costs but do not qualify as energy (kWh or gallons of fuel oil) saving projects.

### *5.2.1 ESM #1 Power Factor Correction*

#### *Description*

The rate schedule for the Brattleboro WWTF has a penalty for not maintaining a power factor above 90%. Over the last 12 months the facility power bills showed an average power factor of 83%. For this measure we recommend installing capacitors to bring the power factor up to over 95% to provide immediate savings and avoid future charges that are expected in 2020 (see GMP Rate 65 rate schedule excerpt below).

POWER FACTOR ADJUSTMENT:

For service rendered until April 1, 2020:
Customers shall maintain an average power factor of 90% or higher under ordinary load conditions. When the power factor is less than 90% the peak Investment Charge shall be increased by the ration of 90% to the actual power factor, except that no power factor higher than 90% will be used in such determination.

For service rendered April 1, 2020 and thereafter:
Customer shall maintain an average power factor of 95% or higher under ordinary load conditions. When the power factor is less than 95% the peak Investment Charge shall be increased by the ratio of 95% to the actual power factor, except that no power factor higher than 95% will be used in such determination.
Power factor will be determined by Company instrumentation. The Company reserves the right to waive determination and billing of power factor for three-phase demands less than 100 kilowatts. At its option, the Company may assume a power factor of 95% for single-phase circuits and waive measurements thereof.

#### *Savings Calculations*

Savings are based on the power factor penalty charges on the 2016 Brattleboro WWTF electric bills.

**Table 5.1: Energy Bill Costs and Power Factor Penalty**

| Month | Energy Use (kWh) | Peak Demand (kW) | Off Peak Demand (kW) | Power Factor | Power Factor Penalty | Total Bill |
|---|---|---|---|---|---|---|
| Jan | 88,607 | *155.0* | *168.0* | *0.86* | *$185* | $10,633 |
| Feb | 80,619 | *155.0* | *168.0* | *0.86* | *$185* | $9,666 |
| Mar | 78,065 | 155.0 | 168.0 | 0.86 | $185 | $9,666 |
| Apr | 68,116 | 134.0 | 110.0 | 0.87 | $80 | $8,486 |
| May | 61,314 | 125.0 | 110.0 | 0.84 | $177 | $7,866 |
| Jun | 72,096 | 144.0 | 119.0 | 0.80 | $318 | $9,183 |
| Jul | 71,813 | *144.0* | *119.0* | *0.80* | *$318* | $9,071 |
| Aug | 77,906 | 149.0 | 127.0 | 0.84 | $197 | $9,658 |
| Sep | 72,906 | 137.0 | 125.0 | 0.87 | $94 | $8,996 |
| Oct | 56,897 | 125.0 | 110.0 | 0.82 | $232 | $7,608 |
| Nov | 66,140 | 137.0 | 122.0 | 0.86 | $124 | $8,489 |
| Dec | 87,458 | 153.0 | 137.0 | 0.87 | $126 | $10,575 |
| **Totals/Avg** | **881,937** | **143.0** | **132.0** | **0.84** | **$2,221** | **$109,896** |

### *Preliminary Cost Estimate*

To increase the power factor up to 95%, the facility would need to install approximately 31 kVAR of capacitance based on the figures below.

| | |
|---|---|
| Existing Power Factor: | 84% |
| Target Power Factor: | 97% |
| Average Demand: | 143 kW |
| Eaton Power Factor Correction Table Multiplier: | 0.421 |

143 kW * .421 = 60 kVAR

Typical capacitor cost is $15/VAR.

| Item N° | Source | Description | Qty | Unit | Equipment Cost | Labor Cost | Total |
|---|---|---|---|---|---|---|---|
| 1 | -- | Capacitor Cost | 60 | EA | $15 | $0 | $900 |
| 2 | -- | Electrical | 1 | Lot | $1,000 | $2,500 | $3,500 |
| | | | | | | | |
| | | | | **Subtotal** | | | $4,400 |
| | | | | Contractor Overhead & Profit (15%) | | | $0 |
| | | | | Technical Assistance (10%) | | | $0 |
| | | | | **Total with Mark-up** | | | **$4,400** |

### *Cost and Savings Summary*

The cost and savings estimate for this measure is summarized below.

| | | | |
|---|---|---|---|
| Power Factor Penalty Savings | -- | -- | $ 2,221 |
| | | | |
| **Total Energy Cost Savings** | | | **$ 2,221** |
| **Project Cost** | | | **$ 4,400** |
| **Simple Payback** | | | **2.0 years** |

## 5.3 Operational Measures

Operational measures are low cost improvements that can be made without a substantial capital investment, and typically pay for themselves in less than one year.

### *5.3.1 OM #1 Adjust Grit Pump Cycle Time*

#### *Description*

The facility headworks include a grit removal system where the velocity of the flow is reduced and solids are allowed to settle. A peristaltic hose-type grit pump is activated 8 minutes every hour to remove the settled grit by directing it through a low energy classifier/cyclone where the grit is separated from the flow and conveyed to a bin for disposal. The remaining flow stream is redirected back to the treatment process.

Although this system is a low energy process, many wastewater facilities have found that they can extend grit pump run times without adversely impacting the process. For this measure we recommend operating the grit pump approximately 4 minutes every hour instead of 8 minutes per hour.

#### *Savings Calculation*

The savings for this operational adjustment is expected to be approximately 6,000 kWh annually (including reduced classifier and conveyor hours). Based on the summary of energy use below.

**Table 5.2: Estimated System Energy Use Before and After Measure**

| Equipment | Motor Hp | Power Draw (kW) | 2016 Annual Hours | Energy Use (kWh) | New Proposed Hours | New Energy Use (kWh) |
|---|---|---|---|---|---|---|
| Fine Screen | 3.00 | 1.79 | 321 | 575 | 321 | 575 |
| Grit Chamber Drive | 1.00 | 0.60 | 8742 | 5,217 | 8742 | 5,217 |
| Grit Classifier | 1.00 | 0.60 | 1303 | 778 | 652 | 391 |
| Grit Pump | 15.00 | 8.95 | 1196 | 10,707 | 598 | 5,352 |
| Screenings/Grit Conveyor | 3.00 | 1.79 | 2047 | 3,665 | 1449 | 2,594 |
| **Total** | | | | **20,941** | **--** | **14,129** |

#### *Cost and Savings Summary*

The cost and savings estimate for this OM is summarized below.

| | | | |
|---|---|---|---|
| Annual Energy (kWh) Savings | 6,812kWh | $ 0.076/kWh | $ 518 |
| Annual On-Peak Demand (kW) Savings | 0 kW | $ 17.71/kW | $ 0 |
| Annual Off-Peak Demand (kW) Savings | 0 kW | $ 3.79/kW | $ 0 |
| | | | |
| **Total Energy Cost Savings** | | | **$ 518** |
| **Project Cost** | | | **N/A** |
| **Simple Payback** | | | **--** |

### *5.3.2 OM #2 Adjust Septage Blower Cycle Time*

#### *Description*

The facility is equipped with a septage receiving station in the Headworks Building. Septage and dairy waste haulers discharge waste through a fine screen unit before it is stored in three below grade tanks (one tank is typically used). The screenings are washed, compacted and dewatered before being conveyed to a hopper. Spray water for the unit is supplied by the plant water system.

The septage/dairy waste is aerated with one of two 5 hp Aerzen Blowers equipped with VFDs. The facility typically uses one blower 50% of the time with hours allocated as shown below. Based on discussions with staff, there may be opportunity to reduce the septage blower cycle time by decreasing the blower run time by an additional 50%. Savings are shown below

#### *Savings Calculation*

System annual energy use is estimated in Table 5.3 based on average field power measurements.

