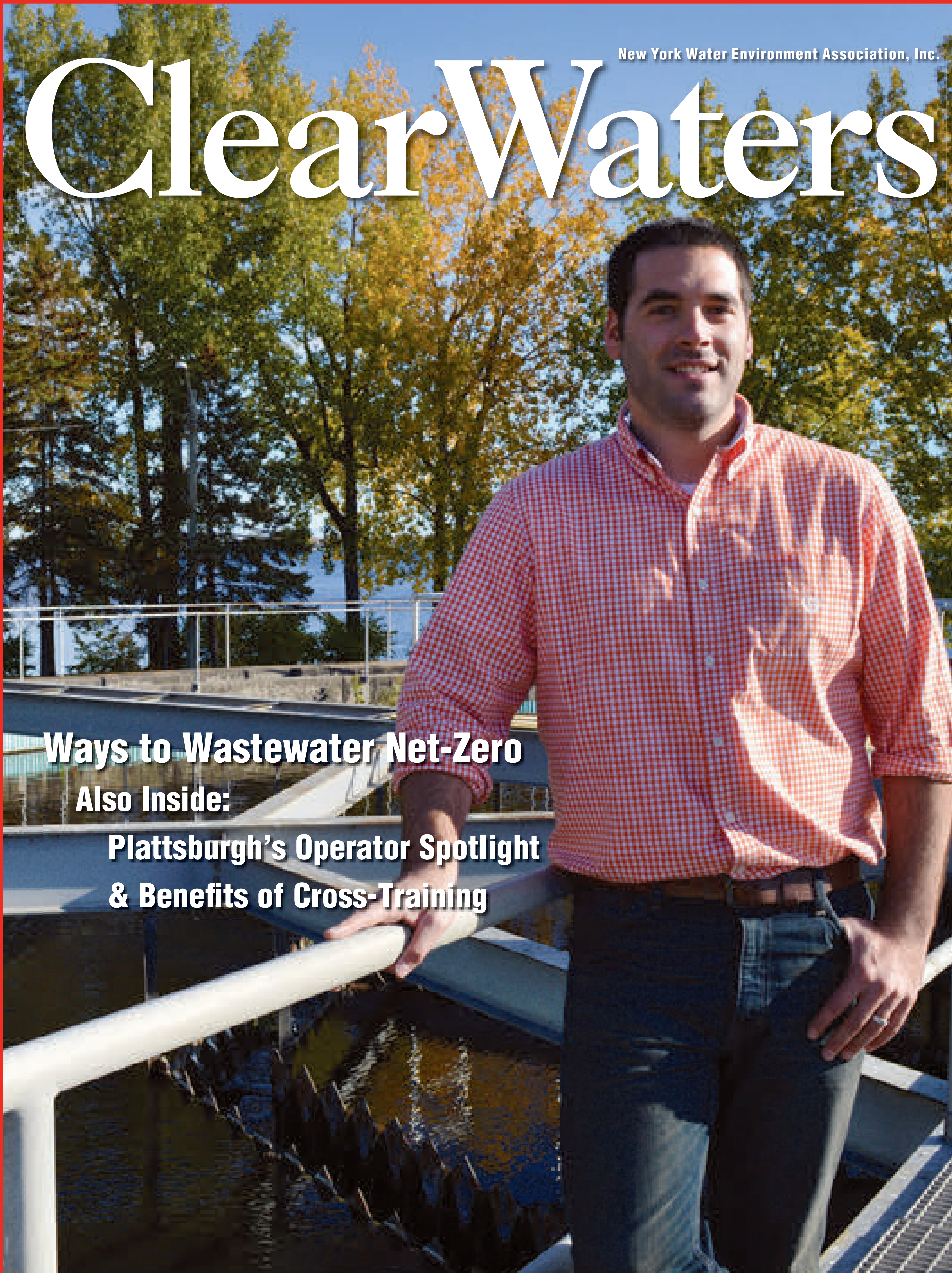
Winter 2015, Vol. 45, No. 4

New York Water Environment Association, Inc.

ClearWaters



Ways to Wastewater Net-Zero

Also Inside:

Plattsburgh's Operator Spotlight

& Benefits of Cross-Training

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Cover Image: Kristofer Gushlaw, assistant chief plant operator at the Plattsburgh Wastewater Treatment Plant with final clarifier and Lake Champlain in background
Photo by Sandra Geddes, City of Plattsburgh

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88th Annual Meeting

I am pleased the New York Water Environment Association's 88th Annual Meeting will celebrate the Year of the Operator! Back in February, it was my honor to declare 2015 as the Year of the Operator, so it seems only fitting to feature our year-long celebration of our dedicated and diverse water resource recovery operators! The Annual Meeting will be held in New York City at the popular Marriott Marquis in Times Square from Monday, February 8, through Wednesday, February 10, 2016.

Featured during the three-day conference will be 26 technical sessions on relevant topics, such as disinfection, ethics, environmental compliance and resiliency. Whether you need professional or operator credits or just want to learn more about hot topics in the water industry, you won't want to miss these technical offerings, the expansive exhibit hall and networking opportunities!

I am so appreciative of Joyette Tyler (chair) and Dave Barnes (co-chair) of the Conference Management Committee and their tireless efforts to plan what I expect to be a successful Annual Meeting. As part of the Opening Session, we will conduct an Operator Panel along with experts from New York State. I always look forward to Wednesday's Award Luncheon featuring deserving members and their notable contributions toward advancing our mission.

Please join us in the Big Apple for the largest water quality technical conference and exhibition in the state!

Year in Review

It seems like yesterday when I accepted the gavel from Past President and Water Ambassador Steve Fangmann at last year's Annual Meeting. I'm pleased with the forward progress that NYWEA has made and the worthwhile and memorable events we've all participated in throughout 2015.

I am so pleased that the Year of the Operator has resonated throughout NYWEA and beyond! I'm grateful for the work by the entire Operator of the Future Task Force led by Jonathan Ruff (City of Plattsburgh) and Bill Grandner (formerly NYCDEP). Their work will provide a useful resource for utilities throughout the state to attract new and retain existing operators in the water industry. We've kept our commitment to prominently feature operators, whether on the cover of NYWEA publications, at conference discussions or through new operator scholarships to celebrate and recognize their unwavering commitment and dedication to protect human health and the environment. Operators from the Plattsburgh plant are spotlighted on the cover and inside this edition. I hope we continue to make every year the Year of the Operator!

In April, we traveled to Capitol Hill continuing our annual tradition of advocacy on important issues that impact New York State water resource recovery utilities and the water environment. We carried our spirit of advocacy to state representatives at NYWEA's annual Legislative Dialogue in May which was well planned and well attended thanks to Boris Rukovets (Suffolk County) and members of the Government Affairs Committee.

May continued to be busy with back-to-back events from WEFMAX in Quebec City to the Spring Technical Conference at the Sagamore Resort on Lake George. It was an honor to share NYWEA's financial success with other Member Associations across North America as well as learn from their challenges and accomplishments. The Spring Meeting was a special event that began and ended with unbridled camaraderie and was filled with engaging panel discussions, technical sessions, networking events and a competitive Operations Challenge.

In July, we conducted a successful second CHAPEX event at the Otesaga in Cooperstown that strengthened the relationships and continuity of our seven state chapters followed by a meeting to conceive NYWEA's 2016-2020 Strategic Plan. I am very grateful for the time and effort by those who helped create NYWEA's five-year strategic road map!

WEFTEC in Chicago was an inspiring and memorable event in so many respects. I was very proud of our own Brown Tide Team from the Long Island Chapter who placed seventh overall in the Operators Challenge. Leadership Day gave me, Executive Director Patricia Cerro-Reehil and Tony Della Valle (Westchester County) the opportunity to present NYWEA's formula for financial success to other Member Associations. I was also honored to accompany Monroe County Executive Maggie Brooks who received WEF's Public Officials Award.

NYWEA continued building strong relationships with other agencies and associations in the water industry. I am pleased that NYWEA and the New York Section of AWWA will collaborate on our first joint Energy Specialty Conference in 2016. It was my pleasure to personally meet with Sabrina Ty, president and CEO of NYSEFC, as well as Tim Burns from NYSEFC who presented to our membership at the Spring Meeting and Watershed Conference.

In 2015, we created three very important Task Forces; namely, Operators of the Future, Disinfection, and Pre-Certification. I am grateful to Jon Ruff (City of Plattsburgh), Drew Smith (Monroe County) and Paul McGarvey (GHD) for chairing these Task Forces, respectively, and to those dedicated professionals who volunteered their time to address these important issues

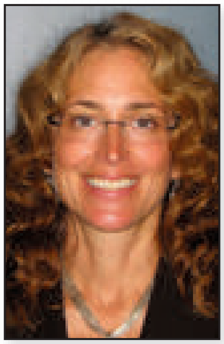
My Personal Thanks

I would like to extend a personal debt of gratitude to Past President and Water Ambassador Steve Fangmann for his guidance, support and friendship. Throughout the year, I have made many new friends and deepened existing relationships. NYWEA is blessed with so many dedicated, competent and enthusiastic members and volunteers. I am in awe of NYWEA's collective spirit of volunteerism and professionalism dedicated to improving the water quality environment. Thank you so much for all you do! I would also like to thank the Past Presidents, Executive Committee and the Board of Directors for their support during the year. We are a great team and will continue to accomplish great things!

A heartfelt thanks to Patricia Cerro-Reehil and to all of the executive staff for their exceptional daily efforts and steadfast support to make NYWEA the best it can be!

It will be my honor to pass the gavel at the Annual Meeting to the talented and capable President-Elect Joe Fiegl who I expect will hit the ground running to carry our mission forward!

Michael J. Garland, PE, NYWEA President



I recently visited with a cousin I don't see often. After catching up on family news, the conversation shifted to work. Jeff works at NASA and was sharing some of the challenges regarding energy efficiency and waste management for astronauts and space stations. I had just returned from the WEFTEC conference excited about the opening session and hearing both WEF President Ed McCormick and guest speaker Rob Stewart speak about the "water revolution" we are experiencing concerning the paradigm shift from traditional wastewater treatment plants to water resource recovery utilities. In sharing the opening session story with my cousin, there was an interesting synergy between the challenges in our industry and those of his at NASA. When the concept of shifting to "no waste in wastewater" came up, Jeff asked if I remembered the passage in *Les Miserables* (Chapter One), a book written in 1862, regarding waste recovery. That night I found and re-read the passage:

> *"Paris casts twenty-five millions yearly into the water. And this without metaphor. How, and in what manner? Day and night. With what object? With no object. With what intention? With no intention. Why? For no reason. By means of what organ? By means of its intestine. What is its intestine?*
>
> *The sewer.*
>
> *Twenty-five millions is the most moderate approximative figure which the valuations of special science have set upon it.*
>
> *Science, after having long groped about, now knows that the most fecundating and the most efficacious of fertilizers is human manure. The Chinese, let us confess it to our shame, knew it – before us. Not a Chinese peasant – it is Eckberg who says this – goes to town without bringing back with him, at the two extremities of his bamboo pole, two full buckets of what we designate as filth. Thanks to human dung, the earth in China is still as young as in the days of Abraham. Chinese wheat yields a hundredfold of the seed. There is no guano comparable in fertility with the detritus of a capital. A great city is the most mighty of dung-makers. Certain success would attend the experiment of employing the city to manure the plain. If our gold is manure, our manure, on the other hand, is gold.*
>
> *What is done with this golden manure? It is swept into the abyss.*
>
> *Fleets of vessels are despatched, at great expense, to collect the dung of petrels and penguins at the South Pole, and the incalculable element of opulence which we have on hand, we send to the sea. All the human and animal manure which the world wastes, restored to the land instead of being cast into the water, would suffice to nourish the world.*
>
> *Those heaps of filth at the gate-posts, those tumbrils of mud which jolt through the street by night, those terrible casks of the street department, those fetid drippings of subterranean mire, which the pavements hide from you – do you know what they are?*
>
> *They are the meadow in flower, the green grass, wild thyme, thyme and sage, they are game, they are cattle, they are the satisfied bellows of great oxen in the evening, they are perfumed hay, they are golden wheat, they are the bread on your table, they are the warm blood in your veins, they are health, they are joy, they are life. This is the will of that mysterious creation which is transformation on earth and transfiguration in – heaven.*
>
> *Restore this to the great crucible; your abundance will flow forth from it. The nutrition of the plains furnishes the nourishment of men.*
>
> *You have it in your power to lose this wealth, and to consider me ridiculous to boot.*
>
> *This will form the masterpiece of your ignorance."*
>
> ***– Victor Hugo***

At the beginning of this New Year, I thought it would be encouraging to share this conversation with my cousin and how Hugo's visionary passage turned our discussion of space, waste and efficiency into a timeless refrain – a poetic affirmation of almost everything we are doing in our industry today.

If you were not in attendance at WEFTEC, I encourage you to watch the videotaped portion of President McCormick's presentation on the Water Environment Federation's website or via YouTube. It can truly make you feel inspired and privileged to work in the water resource recovery field.

This issue of *Clear Waters* is the last for our editor of 10 years, Lois Hickey. I would like to extend my great appreciation of her dedication and working above and beyond to make our magazine the well respected industry publication that it has become. Please join me in wishing Lois all the best in her "next chapter" as she becomes a grandmother and enjoys new opportunities that the written word will provide her!

Plan Public Outreach Activities!

The theme of our summer edition will be Public Outreach. We would like to feature several stories about the public outreach activities your utility sponsors. Plan them now, invite local schools in for tours during the spring, submit a brief description of the activities, include photos and graphics and submit all by April 15th to the Executive Director at *pcr@nywea.org*.

Photo by Kim Buhl

Some members of Ithaca's wastewater treatment facility participated in costume for public outreach in a recent Ithaca spring parade.

Patricia Cerro-Reehil
pcr@nywea.org

Water Views | Winter 2015

Energy and Wastewater Treatment

Wastewater treatment facilities use approximately 1 to 1.5 percent of the state's energy to move and clean wastewater. Increasing energy efficiency at treatment plants, or obtaining needed energy from burning digester gas, can result in big savings in addition to cleaner air. So, reducing energy use at wastewater treatment plants has become a high priority for many municipalities.

Many operators have started with incremental changes to begin lowering energy bills and decreasing greenhouse gas emissions. For example, consistently replacing worn out equipment with more energy efficient models is a simple, yet effective, strategy. Another option is asset management and planning. The NYSDEC is encouraging municipalities to complete and implement asset management plans for their wastewater facilities that focus on energy efficiency, in addition to proper facility maintenance and resiliency in the face of extreme weather.

Facilities that want to reduce energy bills while limiting ratepayer costs have a number of resources they can turn to. The USEPA, for example, has developed a step-by-step workbook to help municipalities reduce energy use. You can access the workbook, plus other guidebooks, at *http://water.epa.gov/infrastructure/sustain/cutting_energy.cfm*.

The New York State Energy Research and Development Authority has the *Water and Wastewater Energy Management Best Practices Handbook* to provide information on effectively developing and implementing an energy conservation program at wastewater treatment facilities *(https://www.nyserda.ny.gov/-/media/Files/EERP/Commercial/Sector/Municipalities/water-wastewater-energy-management.pdf)*.

The NYSERDA guide includes short fact sheets on specific energy efficiency best management practices. There are approximately 50 best management practices applicable to wastewater treatment operations. The NYS Environmental Facilities Corporation uses NYSERDA's guidance to assist municipalities who pursue financial assistance through the Clean Water State Revolving Fund.

Anaerobic digestion (AD) is an option that some municipalities have implemented to condition bio-solids and produce methane and carbon dioxide for power generation. AD is a natural biological process where microorganisms break down biodegradable matter in the absence of oxygen. The AD process generates biogas that can be burned for heat and electricity.

Such operations can present opportunities to reduce energy costs and generate revenue by accepting, at a price, biodegradable waste. More than 130 of the state's wastewater treatment facilities have installed AD capacity, with many of the facilities beneficially using the biogas for heat and power. AD operations offset greenhouse gas emissions that would otherwise be associated with burning fossil fuels to heat and power these plants. NYSERDA has a number of resources on anaerobic digestion, achieving a net-zero wastewater treatment facility, and low-energy innovative treatment technologies to view at *http://www.nyserda.ny.gov/About/Publications/Research-and-Development-Technical-Reports/Water-and-Wastewater-Technical-Reports*.

Today just about everyone wants to save money and reduce greenhouse gas emissions. Improving energy efficiency at a wastewater treatment facility can save a community thousands of dollars. The NYSDEC encourages municipalities to use the resources available and make the changes because small incremental investments add up to big savings.

– James Tierney, Assistant Commissioner for Water Resources
NYS Department of Environmental Conservation

Focus on Safety | Winter 2015

Working on our Night Moves

One summer in high school, I worked the night shift. I didn't know when to sleep or get up, what meal to have or when to have it. I went to work tired and drove home more tired. All my friends had day jobs. I slept in the cellar and was more miserable than the usual teenager should have been.

Shiftwork has become a more standard practice. It has essentially become "easier" to have a shiftwork business place. We have become a 24-hour service society. Not only do we need to fill up the tank, get coffee and buy groceries at any hour we choose, we must run and maintain vital critical services 24/7. No longer is it acceptable to perform maintenance on a utility system during the day, it needs to be in the middle of a Saturday night so as not to inconvenience anyone. It's either calling in workers to perform these critical repairs on their days off during the wee hours, or waiting for the (probably rotating) night shift. What could be the harm?

