Benchmarking and Optimization for Reducing Energy Footprint

TEAM

Our utility driven partnership brings together many years of technical experience in real-time control of intelligent water systems.

Jeff Prevatt, Deputy Director, Pima County RWRD (Team Leader), has 25 years of experience in water utility operations, regulatory compliance and utility management. He is the leader for RWRD research and innovation and the creator of the Water, Energy & Sustainable Technology Center (WEST Center) in conjunction with the University of Arizona. jeff.prevatt@pima.gov

Allan Anthon, Maintenance Assistant Manager, Pima County RWRD (Electrical, Instrumentation and Controls), evaluating treatment operations, electrical energy usage and in-line instrumentation and controls. He has extensive background in optimizing equipment efficiency and energy usage. allan.anthon@pima.gov

Tim Mason, Process Optimization Program Manager, Pima County RWRD (Data Management and Process Optimization). As a previous Plant Manager, he has extensive knowledge of wastewater treatment operations, data collection and interpretation and assisting team members with the resources necessary to facilitate the project. timothy.mason@pima.gov

Dean Moulis, P.E. Technical Services Manager, Pima County RWRD, (Data Collection). He is a Civil Engineer with both process control and project management experience and is responsible for evaluating equipment operation and energy usage. dean.moulis@pima.gov

Larry Sawicki, P.E. SCADA Program Manager, Pima County RWRD, (SCADA System Programming). He is an Electrical/Control Systems Engineer with extensive expertise in systems integration and automation. His responsibilities include collection and retrieval of data from our data historian and programming code for process optimization. larry.sawicki@pima.gov

Barry Holbert, Program Manager, Pima County RWRD, (Continuous Improvement). He works with our intra-utility teams to develop key performance metrics and applies the Six-Sigma DMAIC process necessary for documenting data evaluation techniques and associated process implementations for achieving desired improvements. barry.holbert@pima.gov

PLAN

The goal was to build upon existing in-line data systems along with previous benchmarking studies to develop both and energy assessment footprint and an energy reduction roadmap for implementation at our eight wastewater reclamation facilities.

Problem Statement Electrical energy usage is a substantial operating cost and can often be the single largest expenditure, second only to labor costs for most utilities. In 2018, EPA estimated nationwide energy usage amongst water utilities at over 56 billion kilowatts annually with a combined cost of over $4 billion dollars. Like many utilities, RWRD continually seeks ways to minimize customer rate increases while optimizing operations therefore an effective energy management program is essential for reducing energy usage.

Despite having performed benchmarking audits and participation in the Department of Energy's Better Plants Challenge program, RWRD still struggles to develop a comprehensive energy reduction program. Our modern, SCADA operated facilities are capable of generating massive amounts of data usage yet progress has been slow because staff are often preoccupied with daily responsibilities and new projects continuously compete for available staff time.

A key component of this challenge is therefore a comprehensive data mining effort that includes:

- Monitoring data systems for documenting energy usage in 15-minute intervals for tracking kWh trends.
- Capturing major energy usage for aeration, pumping, lighting and HVAC.
- Correlating energy information with diurnal flow patterns, water quality and odor control efficiencies.
- A deep review of strategies for reducing energy footprint by 15% at our Tres Rios WRF.
- Creation of an energy assessment framework for reproduction at each all of our treatment facilities.

Characterization of the Intelligent Water System The Tres Rios WRF is a 50 MGD facility producing A+ reclaimed water and located in Tucson, AZ. The average annual energy expenditure for the Tres Rios WRF is $2.8 million with treatment systems relying heavily on automation and control using a variety of intelligent data systems including:

- 64 Allen Bradley programmable logic controllers (PLCs).
- A comprehensive systems control and data acquisition (SCADA) system by Wonderware.
- Over 790 in-line data sensors by HACH, YSI, E&H, ABB, S:CAN and others for monitoring process control parameters for achieving nutrient removal.
- 58 in-line Eaton power meters located at power distribution panels and motor control centers.
- Regulatory compliance data is generated daily from our in-house, licensed laboratory and compiled in an Element LIMS database by Promium.
- Real-time odor monitoring data is achieved via a network of 24 individual Envirosuite odor and hydrogen sulfide sensors located throughout the treatment processes at key process areas.

Data generated from these systems is compiled and stored in a data historian and is used to develop long term, and seasonal, data trends for energy usage. Average daily electrical power consumption at the Tres Rios WRF is 94 MWh with an average peak demand of 4.9 MW. Although supplemented by 1 MW of on-site solar, solar typically has its own unique diurnal pattern for power production affected both seasonally and daily with changing weather conditions. As a result, a 1 MW peak demand solar array producing 4.81 MWh of power an average 11 hour day generates only 0.44 MW of power production. Energy usage figures are captured in fifteen-minute intervals and correlated with water quality, diurnal flow patterns and odor control performance.