**Table 5.3: Estimated Energy Use Before and After Measure**

| Equipment | Motor Hp | Power Draw (kW) | 2016 Annual Hours | Energy Use (kWh) | New Proposed Hours | New Energy Use (kWh) |
|---|---|---|---|---|---|---|
| Septage Blower #1 | 5.0 | 1.87 | 2584 | 4,819 | 1,292 | 2,416 |
| Septage Blower #2 | 5.0 | 1.87 | 2825 | 5,269 | 1,412 | 2,641 |
| **Total** | | | | **10,008** | **--** | **5,057** |

#### *Cost and Savings Summary*

The cost and savings estimate for this OM is summarized below.

| | | | |
|---|---|---|---|
| Annual Energy (kWh) Savings | 5,031 kWh | $ 0.076/kWh | $ 382 |
| Annual On-Peak Demand (kW) Savings | 0 kW | $ 17.71/kW | $ 0 |
| Annual Off-Peak Demand (kW) Savings | 0 kW | $ 3.79/kW | $ 0 |
| | | | |
| **Total Energy Cost Savings** | | | **$ 382** |
| **Project Cost** | | | **N/A** |
| **Simple Payback** | | | **--** |

### *5.3.3 OM #3 Extend Offline Hours for RBC Trains*

#### *Description*

The RBC system at the Brattleboro facility consists of twenty units, which include low density, medium density, and high-density units. The shafts are slowly rotated with 5 hp drive units coupled with gear reducers. The RBC units are arranged in three treatment stages in four parallel trains. The staff currently tracks shaft weight on a regular basis to be sure each RBC is operating in the optimal range. When the shaft weight in the last stage is in the 20,000 to 25,000 lb range, the staff takes a train off line.

This ECM proposes continuing the existing staff efforts and when possible extending the off time for the RBC units by using the above 25,000 lb value instead of the 20,000 lb value more often to extend the RBC unit off time. The potential savings for extending the off time by 20% is calculated below.

#### *Savings Calculations*

The estimated system energy use shown below is based on averaged spot measurements of the RBC units. The proposed hours and new energy use is calculated with a longer off time for the units taken off line.

**Table 5.4: RBC System Energy Use Before and After Measure**

| Equipment | Motor Hp | Power Draw (kW) | Existing Hours | Energy Use (kWh) | Proposed Hours | New Energy Use (kWh) |
|---|---|---|---|---|---|---|
| RBC 1E | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 2E | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 3E | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 4E | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 5E | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 6E | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 7E | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 8E | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 9E | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 10E | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 1W | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 2W | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 3W | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 4W | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 5W | 5 | 2.05 | 8760 | 17,971 | 8760 | 17,958 |
| RBC 6W | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 7W | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 8W | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 9W | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| RBC 10W | 5 | 2.05 | 7300 | 14,976 | 5840 | 11,972 |
| **Total** | | | | **329,470** | **New Total** | **299,300** |

Energy Savings: 329,470 kWh – 299,300 kWh = 30,170 kWh

***Cost and Savings Summary***

The cost and savings estimate for this OM is summarized below.

| | | | |
|---|---|---|---|
| Annual Energy (kWh) Savings | 30,170 kWh | $ 0.076/kWh | $ 2,293 |
| Annual On-Peak Demand (kW) Savings | 0 kW | $ 17.71/kW | $ 0 |
| Annual Off-Peak Demand (kW) Savings | 0 kW | $ 3.79/kW | $ 0 |
| | | | |
| **Total Energy Cost Savings** | | | **$ 2,293** |
| **Project Cost** | | | **N/A** |
| **Simple Payback** | | | **--** |

### *5.3.4 OM #4 Cycle Sludge Holding Tank Mixer*

#### *Description*

Digested sludge is pumped to the digested sludge storage tank prior to dewatering. The sludge is mixed with a 20 hp hyperbolic mixer equipped with a VFD and timer. Normal operation is to operate the mixer continuously at a VFD speed of approximately 90%. The day before the sludge is dewatered, the mixer is operated with the timer to activate the mixer 10 minutes every hour to allow the sludge to settle. The run time hours in 2016 show the mixer operating 93% of the time.

The staff is currently cycling the mixer on/off to reduce equipment energy use. If this can be done 50% of the time, the savings calculated below will be realized.

#### *Savings Calculations*

The mixer power draw was measured to be 8.9 kW during the field assessment. If the unit were cycled on and off each hour, the following savings would be realized.

Current Baseline energy use: 8.9 kW * 8127 hours (from run time meter) = 72,330 kWh
New energy use with mixer cycling: 8.9 kW * 4,064 hours = 36,170 kWh
Annual energy savings: 72,330 kWh – 36,170 kWh = 36,160 kWh

#### *Cost and Savings Summary*

The cost and savings estimate for this OM is summarized below.

| | | | |
|---|---|---|---|
| Annual Energy (kWh) Savings | 36,160 kWh | $ 0.076/kWh | $ 2,748 |
| Annual On-Peak Demand (kW) Savings | 0 kW | $ 17.71/kW | $ 0 |
| Annual Off-Peak Demand (kW) Savings | 0 kW | $ 3.79/kW | $ 0 |
| | | | |
| **Total Energy Cost Savings** | | | **$ 2,748** |
| **Project Cost** | | | **N/A** |
| **Simple Payback** | | | **--** |

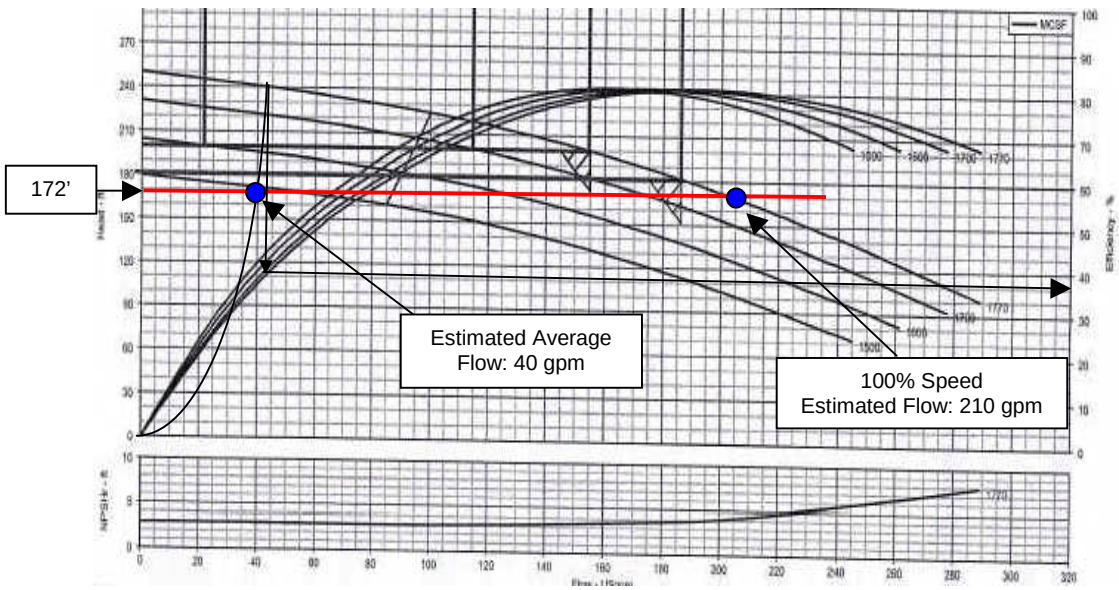
### *5.3.5 OM #5 Adjust Plant Water System Pressure*

#### *Description*

The plant water system consists of three ITT pumps and pressure based control system. Each pump is rated for 155 gpm @ 200' TDH (86.6 psi). The pumps are equipped with 15 hp motors and VFDs. Staff indicated that the system is set-up to maintain 70 psi. The system is not equipped with a flow meter, but based on 81% VFD speed observed during our site visit, the flow was estimated to be 40 gpm using the original pump curve in Figure 5.1.