Humans are, for the most part, daytime creatures. This is because of internal circadian rhythms that determine our times to sleep and those to be awake and alert. Working contrary to the rhythms causes increased sleepiness, decreased concentration and fatigue. Fatigue then decreases performance and increases the probability of error and safety incidents. Some recent significant industrial accidents have occurred during midnight to 4 am. We all have heard of them – Chernobyl, Bhopal, Exxon Valdez, and Three Mile Island – all happened either on an off shift or during extended work hours with sleep deprivation as an implicating factor. There have most certainly been innumerable smaller incidents that did not make it into the headlines – a valve forgotten, a breaker not flipped, a tool dropped, a brake not set. Also consider the effects of sleepiness and fatigue on the worker's drive home. Too often, workers on call-ins or off shifts have difficulty staying awake behind the wheel while traveling home. Others are sharing that same, now dangerous road.

Actions can be taken by both the individual worker and management to mitigate sleep deprivation and fatigue. The night worker should make sure that the time to sleep is as dark and quiet as possible, avoiding caffeine and alcohol for several hours before bed; and on days off, try to sleep about four hours overlapping the night shift sleep period. Management of those shifts is just as important. Decisions about the timing of breaks, variation of activities, the amount of physical labor, permanent or rotating schedules, forward or backward rotation, fast or slow rotation, start times, shift durations, and breaks between shifts -– all have impact. These decisions and actions of individuals and organizations will ultimately contribute to performance and safety. Make our night moves more safe!

– Eileen M. Reynolds, Certified Safety Professional
Owner, Coracle Safety Management

Monitoring Energy Performance of New York's Wastewater Treatment Facilities

by Nancy Andrews, John Willis, Diane Nascimento, Kathleen O'Connor, Colin O'Brien and Lauren Fillmore

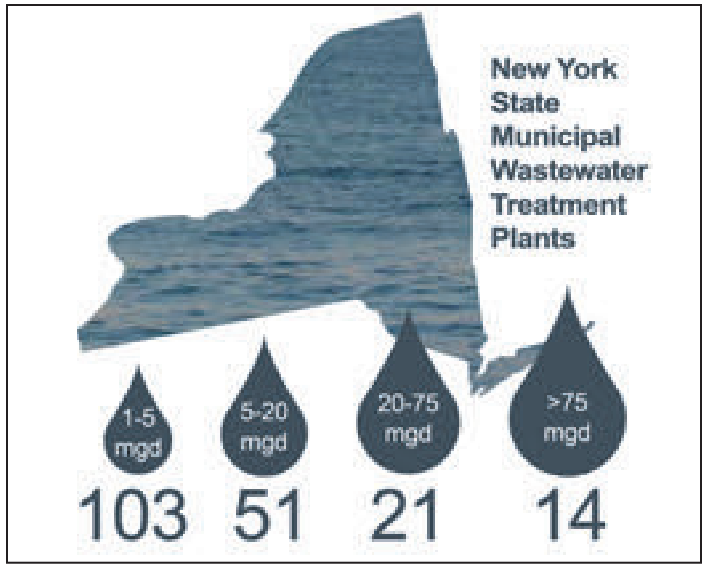
Over the past decade, energy efficiency and onsite energy generation has become an increasingly high priority shared by wastewater utilities across the United States. Although progress in reducing energy use is being made by many, it is clear that these efforts are pushing against many challenges. The Water Environment Research Foundation's (WERF) 2015 study of successful energy programs *(Barriers to Energy Efficiency and Solutions to Promote These Practices)* identified the top barriers to optimizing a wastewater facility's energy performance. They included competing organizational priorities, financial feasibility, missed opportunities to leverage asset management replacement cycles for efficiency improvement, and unreliable process control and performance increasing the perceived need for a "margin of safety" in operating conditions that may restrict energy optimization.

Gaining New Insight

The New York State Energy Research and Development Authority (NYSERDA) is gaining new insight on the current trends in energy position of New York State's water resource recovery facilities (WRRFs). In 2008, NYSERDA published the "Statewide Assessment of Energy Use by the Municipal Water and Wastewater Sector," documenting 2003/2004 energy use at New York State wastewater facilities. Since the publication of these data, interest in energy efficiency and energy generation has grown considerably. At the same time, regulatory and technology changes, such as tighter nutrient limits, have added to many plants' electrical demands.

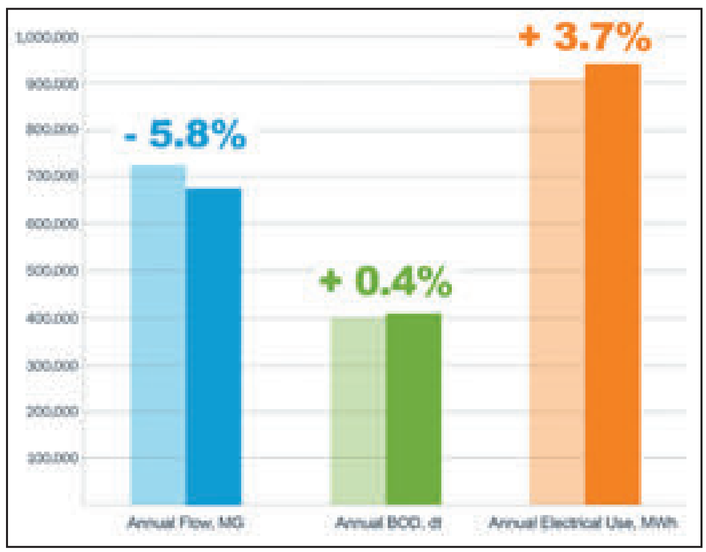
Courtesy of Brown and Caldwell

New research conducted by NYSERDA aims to understand the net effect of competing factors driving energy use at the state's water resource recovery facilities, including nutrient removal, ultraviolet, aging equipment, cogeneration, and co-digestion.



Courtesy of Brown and Caldwell

Nearly 95 percent of New York's citizens are served by a public water supply and treatment system, including 189 WRRFs with a treatment capacity greater than 1 mgd. These plants have a combined design treatment capacity of 3.7 billion gallons per day and are currently treating 2.2 billion gallons per day, consuming an estimated 1.2 MWh per year of electricity in the process.



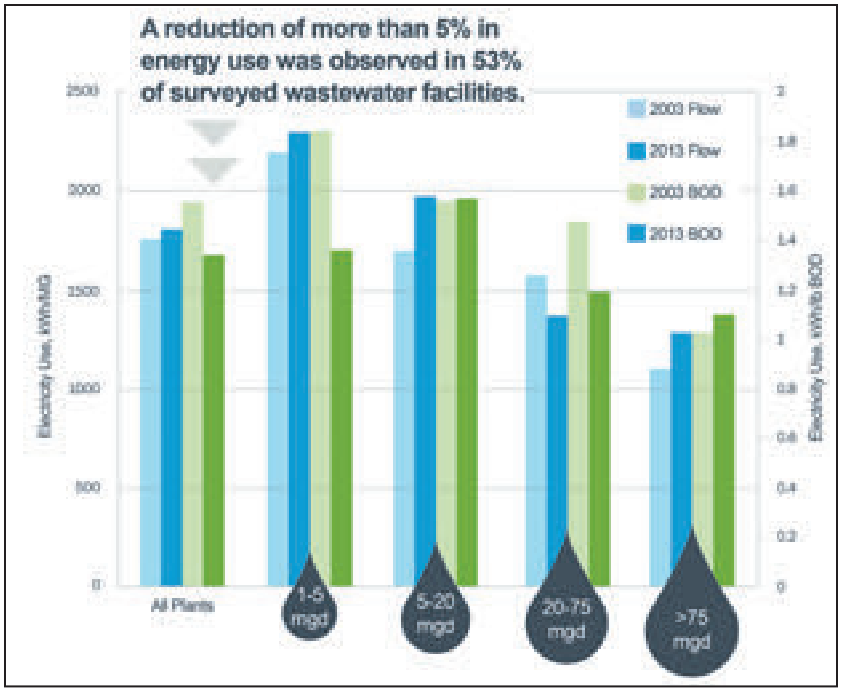
Courtesy of Brown and Caldwell

New York's energy use for wastewater treatment is increasing despite lower flows and nearly level BOD loads, driven largely by increasing energy use at several large WRRFs (comparison of plants with both 2003/2004 and 2012/2013 data).

Recently completed research assesses the magnitude of energy performance shifts over the past 10 years based on the net effect of operations, maintenance, and process changes to improve energy efficiency and permit changes such as increased nutrient removal requirements. The assessment compares trends in flow- and load-normalized energy use for various plant size ranges, process changes impacting energy use, and onsite energy generation. The research also explored the impact of organizational initiatives such as energy benchmarking, energy audits, goal setting, energy use tracking, and internal and external communications.

The NYSERDA research team obtained data on 2012 and 2013 energy use and plant loading conditions for New York State facilities with a design capacity of 1 million gallons per day (mgd) and larger. Two years of annualized electrical consumption in kilowatt hours (kWh), plant flow (mgd), and influent organic loading (pounds of biochemical oxygen demand per day, or lb BOD/d) data were used to calculate flow- and load-normalized energy use.

Study results show a general trend of increased flow-normalized power on a plant-by-plant basis due in part to reductions in wastewater flow associated with infiltration and inflow (I/I) and contin-



On a plant-by-plant basis, BOD-load-normalized power consumption has reduced slightly, primarily through gains made at small and medium WRRFs.

Courtesy of Brown and Caldwell

ued deployment of water efficient plumbing fixtures. Conversely, the BOD-load-normalized power consumption has been reduced slightly, primarily through gains made at small (less than 5 mgd) and medium to large (20–75 mgd) WRRFs.

In facilities larger than 75 mgd, an overall trend toward increased average electrical energy consumption was observed, with recent implementation of nutrient removal being the most significant factor in this trend. Small and medium-sized facilities (less than 75 mgd) appear to be slightly improving their energy performance based on analysis of BOD-normalized energy metrics (kWh/lb of BOD).

While these benchmarks provide a useful starting point for monitoring energy use, specific plant treatment configurations, differing solids handling approaches, and energy-intensive ancillary equipment will drive individual facility energy use higher or lower than estimated industry averages.

Several trends emerged in the data analysis, as listed next, including factors placing upward pressure on energy use *(indicated by upward arrows)* and circumstances leading to reductions in purchased energy *(downward arrows)*.

- ↑ **Nutrient Removal:** Like many treatment facilities across the United States, many of New York's plants have seen increasingly stringent permit limits for nitrogen and phosphorus. Today, 63 percent of New York's WRRFs have tertiary treatment compared to only 25 percent in 2003. Nearly half of survey respondents reported a permit requirement to nitrify, with a similar number required to remove phosphorus. Over a quarter of respondents indicated that their nutrient removal requirement had changed in the last 10 years. While providing significant benefits to the WRRF's watershed, these increasing nutrient standards have triggered significant plant modifications, resulting in notable increases in energy consumption at several large plants. Both the stoichiometric oxygen requirements for nitrification and the additional capacity and infrastructure required for biological nutrient removal have had a major effect on energy intensity in New York plants in recent years.
- ↑ **Plants Operating Below Capacity:** More than 100 of New York's 189 WRRFs larger than 1 mgd have experienced double-digit percentage declines in flow over the past 10 years, with more than 50 seeing declines greater than 20 percent. As plant loadings fall relative to design capacity, fixed electrical base loads push normalized energy use higher.
- ↓ **Organizational Energy Initiatives:** Organizational changes integrating energy efficiency into a wastewater utility's culture, such as those documented in the Water Environment Federation (WEF) Energy Roadmap publication, appear to increase rates of capital project implementation and operational optimization to reduce energy use. *(See also WERF publications on page 12.)*
- ↓ **Onsite Generation:** New onsite generation installations have grown slowly over the past 10 years, but a few plants have made significant progress in this area.

Taking Action

With energy efficiency a top priority and increasingly high demands on facility performance, many of New York's wastewater utilities are continuing to take action with capital projects to improve process efficiency, efforts to optimize operations, maintenance to maintain efficiency, and outside-the-fence-line efficiency approaches.

- **Capital Projects:** Lighting and heating, ventilation, and air conditioning (HVAC) energy projects are the most commonly reported type of energy efficiency project reported by survey respondents, with over 80 percent of respondents completing lighting improvement projects. While these conventional energy improvements provide a good starting point, improving aeration, blower, and pump efficiency will have a much larger impact on plant energy use. This type of project has been the focus of many plants (25 percent), but more opportunities clearly exist in this area. Energy generation is practiced by a minority of WRRFs in the state. Although the most common initiative in the past 10 years was biogas utilization, a significant number of wind and solar projects were also reported.
- **Operational Optimization to Reduce Energy:** A quarter of WRRFs reported optimizing operations to reduce energy use in existing treatment aeration and digestion systems. However, somewhat surprisingly, a majority of plants have not implemented automatic dissolved oxygen (DO) control despite potential energy savings and recent improvements in DO sensing technology reliability.
- **Maintenance to Maintain Efficiency:** Maintenance appears to be an underutilized method to improve WRRF plant energy performance. For example, only 30 WRRFs reported that they are performing regular diffuser cleaning and DO probe cleaning/calibration to proactively maintain energy efficiency.
- **Outside-the-Fence-Line Efficiency Approaches:** Many WRRFs are taking a broader view of energy efficiency by considering initiatives outside the plant boundaries that can reduce WRRF energy consumption or increase renewable energy use, sometimes in conjunction with achieving other treatment goals. For example, utilities implementing water conservation (or I/I reduction) can receive ancillary benefits from reduced pumping energy.

continued on page 10

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Courtesy of Brown and Caldwell

Over the past 10 years, the Hornell Water Pollution Control Plant's average daily flow rate decreased by 44 percent while BOD held steady. Electrical consumption increased by only 13 percent during this time, largely because the plant was not able to reduce equipment energy use commensurate with flow and load reductions. The city has a project, currently underway, to replace mechanical aerators with an ultra-fine bubble aeration system in order to meet the new nutrient requirements, as well as to contribute to its goal to reduce energy use by 33 percent.

Courtesy of NYCDEP

Located in southeastern Brooklyn, the 26th Ward Wastewater Treatment Plant has implemented BNR (nitrification and denitrification), significantly increasing the energy consumption associated with secondary treatment. Ongoing efforts have reduced electrical energy use by 7 percent since BNR implementation in 2006, and secondary treatment energy will be further reduced when a planned high-efficiency blower retrofit project is constructed.

Courtesy of Brown and Caldwell

The Jamestown, NY, wastewater treatment plant has significantly improved its energy efficiency over the last 10 years, reducing load-normalized energy use by 45 percent by decommissioning retired rotating biological contactors and upgrading the trickling filters (above).

Championing Organizational Change

Creating organizational cultures within wastewater utilities that support and foster energy initiatives is essential for a well-developed energy program. Established energy programs guide energy initiatives for 30 out of 83 surveyed WRRFs. The average size of New York's WRRFs with "well-developed" energy programs is considerably larger than the plants with undeveloped programs, perhaps because larger utilities may have more resources for pursuing energy efficiency on several organizational fronts.

The WEF Energy Roadmap publication *(WEF 2013)* established six interrelated energy management topic areas, and proposed a series of practical approaches and levels of progression to be used to prioritize actions to take toward energy sustainability. Many Roadmap approaches are under way at New York WRRFs, including energy audits to identify savings opportunities and partnerships with energy service companies (ESCOs) and electrical utilities. However, a national survey found a higher rate of energy teams and "Energy Champions" as compared to the New York State respondents, and a greater reliance on life-cycle costs to justify equipment with lower energy use.

Looking Ahead

Future improvements are planned across the state that will contribute to energy savings: plans are underway at 65 percent of the surveyed plants to improve energy efficiency at these facilities. Two of New York's wastewater utilities noted in their surveys that they have major WRRF efficiency projects currently in progress, and many others are planning general capital upgrades of aging, inefficient equipment.

Nancy Andrews is the Supervising Engineer – Biosolids at Brown and Caldwell in Saint Paul, MN (nandrews@brwncald.com). She is the project manager for the Water Environment Research Foundation (WERF) Barriers to Energy Efficiency project (see page 12) that supported the research described in this article. John Willis is Biosolids Engineer at Brown and Caldwell out of Atlanta, GA. Both Diane Nascimento and Colin O'Brien are wastewater engineers at Brown and Caldwell in Andover, MA. Kathleen O'Connor is Senior Project Manager for the New York State Energy Research and Development Authority in Albany, NY. Lauren Fillmore is Senior Program Director for WERF in Alexandria, VA.

See related article page 12

NYWEA
LEADING THE WAY IN WATER QUALITY MANAGEMENT

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WERF Research Inspires New Ways to Move Facilities to Net-Zero Energy Best Practices

Behind labor costs, energy is often the second highest operating cost at a water resource recovery facility (WRRF). Additionally, fossil fuels are the basis of most purchased energy, which contributes to a larger carbon footprint, as well as public health risks attributed to air pollution by the wastewater sector.

In recent years, the Water Environment Research Foundation (WERF), with collaboration by the New York State Energy Research and Development Authority (NYSERDA), is advancing knowledge and implementation of energy efficient best practices in the industry, moving WRRFs closer to achieving energy neutrality.

The October issue of the Water Environment Federation's *WE&T* featured a story by the research team for one of these recent studies: A Guide to Net-Zero Energy Solutions for Water Resource Recovery Facilities *(WERF Report No. ENER1C12)* and its companion report, Utility of the Future Energy Findings *(WERF Report No. ENER6C13)*.