Plan The complexity of the Tres Rios WRF data sources required documenting historical energy usage for process functions followed by an intensive correlation with diurnal patterns, loadings, time of use, and demand charges. Understanding these conditions is necessary not only for tracking component kWh usage, but also necessary for understanding conditions incurring the greatest electrical demand charges. An assessment documented the process functional areas identified for improvements, which are responsible for the greatest electrical usage based on weekly totalizer readings.

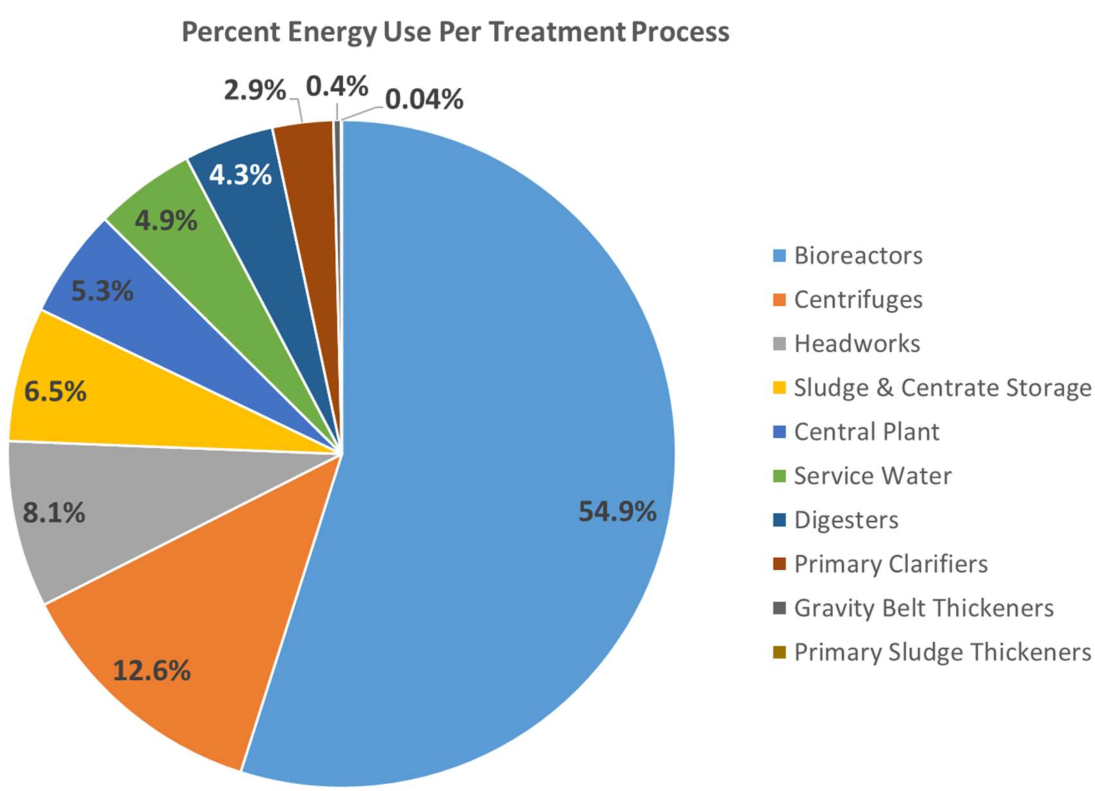
Function	Energy Usage
Aeration & Fans	45%
Pumping	25%
Mixing	20%
HVAC & Lighting	10%

Team members were assigned to functional areas for an in-depth evaluation and identification of fixtures, motors, pumps, controls and drives for evaluating energy reduction possibilities while taking into account both time of use considerations and peak demand charges. Grading of options used the following criteria.

- Compiled energy usage.
- Identification of key process areas for improvement.
- Prioritize improvements based on ease of implementation or greatest energy reduction.
- Improvement implementation strategy.

An implementation strategy was developed to achieve the greatest quantifiable energy reductions reflected in both kWh, and dollar savings. Areas selected to move forward were those offering the greatest return on investment and resulting ease of implementation receiving priority.

Because pumping, mixing, aeration, lighting and HVAC functions are features used at multiple locations throughout the treatment process, energy usage was further broken down to specific process areas attributed to these functions. Areas with the greatest power consumption were then chosen to move forward in the review process for strategizing improvements. The process areas identified for the greatest energy usage were as follows:



Our cross-functional process team then applied six-sigma continuous process improvement techniques to establish baseline metrics with respect to energy usage, diurnal patterns and time of use demand for realizing energy savings through conservation and initiatives that focus on:

- Converting lighting fixtures, motors, and drives where there are significantly more energy efficient alternatives.
- Evaluating process load patterns where excess capacity and opportunities to idle equipment exists.
- Implementation of process controls to improve operations and efficiency.
- Application of a calibrated process model and simulator for process optimization.