Plant water is used for site hydrants, spray water for the fine screen unit, rotary press wash water and the water source heat pumps. With the constant use of flow required for the water source heat pumps, there are limited opportunities to reduce plant water system capacity and energy use.

**Figure 5.1: Plant Water Pump Curve**




The power draw measured for one pump operating at 81% speed was 4.5 kW. Although pump capacity and power draw will increase during dewatering or when screen spray water is needed, we would expect that the majority of time, this is a typical value. At this flow rate, pump efficiency is approximately 36% based on the pump curve.

Some packaged plant water systems include a smaller "pony" pump that can provide lower flows at a higher efficiency than the standard sized pumps. This was considered for the Brattleboro system, but preliminary calculations revealed that more savings would be achieved with a simple pressure reduction compared to replacing one of the 15 hp pumps with a smaller unit.

A fine screen wash system is typically the wastewater process with the highest pressure requirements (unless a GBT or BFP is used for dewatering). Wash systems typically require a minimum of 40 gpm @ 30 psi pressure. The facility O&M manual also indicates that 70 psi is the maximum pressure that may be

required for the system. For this measure we recommend adjusting the plant water pressure setpoint to 50 psi, which should be sufficient for end use requirements.

***Savings Calculations***

Calculations are based on a 90% motor efficiency and 95% VFD efficiency, (both slightly lower at reduced loads) and a 36% pump efficiency based on field data and the pump curve. The total baseline head of 172' is based on the 70 psi maintained discharge and a ~10' distance from the pressure transducer to the sump water level. With these same assumptions, the proposed discharge setpoint of 50 psi corresponds to a total head of 126'. The calculated power draw of 4.2 kW is slightly less than the site power measurement of 4.5 kW.

Baseline Energy Use

$$\text{Exiting Pump kW} = \frac{40\text{ gpm} * 172\text{' TDH} * .746}{3960 * 36\% * 90\% * 95\%} = 4.2\text{ kW}$$

Baseline annual energy use: 4.2 kW * 8760 hours = 36,792 kWh

Energy Use with Lower Pressure

$$\text{Exiting Day Pump kW} = \frac{40\text{ gpm} * 126\text{' TDH} * .746}{3960 * 36\% * 90\% * 95\%} = 3.1\text{ kW}$$

New annual energy use: 3.1 kW * 8760 hours = 27,156 kWh

Savings: 36,792 kWh – 27,156 kWh = 9,636 kWh
Demand Savings: 5.1 kW – 3.7 kW = 1.4 kW

***Cost and Savings Summary***

The cost and savings estimate for this OM is summarized below.

| | | | |
|---|---|---|---|
| Annual Energy (kWh) Savings | 9,636 kWh | $ 0.076/kWh | $ 732 |
| Annual On-Peak Demand (kW) Savings | 0 kW | $ 17.71/kW | $ 0 |
| Annual Off-Peak Demand (kW) Savings | 0 kW | $ 3.79/kW | $ 0 |
| | | | |
| **Total Energy Cost Savings** | | | **$ 732** |
| **Project Cost** | | | **N/A** |
| **Simple Payback** | | | **--** |

## 5.4 Energy Conservation Measures

The recommendations discussed in this section are categorized as energy conservation measures, or "ECMs" for projects that require a larger capital investment with simple paybacks exceeding one year.

### *5.4.1 ECM #1 Digester System Repairs*

#### *Description*

The sludge digestion system was originally designed to be a two-phase anaerobic digestion (2PAD) process that included two mesophilic digesters, a thermophilic digester, pre-feed sequencing tank (PFST), feed sequencing tank (FST) and heating tank (HT). Due to equipment/control system repair issues that include gas covers that are not sealing, mixing issues and control system problems, the staff has needed to operate the system manually.

The system equipment/control system issues have required the facility to operate both digesters manually in the mesophilic temperature range (averaged 35 deg C in 2016). Although the system is not able to produce a Class A sludge, the other benefits of anaerobic digestion are still being realized. Although the electric energy use of the system is fairly low, the leaking gas cover and control system issues have created high fuel use to keep the digesters heated.

Most small (< 5 MGD) New England wastewater facilities that have anaerobic digesters use digester gas directly to fuel the boilers, instead of installing generators and using the engine waste heat for digester heating. The facilities listed in Table 5.5 use digester gas for their boilers and have been able to optimize their systems to minimize supplemental fuel. This measure provides an estimate of the boiler fuel savings that Brattleboro could achieve if the digester seals are repaired, and the boiler control system is modified.

**Table 5.5: Facility Digester Gas Flow Comparison**

| Facility | Average Daily Flow (MGD) | Supplemental Fuel Cost | Annual Gas Production ($ft^3$) |
|---|---|---|---|
| Hanover, NH WRF (2016) | 1.26 | $6,500 | 9,610,000 |
| Montpelier, VT WWTF (2013) | 1.86 | $11,737 | 9,127,072 (est) |
| Bennington, VT WWTF (2012) | 3.06 | $650 | 7,447,190 |
| St Johnsbury, VT WWTF (2014) | 0.92 | $7,170 | 4,696,000 |
| **Brattleboro, VT WWTF (2016)** | **1.10** | **$61,000** | **4,833,600 (est)** |

The staff is currently pursuing the following improvements to reduce the $61,000 (estimated for 2016) in annual heating costs.

- Repair the digester cover seal to prevent digester gas from escaping.
- Modify the control system programming to allow the boiler to operate using digester gas directly.
- Install gas flow meters to monitor gas production to verify system performance.

The cost savings for these improvements are estimated below.

### *Savings Calculations*

A summary of how available gas could be used to reduce fuel oil heating costs is shown below. The heating value of the digester gas is based on 600 Btu/$ft_3$ and for the fuel oil heating value is based on 138,500 Btu/gallon.

**Table 5.6: Digester Gas and Fuel Oil Heating Values**

| 2016/ 2017 Month | Fuel Oil Use Average Gallons/Day | Monthly Gallons | Estimated Cost ($2.10/gal) | Equivalent Heating Value (Btu/hr) | Average Plant Flow (MGD) | Estimated Digester Gas Production using 12,000 ft3/mg/day | Equivalent Heating Value (Btu/hr) |
|---|---|---|---|---|---|---|---|
| Jan | 119 | 3,689 | $7,747 | 699,899 | 1.17 | 426,816 | 351,000 |
| Feb | 128 | 3,584 | $7,526 | 679,978 | 1.32 | 481,536 | 396,000 |
| Mar | 121 | 3,751 | $7,877 | 711,662 | 1.39 | 507,072 | 417,000 |
| Apr | 97 | 291 | $611 | 55,210 | 1.21 | 441,408 | 363,000 |
| May | 80 | 2,480 | $5,208 | 470,521 | 1.11 | 404,928 | 333,000 |
| Jun | 83 | 2,490 | $5,229 | 472,418 | 1.05 | 383,040 | 315,000 |
| Jul | 66 | 2,046 | $4,297 | 388,179 | 1.02 | 372,096 | 306,000 |
| Aug | 75 | 2,325 | $4,883 | 441,113 | 1.08 | 393,984 | 324,000 |
| Sep | 52 | 156 | $328 | 29,597 | 1.00 | 364,800 | 300,000 |
| Oct | 69 | 2,139 | $4,492 | 405,824 | 1.00 | 364,800 | 300,000 |
| Nov | 89 | 2,670 | $5,607 | 506,568 | 0.92 | 335,616 | 276,000 |
| Dec | 111 | 3,441 | $7,226 | 652,847 | 0.98 | 357,504 | 294,000 |
| **Avg/Total** | **--** | **29,062** | **$61,030** | **---** | **1.10** | **4,833,600** | **---** |

The data in Table 5.6 can be summarized as follows:

2016/2017 Fuel Oil: 29,062 gallons * 138,500 Btu/gal = 4025 MBtu
Digester Gas Heating Value: 4,833,600 ft3 *600 Btu/ft3 = 2,900 MBtu * 90% boiler eff = 2610 MBtu

Fuel Savings 2610MBtu * 1,000,000 /138,500 Btu/gal = 18,845 gallons

## *Preliminary Cost Estimate*

Based on discussions with staff, the estimated cost to repair the digester seal and modify the boiler control system is $230,000.