Essentially, these research reports state that energy neutrality for the domestic wastewater industry is within reach, and the ENER1 project contributes greatly to the industry's understanding of the complexities, opportunities, and challenges that WRRFs face as they strive for energy neutrality. The research sought to aid WRRFs in moving toward "net-zero" energy use through near-at-hand practices and technologies in the areas of energy conservation, demand reduction, and enhanced production.

The researchers modeled 25 common process configurations at WRRFs and identified the pathway followed by those facilities to achieve energy neutrality. For each baseline configuration, the team developed a model and generated energy outputs displayed as energy-flow diagrams (also called "Sankey" diagrams). From this evaluation, the researchers found:

- Consistent use of best practices resulted in approximately 40 percent lower energy consumption than "typical" performance.
- Improving primary treatment and solids capture had the most significant total positive impact of all the best practices modeled.
- Significant savings in aeration blower electricity usage was achieved by reducing fouling in fine bubble diffusers through improved operation and maintenance procedures – a best practice that is often overlooked.
- Anaerobic digestion with combined heat and power (CHP) was the most advantageous approach to energy recovery, reducing energy requirements by up to 35 percent at WRRFs that have anaerobic digestion.
- Dewatered biosolids still retained a significant portion of the influent chemical energy, presenting opportunity for additional energy recovery

WERF and NYSERDA are demonstrating that conventional secondary treatment and nitrification facilities can become net-energy positive, although biological nutrient removal (BNR) and enhanced nutrient removal (ENR) facilities can only achieve as high as 50-60 percent energy neutrality. Energy positive plants, or those nearly so, can reduce their energy consumption significantly.

Managers, engineers, operators, and the engineering consultants for WRRFs who design upgrades and new facilities can identify the type of facility they operate, examine its process configuration against the Sankey (energy balance) diagrams included, and identify the design elements needed to become more energy efficient. Federal and local policymakers may find this research useful to define assistance or incentives appropriate for accelerating achievement of net-zero wastewater treatment.

WERF is developing a series of studies that can enable new ways of thinking about energy efficiency and recovery, and inspire and motivate WRRFs to consider approaches to move their facilities toward net-zero energy. Findings from these reports provide opportunities to save costs and enhance sustainability, as well as provide solutions to overcome obstacles common to energy projects. To tap into the reports listed, visit the WERF website at *http://www.werf.org/i/ka/Energy/a/ka/Energy.aspx?hkey=75126b7f-4ee8-4da4-9861-51233ef27600.*

This information was contributed by Carrie Capuco (ccapuco@wef.org), director of the Water Environment Research Foundation Office of Communications.

Project Title and Number	Research Focus
Triple-Bottom Line Evaluation of Biosolids Management Options (ENER1C12a)	Uses a TBL approach to evaluate common wastewater solids management technologies and processes relative to their potential for long-term sustainability, including energy neutrality.
Demonstrated Energy Neutrality Leadership: A Study of Five Champions of Change (ENER1C12b)	Documents the steps used by utility leaders at WRRFs close to energy neutrality and the lessons they learned to explain to readers what they achieved in terms of energy and other benefits, and how they accomplished it.
Identification of Barriers to Energy Efficiency and Solutions to Promote Those Practices (ENER7C13)	Uses a national survey of input on barriers from more than 110 wastewater service utilities, along with utility focus groups that captures detailed experiences regarding barriers to successful deployment of energy efficiency initiatives.
State of the Science and Issues Related to the Recovery of Heat from Wastewater (ENER10C13)	Evaluates the state of heat recovery from wastewater by examining the extent of its use, the performance of available technologies, and emerging economic, environmental, social and regulatory issues which could impact its use. Includes theoretical models to help guide utilities to develop heat-recovery projects.
WaterWatts: A Modern Look at Wastewater Power Metering Data (ENER15C15)	Includes a collection and analysis of dis-aggregated power metering data by process, at water resource recovery facilities, including BNR plants.

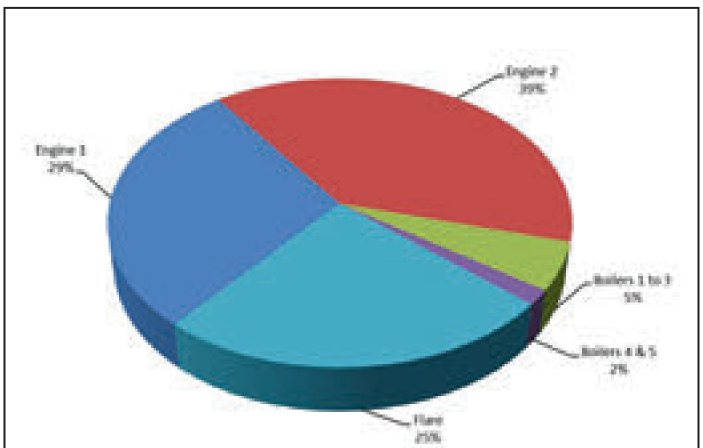
Biogas Generation at a Wastewater Treatment Plant for Vehicle Fuel or Cogeneration, or Both

by Jeremy Holland, Rick Shanley, Perry Sunderland and Bruce Cordon

Wastewater treatment plants around the country are exploring different uses of biogas generated from biosolids and sludge processing to lower the overall greenhouse gas footprint of their operations. Many facilities seek to become "energy neutral" by focusing on energy efficiency and the use of biogas for renewable power generation to achieve "net zero" electricity and fuel. As grid supplied electricity becomes cleaner where wind, solar, hydropower, nuclear or other renewable sources are abundant and price competitive, the use of biogas to displace grid power may not provide much of a greenhouse gas reduction. However, utilities can also offset diesel fuel used in vehicles with compressed natural gas derived from biogas as another approach to achieving greenhouse gas reduction goals. Considering the full range of offsets – and associated local incentives, conditions and prices – will provide utilities with better options for developing a business case for biogas projects. Clean Water Services, the water resources management utility in Hillsboro, Oregon, is in the midst of this very decision at its Rock Creek Advanced Wastewater Treatment Facility. The 39 mgd (million gallons per day) facility has existing cogeneration equipment and is in the early stages of developing a biogas-to-vehicle-fuel facility onsite.

Biogas Production

One of the first steps in consideration of a biogas use project is to determine how much gas is produced, how much is currently being used, and whether current uses will continue or whether a new use should be sized for all of the biogas produced. The Rock Creek facility generates approximately 400 cubic feet per minute of biogas. Cogeneration engines and hot water boilers use 75 percent of the gas, which is a very common practice at wastewater facilities. Use of biogas in boilers and engines is rarely sufficient to use all biogas generated onsite, so often a portion of gas continues to be flared, which is the case for 25 percent of the biogas at Rock Creek ***(Figure 1)***.



Courtesy of Clean Water Services

Figure 1. Breakdown of biogas use at Rock Creek Advanced Wastewater Treatment Facility. About 25 percent of biogas generated is currently flared, presenting an opportunity to increase beneficial use of this renewable resource.

Raw Biogas Composition

Along with understanding how much gas is available, it is also critical to understand the quality of the biogas. Raw biogas contains methane, carbon dioxide, nitrogen, and small amounts of other gases and contaminants. A typical wastewater treatment plant (WWTP) and Rock Creek raw biogas compositions are presented in ***Table 1***. Biogas sampling and analysis is always a challenge. Grab samples of biogas are a snapshot of gas conditions and may not present typical results. The more gas sampling that can be done the better to indicate actual conditions.

Table 1. Average and Sample Raw Biogas Compositions

Constituent	Units	Average WWTP Biogas	Rock Creek Facility Biogas
Methane (CH_4)	% v/v	55 to 65	60.2
Carbon Dioxide (CO_2)	% v/v	35 to 45	38.9
Nitrogen (N_2)	% v/v	0.1 to 1.0	0.5349
Oxygen (O_2)	% v/v	0.1 to.0.5	0.244
Hydrogen Sulfide (H_2S)	ppmV	50 to 1,000	58.8
Siloxanes	ppb	500 to 5,000	<10,000
Temperature	deg. F	~100	~100
Moisture		Saturated	Saturated
Pressure	Inches w.c.	10 to 18	~18

Treatment Requirements: Raw biogas requires treatment prior to any use, including as a renewable energy source, but use in a vehicle fleet requires additional conditioning. The level of treatment required depends on the intended method of delivering vehicle-quality renewable natural gas (RNG) to vehicle fueling stations. The two options are: vessel storage or sending RNG directly to fueling stations; or injection of RNG into a natural gas (NG) pipeline prior to use at a fueling station.

European countries have had established standards for biogas as a vehicle fuel for many years. The Swiss national standards are shown in comparison to a utility pipeline injection requirement in ***Table 2***.

Biogas Treatment Alternatives

Raw digester biogas requires the removal of contaminants and other gases to increase the heating value, or methane content, to meet all RNG vehicle fuel standards. Three standard treatment options to meet the biogas requirements for vehicle fueling quality are:

- Media adsorption and membrane separation
- Water scrubbing
- Pressure Swing Adsorption (PSA)

Media Adsorption and Membrane Separation: Media adsorption is a very common biogas treatment method for wastewater treatment facilities. Systems that don't require removal of CO_2 use the components of media adsorption frequently. For systems that do require CO_2 removal, the addition of membranes for CO_2 separation is a common additional process. For this treatment approach, there are process steps to remove contaminants that will damage the CO_2 removal membranes. Steps remove H_2S and moisture, and then raise pressure for removal of siloxanes and then $C0_2$ through membrane treatment ***(Figure 2)***.

Water Scrubbing

Another system that is used specifically for projects that require RNG quality gas is water scrubbing ***(Figure 3)***. Water scrubbing takes advantage of the variance in solubility between CO_2 and CH_4 when pressurized. The CO_2 and other contaminants (H_2S, siloxanes, VOCs) are more soluble in water than CH_4, so the water acts as a solvent to remove contaminants and CO_2. Contaminants are removed from the biogas with a water scrubber producing a high quality RNG.

Pressure Swing Adsorption (PSA)

Pressure swing adsorption treatment uses the adsorption rates of different constituents under pressure ***(Figure 4)***. Media in PSA systems will adsorb H_2S, siloxanes and CO_2 under pressure. The media is regenerated when held in a vacuum. These systems cycle vessels through various stages to adsorb and then release contaminants.

Cost Analysis

Clean Water Services evaluated the costs of a biogas-to-vehicle-fuel system. The capital cost for a system in the size range being considered ranges between $4 million and $6 million, depending on treatment technology and additional site features. A sensitivity analysis of payback period was done to understand the range of capital costs compared to the price of diesel fuel that would be offset with this RNG. Based on current fuel prices, the payback period is between five to nine years, however, falling fuel prices extend the payback period ***(Figure 5)***.

Challenges to Implementation

Because biogas-to-RNG projects are relatively new, there are limited examples of installations. As a result, there can be challenges to deal with in implementing a project that does not have a significant track record. The following are implementation challenges for consideration on a case-by-case basis.

Land Use: Some jurisdictions have specific land use requirements associated with storage of "vehicle fuel." These land use rules are typically associated with bulk fuel storage for gas stations and propane storage, and are not applicable to wastewater treatment plants. Careful attention to these land use issues are important before making any final project decisions because they could apply onerous conditions making a project too expensive or unbuildable.

Pipeline vs. Vehicle Fuel: If a project intends to use the RNG at a dedicated fueling station the treatment requirements will be lower; however, storage will be required to balance out the continuous supply of fuel produced by the treatment plant with intermittent demand from vehicle fueling. Storage for compressed RNG (or RCNG) is expensive because the vessels for storage are ASME pressure class vessels rated for 5,500 psig. Even at this pressure, large vessels are

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Table 2. Comparison Renewable Natural Gas Specifications

Constituent	Units	Natural Gas Utility Requirements[a]		Swiss Biogas Vehicle Fuel Standard[b]	
		Min.	Max.	Min.	Max.
Methane (CH_4)	% v/v	97.3		95.0	99.0
Higher Heating Value	BTU/scf	985	1,115	NR	NR
Lower Heating Value	BTU/scf	NR	NR	NR	NR
Wobbe Number	BTU/scf	1,290	1,400	1,177	1,400
Carbon Dioxide (CO_2)	% v/v		2.00	NR	NR
Nitrogen (N_2)	% v/v		2.00	NR	NR
Hydrogen (H_2)	% v/v	NR	NR	NR	NR
Total Inerts + Oxygen (O_22)	% v/v		2.70	NR	NR
Oxygen (O_2)	% v/v		0.20		1.0
$CO_2 + O_2 + N_2$	% v/v	NR	NR	NR	NR
Hydrogen Sulfide (H_2S_2)	ppmV		3.92	NR	NR
Total Sulfur	ppmV		85		17.5
Siloxanes	ppb		300	NR	NR
Ammonia	grain/100 cf		5.00		0.87
Mercury	grain/100 cf		BDL	NR	NR
Temperature	deg. F	35	120	NR	NR
Moisture	lb/MMcf		7	NR	NR
Hydrocarbon Dew Point	–		15	NR	NR
Gas Relative Humidity	%	NR	NR	NR	NR
Water Dew Point	deg. C	NR	NR		t^2 - 5

Notes: *NR = no requirement, BDL = below detectible limit, [a] Per NW Natrual Gas Tariff P.U.C. Or. 25, [b] Per "Biogas Upgrading to Vehicle Fuel Standards and Grid Introduction" IEA Bioenergy.*

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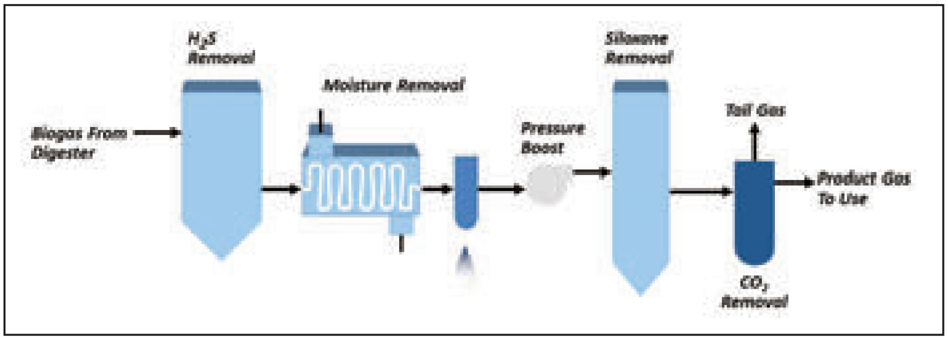
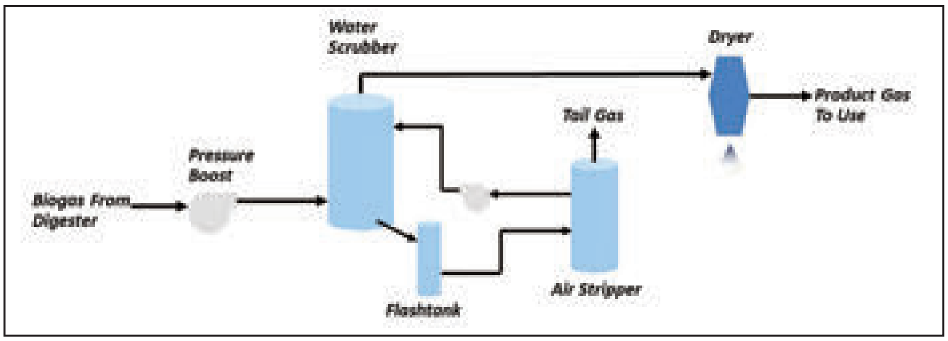


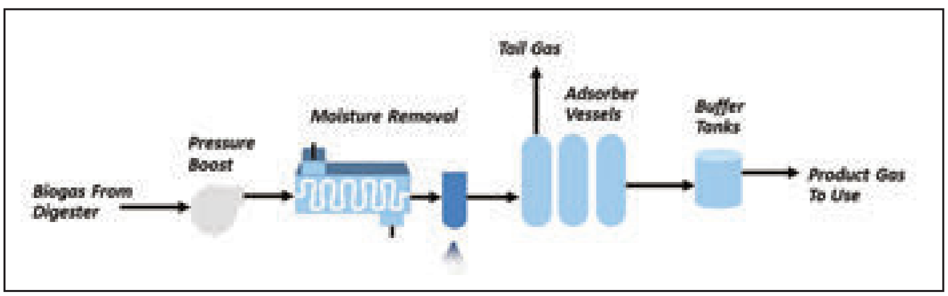
Courtesy of HDR, Inc.

Figure 2. Media Adsorption and Membrane Separation Process Flow



Courtesy of HDR, Inc.

Figure 3. Water Scrubbing Process Flow



Courtesy of HDR, Inc.

Figure 4. Pressure Swing Adsorption (PSA) Process Flow

required for just a few days of storage. Moreover, if the supply and the demand are not well aligned, gas will have to be flared or demand will outstrip onsite generation and storage.

Timed-fill of vehicles can help smooth out the supply and demand balance. Storage of lower pressure gas prior to treatment is also an option; however, it would require modification of digesters to accommodate storage or large footprints for dedicated storage.

A second option to alleviate the supply/demand imbalance is to treat the biogas to pipeline quality standard and inject the gas in a utility pipeline. This provides flexibility to use the gas at other locations and to use the distribution system as storage. The two biggest challenges of pipeline injection are meeting methane content and O_2 requirements. Methane content is quite high for pipeline RNG, therefore, additional processing is required. Some systems will therefore have lower yields in order to meet methane requirements. The O_2 removal requires an additional treatment process to remove O_2, which adds to capital and operating costs.