IMPLEMENT

The implementation strategy focuses on key processes with the highest energy usage throughout the treatment processes in an attempt to evaluate the greatest opportunities for return on investment.

Data and QA/QC Compiling totalized energy usage data as well as 15-minute intervals can generate substantial challenges. Several weeks were required to capture, understand and vet the data prior to strategy development. 15-minute increments energy usage figures were compared with real-time process data monitoring and SCADA control sequences were used for correlation with diurnal demands with respect to flow and nutrient removal. Data quality is continuously verified through multiple sub-panel metering. Process control data is continually validated against in-line sensor values and compliance data and measurements obtained from our certified laboratory.

Analysis & Interpretation Data analysis and interpretation required a thorough review of not only on-site energy usage, but also a comprehensive understanding of utility rate structures. Actual dollar amounts reflected on monthly energy statements are reflective of the quantity of electricity consumed over a period of time, time of use rates, and demand charges. Monthly demand charges are often based on the highest 15-minute peak usage for the month which can have substantial impacts on the utility rates paid.

Having 1MW of on-site solar adds additional complexity because the diurnal output for solar power production is not aligned with the peak diurnal power demand for treatment systems whose peak energy demands often occur in the evening hours, long after the sun has gone down. While solar can serve a beneficial role in daytime peak shaving, standby demand charges are still applicable for covering periods of inclement weather and solar maintenance activities.

Taking a holistic review of power usage and time of use throughout the treatment process, our team targeted the six functional categories of aeration, foul air fans, pumping, power factor correction, HVAC, service water usage and lighting as they favored the goals relating to ease of implementation and greatest gains. The results of these efforts are described as follows :

Aeration Blowers The Tres Rios WRF presently has two internal liquid treatment trains, east, and west. Each treatment train contains four aeration blowers, two rated at 1000 HP and two at 600 HP. Presently each aeration header operates independently with its own blower. Consideration has been given to combining the two separate aeration headers into one common aeration header to provide redundancy, operational flexibility and improved granularity of blower energy usage. During low flows, both basins could be operated from a single 1000 HP blower, instead of two independent 600 HP for a potential annual savings of $104,000.

Foul Air Fans Tres Rios WRF Tres Rios currently has 570.5 HP applied for continuous odor control systems across the facility. The annual energy value consumed by these fans at 0.083 $/kWh when operated per design is $325,000. Conversion to direct drives will result in a 5% improvement in fan efficiency, for a cost savings of approximately $16,250.$1

Optimizing odor control fans in a flow-proportional operation and controlled via variable frequency drives (VFDs), results in a 15% power savings of $48,750 annually along with increased service life of equipment.

Pumping Systems The Tres Rios WRF influent flow has a typical diurnal pattern and utilizes four Archimedes screw pumps located in the headworks with each screw rated for 32 MGD at 250 HP and drawing 186 kW of power with an annual power cost of $130,305 per screw. To accommodate peak diurnal flows operations staff currently place a second screw into service each day at 7:30 AM which operates for 18 hours or until the flow drops below 32 MGD which results in an additional cost of $97,820 per year.

Automating screw pump operation to track with a measured diurnal flow demand instead of an arbitrary schedule results in at least 5 hours of reduced operation each day and $27,146 in annual savings plus associated reductions in “wear and tear” maintenance costs.

Service Water Service water to the centrate header will be stopped completely to reduce pumping costs associated with this water equal to 250 GPM or approximately $14,450. The centrifuge building also utilizes a 25 HP booster pump to increase pressure. The energy savings resulting from not using this booster pump would be an additional savings of $2,440 per year.

Clarifier Spray-bar service water piping will be rerouted so that the spray-bars start in the center of the clarifier. This will allow two spray-heads remaining to break-up solids in the center ring. There are twelve spray-heads on each of the four clarifiers in operation at the West plant with each nozzle using 15 gpm. Savings on the reduction of 150 GPM will be approximately $8,670. On the East plant, there are currently fifteen spray-heads on each of the secondary clarifiers, each with 10 gpm nozzles. The savings on the reduction of 130 GPM on the East clarifiers will be approximately $7,520.

Prior to sending reclaimed water near the dead end of the service water system, the facility dumps service water into a manhole near the headworks of the plant to prevent solids build-up and stagnation of the service water. Although this discharge has been continuous and unmonitored for some time, this evaluation resulted in the discharge being reduced from 35 GPM to 5 GPM, for an approximated savings of $1,740.