### *Cost and Savings Summary*

The cost and savings estimate for this measure is summarized below.

| | | | |
|---|---|---|---|
| Annual Fuel Oil Savings | 18,845 gallons | $2.10/gallon | $ 39,575 |
| | | | |
| **Total Energy Cost Savings** | | | **$ 39,575** |
| **Project Cost** | | | **$ 230,000** |
| **Simple Payback** | | | **5.8 years** |

# APPENDIX A: UTILITY RATE SCHEDULE

GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

AVAILABLE:

Throughout the Company's service territory.

APPLICABLE:

Except as noted below, service under this rate is available to all Customers.

Each metered location at which the Customer is taking service from the Company shall be an individual account for service under this tariff.
Special contract rates may be required for Customers whose unique requirements impose significant costs upon the Company that are not recovered through application of the Company's standard tariffs. Special contract rates will be subject to approval of the Vermont Public Service Board.

This rate is required for Customers whose average consumption during any four consecutive months is greater than 7600 kWh per month or whose average actual demand during any four consecutive months is greater than 200 kW. Customers shall remain on Time-of-Use Rate 63 for a minimum of 12 monthly billing periods and thereafter unless consumption is less than 6600 kWh and billing demand is less than 150 kW during each of twelve (12) consecutive months.

Electric generation facilities required to be served under this rate during periods in which they are not generating electricity ("Station Service") shall not be charged the peak Investment Charge. For these Customers, all times in the billing month shall be considered off-peak for Investment Charge purposes. Except as noted above, all other charges and credits shall be billed according to the tariff. Only Customers whose primary use of electricity purchased hereunder is to serve an off-line generation facility may take Station Service.

EFFECTIVE: On Bills Rendered on or after April 1, 2016
GREEN MOUNTAIN POWER CORPORATION

By: Charlotte Ancel

Charlotte B. Ancel
Vice President, General Counsel, Power Resources, and Corporate Secretary
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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

RATES:

For Customers at service locations transitioned to Rate 63/65 from **legacy-CVPS Rate 2D**:

| | Customer Charge-1 Phase | Customer Charge-3 Phase |
|---|---|---|
| For service rendered: | | |
| April 1, 2016 – March 31, 2017 | $1.095 per day | $1.913 per day |
| April 1, 2017 – March 31, 2018 | $1.607 per day | $2.302 per day |
| April 1, 2018 – March 31, 2019 | $2.159 per day | $2.682 per day |
| April 1, 2019 – March 31, 2020 | $2.787 per day | $3.073 per day |

| | First 5 kW | All additional kW |
|---|---|---|
| For service rendered: | | |
| April 1, 2016 – March 31, 2017 | $4.156 per kW | $14.665 per kW |
| April 1, 2017 – March 31, 2018 | $8.312 per kW | $15.318 per kW |
| April 1, 2018 – March 31, 2019 | $12.472 per kW | $15.977 per kW |
| April 1, 2019 – March 31, 2020 | $16.642 per kW | $16.642 per kW |

| | First 500 kWh | Next "A" kWh | Add'l kWh |
|---|---|---|---|
| For service rendered: | | | |
| April 1, 2016 – March 31, 2017 | $0.12790/kWh | $0.12790/kWh | $0.08611/kWh |
| April 1, 2017 – March 31, 2018 | $0.11438/kWh | $0.11438/kWh | $0.08602/kWh |
| April 1, 2018 – March 31, 2019 | $0.10066/kWh | $0.10066/kWh | $0.08593/kWh |
| April 1, 2019 – March 31, 2020 | $0.08662/kWh | $0.08662/kWh | $0.08588/kWh |

EFFECTIVE: On Service Rendered on or after October 1, 2016
GREEN MOUNTAIN POWER CORPORATION

By: Charlotte Ancel

Charlotte B. Ancel
Vice President, General Counsel, Power Resources, and Corporate Secretary
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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

"A" = 3.0 * (peak kW demand – 5 kW) * number of days in the current billing period. When peak demand is less than 5, "A" = 0. The billing demand will be the highest 15-minute peak established during the current month, except that when the maximum demand established during the billing months of December through March shall be 100 kW or greater, the billing demand applicable to billings rendered during the next succeeding 11 months shall be not less than 60 percent of the value, except that when the maximum demand established during any billing period shall be 500 kW or greater, the billing demand applicable to billings rendered during the next succeeding eleven months shall not be less than 100% of that value. Whenever metering is at primary distribution voltage, the kWh and kW consumption shall be reduced by 3 percent. If the Customer furnished all transformer and substation facilities, a credit of $0.7298 per kW of billing demand will be allowed.

| For service rendered: | 4/1/20 & thereafter |
|---|---|
| Daily Customer Charge | $3.455 |
| Peak kW | $13.592 |
| OffPeak kW | $3.915 |
| Peak kWh | $0.09591 |
| OffPeak kWh | $0.07290 |
| Primary Voltage Discount | 4.00% |
| Transformer Ownership Credit | ($0.7303) |

For Customers at service locations transitioned to Rate 63/65 from **legacy-CVPS Rate 10**:

| For service rendered: | 4/1/16 to 3/31/17 | 4/1/17 to 3/31/18 | 4/1/18 to 3/31/19 |
|---|---|---|---|
| Daily Customer Charge | $2.998 | $3.111 | $3.224 |
| Daily Customer Charge (Prim. Meter) | $12.248 | $10.049 | $7.852 |
| Peak kW | $20.338 | $18.719 | $16.859 |
| OffPeak kW | $1.219 | $2.189 | $2.933 |
| Peak kWh | $0.08832 | $0.09017 | $0.09206 |
| OffPeak kWh | $0.07506 | $0.07463 | $0.07411 |
| Primary Voltage Discount | 4.00% | 4.00% | 4.00% |
| Transformer Ownership Credit | ($0.3069) | ($0.4125) | ($0.5181) |

EFFECTIVE: On Service Rendered on or after October 1, 2016
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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

| For service rendered: | 4/1/19 to 3/31/20 | 4/1/20 & thereafter |
|---|---|---|
| Daily Customer Charge | $3.340 | $3.455 |
| Daily Customer Charge (Prim. Meter) | $5.655 | $3.455 |
| Peak kW | $15.158 | $13.592 |
| OffPeak kW | $3.502 | $3.915 |
| Peak kWh | $0.09399 | $0.09591 |
| OffPeak kWh | $0.07354 | $0.07290 |
| Primary Voltage Discount | 4.00% | 4.00% |
| Transformer Ownership Credit | ($0.6242) | ($0.7303) |

For Customers at service locations transitioned to Rate 63/65 from **legacy-CVPS Rate 4**:

| For service rendered: | 4/1/16 to 3/31/17 | 4/1/17 to 3/31/18 | 4/1/18 to 3/31/19 |
|---|---|---|---|
| Daily Customer Charge | $12.186 | $11.462 | $6.993 |
| Peak kW | $18.566 | $17.318 | $16.074 |
| OffPeak kW | $5.569 | $5.154 | $4.742 |
| Peak kWh | $0.09549 | $0.09556 | $0.09565 |
| OffPeak kWh | $0.07400 | $0.07263 | $0.07270 |
| Primary Voltage Discount | 15.81% | 12.90% | 9.90% |
| Transformer Ownership Credit | ($0.7289) | ($0.7290) | ($0.7293) |

| For service rendered: | 4/1/19 to 3/31/20 | 4/1/20 & thereafter |
|---|---|---|
| Daily Customer Charge | $4.314 | $3.455 |
| Peak kW | $14.835 | $13.592 |
| OffPeak kW | $4.329 | $3.915 |
| Peak kWh | $0.09578 | $0.09591 |
| OffPeak kWh | $0.07279 | $0.07290 |
| Primary Voltage Discount | 7.00% | 4.00% |
| Transformer Ownership Credit | ($0.7298) | ($0.7303) |