In addition to these costs, utility interconnection and monitoring costs can be substantial. Capital costs for interconnects and monitoring can run into the several hundred-thousand dollar range or more, depending on the local utility requirements. Also, with injection there must be a large enough gas distribution line or, preferably, a high pressure transmission line nearby to limit the costs of piping the RNG to a location that can accommodate the flows.

At present, projects going forward are leaning toward injection because the CNG fueling market is still relatively new so demand for vehicle fuel facilities will be well below supply.

Supply vs. Demand: The discussion on storage versus pipeline injection includes an explanation of supply and demand issues. For a wastewater facility this is a real challenge as the outreach for fuel users demonstrates that the CNG fueling market is currently small. Heavy vehicle owners are exploring conversion to CNG so the market will continue to grow, but near term, RCNG and CNG fueling projects are challenged to find a customer demand that will fully use system capacity, which thereby limits the revenues projected for onsite fueling.

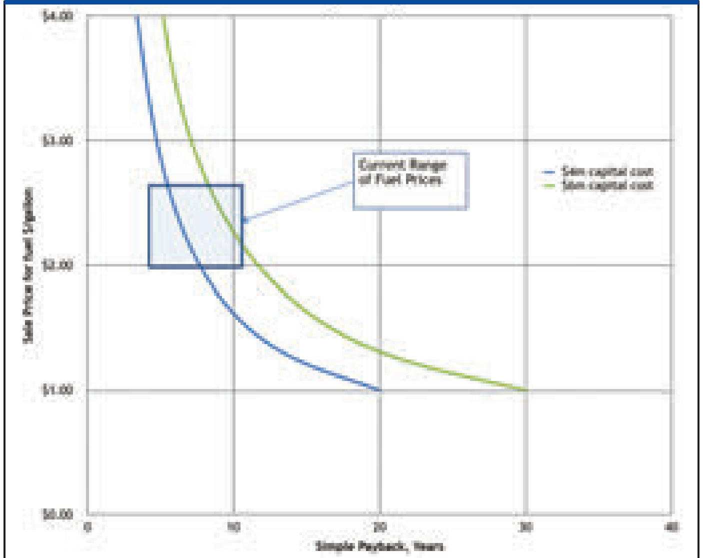
Other Project Considerations: Beyond the issues already described, there are other considerations which must be factored into decisions about sizes of systems and the practicality of RCNG facilities. Those include diesel fuel prices, vehicle conversion costs, and vehicle maintenance facility conversion costs. Fuel prices for diesel fell by 50 percent from August 2014 to December 2014 and have remained significantly lower since. While it is anticipated that fuel prices will eventually return to higher levels, it does present challenges to model project values at current fuel prices. Incentive programs such as Renewable Fuel Standards and Low Carbon Fuel Standards offset production costs of RCNG fuels, however, paybacks are extended when fuel prices fall.

In addition to fuel prices, projects must consider the costs of vehicle conversions and maintenance facility conversions in order to use RCNG. New dedicated CNG vehicles carry a premium. Depending on the vehicle, this premium can add up to 15 percent to the total vehicle price. Shop conversion costs can vary greatly depending on the type of structure used for maintaining vehicles and the types of modifications needed. These costs can range from minor costs to millions of dollars. These costs may need to be factored in depending on who is using the fuel and how those costs are born. It may be necessary for RCNG developers to support conversion costs in order to develop demand for their fuel.

Benefits of Biogas to CNG

There are a lot of exciting reasons to consider biogas to CNG projects. When offsetting diesel fuel at the Rock Creek facility, the amount of greenhouse gas reductions is significant and localized. When vehicles switch from diesel fuel to RCNG, they generate significantly less emissions directly in the community and the local impact of truck traffic. Some greenhouse gas studies have demonstrated that switching to RCNG derived from anaerobic digestion has a negative carbon offset, meaning that it actually reduces greenhouse gases more than simply eliminating the use of the original fossil fuel alone. Further, vehicles operating on CNG are quieter,

Sensitivity of Payback Period



Courtesy of Clean Water Services

Figure 5. Sensitivity Analysis of Payback Period for RNG

generate emissions with fewer negative health effects, and result in less operator fatigue, providing excellent social benefits.

Beyond environmental and social benefits, offsetting the cost of diesel fuel, even at current reduced prices, is financially attractive. As Clean Water Services has found, production of a diesel gallon equivalent will cost the facility's district approximately $1 per gallon; and, if used to offset diesel, will result in savings of $1.50 to $2 per gallon in direct fuel costs. Renewable fuels are also eligible for federal incentives through the Renewable Fuel Standard (RFS) program. Renewable fuel incentives, referred to in the RFS program as RINs, are market based, tradable financial instruments. While the value of RINs varies based on market supply and demand, it generally ranges between $1 and $2 per gallon of renewable fuel generated. With direct fuel savings and RINs combined, these projects can be a significant source of cost reduction to a municipality or become a new revenue stream to help offset wastewater treatment costs.

Wastewater treatment plants are quickly embracing the concept of becoming energy neutral and, as a result, have focused on the generation of heat and electricity to reach their target. As the concept of being energy neutral becomes embedded in the goals of these facilities, it only makes sense for that definition to encompass a broader range of energy uses at these facilities. Vehicle fuel is also a very significant and very local energy use and emission generator. As such, the goals of energy neutrality at wastewater treatment plants should be expanded to consider this as part of the facility's overall carbon footprint. Biogas to RCNG projects can significantly reduce the size of that footprint, and Rock Creek is well on its way to realizing the benefits of an RCNG facility.

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Comprehensive Evaluation of Food Waste Co-Digestion

by Robert Sharp, Anthony Fiore, Allen Fok, Keith Mahoney, Sarah Galst, Tami Lin and Matthew Van Horne

The New York City Department of Environmental Protection (NYCDEP) has embarked on a three-year study to evaluate the impacts of adding source separated organic food waste to the anaerobic digesters at its largest wastewater treatment facility, the Newtown Creek Wastewater Treatment Plant. The motivation behind this significant undertaking by NYCDEP, with the results of the bench-scale food waste co-digestion study and details of the planned full-scale food waste co-digestion demonstration, are described on these pages. Additionally, the ongoing effort to synthesize the successes, challenges and operational lessons learned into a spreadsheet-based economic/business case tool as part of a Water Environment Research Foundation (WERF) supported project *(ENER8R13)* is summarized. Overall, the diversion of organic food waste away from landfills and into anaerobic digesters at wastewater treatment plants represents the convergence of two of New York City's environmental priorities: increasing recycle rates and investing in clean, affordable energy.

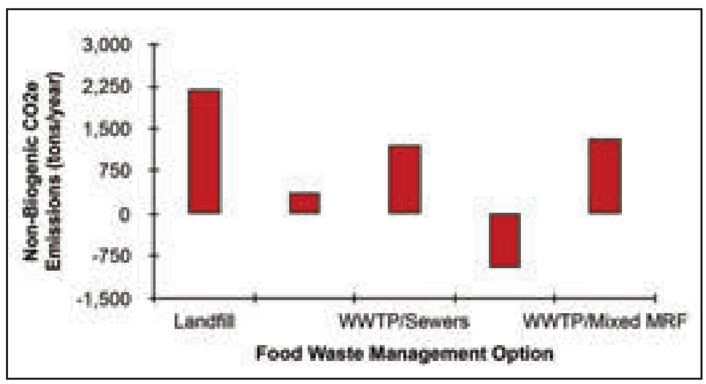
Waste Treatment Goals and Initiatives

In 2015, Mayor Bill de Blasio presented the publication of *One New York: The Plan for a Strong and Just City* (or OneNYC). OneNYC describes the steps that must be taken in order to foster the development of a responsive government, and which include the potential threats posed by climate change. OneNYC builds upon initiatives previously launched by the de Blasio administration in which New York City committed to having greenhouse gas emissions (GHGs) in 2050 that are 80 percent less than those recorded for 2005 (80 x 50). OneNYC broadened the scope from mainly focusing on energy use in buildings to include aspects of energy supply, transportation and solid waste in a comprehensive action plan to achieve 80 x 50. Two major goals that were identified in the plan as a means for reaching 80 x 50 included sending zero waste to landfills by 2030 and operating net energy neutral wastewater treatment plants by 2050.

Thus far, New York City has made progress toward its GHG emission goals as evidenced by current GHG emissions being 20 percent less than 2005 levels. The majority of this reduction can be attributed to the replacement of coal and oil with natural gas for electricity generation, as well as other improvements to utility operations. Although these modifications to energy supply are significant, these specific strategies cannot be replicated and future GHG reductions will be more challenging. The city's current air quality is certainly encouraging, as it is the cleanest it has been in over 50 years; however, additional strain will be added to air quality improvement efforts with a growing population and increasing needs for basic infrastructure, e.g., water and wastewater treatment. For example, 2030 projections include a 14 percent increase in heating fuel demand and a 44 percent increase in energy consumption *(PlaNYC 2030)*.

In addition to increased infrastructure and energy needs, a growing population will also result in an increase in solid waste production. Effective solid waste management is essential for achieving 80 x 50 because landfills are a significant source of GHGs. Across the US, landfills account for 18 percent of total methane emissions, thus indicating that landfills contribute approximately 6 percent to today's total anthropogenic global warming *(USEPA 2015; Global Methane Initiative 2014)*. New York City generates approximately 25,000 tons of residential, business and institutional garbage every day, with a corresponding recycling rate of only 15.4 percent *(DSNY [NYC Department of Sanitation] 2015; DSNY 2014)*. Minimizing the amount of methane generating waste, such as food waste, that ends up in landfills, and opting for an alternative management strategy is one potential method for reducing GHG emissions from landfills.

Food waste represents 14.5 percent of municipal solid waste in the US and previous work has concluded that co-digestion of hauled-in food waste with wastewater treatment plant (WWTP) residuals is the only carbon negative, i.e., GHG reducing, food waste management strategy ***(Figure 1)*** *(WERF 2012)*. The food waste management strategies that were compared included landfilling, composting, and anaerobic co-digestion at wastewater treatment plants, with co-digestion options including the following permutations: curbside collection of source separated food waste hauled to a WWTP (WWTP/hauled), household food waste disposer with sewer transport of food waste to WWTP (WWTP/sewers), and separation of food waste at a mixed materials recovery facility (MRF) with subsequent hauling to a WWTP (WWTP/mixed MRF). By diverting source separated food waste away from landfills and into existing WWTP digesters, communities are able to not only dispose of food waste in a way that produces less GHGs than landfilling, but also to help facilitate net energy neutrality at WWTPs through the enhanced production of anaerobic digester gas that can be used as an energy source.



Courtesy of NYCDEP

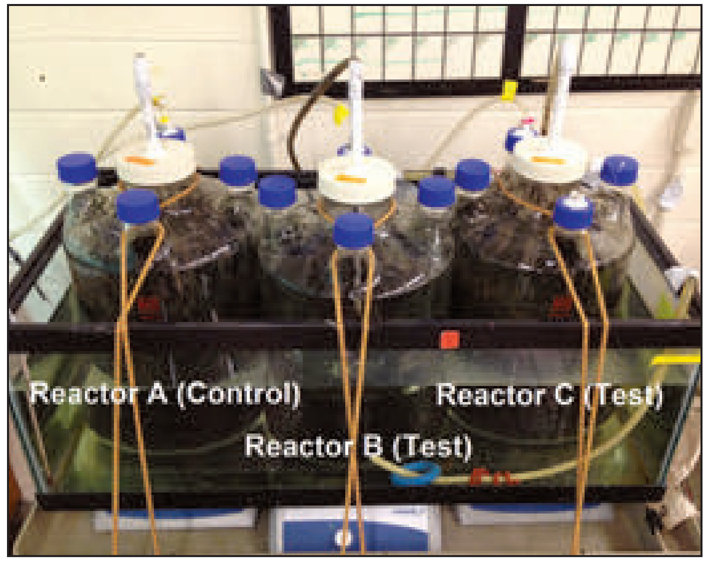
Figure 1. Non-biogenic greenhouse gas emissions (in terms of CO_2 equivalents) resulting from different food waste management strategies *(WERF 2012)*

The New York City DEP operates 14 WWTPs throughout the five boroughs, ranging in size from 30 to 310 million gallons per day (mgd) of design dry weather flow. All 14 WWTPs are equipped with anaerobic digestion. Current anaerobic digester gas production is approximately 3.5 billion cubic feet per year and ~40 percent of this gas is beneficially used as a fuel in boilers or engines to produce electricity. Optimized anaerobic digestion at NYCDEP's WWTPs, including operational changes, capital investments, and importation of high strength wastes, e.g., food waste, is expected to result in the production of enough anaerobic digester gas to meet 60 to 70 percent of each plant's electrical needs and 100 percent of each plant's heating demands. To test this hypothesis, NYCDEP is undertaking a three-year demonstration project to add source separated organic food waste to the anaerobic digesters at the Newtown Creek Wastewater Treatment Plant. The Newtown Creek WWTP treats an average of 240 mgd of dry weather flow. The plant does not utilize primary settling and operates at an average solids retention time of less than two days. The three-year demonstration project follows a one-year pilot-scale test conducted between April 2013 and April 2014 that added 1.5 tons per day of source separated organic food waste collected from schools and greenmarkets to the digesters. Lab and full-scale studies are also being supported by the New York State Energy Research and Development Authority (NYSERDA) to determine the lifecycle benefits and costs of food waste co-digestion at the Newtown Creek WWTP *(NYSERDA 2008)*.

The significance of this co-digestion initiative stems from the fact that the capacity of the Newtown Creek facility for anaerobic digestion of source separated organic food waste is expected to be 500 tons per day, which accounts for 8 percent of New York City's entire organic food waste, provides enough power to heat 5,100 homes, and offsets GHG emissions equivalent to removing 19,000 vehicles from the road. This cross-sector project reflects efficient government operations – connecting food consumption practices, solid waste, and wastewater. It allows government agencies to contribute to a citywide issue in a manner consistent with their core competencies, involves private sector businesses where they have expertise and assets, and brings in an education component to ensure the city's future residents and business leaders have the tools needed to make changes.

Results of Lab-Scale Studies

Operation of Lab-Scale Digesters: The purpose of the lab-scale study was to evaluate the quantity and quality of anaerobic digester gas produced as a function of organic food waste mixing ratios with waste activated sludge. The performance of two 10-liter semi-continuous feed digesters that received varying ratios of food waste slurry mixed with thickened waste activated sludge (Reactors B and C) was compared to that of a control digester (Reactor A), which received only raw thickened waste activated sludge ***(Figure 2)***. The digesters were operated at a 15 day solids retention time and at 95 degrees Celsius, with feed stock inputs three times per week. The two experimental digesters were operated with influent food waste fractions ranging from 10 to 30 percent of the feed volume and all digesters were operated for approximately four to five solid retention times (60 to 75 days) at each food waste fraction. Food waste grab samples were provided by Waste Management and thickened waste activated sludge was collected from the thickening centrifuges at the Newtown Creek WWTP. It should be noted that the Newtown Creek thickened waste activated sludge is a product of a wastewater treatment plant with no primary settling and a low solids retention time (< 2 days); previous work has demonstrated



Provided by Robert Sharp

Figure 2. Bench-scale control and test anaerobic digester setup

the highly biodegradable nature of this sludge and the greater potential for anaerobic digester gas production than typical primary/secondary combined sludge undergoing mesophilic digestion. Characterization of the food waste and thickened waste activated sludge feed stock is provided in ***Table 1***. Two sets of food waste samples from Waste Management were used throughout the study, one set of samples from New York City, and the other samples from a California food waste pre-processing facility. The New York City food waste sample was used for the digester runs with food waste input ratios of 10 and 15 percent, and the California food waste sample was used for the remainder of the digester runs.

Digestate and Gas Production from Lab-Scale Digesters: The quality of the thickened waste activated sludge and food waste samples varied throughout the study. However, the percent of total solids, percent of volatile solids, COD concentration, and volatile acids concentration in the digestate all decreased as the food waste input ratio into the digester increased. Total Kjeldahl nitrogen (TKN) and ammonia concentrations in the digestate varied as a function of feed stock quality, but showed an overall negative correlation with the food waste input ratio due to the low TKN content of food waste feed. The volatile acid to alkalinity ratio decreased significantly with each incremental increase in the food waste input ratio. As a rule of thumb, volatile acid to alkalinity ratios should be above 0.05 in digestate in order to encourage a more consistent and stable digester performance *(WEF 2006)*. The volatile acid to alkalinity ratio dropped below the recommended 0.05 only when the food waste input ratio reached 25 percent; however, no measurable or observable upsets occurred during the 25 percent ratio testing. Throughout the study there was no significant foaming

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Table 1. Characterization of food waste and thickened waste activated sludge feed stock

Food Stock	pH	Total Solids (%)	Volatile Solids (%)	Total COD (mg/L)	Volatile Acids (mg/L) CH_3COOH)	NH_3-N (mg/L)
Food Waste Sample NYC	3.94	10.5	86.6	192,805	17,419	401
Food Waste Sample – California	3.97	13.6	90.4	211,688	15,886	653
Food Waste Sample – Average	3.96	12.0	88.5	202,247	16,653	527
Thickened Waste Activated Sludge	5.94	6.8	82.9	123,825	4,796	1,274

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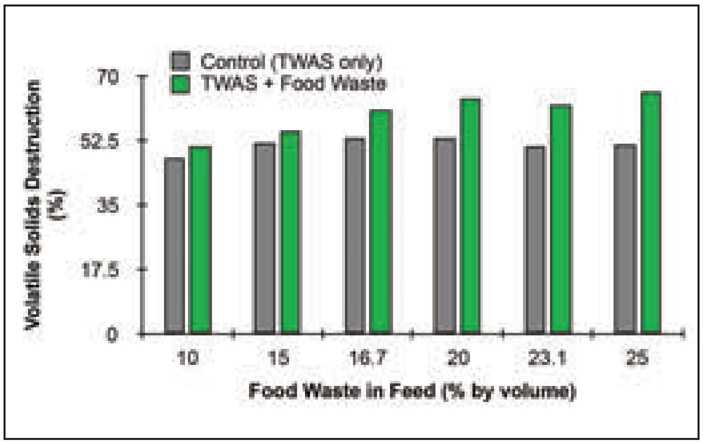
in the digesters, and microscopic inspection of the sludge did not indicate any struvite crystal formation. In addition, no struvite was formed within the reactors.