Currently the plant uses a large pump to fill these trucks in five to ten minute intervals. The Klein tank will allow the service water to be loaded into the tank through the service water system, making the 60 HP pump obsolete. The team expects that filling the tank slowly over the course of 30 minutes by drawing water from the existing system will be much cheaper than rapidly filling with a large pump. Using the run time of the pump, it was estimated that the plant would save $6,310 by making the pump obsolete.

HVAC The HVAC systems have been integrated with a central server allowing remote monitoring and control optimization. Additional controls have been put in place for enthalpy controlled economizer dampers, CO_2 space monitoring, and most open valve control for offsetting the static pressure, heating and cooling setpoints. Programming changes to the electric chillers have allowed them to idle off during low demand while using the plants secondary loop as a heat sink for areas requiring cooling 24/7. Centralized controls have resulted in an annual electrical savings of $29,082.

Lighting Common lighting systems can consume a significant percentage of energy and create additional heat that must be handled by HVAC systems. Over the past few years, we have migrated from conventional to cold cathode fluorescent and high efficiency LED lighting systems.
The previous site lighting systems incurred an annual electrical cost of $35,025 plus maintenance fees for lamp replacement and crane/lift rental needed for access. The facility undertook a full review of a permanent retrofit of all high mast lighting and low mast lighting systems and these systems were upgraded to high efficiency LED lighting fixtures. This change resulted in an annual electrical savings of $21,624.

Power Factor Correction Power factors represent penalty charges typically applied to large utility systems to account for reactive power losses and the need for additional current. These penalties are easy to correct but necessitate the utility performing an audit of induction motors and loadings, and installation of capacitors to minimize the reactive power effects.

The Tres Rios WRF received a power correction charge of $97,268 annually, therefore a comprehensive audit of motors was conducted and it was decided to add an automated power factor correction capacitor bank at our 13.8kV distribution center. This will eliminate the penalty, resulting in a $97,268 annual savings.

Project Areas	Annual Electrical Costs				Cost to Implement
	Before	*After*	*Savings*		
Aeration Blowers	$1,070,478	$966,248	$104,230	9.7%	$661,300
Fans (direct drive conversion)	$325,000	$308,750	$16,250	5.0%	$523,173
Fans (VFD conversion)	$325,000	$276,250	$48,750	15.0%	$143,338
Screw pumps run time automation	$228,125	$200,979	$27,146	11.9%	$0
Service Water	$136,327	$95,186	$41,141	30.2%	$77,500
HVAC	$290,819	$261,737	$29,082	10.0%	$29,000
Lighting (low mast)	$7,781	$2,259	$5,522	71.0%	$56,250
Lighting (high mast)	$27,244	$11,143	$16,101	59.1%	$290,802
Power factor correction	$97,268	$0	$97,268	100.0%	$784,112
Total Plant Energy	$2,777,705	SAVINGS:	$385,490	13.9%	

Communication & Use As a result of these benchmarking and implementation measures, our team was able to develop a framework strategy for assessing energy usage and reducing the energy footprint at our Tres Rios WRF using the six-sigma continuous improvement methodologies. To make maximum use of this effort, the team is memorializing the audit and benchmarking process in the form of an *Energy Reduction Roadmap* for use at all wastewater utilities. An easy to use fillable spreadsheet is under development that includes formulas for calculating energy usage, cost, savings and return on investment along with guidance examples for reproduction by other utilities. We believe this tool will prove useful for the most novice of users to quickly benchmark their facilities and make informed decisions for reducing their energy usage.

The Solution The value of this work proved to be valuable on many levels including the following:

- It allowed our utility to perform a comprehensive audit of energy usage and explore multiple areas for reducing the energy footprint at our largest water reclamation facility.

- The collaborative team approach proved to be educational for team member understanding electrical power usage and associated electrical rates and the application of demand charges.
- The resulting Energy Reduction Roadmap will provide a template for reproducing savings at other WRFs.
- The resulting savings will help stabilize operational expenditures and offset future ratepayer increases.

This endeavor provided the perfect opportunity to leverage the value of our data systems and energy audits in a meaningful way. By bringing a team together to focus on an overall energy footprint, a greater understanding of system operations and opportunities for savings developed. The calculated savings performed by our team are conservative at 13.9% and implementation are underway.

We are still evaluating additional operational controls including ammonia based aeration control and nitrate based intermediate mixed liquor return for further reductions in aeration and mixing control as these represent approximately 60% of the energy consumed for greater savings. Given additional time and further evaluation, additional reductions are reasonably achievable.