EFFECTIVE: On Service Rendered on or after October 1, 2016
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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

For Customers at service locations transitioned to Rate 63/65 from **legacy-CVPS Rate 5:**

| For service rendered: | 4/1/16 to 3/31/17 | 4/1/17 to 3/31/18 | 4/1/18 to 3/31/19 |
|---|---|---|---|
| Daily Customer Charge | $31.770 | $24.693 | $17.619 |
| Peak kW | $18.566 | $17.318 | $16.074 |
| OffPeak kW | $5.569 | $5.154 | $4.742 |
| Peak kWh | $0.09549 | $0.09556 | $0.09565 |
| OffPeak kWh | $0.07400 | $0.07263 | $0.07270 |
| Sub-Transmission Voltage Discount | 29.12% | 26.82% | 25.11% |
| Sub-Transmission Voltage Discount >20MW | 29.12% | 28.13% | 26.44% |
| Transformer Ownership Credit | ($0.7289) | ($0.7290) | ($0.7293) |

| For service rendered: | 4/1/19 to 3/31/20 | 4/1/20 & thereafter |
|---|---|---|
| Daily Customer Charge | $10.542 | $3.455 |
| Peak kW | $14.835 | $13.592 |
| OffPeak kW | $4.329 | $3.915 |
| Peak kWh | $0.09578 | $0.09591 |
| OffPeak kWh | $0.07279 | $0.07290 |
| Sub-transmission Voltage Discount | 23.40% | 21.65% |
| Sub-transmission Voltage Discount >20MW | 24.75% | 23.04% |
| Transformer Ownership Credit | ($0.7298) | ($0.7303) |

For Customers at service locations transitioned to Rate 63/65 from **legacy-CVPS Rate 16:**

| For service rendered: | 4/1/16 to 3/31/17 | 4/1/17 to 3/31/18 | 4/1/18 to 3/31/19 |
|---|---|---|---|
| Daily Customer Charge | $14.448 | $14.450 | $14.456 |
| Peak kW | $11.507 | $12.470 | $12.734 |
| OffPeak kW | $6.904 | $6.509 | $5.653 |
| Peak kWh | $0.09572 | $0.09573 | $0.09577 |
| OffPeak kWh | $0.07275 | $0.07276 | $0.07279 |

EFFECTIVE: On Service Rendered on or after October 1, 2016
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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

| | | | |
|---|---|---|---|
| Primary Voltage Discount | 4.00% | 4.00% | 4.00% |
| Sub-Transmission Voltage Discount | 12.45% | 14.91% | 17.36% |
| Transformer Ownership Credit | ($0.3069) | ($0.4125) | ($0.5181) |

| For service rendered: | 4/1/19 to 3/31/20 | 4/1/20 & thereafter |
|---|---|---|
| Daily Customer Charge | $14.466 | $3.455 |
| Peak kW | $13.001 | $13.592 |
| OffPeak kW | $4.760 | $3.915 |
| Peak kWh | $0.09584 | $0.09591 |
| OffPeak kWh | $0.07284 | $0.07290 |
| Primary Voltage Discount | 4.00% | 4.00% |
| Sub-Transmission Voltage Discount | 19.82% | 22.27% |
| Transformer Ownership Credit | ($0.6242) | ($0.7303) |

For Customers at service locations transitioned to Rate 63/65 from **legacy-GMP Rate 63/65 and Customers at new service locations:**

| For service rendered: | 4/1/16 to 3/31/17 | 4/1/17 to 3/31/18 | 4/1/18 to 3/31/19 |
|---|---|---|---|
| Daily Customer Charge | $3.064 | $3.199 | $3.318 |
| Peak kW | $13.189 | $13.252 | $13.356 |
| OffPeak kW | $3.411 | $3.524 | $3.650 |
| Peak kWh | $0.09473 | $0.09448 | $0.09480 |
| OffPeak kWh | $0.07031 | $0.07054 | $0.07119 |
| Primary Voltage Discount | 2.50% | 2.50% | 2.50% |
| Sub-Transmission Voltage Discount | 4.00% | 7.86% | 12.48% |
| Sub-Transmission Voltage Discount >20MW | 29.12% | 28.13% | 26.44% |
| Transformer Ownership Credit | ($0.7289) | ($0.7290) | ($0.7293) |

EFFECTIVE: On Service Rendered on or after October 1, 2016
GREEN MOUNTAIN POWER CORPORATION

By: Charlotte Ancel

Charlotte B. Ancel
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Cancels Original Sheet 97

# GREEN MOUNTAIN POWER CORPORATION
# COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

| For service rendered: | 4/1/19 to 3/31/20 | 4/1/20 & thereafter |
|---|---|---|
| Daily Customer Charge | $3.436 | $3.459 |
| Peak kW | $13.461 | $13.592 |
| OffPeak kW | $3.778 | $3.915 |
| Peak kWh | $0.09516 | $0.09591 |
| OffPeak kWh | $0.07190 | $0.07290 |
| Primary Voltage Discount | 2.50% | 4.00% |
| Sub-Transmission Voltage Discount | 17.07% | 21.65% |
| Sub-Transmission Voltage Discount >20MW | 24.75% | 23.04% |
| Transformer Ownership Credit | ($0.7298) | ($0.7303) |

ALTERNATIVE REGULATION PLAN:

This rate schedule is subject to the Company's Alternative Regulation Plan Rider ("ARP Rider"), which includes an annual Power Adjustor, an annual Exogenous Change Adjustment and an annual Earnings Sharing Adjustor.

PEAK HOURS:

Peak hours shall be a period of 16 consecutive hours selected by the Company between the hours of 6:00 a.m. and 11:00 p.m. on weekdays (Monday through Friday). All other hours are considered off-peak.

BILLING DEMAND:

When the rates for billing demand are differentiated by peak and off-peak hours, the demand in kilowatts will be the greater of the following:

Peak Hours:

A number of kilowatts equal to the greatest fifteen-minute peak occurring during the peak hours during such month; but not less than 50% of the highest fifteen-minute peak occurring during the preceding eleven months' peak hour periods.

Off-Peak Hours:

A number of kilowatts equal to the greatest fifteen-minute peak occurring during off-peak hours during such month.

EFFECTIVE: On Service Rendered on or after October 1, 2016
GREEN MOUNTAIN POWER CORPORATION

By: Charlotte Ancel

Charlotte B. Ancel
Vice President, General Counsel, Power Resources, and Corporate Secretary
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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

When two or more meters are used at an individual Customer service location, the demand from all meters at that service location may be made coincident by the Company for billing purposes; if the Company does so, the coincident demand will be billed in accordance with the procedures described above, except that the Company may impose a minimum billing demand for coincidentalized accounts. Customer service at two or more different business/service locations will not be made coincident for billing purposes.

POWER FACTOR ADJUSTMENT:

For service rendered until April 1, 2020:
Customers shall maintain an average power factor of 90% or higher under ordinary load conditions. When the power factor is less than 90% the peak Investment Charge shall be increased by the ration of 90% to the actual power factor, except that no power factor higher than 90% will be used in such determination.

For service rendered April 1, 2020 and thereafter:
Customer shall maintain an average power factor of 95% or higher under ordinary load conditions. When the power factor is less than 95% the peak Investment Charge shall be increased by the ratio of 95% to the actual power factor, except that no power factor higher than 95% will be used in such determination.
Power factor will be determined by Company instrumentation. The Company reserves the right to waive determination and billing of power factor for three-phase demands less than 100 kilowatts. At its option, the Company may assume a power factor of 95% for single-phase circuits and waive measurements thereof.