Table 2 shows the average results for anaerobic digester gas production (quantity and quality) during steady-state operation for the different food waste input ratios. Across the experimental trials, increased food waste inputs resulted in an increase in the percent of volatile solids destroyed, the methane content of the produced gas, the specific gas production rate, and the total quantity of gas produced. ***Figure 3*** shows the percent volatile solids destruction for digester runs with food waste input ratios ranging from 10 percent to 25 percent by volume, as compared with the control digesters (0 percent food waste) that were run at the same time as each food waste trial. The consistent increase in percent volatile solids destruction for the digester with food waste inputs relative to the control is due to the fact that food waste is more biodegradable than thickened waste activated sludge.

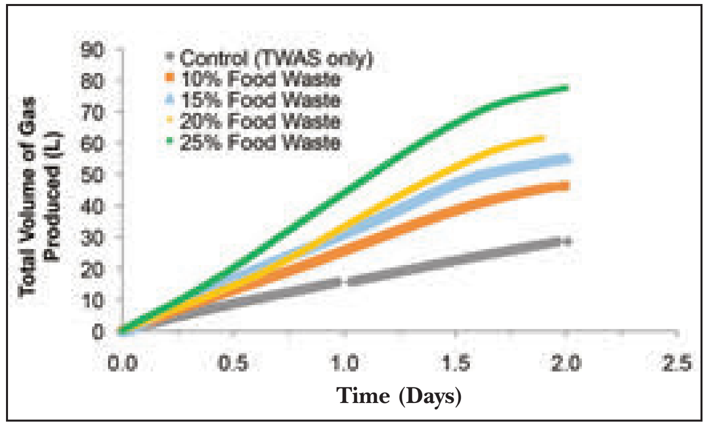


Provided by Robert Sharp

Figure 3. Volatile solids destruction for digesters with food waste input ratios ranging from 10 percent to 25 percent by volume (green columns), as compared with the control digesters (TWAS only, 0 percent food waste) that were run with each food waste trial (grey columns)

The improved biodegradability of feed stock with the addition of food waste not only improves volatile solids destruction, but also increases the total volume of gas produced. The trends shown in ***Figure 4*** are an example of the total volume of gas produced in various bench-scale digester runs as a function of the digester operation time for all tested food waste input ratios. ***Figure 4*** shows that after two days of operation, the digester with 0 percent food waste (grey series) produced a total of 28.6 L of gas, while the digester with 25 percent food waste (green series) produced 77.6 L of gas. The increase in total gas produced for digesters with food waste inputs can be explained by the increased volatile solids destruction with food waste ***(Figure 3)***, as well as the improved specific gas production associated with food waste inputs ***(Figure 5)***. The energy content of the anaerobic digester gas also improved with the addition of food waste, with methane content increasing by an average of 12 percent throughout the study compared to the control. This increase in methane content was expected because digestion of pure food waste has been shown to produce biogas that contains up to 73 percent methane *(Zhang et al. 2007)*. In addition, co-digestion of activated sludge with a highly biodegradable organic waste such as food waste and grease trap residuals (fats, oils and grease - FOG) appears to have a synergistic effect, whereby the total VS (volatile solids) or COD (chemical oxygen demand) destruction, and thus the biogas production, is enhanced during co-digestion.

Recent studies performed by Georgia Tech and Hazen and



Provided by Robert Sharp

Figure 4. Total anaerobic digester gas produced as a function of time for digesters with food waste input ratios ranging from 0 percent (control) to 25 percent by volume

Sawyer for a co-digestion project for Gwinnett County Georgia evaluated the biodegradability of various organic wastes, including FOG. The results from this study showed the synergistic effect of co-digestion can increase overall sludge biodegradability by an additional 10 percent or more *(Hardy et.al. 2012)*. Similar levels of synergistic impacts on biodegradability of the TWAS (thickened waste activated sludge)/food waste sludge feed was evident during this study.

Ultimately, the food waste induced increase in total gas production combined with an increase in the methane content of the gas produced resulted in a significantly improved net energy production from the anaerobic digestion process. ***Figure 6*** shows that the net energy produced in these ideal bench-scale anaerobic digester studies increased by as much as ~160 percent with the addition of 25 percent food waste in the feed stock by volume, as compared with the control (0 percent food waste in feed stock). The total increase in total energy produced with increased food waste addition is a result of:

- Increased VS in the feed sludge
- Increased methane content in the biogas
- Increased specific gas production
- Increased total gas production
- Significant increased overall VS destruction due to increased biodegradability of the food waste and synergistic effects of co-digestion

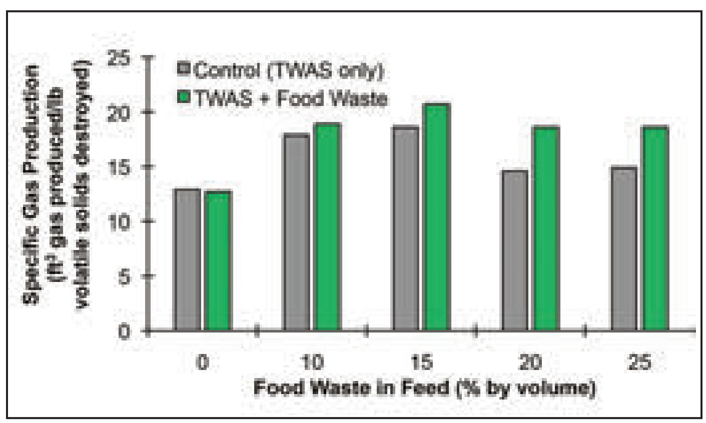


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Figure 5. Specific gas production (cubic feet of gas produced per pound of volatile solids destroyed) for digesters with food waste input ratios ranging from 0 percent to 25 percent (green columns), as compared with control digesters (TWAS only, 0 percent food waste) that were run with each food waste trial (grey columns)

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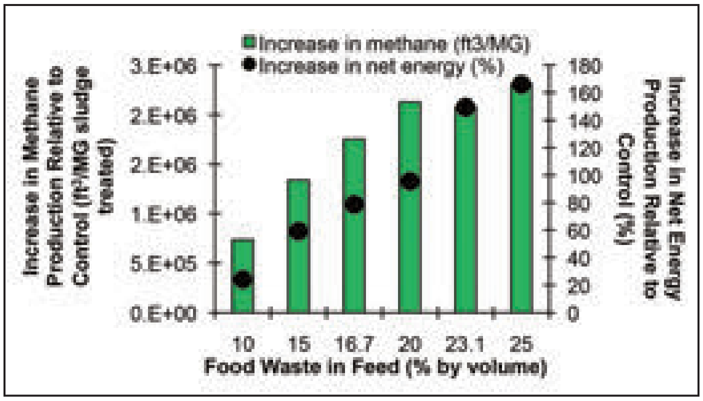

Provided by Robert Sharp

Figure 6. The increase in methane (green columns) and net energy (black dots) produced for anaerobic digesters with food waste input ratios ranging from 10 percent to 25 percent by volume relative to the control (TWAS only, 0 percent food waste)

Overall, the bench-scale results demonstrate a wide range of benefits that may be achieved through co-digestion of source separated organic food waste and wastewater treatment residuals. Insights gained from these bench-scale studies have informed the comprehensive monitoring and testing program for the full-scale demonstration project at the Newtown Creek Wastewater Treatment Plant.

Full-Scale Food Waste Demonstration Evaluation

Full-scale demonstration of source separated organic food waste co-digestion with wastewater treatment plant residuals will be conducted at the NYCDEP's largest wastewater treatment facility, the Newtown Creek Wastewater Treatment Plant. The Newtown Creek WWTP treats approximately 240 mgd of dry weather flow and has eight egg-shaped anaerobic digesters, each with a storage capacity of three million gallons. The plant produces approximately 100,000 cubic feet of sludge per day and more than 500 million cubic feet of anaerobic digester gas per year. As part of the NYSERDA sponsored full-scale food waste co-digestion demonstration study, source separated organic waste will be pre-processed by Waste Management of New York to remove inorganic contaminants, such as styrofoam, metal, and plastics, and to homogenize the organic content into an approximately 14 percent total solids bioslurry. The bioslurry will be transported to the Newtown Creek WWTP and pumped into an 180,000 gallon holding tank that will be mixed using hydraulic jet mixing. The bioslurry will be added to the digesters at a food waste input ratio of 10 to 20 percent by feed volume with thickened waste activated sludge. The demonstration project will begin with the addition of 50 tons per day of source separated organic food waste and scale up to 250 tons per day by the end of the study. One of the main goals of the NYSERDA project is to comprehensively evaluate the effects of food waste co-digestion on the following:

- Digester gas quantity and quality, e.g., methane, siloxanes, hydrogen sulfide content
- Digester chemistry, e.g., pH, alkalinity, ion balance, volatile fatty acid content
- Digester rheology, i.e., the impact of mixing characteristics on foaming and gas hold-up
- Digester cation balance and impacts on polymer demand and dewaterability performance
- Centrate quality, i.e., nutrient load, and potential impacts on biological nutrient removal performance
- Potential for struvite formation, i.e., struvite chemistry including ammonia, phosphate, and magnesium content
- Cake quality, e.g., odor potential and regrowth of pathogens

The sampling program will be carried out in two phases at each food waste addition level. The first sampling phase will monitor overall digester performance during the initial stages of food waste addition to make sure there are no significant negative operational or process impacts from the food waste addition. After steady-state operation has been achieved at a given food waste loading rate, the second phase of sampling will begin, including higher frequency sampling and evaluation of the digestate and biogas from both the control digester and the test digester. ***Table 3*** shows the type and schedule of sampling that will be included in the steady-state sampling phases, which will be carried out at both a 10 percent and 20 percent food waste ratio input.

Business Case Model for Co-Digestion

Concurrent with bench- and full-scale applied research, Hazen and Sawyer has been focusing its efforts on "Developing Solutions to Operational Side Effects Associated with Co-Digestion of High Strength Organic Wastes" through a WERF supported endeavor *(ENER8R13)*. Thus far, the project has consisted of two phases of an online survey, in which 13 utilities currently practicing co-digestion provided operational data. These data were collected and analyzed to determine if any common operational or economic trends could be identified. The majority of these surveyed utilities practice co-digestion with high strength organic waste (HSW) due to similar drivers, including increased biogas production, revenue generation, and positive public perception. The increased biogas is primarily used for electricity and heat generation, which results in a reduction in energy costs for these utilities. Some facilities

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Table 2.

Volume % Food Waste in Feed Stock	SRT (days)	Specific Gas Production (ft_3/lb volatile solids destroyed)	% Increase in Specific Gas Production	% Methane	% Increase in Methane	H_2S (ppm)	Siloxanes
0 (TWAS only)	15	15.7–18.5	n/a	56.2	n/a	11–101	78
10	15	18.8	5.6	63.3	9	109	43
15	15	22.7	11.2	61	21	107	26
16.7	12.5	22	31	66	11	140	233
20	15	21.8	27.5	67	12	176	43
25	15	18.6	26	67	19	130	143

Anaerobic digester gas quantity and quality at different food waste ratios. "% increase" refers to the percent increase in a parameter for an experimental run with food waste relative to the baseline condition for that experimental run with thickened waste activated sludge (TWAS) feed stock only.

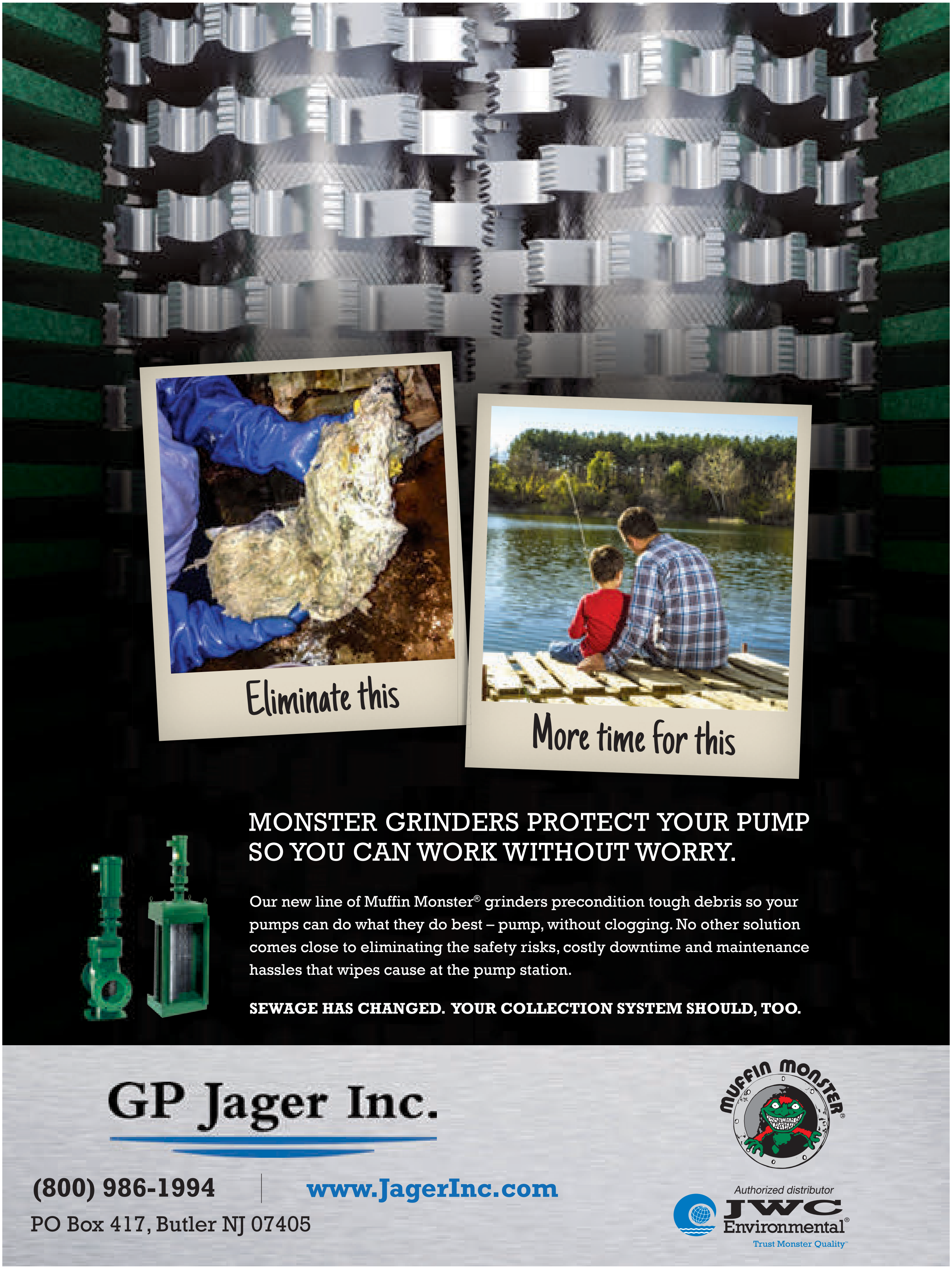
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Table 3. Sampling schedule for full-scale food waste co-digestion demonstration study at the Newtown Creek Wastewater Treatment Plant in New York City

	Parameter	Units	Sampling Frequency
Feed Streams	Flow rate	gal/day	Daily
	Total solids	g/L	2–5x/wk
	Volatile solids	g/L	1–5 x/wk
Digesters (Test/Control)	Temperature	°C	Daily
	pH	s.u.	2–5 x/wk
	Volatile acids	mg/l	2–5 x/wk
	Alkalinity	mg/L $CaCO_3$	2–5 x/wk
	Total dissolved solids	mg/L	1–3 x/wk
	Total solids	g/L	2–5 x/wk
	Volatile solids	g/L	2–5 x/wk
	Total nitrogen	mg/l	2–3 x/wk
	Soluble toal nitrogen	mg/l	2–3 x/wk
	Total Kjeldahl nitrogen	mg/L	2–3 x/wk
	Soluble total Kjeldahl nitrogen	mg/L	2–3 x/wk
	Ammonium	mg/L	2–3 x/wk
	Total phosphorus	mg/L	2–3 x/wk
	Soluble total phosphorus	mg/L	2–3 x/wk
	Soluble orthophosphate	mg/L	2–3 x/wk
	Soluble COD	mg/L	2–3 x/wk
	Calcium	mg/L	2–3 x/wk
	Magnesium	mg/L	2–3 x/wk
	Foam potential testing	n/a	1–2 x/wk
	Surface tension	n/a	1–2 x/wk
	Rheology/rapid rise	n/a	1–2 x/wk
	Elemental analysis	n/a	3x
	Odor production	n/a	3x
	Cake regrowth	n/a	3x
	Dewaterability test	n/a	3x
	Visual inspection/steroscope imaging	n/a	3x
Anaerobic Digester Gas	Gas production	Cfm	Daily
	Methane	%	2–5 x/wk
	Carbon dioxide	%	2–5 x/wk
	Hydrogen sulfide	ppmv	2–5 x/wk
	Siloxanes	ppmv	4x

have become net energy producers as a result of co-digestion. The tipping fees that haulers pay to dispose of HSW loads have also become a source of revenue for these utilities.

In order to take a comprehensive approach to co-digestion, survey questions also pertained to any costs or challenges incurred by the utilities. The most commonly reported costs were related to HSW receiving and pretreatment facilities, such as those required for additional odor control, labor, and equipment maintenance. Survey results indicated that once HSW was blended with wastewater treatment residuals and conveyed to digesters, the operations impacts of co-digestion were minor. Few survey respondents identified downstream effects on the quality of digested sludge, digester gas, or sidestream water upon the introduction of HSW.

As a part of the ENER8R13 project, quantifiable results from the survey have been incorporated into a spreadsheet-based economic tool which is still under development. The tool will assist utility owners considering co-digestion in estimating the net present value, payback period, and operational impacts of a co-digestion program at their facilities. The tool will also include a business case evaluation model which will allow users to weigh non-quantifiable considerations and compare the overall costs and benefits of co-digestion to the baseline of existing facility operations. The tool was beta tested during the 2015 WEFTEC workshop titled, "WEF/WERF Food Waste Co-digestion: Pretreatment, Performance, and Plant Wide Operation and Maintenance Issues." This decision making tool will provide a comprehensive understanding of co-digestion in a given setting, including potential sources of both revenue and cost. During the workshop, approximately 50 participants were able to test the sensitivity of the tool under different feed source, operational and economic scenarios to evaluate the economic feasibility and attractiveness of co-digestion. The tool will be available to WERF subscribers once completed in 2016.

Beneficial Impacts of Co-Digestion

Current waste management in New York City involves significant inputs of food waste into landfills, thus resulting in the production of GHGs. Additionally, WWTPs have the ability to produce energy onsite through the implementation and operation of anaerobic digestion; however, supplemental inputs of high strength organic

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waste, such as food waste, are needed in order for the majority of the electricity needs at WWTPs to be met via anaerobic digestion. Co-digestion of food waste with WWTP residuals as an alternative to landfilling allows for progress to be made in both the areas of recycling and clean energy production, which are priorities for New York City. Bench-scale results show that food waste additions to thickened waste activated sludge in anaerobic digesters significantly increase the total energy value of anaerobic digester gas, as measured by total gas production, specific gas production, and methane content. Monitoring of pH, methane generation, percent volatile solids destruction, and foaming showed that process stability and performance was maintained in the bench-scale digesters with increasing food waste input ratios up to 25 percent. At a 25 percent food waste input ratio, the volatile acid to alkalinity ratio dropped below the recommended value of 0.05; however, no process issues were observed.

Potential challenges to be investigated in the full-scale study include the effectiveness of mixture/incorporation of food waste into the thickened waste activated sludge feed, the impacts of debris accumulation in the digester, struvite formation within the reactors and dewaterability of co-digested sludge. In addition to ongoing bench- and full-scale studies, this comprehensive evaluation of co-digestion also includes a thorough analysis of currently operating facilities, which is being addressed by Hazen and Sawyer as part of the WERF ENER8R13 project. The coupling of in-depth research endeavors with the practical experiences of full-scale applications will enable utilities to evaluate whole plant impacts of co-digestion, and quantify the expected benefits and costs of co-digestion for their specific application.

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There is No 'One Size Fits All' for Co-Digestion

by Dennis Clough and George Bevington

In recent years, the wastewater field has been challenged to redefine the role of wastewater treatment plants, elevating their importance through labels such as, "Utilities of the Future" and reclassifying the plants as "Water Resource Recovery Centers." Confirming this need for wastewater treatment plants to evolve, the Water Environment Federation stated in October 2014:

"Resource recovery is an emerging societal need due to the ever increasing pressures on limited resources such as water, nutrients, and energy, and it is critical to recover these resources from waste streams."

While this need is apparent, the method by which a wastewater treatment plant retools itself to recover these resources and to truly become a Utility of the Future is more complicated and can vary greatly from one facility to another. Highlighted here are the different methods being applied by three wastewater treatment facilities, which vary in size and are in different stages of the process of upgrading and enhancing their infrastructures. All have the common goal of becoming less dependent on fossil fuels via energy recovery, reducing their carbon footprints and, in one case, commencing nutrient recovery in order to provide the services required to become a Utility of the Future.

Large Wastewater Treatment Facility

Winchester, Virginia: The Frederick-Winchester Service Authority (FWSA) is an organization that has been a quiet anchor of the community. Since 1974, FWSA has provided reliable and effective sewage treatment for the citizens and businesses of Frederick County and the City of Winchester, VA. In recent years, FWSA has focused on becoming a more efficient organization, identifying ways to minimize costs to citizens and the community while providing new services and supporting local future economic development. In 2010, FWSA expanded its Opequon Water Reclamation Facility (WRF) to 12.6 millions of gallons per day (mgd) and upgraded for enhanced nutrient removal capabilities that met Virginia Department of Environmental Quality requirements.

Despite the expanded capacity of the facility, however, the 12.6 mgd enhanced nutrient removal facility was limited to aerobic treatment; no anaerobic treatment systems were present. Specifically, the liquid stream processes consisted of:

- Two headworks with screening and grit removal
- One influent pumping station
- Four primary clarifiers
- Five bioreactors
- One secondary anoxic/reaeration tank
- Six secondary clarifiers
- Two effluent filters
- Two chlorination basins
- Re-aeration cascade

The solids treatment processing included:

- Four gravity thickeners
- Four sludge holding tanks
- Sludge reaction tank
- Sludge retention tank
- Plate and frame filter presses with lime stabilization
- Landfill disposal for biosolids cake

FWSA, in keeping with its goals of minimizing costs to citizens and the community while providing new services and supporting local future economic development, sought to further expand the operations at this facility. Currently under construction, and preparing for full operations in May 2016, FWSA's Opequon Water Reclamation Facility is being further improved through a $45 million facility-wide organics co-digestion, cogeneration and operational efficiency project. When completed, the Opequon WRF will be the first enhanced nutrient removal facility in the United States, with strict limits of nitrogen at 3 mg/L and phosphorus at 0.197

Courtesy of Energy Systems Group

An aerial view of the construction of the FWSA Green Energy Facility, where the primary digesters are at rear of the control building and the secondary digester is in foreground.

Courtesy of Energy Systems Group

Seen here are the two 1.25 million gallon primary digesters of the new Green Energy Facility.

mg/L, to become a nearly net energy zero facility.

The centerpiece of the FWSA project is the Green Energy Facility – a new anaerobic digestion complex sized and designed, from inception, for high-strength organic waste co-digestion and electric cogeneration. The facility consists of three 1.25 million gallon digesters with a central digester control building, electrical cogeneration, and liquid/cake waste receiving. The high-strength organic waste receiving station allows tankers of pumpable waste to be unloaded at 400 gallons per minute to the storage/mix tank. The storage/mix tank provides a system waste wide spot allowing for intermixing via pumping of thickened WAS (waste activated sludge) with the trucked in organic wastewater and near constant digester feeding. At full operation the facility will have acceptance capability of 125,000 gallons per day of high-strength organic waste and co-digest this material with plant sludge in the primary anaerobic digesters. The identified organic wastes that will be accepted include trap grease, dairy processing waste, meat processing DAFT (dissolved air floatation thickener) sludges, beverage production wastes, and pretreatment/municipal biosolids cake. The biogas produced will run 848 kilowatts of electrical cogeneration that, at start-up, will meet the majority of the treatment plant's electrical needs.

Another unique aspect of this project is the installation of the Ostara Pearl® Process to recover and reduce phosphorus nutrient loading of anaerobic side streams to the liquid portion of the plant. The FWSA determined early in the design process that the receipt of organics could not consume any of the plants permitted liquid-side phosphorus treatment capacity. With dairy waste, which is high in phosphorus, forecasted to be a considerable portion of the incoming organic waste, this product was determined to be the most cost effective solution for side stream treatment. Since phosphorus is an element that may only be mined and is an essential ingredient for fertilizer and crop production, this process provides additional beneficial reuse.

Significant infrastructure renewal is part of the project as well, including aeration system improvements, new sludge conveyance and dewatering, primary electrical and emergency back-up systems, and facility improvements.

As a result of this innovative and multi-faceted project, FWSA has substantially increased its value to the community. Through increased revenue streams and enhanced efficiency, the facility has been able to self-fund needed infrastructure improvements without increasing costs to rate payers.

Courtesy of Energy Systems Group

Rome's existing anaerobic digester complex is seen here, which was constructed in the 1980s.

Courtesy of Energy Systems Group

This is the proposed location of the new 1.5 million gallon primary digester, which will increase the Rome facility's organic waste receiving capabilities.

Medium Wastewater Treatment Facility

Rome, New York: The City of Rome, NY is located about 40 miles east of Syracuse in the Mohawk Valley. While rich in history, the City of Rome has experienced a decline in population growth since the 1970s and currently is home to 33,000. Changes in the local leather stocking industry and the closing of Griffith Air Force Base contributed to this diminished growth. In response to these events, the city's leadership sought out opportunities to enhance the area's existing assets, help drive economic development, and increase revenue resiliency. As a result, expanding Rome's treatment plant facility in order to better serve the thriving dairy, food processing, and organics markets in upstate New York became a high priority.

Constructed in 1932, the Rome Water Pollution Control Facility (WPCF) was the first major treatment plant in the Mohawk Valley. The 12 mgd activated sludge plant facility has a long environmental treatment history and has undergone multiple improvement projects over the past several decades. The facility's anaerobic digestion capabilities have been operational for decades, and the facility operates a small engine to generate electrical power from biogas. (Currently, biogas from the anaerobic digestion system is used for digester heating only).

Plant personnel determined that the anaerobic digestion system was the best candidate for upgrade because the existing digester equipment is beyond useful life. A two-part feasibility study is currently underway to determine the viability of a $15 million facility and infrastructure upgrade project. The first part of the study will determine if the Rome WPCF's capacity is sufficient to accept high-strength organic waste. Based on the results of this study, the city will begin implementing upgrades, which will include: the installation of a new 1.5 million gallon digester, new control building, and upgrades to the existing 800,000 gallon primary digester (new cover and linear motion mixing system). In addition, a new high-strength organic waste receiving station for grease waste, dairy waste and liquid sludge will be installed. These materials will be combined as digester feedstock, and the resulting mixture will be fed uniformly to the primary anaerobic digesters for co-digestion with WAS and primary sludge. As a result, there will be a substantial

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increase in biogas generation which will drive an 800 kW generator system, sufficient for the Rome WPCF to become a net energy zero facility and export about 400 kilowatts back to the electric grid. Other improvements include dewatering, biogas storage, and miscellaneous items.

The second aspect of the feasibility study will determine if there is an adequate organics "wasteshed" within 100 miles of the Rome facility that can generate the tipping fees needed to justify the infrastructure investment. Preliminary discussions with haulers and generators indicate that there is in excess of 400,000 gallons per day of various types of organic wastes that would be suitable for acceptance at the Rome facility. Because this waste is within the acceptable distance for cost effective transportation, Rome is a desirable disposal option for these companies. The study will be completed in December 2015 with detailed design for the project beginning in early 2016.

Implementation of these measures is an essential step for the City of Rome as the community continues to seek out ways to increase economic development and provide essential services through its wastewater treatment facilities.

Relatively Small Wastewater Treatment Facility

Middletown, New York: The City of Middletown, NY has undertaken a citywide energy efficiency and sustainability project, looking to reduce operating costs and increase revenues through a variety of improvements across all city departments. A primary target for increased efficiency and added revenue opportunity is Middletown's wastewater treatment plant because the plant is the city's largest single user of energy and has an existing digester complex that is currently under loaded. Additional measures, such as building systems efficiency, LED traffic signals and streetlights, water meter replacements, and solar power systems, are also being addressed and will help the city fund needed improvements through utility and operational savings as well as enhanced revenue streams.

The wastewater treatment plant was designed to treat, on average, 8.5 mgd of sanitary wastewater from the City of Middletown and surrounding areas. The general process description is screening/grit removal, primary clarification, aeration tanks with activated sludge, final clarification and ultraviolet disinfection. Sludge is thickened – anaerobically digested in two 200,000 gallon primary digesters and one 300,000 gallon secondary digester – and dewatered by belt filter press. At present, biogas generated by the anaerobic digestion process is fired in a boiler to generate hot water to heat the digesters, and excess biogas is flared.

As part of the citywide efficiency project, the city plans to accept organic waste for co-digestion to increase biogas production and operate a cogeneration system to make the wastewater plant a net energy zero facility. Based on forecasted municipal flows, the Middletown facility has the capacity to accept 45,000 gallons per day of organic wastes, which makes this goal feasible.

The Middletown facility is smaller than the typical co-digestion plant, and is predominantly utilizing existing and repurposed infrastructure to become a Utility of the Future. The city does not want to build new digesters; rather, its officials want to maximize the functionality of their existing equipment. In order to accomplish the goal of operating a net energy zero facility, the city will embark upon a $15 million project, which is expected to begin construction in 2016. The scope of this project will include converting the existing secondary digester into a primary digester, converting an abandoned thickener tank into a digestate tank, installing two gravity belt thickeners, modifying and expanding the abandoned RAS/WAS (return activated sludge/waste activated sludge) building, replacing the gas flare, installing a 27,000 cubic feet biogas storage vessel, providing an organic waste receiving station, constructing a 180,000 gallon organic waste storage tank, and installing a 400 kilowatt biogas engine/generator with electrical interconnection and a biogas conditioning skid, along with miscellaneous piping and valves. No power export will occur. New odor control facilities will also be provided for the new sludge thickening and organic waste facilities.

Middletown's comprehensive approach to increased efficiency with a focus on revitalizing the wastewater treatment plant will allow it to conserve resources, preserve funds, and enhance the livability of the community.

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Courtesy of Energy Systems Group

The Middletown facility's existing 200,000 gallon anaerobic digesters are in the distance, with the proposed location of the organics receiving facility shown in the foreground.

Courtesy of Energy Systems Group

These are the existing covers of the anaerobic digesters.

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What Ties All These Projects Together?

Each of the projects uses high-strength organic waste co-digestion as a tool to address their community's needs. Issues concerning economic development, revenue resiliency, and operational efficiency will all be addressed without requiring additional funds from rate payers. With so many significant benefits, however, one must ask why projects of this nature are not being implemented on a widespread basis.

According to the National Biosolids Partnership, there are 1,238 wastewater resource recovery facilities in the United States with operating anaerobic digesters. While the practice of organics co-digestion is widely discussed, it is not widely implemented, leading to the conclusion that clearly accepted technology and available infrastructure are not the issue.

The secret to the success of these projects is the people. Projects, like those highlighted, require commitment, determination, and a vision that goes beyond simple permit compliance. Developing a vision for what the utility can become – an integral part of the community and its economic structure – is the key to becoming a Utility of the Future.

Each of these projects was championed by dedicated, visionary leaders, and they are why the projects will be successful. In Winchester, FWSA Executive Director Jesse Moffett and Chief Operator Richard Wadkins ensure that their project gets top priority. In Rome, Department of Public Works Commissioner Frank Tallarino and Chief Operator Rick Kenealy serve as project advocates. In Middletown, Public Works Commissioner Jacob Tawil and Chief Operator Ben Brunning provide the vision for their utility's future. These champions are advancing these projects and building support from the approval boards and the public to get the necessary financing to move forward.

Another common principle at the core of these projects is leadership's desire to generate revenue from sources other than the ratepayers. Each currently raises revenue via wastewater charges at the head of the plant. The acceptance of high-strength organic waste that arrives by tanker will generate much needed new tipping fee revenue that will be used to pay for the necessary infrastructure, now and in the future. In addition, the New York facilities have applied for funding from the New York State Energy Research and Development Authority (NYSERDA) PON 2828, requesting financial assistance to install the necessary gas cleaning and engine generators required to make these facilities net zero. The NYSERDA grants have been instrumental in moving many New York State "green energy" projects forward over the past decade.

Co-digestion can work at many wastewater plants nationally with executive leadership vision, proper design, equipment selection and careful attention to understanding the organics wasteshed and securing sources of high strength organic waste for anaerobic digestion. Co-digestion can be one of the tools that wastewater facilities utilize to become a resource recovery facility similar to Winchester, Rome, and Middletown.

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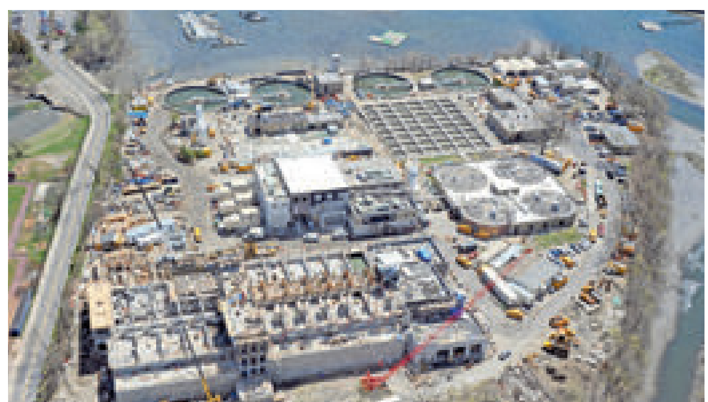
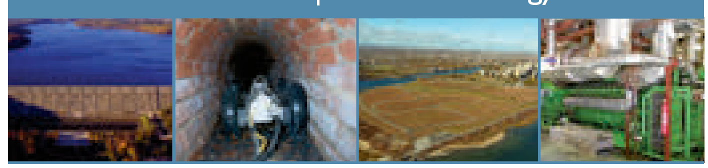
Energy Performance Project Delivery

Each of the projects described here are being developed by Energy Systems Group via the energy performance contracting project delivery method. An energy savings performance contract is a contractual agreement with a company for the scope development, design, construction, and performance measurement of system and infrastructure improvements that will result in annual operational cost savings or new revenue generation.