EFFECTIVE: On Bills Rendered on or after April 1, 2016
GREEN MOUNTAIN POWER CORPORATION

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Charlotte B. Ancel
Vice President, General Counsel, Power Resources, and Corporate Secretary
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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

PRIMARY SERVICE DISCOUNT:

A primary service discount will be applied to the sum of the Investment and Energy charges for Customers who: (1) own and maintain all required transformers, voltage regulation equipment, protective devices and all associated structures and (2) take delivery from a primary distribution line at nominal voltage of 2.4 kV to 34.5 kV. When the Company has elected to meter on the secondary side of the Customer's transformers, the kW and kWh consumption registered by the meter shall be increased to include transformer losses. When the Customer is served by one transformer or bank of transformer of a capacity not in excess of 500 kVa, the transformer loss adjustment may be accomplished by multiplying the kW and kWh values recorded on the secondary side of the Customer-owned transformer(s) by a factor of 1.03.

SUB-TRANSMISSION SERVICE DISCOUNT:

A sub-transmission service discount will be applied to the sum of the Investment and Energy charges for Customers who: (1) own and maintain all required transformers, voltage regulation equipment, protective devices, and all associated structures and (2) take delivery from a sub-transmission line at nominal voltage of 33 kV to 69 kV. When the Company has elected to meter on the secondary side of the Customer's transformers, the kW and kWh consumption registered by the meter shall be increased to include transformer losses.

Customers with monthly demand greater than 20 MW shall be eligible for a separate subtransmission voltage discount. A Customer receiving a sub-transmission service discount will not also be entitled to the primary metering discount offered under this rate.

TRANSFORMER OWNERSHIP CREDIT:

If the Customer furnishes all transformers which may be required, or if the Customer utilizes electricity at the point of delivery at the voltage, not less than 2,300, at which it is transmitted by the Company, so that the Company is not required to furnish any transformers, there will be credited against the amount of the bill for the month after any and all discounts, a transformer ownership credit for each kilowatt of demand, either peak hour or off peak hour demand whichever is the largest, used for billing purposes.

EFFECTIVE: On Bills Rendered on or after April 1, 2016
GREEN MOUNTAIN POWER CORPORATION

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GREEN MOUNTAIN POWER CORPORATION
COMMERCIAL AND INDUSTRIAL TIME-OF-USE RATE SCHEDULE

COMPANY DESIGNATION: 63/65

POINT OF DIVISION OF EQUIPMENT OWNERSHIP:

The location of the Company's metering equipment shall constitute the point of division of equipment ownership between the Company and the Customer unless the Company, at its option, agrees to a different location. For all primary metered Customers, the Customer will own all primary equipment and all required step down transformation beyond the location of the Company's metering equipment. The Customer will be required to build and maintain their primary system according to the Company's standards, coordination of fusing and other operating requirements to protect the integrity of both systems. The Company will provide appropriate standards for each individual Customer upon request.

METERING:

The Customer will be required to make all necessary provisions to take total service requirements through one meter at one metering location. The Company may, at its option and for its convenience, meter the Customer's total service with two or more meters at different locations. When the Company elects to do so, the consumption of all meters will be added together for billing purposes and be billed to the Customer as one account. Two or more meters may be added together for billing purposes only when the facilities on the Customer's side of the meters are physically interconnected such that all business activities in those facilities are dependent upon simultaneous service from all of the applicable meters, or consist of functions that are an integral part of a single business operation. Common ownership of facilities will not be considered sufficient reason, in and of itself, for coincidental billing of two or more fully functional but separately located business units.

SUSPENSION OF SERVICE:

If the Customer requests service to be reconnected less than 12 months after suspension, the minimum billing demand as described above (*see* Section BILLING DEMAND,) shall be retroactively billed, as though the Customer were active for each month, to the date of suspension.

DURATION:

Customers shall contract for service under this rate with the Company, in writing if required by the Company, for an initial term of not less than one year.

EFFECTIVE: On Bills Rendered on or after April 1, 2016
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# APPENDIX B: ENERGY BALANCE

| Facility: Brattleboro WWTF | | | | | |
|---|---|---|---|---|---|
| **Existing Equipment** | **Hp** | **Estimated Load** | **kW** | **2016 Annual Estimated hours** | **Existing kWh** |
| | | | | | |
| **Septage** | | | | | |
| Septage Receiving Station | 2.0 | 0.80 | 1.19 | 196 | 234 |
| Septage Grinder | 3.0 | 0.80 | 1.79 | 196 | 351 |
| Septage Pump #1 | 5.0 | 0.80 | 2.98 | 50 | 149 |
| Septage Pump #2 | 5.0 | 0.80 | 2.98 | 50 | 149 |
| Septage Blower #1 | 5.0 | 0.50 | 1.87 | 2584 | 4,819 |
| Septage Blower #2 | 5.0 | 0.50 | 1.87 | 2825 | 5,269 |
| Septage Odor Control Fan #1 | 2.0 | 0.70 | 1.04 | 4380 | 4,574 |
| Septage Odor Control Fan #2 | 2.0 | 0.70 | 1.04 | 4380 | 4,574 |
| | | | | | |
| | | | **8** | | **20,120** |
| **Preliminary Treatment** | | | | | |
| Fine Screen | 3.00 | 0.80 | 1.79 | 321 | 575 |
| Grit Chamber Drive | 1.00 | 0.80 | 0.60 | 8742 | 5,217 |
| Grit Classifier | 1.00 | 0.80 | 0.60 | 1303 | 778 |
| Grit Pump | 15.00 | 0.80 | 8.95 | 1196 | 10,707 |
| Screenings/Grit Conveyor | 3.00 | 0.80 | 1.79 | 2047 | 3,665 |
| | | | | | |
| | | | **11** | | **20,941** |
| **Influent Pumps** | | | | | |
| Influent Pump 1 | 35.0 | 0.25 | 6.53 | 2214 | 14,452 |
| Influent Pump 2 | 35.0 | 0.25 | 6.53 | 2148 | 14,021 |
| Influent Pump 3 | 35.0 | 0.25 | 6.53 | 2123 | 13,858 |
| Influent Pump 4 | 35.0 | 0.25 | 6.53 | 2151 | 14,041 |
| Riverside PS Pump #1 | 5.0 | 0.50 | 1.87 | 379 | 707 |
| Riverside PS Pump #2 | 5.0 | 0.50 | 1.87 | 283 | 528 |
| | | | | | |
| | | | **15** | | **57,606** |
| **Primary Clarifiers** | | | | | |
| Primary Clarifier Drive #1 | 0.50 | 0.80 | 0.30 | 8760 | 2,614 |
| Primary Clarifier Drive #2 | 0.50 | 0.80 | 0.30 | 6000 | 1,790 |
| Primary Sludge/Scum Pump #1 | 5.0 | 0.80 | 2.98 | 238 | 710 |
| Primary Sludge/Scum Pump #2 | 5.0 | 0.80 | 2.98 | 247 | 737 |
| Primary Sludge Grinder | 3.0 | 0.80 | 1.79 | 995 | 1,781 |
| | | | | | |
| | | | **5** | | **5,852** |
| **Fixed Film Selector** | | | | | |
| Blower #1 | 25.00 | 0.60 | 11.19 | 252 | 2,820 |
| Blower #2 | 25.00 | 0.60 | 11.19 | 967 | 10,821 |
| Blower #3 | 25.00 | 0.60 | 11.19 | 1593 | 17,826 |
| Recycle Pump #1 | 20.00 | 0.40 | 5.97 | 866 | 5,168 |
| Recycle Pump #2 | 20.00 | 0.40 | 5.97 | 1982 | 11,829 |
| Mixer #1 | 6.10 | 0.70 | 3.19 | 193 | 615 |
| Mixer #2 | 6.10 | 0.70 | 3.19 | 6 | 19 |
| Air Sparger Compressor | 5.00 | 0.70 | 2.61 | 300 | 783 |
| | | | | | |
| | | | **20** | | **49,880** |
| **RBCs** | | | | | |
| RBC 1E | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 2E | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 3E | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 4E | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 5E | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 6E | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 7E | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 8E | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 9E | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 10E | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 1W | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 2W | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 3W | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 4W | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 5W | 5.0 | 0.55 | 2.05 | 8760 | 17,971 |
| RBC 6W | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 7W | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 8W | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 9W | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| RBC 10W | 5.0 | 0.55 | 2.05 | 7300 | 14,976 |
| | | | | | |
| | | | **35** | | **329,471** |
| **Secondary Clarifiers and Waste Pumps** | | | | | |
| East Secondary Clarifier Drive | 0.50 | 0.80 | 0.30 | 8760 | 2,614 |
| West Secondary Clarifier Drive | 0.50 | 0.80 | 0.30 | 6000 | 1,790 |
| Secondary Sludge Pump #1 | 3.00 | 0.60 | 1.34 | 3120 | 4,190 |
| Secondary Sludge Pump #2 | 3.00 | 0.60 | 1.34 | 3325 | 4,465 |
| | | | | | |
| | | | **4** | | **13,059** |

| | | | | | |
|---|---|---|---|---|---|
| **Sludge Digesters** | | | | | |
| | | | | | |
| **Pre Feed Sequencing Tank** | | | | | |
| Pump 1 A | 7.5 | 0.60 | 3.36 | 500 | 1,679 |
| Pump 1 B | 7.5 | 0.60 | 3.36 | 466 | 1,564 |
| Grinder | 5.0 | 0.30 | 1.12 | 966 | 1,081 |
| Heat Exchanger | | | | | |
| **Feed Sequencing Tank** | | | | | |
| Pump 2 A | 7.5 | 0.60 | 3.36 | 0 | 0 |
| Pump 2 B | 7.5 | 0.60 | 3.36 | 0 | 0 |
| Heat Exchanger | | | | | |
| Heating Tank | | | | | |
| **Thermophilic Digester** | | | | | |
| Thermophilic Digester Compressor | 10.0 | 0.50 | 3.73 | 1849 | 6,897 |
| Cannon Mixer | | | | | |
| Heating Jacket | | | | | |
| Pump 3 A | 7.5 | 0.60 | 3.36 | 481 | 1,615 |
| Pump 3 B | 7.5 | 0.60 | 3.36 | 487 | 1,635 |
| Grinder | 5.0 | 0.30 | 1.12 | 968 | 1,083 |
| Heat Recovery Exchanger | | | | | |
| Cooling Exchanger (using PW) | | | | | |
| **Mesohilic Digester #1** | | | | | |
| Mesohilic Digester #1 Compressor | 15.0 | 0.50 | 5.60 | 0 | 0 |
| Cannon Mixer | | | | | |
| Heating Jacket | | | | | |
| **Mesohilic Digester #2** | | | | | |
| Mesohilic Digester #2 Compressor | 15.0 | 0.50 | 5.60 | 1285 | 7,190 |
| Cannon Mixer#1 | | | | | |
| Heating Jacket | | | | | |
| Cannon Mixer#2 | | | | | |
| Heating Jacket | | | | | |
| Cannon Mixer#3 | | | | | |
| Heating Jacket | | | | | |
| Pump 4 A | 7.5 | 0.60 | 3.36 | 300 | 1,007 |
| Pump 4 B | 7.5 | 0.60 | 3.36 | 300 | 1,007 |
| **Digester Gas/Microturbine System** | | | | | |
| Gas Conditioner Skid | 1.5 | 0.70 | 0.78 | 0 | 0 |
| Gas Booster #1 | 1.5 | 0.70 | 0.78 | 0 | 0 |
| Gas Booster #2 | 1.5 | 0.70 | 0.78 | 0 | 0 |
| Gas Treatment Blower | 5.0 | 0.70 | 2.61 | 0 | 0 |
| Gas Treatment Compressor | 10.0 | 0.70 | 5.22 | 0 | 0 |
| Chiller | 10.0 | 0.70 | 5.22 | 0 | |
| | | | | | |
| | | | **25** | | **24,757** |
| **Sludge Storage/Dewatering** | | | | | |
| Sludge Storage Mixer | 20.0 | 0.60 | 8.95 | 8127 | 72,753 |
| Rotary Press Feed Pump #1 | 5.0 | 0.50 | 1.87 | 1153 | 2,150 |
| Grinder #1 | 3.0 | 0.50 | 1.12 | 1153 | 1,290 |
| Rotary Press Feed Pump #2 | 5.0 | 0.50 | 1.87 | 1255 | 2,341 |
| Grinder #2 | 3.0 | 0.50 | 1.12 | 1255 | 1,404 |
| RSP Floc Tank #1 | 2.0 | 0.50 | 0.75 | 1153 | 860 |
| Rotary Press #1 | 15.0 | 0.50 | 5.60 | 1153 | 6,451 |
| RSP Floc Tank #2 | 2.0 | 0.50 | 0.75 | 1255 | 936 |
| Rotary Press #2 | 15.0 | 0.50 | 5.60 | 1255 | 7,022 |
| Dry Polymer Screw | 0.8 | 0.50 | 0.28 | 1255 | 351 |
| Conveyor Blower | 2.5 | 0.50 | 0.93 | 1255 | 1,170 |
| Polymer Pump #1 | 0.5 | 0.50 | 0.19 | 1153 | 215 |
| Polymer Pump #2 | 0.5 | 0.50 | 0.19 | 1255 | 234 |
| Polymer Mixer | 0.8 | 0.50 | 0.30 | 1255 | 374 |
| Sludge Conveyor #1 | 3.0 | 0.50 | 1.12 | 1255 | 1,404 |
| Sludge Conveyor #2 | 3.0 | 0.50 | 1.12 | 1255 | 1,404 |
| Pump Gallery Odor Control Fan #1 | 2.0 | 0.50 | 0.75 | 2000 | 1,492 |
| Pump Gallery Odor Control Fan #2 | 2.0 | 0.50 | 0.75 | 2000 | 1,492 |
| Sidestream Pump #1 | 3.0 | 0.50 | 1.12 | 104 | 116 |
| Sidestream Pump #2 | 3.0 | 0.50 | 1.12 | 114 | 128 |
| | | | | | |
| | | | **15** | | **103,589** |
| **Plant Water, Disinfection & Misc Process** | | | | | |
| Hypo Pump #1 | 0.3 | 0.70 | 0.13 | 4380 | 572 |
| Hypo Pump #2 | 0.3 | 0.70 | 0.13 | 4380 | 572 |
| Hypo Pump #3 | 0.3 | 0.70 | 0.13 | 0 | 0 |
| Hypo Pump #4 | 0.3 | 0.70 | 0.13 | 0 | 0 |
| Flash Mixer | 1.5 | 0.50 | 0.56 | 8648 | 4,839 |
| Caustic Pump #1 | 0.3 | 0.70 | 0.13 | 4380 | 572 |
| Caustic Pump #2 | 0.3 | 0.70 | 0.13 | 4380 | 572 |
| Caustic Pump #3 | 0.3 | 0.70 | 0.13 | 0 | 0 |
| Plant Water Pump #1 | 15.0 | 0.40 | 4.48 | 2984 | 13,356 |
| Plant Water Pump #2 | 15.0 | 0.40 | 4.48 | 2839 | 12,707 |
| Plant Water Pump #3 | 15.0 | 0.40 | 4.48 | 2923 | 13,083 |
| | | | | | |
| | | | **10** | | **46,273** |