These financial benefits are sufficient to cover some or all of the cost of the project. As part of the contract, the company provides a financial guarantee for the annual financial benefits for the life of the contract. This guarantee helps to minimize the owner's financial project risk. This financial guarantee is different from the performance guarantees product manufacturers provide in order to insure their equipment meets a minimum output, result or set of characteristics. Energy savings performance contracting is a turn-key service, sometimes compared to progressive design/build contracting, with the addition of the overall project financial savings guarantee.





Harvesting Organics from Wastewater for More Energy Value

by Alex Wright and Mark Greene

Municipal wastewater treatment and conveyance accounts for up to 1-2 percent of total US energy consumption, according to the Energy Power Research Institute. At the plant level, the activated sludge process accounts for up to 60 percent of its energy consumption and facilities are many times the largest single energy consumers in their communities. It is also often stated that the organics in wastewater contain more energy than is required to treat it.

In August, the Water Environment Research Foundation brought leaders in the wastewater industry together to cultivate the "Intensification of Resource Recovery." There is a national movement to recognize wastewater treatment plants as water resource recovery facilities (WRRFs). The informational purpose of the following is in recognition of the products and benefits that can be derived from wastewater treatment.

Where the Energy Goes

Water resource recovery facilities most often consist of two main treatment steps – primary and secondary treatment. Primary treatment is historically intended to remove suspended and floating solids from raw sewage and typically consists of sedimentation by gravity. Conventional primary treatment can reduce the five-day biochemical oxygen demand (BOD_5) of the incoming wastewater by 20–30 percent and the total suspended solids (TSS) by 50–60 percent. By only removing 20–30 percent of the organics in the primary treatment stage means that the majority of the organics are left in the wastewater to move onto secondary biological treatment where they are consumed by bacteria and converted into carbon dioxide (CO_2) and biomass. It has been proven that the sludge produced from the secondary biological processes has significantly less methane generation potential than the sludge captured by primary treatment. Thus, in the current paradigm of wastewater treatment, a large amount of energy is expended to reduce the energy potential of the organics found in the wastewater.

It is clear that the path forward to converting wastewater treatment facilities into WRRFs is to reduce the energy consumed in aeration and to capitalize on the energy value contained in the wastewater itself by diverting organics through anaerobic digestion. One method of doing so that is currently being implemented is through the use of enhanced primary treatment (EPT) technologies that remove the majority of organics in the primary treatment stage where these organics have their highest energy potential. By doing so, it reduces the organic load to the secondary treatment process, thus reducing its energy consumption and diverting the higher energy potential primary organics to the anaerobic digester for energy generation. ***Table 1*** details the various enhanced primary treatment technologies being implemented today.

CEPT versus Organics Harvesting

Chemically enhanced primary treatment (CEPT) involves the addition of chemicals in the form of coagulants and polymers to conventional primary clarification to promote more rapid settling of solids. Chemical addition binds small solid particles together to form larger floc for filtration or a heavier particle mass to improve gravitational settling. As a result, chemical addition and physical processes are usually employed together to provide treatment. The chemicals utilized in CEPT are the same ones commonly added in potable water treatment as well as in wastewater treatment for tertiary phosphorus polishing (e.g., ferric chloride or aluminum sulfate).

The CEPT process has grown to include ballasted flocculation and contact clarification technologies. Such technologies are often implemented in wet weather, high flow scenarios, and with high rates of 3,000–6,000 gallons per day per square foot (gpd/sf) of surface overflow to treat diluted sewage within the same primary clarifier footprint as typical primary clarifiers have 1,000 to 1,500 gpd/sf surface overflow rates. Due to the wet weather application of the CEPT process, it is typically used on dilute wastewater which does not offer the opportunity for organics harvesting for energy generation.

Enhanced primary treatment, as opposed to conventional CEPT, has the capability to perform enhanced organics and solids removal with or without chemical. The Harvester (by ClearCove) is one such technology that retains flocculated and particulate solids >50-microns, all visible hair, and fibers in the tank, for a cleaner, low organic and low suspended solids effluent to flow to the secondary process. The captured solids from this process are screened through a sludge classifying press (SCP) where the hair and

Table 1. Clarification Alternatives

Settling-Based	Filtration-Based	Flotation-Based
1. Conventional Settling -Rectangular, Circular, Square, RTB, Shaft	1. Shallow Granular Media	1. Conventional Floatables Removal -Skimmers, Scum baffles
2. Vortex (Swirl Concentrator)	2. Deep Granular Media	
3. Lamella Settler	3. Microscreens, Woven Media -Salsnes Filter, Eco MAT™ Filter	2. Dissolved Air Flotation (DAF)
4. Chemically Enhanced Settling a. Conventional Basin b. Sequencing Batch - e.g. ClearCove Flatline EPT	4. Floating Media -MetaWater HRFS, BKT BBF-F	
c. Lamella Settler	5. Pile Cloth Media -Aqua-Aerobic Systems	3. Polymer-aided DAF -Various suppliers
d. Solids Contact / Recirculation - e.g. DensaDeg®, CONTRAFAST®	6. Compressible Media -Fuzzy Filter™, WWETCO FlexFilter™	
e. Ballasted Flocculation - Microsand (e.g. ACTIFLO®, RapiSand™) - Magnetite (e.g. CoMag™)	7. Fixed-Film Contact -Biological Aerated Filter (BAF), BioFlexFilter™	4. Biocontact + DAF -Captivator®
5. Suspended Growth Contact -BIOACTIFLO™, BioMag™, Bio-CES		

Primary Removal Equivalent * | Small Footprint (High-Rate Treatment) | Enhanced Removal

* If coagulation/flocculation provided, then HRT → EHRT

Table provided by Black & Veatch

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trash are removed from the sludge prior to delivery to the anaerobic digester or solids holding tank. Technologies such as the Harvester system are complete headworks and primary treatment solutions that combine the capabilities of primary clarification, flow equalization, fine screening, grit removal, fiber removal, FOG (fats, oil & grease) removal, phosphorus removal and floatables removal in a single treatment step. This technology also provides micro-screening of its effluent through a 50-micron screen, preventing any solids larger than 50-microns from flowing to the secondary process and removing 100 percent of all the visible hair and fibers. This technology is an example of the ability to operate with or without chemical addition while still providing BOD removal greater than that of conventional primary treatment. The Harvester system performs its chemical mixing through fluid dynamics, while CEPT chemical mixing involves the addition of mechanical components for chemical mixing ***(Table 2)***.

Table 2. Differences between an EPT Technology and Conventional CEPT

Feature	ClearCove Harvester	Conventional CEPT
Typical Flow Range	Peak/Average/Low	Peak
Chemical Usage	Optional	Chemical
BOD Removal	50-85%	50-60%
Primary Clarification	✔	✔
Flow Equalization	✔	
Grit Removal	✔	
FOG/Floatables Removal	✔	
Micro Screening	✔	
Automated Process	✔	
Ballasting		Sometimes
Chemical Mixing	Non-mechanical	Mechanical

Provided by ClearCove

The applications of conventional CEPT and EPT also differ. Traditional CEPT is usually used for high flow, wet weather scenarios to increase the surface overflow rate (SOR) of gravity primary clarifiers. However, EPTs such as the Harvester system provide a higher return on investment (ROI) when designed to capture the carbon in the average daily flow for the purpose of energy generation. EPT can also be designed to treat high wet weather flows like CEPT as well.

Conventional CEPT upgrades include new chemical addition equipment but use conventional gravity primary clarifiers that have a flow pattern which commonly re-suspends the flocculated settled solids and carries those solids and the colloidal content to the effluent launder ***(Figure 1)***. The flow patterns and operation of

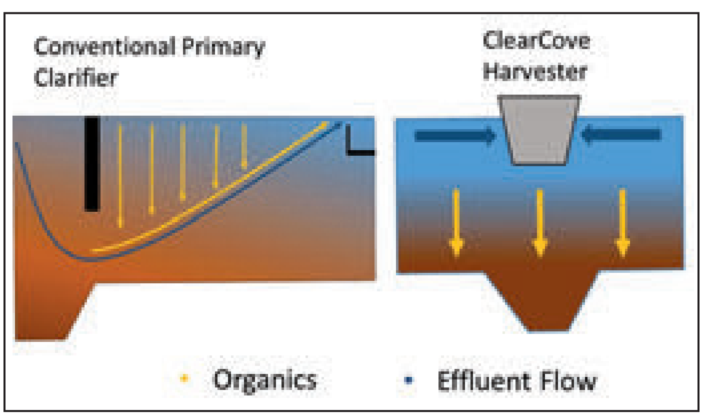

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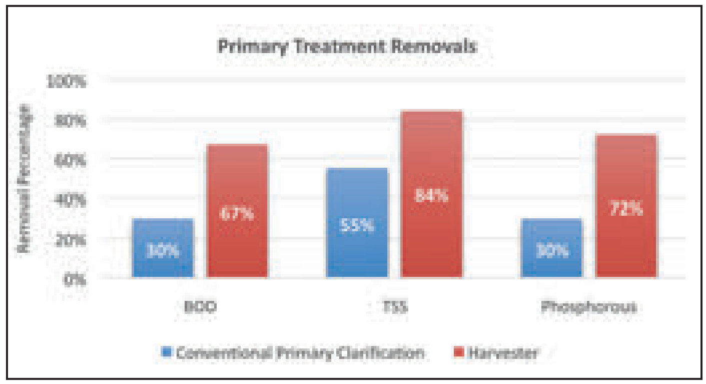
Figure 1. Flow Pattern Differences of Conventional CEPT and an EPT Example

the Harvester EPT are different in that the flow is stopped to allow the flocculated solids to settle and sweep downward to the bottom capturing a portion of the colloidal organics and the effluent flows through the 50-micron screen at a controlled velocity to filter the larger floc. This flow and operational difference enables the EPT to achieve greater organics and solids removal than conventional primary clarification and CEPT.

Enhanced Primary Treatment for Water Resource Recovery

Enhanced primary treatment is a critical component of the WRRFs enabling facilities to become renewable energy generators. A recent demonstration project of the Harvester (pilot) technology at the Ithaca Area Wastewater Treatment Facility (IAWWTF) provided proof of the ability of EPT to drive facilities to net-positive energy.

The goal of the demonstration project was to validate that enhanced removal of BOD_5 could be achieved in the primary treatment stage and that the sludge captured in the process would generate more methane gas than the sludge from the conventional process.



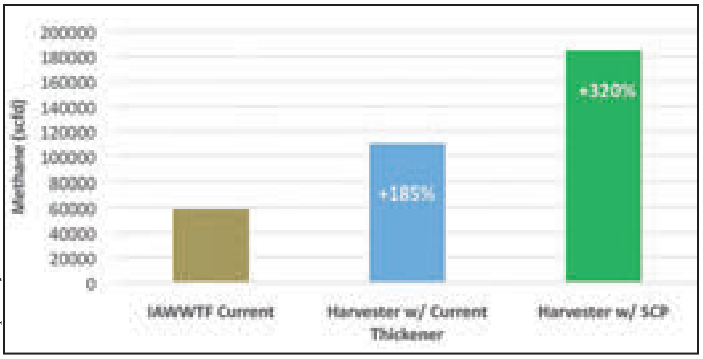
Graphic by ClearCove

Figure 2. Ithaca Demonstration Project Enhanced Removals

The new system achieved an average BOD_5 removal of 67 percent, over double that of conventional primary treatment removal of 30 percent ***(Figure 2)***. With the load of BOD_5 to secondary treatment significantly reduced, it is expected that there would be a 50 percent reduction in the IAWWTF's aeration energy consumption, which equates to approximately $56,000 per year in savings.

The sludge from the pilot system was fed to a pilot-scale anaerobic digester alongside sludge from the conventional primary clarifiers. It was found that the enhanced primary sludge from the pilot system generated over double the methane gas per pound of volatile solids destroyed in the reactor than the conventional primary sludge. When installed at full scale, the ratio of primary to secondary sludge will be shifted due to the enhanced capture of solids in the pilot system as demonstrated through the enhanced TSS removal. The increased primary sludge quantity in combination with the increased methane yield of the enhanced primary sludge is expected to result in the IAWWTF producing up to 320 percent more methane from treatment residuals, as illustrated in ***Figure 3***.

The combination of these two energy benefits is expected to enable the IAWWTF to go from consuming approximately 1.1 GWh per year to generating between 1.25 – 4.35 GWh per year more energy than the facility consumed if all methane is converted to electricity. The excess methane could also be converted into other forms, such as renewable natural gas (RNG), and utilized to fuel city buses and other municipal vehicles for further economic benefits to the Ithaca community.



Graphic by ClearCove

Figure 3. IAWWTF Energy Production Impact

The results of the demonstration program have been published in *NYSERDA Report #15-22, June 2015.*

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The Path to Energy Efficiency Improvements

by Brian Sibiga, Jamie Johnson, Joseph DeFazio, Joseph Fiegl, Garry Pecak and Joseph Brilling

Wastewater treatment plants continue to experience challenges related to meeting stricter discharge limits and increasing energy/operating costs with their inefficient aging infrastructure and fixed capacity treatment facilities. The cost to implement capital improvements to address these issues without impacts to tax payers is a challenge, emphasizing the need for an economically sustainable approach to capital improvements planning.

The Erie County Department of Environment and Planning's Big Sister Creek facility in Angola, New York, and the Washington County Sewer District No. 2 in Fort Edward, NY were able to use utility cost savings to improve the energy efficiency of their treatment plants. Their ultimate goals were to implement capital improvements to address more stringent effluent requirements; reduce operational and maintenance costs through utility cost savings; mitigate taxpayer burden to the extent possible; and reduce the overall municipal carbon footprint for each.

Both Big Sister Creek and Washington County projects were implemented through energy performance contracting where the savings generated by the improvements can be utilized to cover the equipment procurement and installation costs. Financing of the energy performance contracting was provided through municipal leasing or conventional bonding, along with grants, incentives (described later) and capital reserves.

Methodology

Each project entailed a detailed study and planning phase that included the completion of an investment grade energy audit. As part of the energy audit, a baseline was calculated utilizing methods approved by the US Department of Energy's International Performance Measurement and Verification Protocol.

Energy and efficiency conservation measures were identified by a walkthrough of the existing facilities and interviewing the operations staff. Baseline data for the energy and efficiency conservation measures identified during the walkthrough were determined using remote and existing logging equipment to establish run hours and/or equipment kW. Plant specific loading characteristics, historical utility data, and operator interviews were utilized to normalize the calculations for facility usage and significant facility seasonal variations. The data were utilized to form the baseline from which energy and operational savings were calculated.

The detailed study and planning phase provided recommended energy and operational efficiency improvements for various systems throughout the plants. The recommended improvements met the individual entity's payback and return on investment criteria to provide an economically sustainable implementation model.

Erie County DEP Big Sister Creek WWTP

The recommended energy efficiency improvements for the Erie County DEP Big Sister Creek project focused on the automation of existing equipment to enhance operations while simultaneously improving overall efficiency. The energy efficiency improvements implemented are described below:

- **Automated Dissolved Oxygen (DO) Control System**
  - o Making the existing activated sludge process more efficient was achieved by installing one new DO probe in each aeration basin, new electric actuators on the existing blower inlet valves, and a new PLC-based control panel.
  - o Following these installations, the automated DO control system enabled the aeration blower to modulate output based on the actual air demand of the system.

Courtesy of Wendel

The new DO system controls the air supply in the Erie County Big Sister Creek aeration basins.

Courtesy of Wendel

This is the control building which houses the plant-wide energy management system for the Erie County Big Sister Creek facility.

Courtesy of Wendel

Seen is the green roof installed on the control building for the Erie County plant.

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- **Return Activated Sludge (RAS) Pump Variable Frequency Drives (VFD) and Controls Upgrades**
  - o Prior to implementing this improvement, the RAS flow rates were on the order of 200–250 percent of the influent plant flow. However, a more common range of RAS flow rates are 30–100 percent of the influent plant flow. These improvement measures allowed for the modulation of RAS flow rates based on actual process requirements, thereby reducing RAS flow rates and improving the overall efficiency of the system.
  - o New PLC control system and VFDs were installed to allow the RAS flow rates to adjust based on meeting a percentage of the influent plant flow.
  - o To further enhance performance, a total suspended solids (TSS) probe was installed to aid in determining the mean cell residence time (MCRT) of the mixed liquor in the recycled flow.
- **Aerobic Digester VFD and Controls Upgrades**
  - o These improvements enhance the operation of the existing aerobic digesters while also improving their efficiency. To achieve this, new VFDs on the existing blowers, new DO probes in the digesters, and electric actuators on the existing blower inlet valves were installed.
  - o Following these installations, the aerobic digester blower output can be modulated based on actual process requirements, as can the aerobic digester tank level.
- **Automated Energy Management System**
  - o A computerized environmental management system (CEMS) is a set of protocols, competencies, integrated hardware and practices established to achieve overall environmental performance goals related to the plant treatment process operations.
  - o To implement a CEMS, the major wastewater treatment systems were equipped with a modern Supervisory Control and Data Acquisition (SCADA) system with the capability to remotely monitor and control the plant processes from a central location.
  - o The overall benefits realized following implementation of this measure include enhanced system monitoring, early detection of failures, flow adjustments, control decisions, reduced labor costs, reduced chemical usage and reduced equipment operating hours.
  - o As part of the energy management system, a building addition was provided that included a green roof. The green roof was constructed to act as a pilot demonstration.
- **Lighting Upgrade**s
  - o Inefficient lighting was replaced with modern fixtures and technologies, including LED lighting.