| | | | | | |
|---|---|---|---|---|---|
| **Building Systems** | | | | | |
| | | | | | |
| Boiler #1 | | | 1.00 | 4500 | 4,500 |
| Boiler #2 | | | 1.00 | 300 | 300 |
| | | | | | |
| Control Bldg Heat Pump HP-4 | | | 0.70 | 4380 | 3,066 |
| Control Bldg Heat Pump HP-5 | | | 0.60 | 4380 | 2,628 |
| Control Bldg Heat Pump HP-6 | | | 0.70 | 4380 | 3,066 |
| Control Bldg Heat Pump HP-7 | | | 1.00 | 4380 | 4,380 |
| Control Bldg Heat Pump HP-8 | | | 1.00 | 4380 | 4,380 |
| Control Bldg Heat Pump HP-9 | | | 1.00 | 4380 | 4,380 |
| Control Bldg Heat Pump HP-10 | | | 2.30 | 4380 | 10,074 |
| Control Bldg Heat Pump HP-11 | | | 1.00 | 4380 | 4,380 |
| Control Bldg Heat Pump HP-12 | | | 1.00 | 4380 | 4,380 |
| Control Bldg ERU-2 Supply | 0.7 | 0.50 | 0.26 | 0 | 0 |
| Control Bldg ERU-2 Exhaust | 0.7 | 0.50 | 0.26 | 0 | 0 |
| | | | | | |
| HDWRKS HRU-1 Supply | 5.0 | 0.50 | 1.87 | 0 | 0 |
| HDWRKS HRU-1 Exhaust | 5.0 | 0.50 | 1.87 | 0 | 0 |
| HDWRKS ERU-1 Supply | 1.5 | 0.50 | 0.56 | 0 | 0 |
| HDWRKS ERU-1 Exhaust | 1.5 | 0.50 | 0.56 | 0 | 0 |
| HDWRKS EX Fan #1 | 2.0 | 0.50 | 0.75 | 0 | 0 |
| | | | | | |
| Pump Gallery ERU-3 Supply | 1.0 | 0.50 | 0.37 | 8760 | 3,267 |
| Pump Gallery ERU-3 Exhaust | 1.5 | 0.50 | 0.56 | 8760 | 4,901 |
| Pump Gallery SF-7 | 0.5 | 0.50 | 0.19 | 0 | 0 |
| Pump Gallery Heat Pump HP-13 | | | 1.7 | 4380 | 7,446 |
| | | | | | |
| | | | | | |
| Digester Bldg CAF-1 Boiler Room | 2.0 | 0.40 | 0.60 | 0 | 0 |
| Digester Bldg CAF-2 Cogen Room | 2.0 | 0.40 | 0.60 | 0 | 0 |
| Digester Bldg EF-11 Cogen Room | 0.5 | 0.40 | 0.15 | 0 | 0 |
| Digester Bldg EF-12 Boiler Room | 0.5 | 0.40 | 0.15 | 0 | 0 |
| Digester Bldg Elect Room FCU-3 | 0.5 | 0.40 | 0.15 | 500 | 75 |
| Digester Bldg Elect Room EF-10 | 0.5 | 0.40 | 0.15 | 0 | 0 |
| Digester Bldg Fan SF-3 | 0.5 | 0.40 | 0.15 | 0 | 0 |
| Digester Bldg Fan SF-4 | 3.0 | 0.40 | 0.90 | 0 | 0 |
| Digester Bldg Fan SF-5 | 3.0 | 0.40 | 0.90 | 0 | 0 |
| Digester Bldg Control Room SF-6 | 0.5 | 0.40 | 0.15 | 0 | 0 |
| Digester Bldg Fan EF-16 | 2.0 | 0.40 | 0.60 | 0 | 0 |
| Digester Bldg Fan EF-17 | 2.0 | 0.40 | 0.60 | 0 | 0 |
| Digester HW Pump 5 | 7.5 | 0.40 | 2.24 | 4416 | 9,883 |
| Digester HW Pump 6 | 7.5 | 0.40 | 2.24 | 4341 | 9,715 |
| Digester HW Pump 7 | 7.5 | 0.40 | 2.24 | 4389 | 9,823 |
| Digester HW Pump 8 | 7.5 | 0.40 | 2.24 | 4366 | 9,771 |
| Digester HW Pump 9 | 1.5 | 0.40 | 0.45 | 4235 | 1,896 |
| Digester HW Pump 10 | 1.5 | 0.40 | 0.45 | 4258 | 1,906 |
| Digester HW Pump 11 | 2.0 | 0.40 | 0.60 | 170 | 101 |
| Digester HW Pump 12 | 2.0 | 0.40 | 0.60 | 0 | 0 |
| Digester HW Pump 13 | 2.0 | 0.40 | 0.60 | 742 | 443 |
| Digester HW Pump 14 | 2.0 | 0.40 | 0.60 | 0 | 0 |
| Digester HW Pump 15 | 5.0 | 0.40 | 1.49 | 601 | 897 |
| Digester HW Pump 16 | 5.0 | 0.40 | 1.49 | 329 | 491 |
| | | | | | |
| Microturbine Heat Recovery Unit Pump #3 | 3.0 | 0.50 | 1.12 | 0 | 0 |
| | | | | | |
| RBC Valve Vault Htr | | | 2.6 | 1500 | 3,900 |
| | | | | | |
| Gas Treatment Room SF-3 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| Gas Treatment Room EF-13 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| | | | | | |
| Dewater Bldg FCU-1 | 1.0 | 0.50 | 0.37 | 8760 | 3,267 |
| Dewater Bldg FCU-2 | 1.0 | 0.50 | 0.37 | 8760 | 3,267 |
| Dewater Bldg EF-6 | 0.5 | 0.50 | 0.19 | 0 | 0 |
| Dewater Bldg EF-7 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| Dewater Bldg EF-8 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| Dewater Bldg AHU-1 | 2.0 | 0.50 | 0.75 | 8760 | 6,535 |
| Dewater Bldg HRU-2 Supply | 3.0 | 0.20 | 0.45 | 0 | 0 |
| Dewater Bldg HRU-2 Exaust | 2.0 | 0.20 | 0.30 | 0 | 0 |
| | | | | | |
| Plant Water EF-15 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| Plant Water Unit Heater | | | 2.6 | 2500 | 6,500 |
| | | | | | |
| Chlorine EF-3 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| Chlorine EF-4 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| Chlorine EF-5 | 1.0 | 0.50 | 0.37 | 0 | 0 |
| Chlorine Bldg Storage Room HP-1 | | | 4.6 | 500 | 2,300 |
| Chlorine Bldg Storage Room HP-2 | | | 4.6 | 500 | 2,300 |
| Chlorine Bldg Electric Room HP-3 | | | 0.7 | 500 | 350 |
| Generator Block Heater | | | 1.5 | 500 | 750 |
| Lighting | | | 4.00 | 2300 | 9,200 |
| Outside Lights | | | 2.00 | 4380 | 8,760 |
| | | | | | |
| | | | **20** | | **153,278** |

| Plant System | Annual Energy Baseline (kWh) | | Total | kW | |
|---|---|---|---|---|---|
| Septage | 20,120 | | 2% | 8 | |
| Preliminary Treatment | 20,941 | | 3% | 11 | |
| Influent Pumping | 57,606 | | 7% | 15 | |
| Primary Clarifiers | 5,852 | | 1% | 5 | |
| Fixed Film Selector | 49,880 | | 6% | 20 | |
| RBCs | 329,471 | | 40% | 35 | |
| Secondary Clarifiers and Waste Pumps | 13,059 | | 2% | 4 | |
| Digesters | 24,757 | | 3% | 25 | |
| Sludge Storage & Dewatering | 103,589 | | 13% | 15 | |
| Plant Water & Chemical Systems | 46,273 | | 6% | 10 | |
| Building Systems | 153,278 | | 19% | 20 | |
| **Annual Total** | **824,826** | | **100%** | **168** | |
| **Annual Electric Use 2016 Data** | **881,937** | | | | |
| | 94% | | | | |

PROCESS ENERGY SERVICES, LLC

WATER ♦ WASTEWATER ♦ INDUSTRIAL