Washington County Sewer District No. 2 WWTP

The Washington County Sewer District No. 2 Wastewater Treatment Plant (WCSD WWTP) was constructed in the mid-1960s. The plant had a SPDES permitted flow of 2.5 mgd based on a 12 month rolling average with maximum day flows as high as 6 mgd. To meet new effluent limits associated with the Hudson River, seasonal ultraviolet (UV) disinfection was installed in 2009.

In January 2012, the New York State Department of Environmental Conservation put the WCSD WWTP under an Order of Consent due to effluent water quality violations. The origin of the plant's effluent water quality issues were directly related to faulty and aging activated sludge equipment that included:

- Mechanical issues with the blowers, preventing them from pro-

Courtesy of Wendel

New ultra-fine bubble diffusers with an oxygen transfer efficiency of 36 percent. Also shown, new baffle wall to encourage mixing in different modes of operation (conventional, step-feed, and contact-stabilization).

Courtesy of Wendel

New 50 HP turbo blowers coupled with new automated DO control system will modulate blower output based on actual process demands.

viding enough air to the aeration tanks, coupled with a broken air distribution header
- 1970s vintage diffusers with poor oxygen transfer efficiency
- Operational inflexibility that prevented WWTP personnel from modifying plant operations to better handle and/or react to changes in influent water quality and quantity

The above issues resulted in insufficient DO levels in the activated sludge process. The insufficient DO levels thereby led to water quality issues in the downstream process including filamentous growth and an inadequate level of biological treatment.

Contracted with the WCSD WWTP, Wendel developed a capital improvement program to address the Order of Consent. The team paid particular attention to realizing energy, operational and maintenance savings to offset the anticipated high capital costs required for the improvements.

The improvements to the activated sludge treatment process are described here:

- **New 50 HP Turbo Blowers**
  - o Two existing 75 HP centrifugal blowers were replaced with two 50 HP turbo blowers; one existing centrifugal blower remained for emergency/backup.
- **Piping Upgrades**
  - o Faulty buried air distribution pipe was replaced with above grade stainless steel piping.
- **New Ultrafine Bubble Diffuser**s
  - o The existing diffusers with oxygen transfer efficiencies near 15 percent were replaced with new ultrafine bubble diffusers with transfer efficiencies in excess of 35 percent. The improvement in transfer efficiency results in increased treatment capacity in the existing tanks – an important detail for a fixed capacity treatment facility looking for additional operational flexibility during wet weather events.
- **Modifications to Aeration Basin**s
  - o Structural modifications to the existing aeration basins were made to provide additional operational flexibility. Prior to this, the WCSD WWTP could only operate its activated sludge process in a conventional, plug-flow model. Following structural modifications, including the addition of a baffle wall and installation of additional slide gates, the plant can now operate in a step-feed mode or a contact-stabilization mode in addition to the conventional plug-flow mode. This provides WWTP staff with the opportunity to adjust the mode of operation to better respond to actual process needs, specifically during wet weather events.

Measurement and Verification

The measurement and verification phase is an important step to an energy efficiency improvement project because it provides validation of the original energy savings projections and an opportunity for further commissioning of the improvements to enhance savings. The measurement and verification phase in both projects was in conjunction with training of operations staff to ensure the effective use and performance of the installed equipment, further reducing the time for the savings to re-pay the improvements.

Total Program Benefits

Tables 1 and 2 show actual energy savings resulting from the energy conservation measures put in place and that are operating successfully at each plant.

Savings at Erie County Big Sister Creek: The improvements implemented at the Big Sister Creek facility provided savings totaling over $130,000 per year for a project cost of roughly $1.2 million. On its own, the project had an acceptable return on investment of approximately 9.4 years. However, Erie County actively pursued and was awarded grant funding from the New York State Energy Research and Development Authority's Green Innovation Grant Program (GIGP) and energy incentives from the electric service provider. The GIGP grant and incentives reduced the total return on investment of the improvements to approximately 2.6 years, pro-

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Table 1. Erie County DEP Big Sister Creek WWTP Costs-Savings

Facility Improvement Measures*	Annual Energy & Operational Savings	Total Measure Cost	Energy Incentives	GIGP Grant Funding	Simple Payback with Incentive
Lighting Upgrades	$7,132	$80,780	$3,465	$55,075	3.1 years
DO Control Upgrades	$24,671	$46,852	$57,485	$31,944	0 years
Energy Management System (SCADA)	$58,272	$922,452	$30,000	$538,619	6.1 years
RAS Pump Upgrades	$26,972	$57,008	$15,211	$38,869	0.1 years
Digester Aeration Blowers	$14,488	$125,390	$36,209	$85,493	0.3 years

**Not all energy conservation measures included in the above table are discussed in the article*

Table 2. Washington County Sewer District No. 2 WWTP Costs-Savings

Facility Improvement Measures*	Annual Energy & Operational Savings	Total Measure Cost	Energy Incentives	Simple Payback with Incentive
Aeration System Improvements	$66,300	$1,132,900	$135,000	15.1 years
Solids Dewatering & Polymer Upgrades	$143,300	$1,451,500	$9,900	10.1 years
EMS + Instrumentation Upgrades	$55,400	$1,326,600	$0	23.9 years
Lighting Upgrades & Controls	$2,600	$41,200	$1,800	15.2 years

**Not all energy conservation measures included in the above table are discussed in the article*

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viding a more immediate benefit to the county.

Savings at Washington County Sewer District No. 2: The energy efficiency improvements implemented provided energy and operational savings totaling approximately $267,600 per year. An additional $146,700 of energy incentives further reduced the total return on investment of the improvements to 16.1 years.

The case studies presented in this article demonstrate how wastewater treatment plants are able to undertake necessary capital improvements while improving energy efficiency and taking advantage of available incentives to improve facilities – all while saving more than they spend. The case studies further highlighted that various implementation methods and funding sources could be successfully utilized to incorporate energy and operational efficiency improvements.

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Improved Monitoring Techniques for Managing Disinfection By-Products from Drinking Water Treatment

by Ben Wright, William Becker, Justin Irving, Ben Stanford and Dave Reckhow

New York State is fortunate to have many high quality water supplies. From Lake Ontario to the Finger Lakes, to New York City's unfiltered Catskill/Delaware system, water utilities throughout the state have historically had the luxury of treating water with conventional, low energy treatment techniques. However, increasing regulatory pressure to remove disinfectant byproducts (DBP) coupled with increasing frequency of extreme weather events that result in DBP precursor (i.e., natural organic matter) spikes, may require the use of advanced treatment that is more energy intensive and expensive.

It is estimated that 1.4 megawatt hours of electricity is required to produce one million gallons of domestic drinking water. However, 80 to 85 percent of the electricity required for drinking water treatment and distribution is for pumping water. The actual treatment of water by conventional means (coagulation, flocculation, sedimentation, filtration and disinfection) is a relatively small proportion of the overall energy consumed for many public water supply systems. In New York, these estimates trend lower because over 50 percent of the surface water supplied in the state is for New York City, which is covered under a filtration avoidance determination due to its high quality and is predominantly a gravity flow system. Both factors substantially reduce the electricity consumption for water treatment in the state and make New York City's water system one of the "greenest" in the nation.

Disinfection byproducts may require additional treatment and add to the challenges, complexity, and energy demands of water supply management, treatment and distribution. Advanced treatment processes that address DBPs include the use of alternative disinfectants that are less likely to produce DBPs, or the addition of processes to remove precursor material (to prevent formation) or remove DBPs after formation. These processes tend to require higher levels of electricity than current conventional treatment ***(Table 1)***. If these processes were implemented across the state, it would have the potential to increase energy consumption for public drinking water supplies in the state by 10 percent to over 150 percent current levels.

Table 1: Energy Use for Water Treatment Processes

Trreatment Process	Energy Consumption (kWh/MG)
UV Disinfection	70 to 100
Ozone	170 to 350
Granular Activated Carbon	Up to 250
Filtration (ultra, nano reverse osmosis)	1,000 to 2,500

Measuring Variables that Drive DBPs

Disinfectant byproducts are not, however, a persistent problem for most drinking water supplies in the state, but short term spikes may occur from seasonal weather patterns or extreme events. Climate change has the potential to further increase the potential for DBPs from more frequent extreme events and warmer temperatures. The drivers of natural organic matter (NOM) production in the watershed, fate and transport processes, and in-reservoir processes are complex and make it difficult to identify exactly how weather influences the formation, mobilization and degradation of NOM in the environment. Further complicating management efforts for NOM is that DBPs form over time in the distribution system after leaving the treatment plant. Current methods for measuring DBP formation potential (DBPFP) take one or more days and have limited usefulness for treatment process optimization for short-term excursions in water quality. A few parameters are available that provide surrogate measures for DBPFP, such as total organic carbon, dissolved organic carbon, and ultraviolet (UV) absorbance at 254 nm. However, these have limited accuracy. Improved measurement techniques or surrogate parameters could improve a utility's ability to manage DBPs through flexible treatment, selective withdrawals or source rotation without resorting to broad scale treatment.

Recently, a research project was conducted with the support of the New York State Energy Research and Development Authority (NYSERDA) with the primary purpose of analyzing effective real-time monitoring tools that can detect changes in the character and amount of NOM and its associated DBP precursor concentration. The focus of this project was to use full spectrum UV absorbance and fluorescence as surrogate measures for DBPFP. Some NOM molecules absorb light in the UV and visible range. Ultraviolet absorbance at 254 nm is one example; however, light is absorbed at other wavelengths as well. A UV-Vis (visible) "spectro::lyser" analyzer *(S::CAN, Messtechnik GmbH, Vienna, Austria)* was used to measure UV-Vis absorbance in the laboratory across a wavelength range of 220 to 750 nm at a 2.5 nm resolution, both in the field and in the laboratory. In addition to absorbing light, some NOM molecules fluoresce when excited by light in the UV and blue region of the light spectrum. Dissolved organic molecules that fluoresce vary based on the chemical structure. A three-dimensional excitation-emission matrix spectroscopy using a Horiba Aqualog fluorometer (HORIBA International Corporation, Edison, NJ) was also used as a means to characterize the type and concentration of NOM present in a water sample.

Monthly and quarterly water samples were collected from seven New York utilities with diverse water quality characteristics and sources ***(Table 2)***. The DBP formation potential (DBPFP), UV absorbance, and fluorescence were measured for each sample, and the data were analyzed to identify combinations of wavelengths that most accurately predicted DBPFP. The DBPFP and UV absorbance measurements were conducted at the University of Massachusetts Environmental and Water Resources Engineering Laboratory. Fluorescence measurements were conducted at a Hazen and Sawyer laboratory in Raleigh, NC. Samples were dosed with chlorine based on target residual of four mg Cl_2/L after a seven-day incubation at the temperature of 20ºC. The DBPs were measured using an Agilent 6890 gas chromatograph (Agilent Technologies, Santa Clara, CA) per USEPA standard methods for trihalomethane (THM) and haloacetic acids (HAA). In addition to the four regulated THMs and five regulated HAAs, unregulated DBPs, such as acetonitriles and haloketones, were also measured.

Table 2: Participating Utilities

Utility	Raw Water Supply	Type of Supply
NYCDEP	**Catskill and Delaware Watershed**	**Upland Protected Reservoir System**
Monroe County Water Authority	Lake Ontario	Great Lake
Onondaga County Water Authority	Otisco Lake	Finger Lake
Village of Waterloo	Seneca Lake	Finger Lake
Latham Water	Mohawk River	Major River
City of Watertown	Black River	Adirondack River
Mohawk Valley Water Authority	Hinckley Reservoir	Adirondack Reservoir

Multiple techniques were used to analyze and compare the data, and one of the more promising approaches developed was the application of partial least squares regression (PLSR) to the full fluorescence excitation-emissions matrix. The method PLSR models a response variable when there are a large number of predictor variables, and those predictors are highly correlated, or even collinear. It constructs new predictor variables, known as components, which are linear combinations of the original predictor variables. The PLSR method uses the full dataset, and the components weight the individual wavelengths based on contribution to the value being predicted.

Figure 1 and ***Figure 2*** present the results as a comparison of lab data and prediction data for one analysis using the combined dataset from all water sources. The extremely large range in DBPFP leads to a relatively high R-squared value, but with a relatively wide window of predictions. These results are promising and improved accuracy is expected as the dataset for each water source is expanded.

Results from this study confirm that UV-Vis spectroscopy and fluorescence can be a useful estimator of NOM and DBPFP that may enable operational refinements (e.g., selective withdrawal or treatment based on higher-than-normal DBPFP) of water treatment plants based on DBP precursor surrogates. Selective management through treatment or other means is anticipated to require less energy and be more cost effective than broad scale treatment of source waters. Improved surrogate measures for DBP precursors will be invaluable for tracking changes in water quality due to short-term weather events and long-term changes in the watershed or climate to facilitate near real-time management of water supplies and may also serve to signal the need to update treatment process infrastructure.

While promising, the results also indicate that optical measurements do not capture all of the potential variability in DBPFP and that further study is needed to improve surrogate measures. However, it is important to note as well that these techniques are not meant to predict DBP concentrations in the distribution system, or to provide an exact prediction of the total DBPFP. Rather, the techniques are meant to be used as a method by which one can observe changes in precursor concentration from a supply and then make subsequent decisions about selective withdrawal or treatment changes that may be needed to manage NOM fluctuations. More detailed information on this study will be available in a forthcoming report to be published by NYSERDA.

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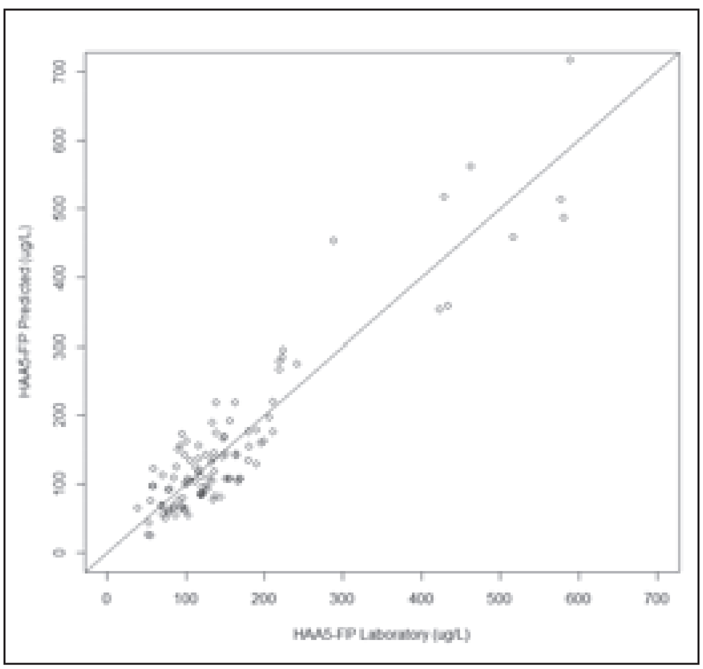

Figure 1: Regulated HAA (a DPB) formation predictions based on fluorescence PLSR model. *R-squared = 0.81.*

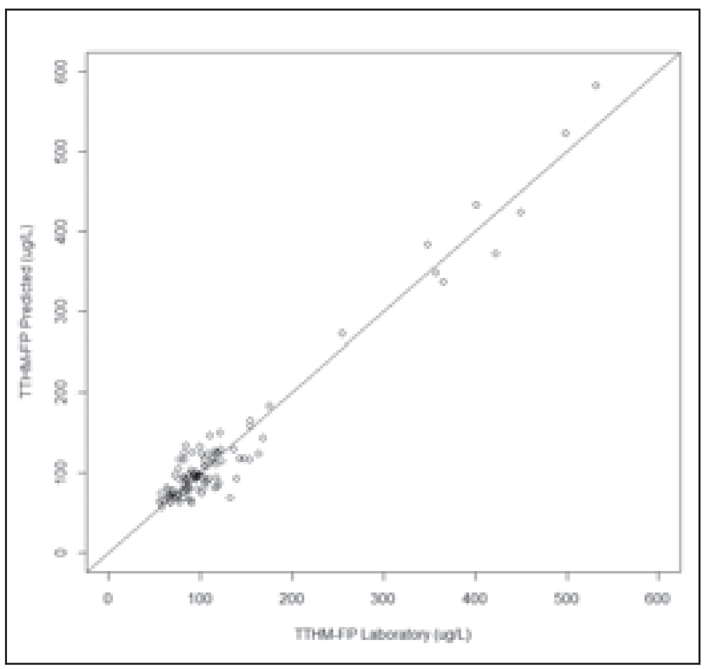

Figure 2: Regulated THM (a DPB) formation potential predictions based on fluorescence PLSR model. *R-squared = 0.94*

Defining, Establishing and Implementing an Effective Energy Management Program – A Case Study

by Silvia Marpicati and Timothy Noyes

Energy Management Programs are effective tools to support water utilities in their goals of managing energy use at water and wastewater treatment facilities and pumping systems. Energy savings translate into cost savings, greenhouse gas emissions reduction, and an overall more sustainable way to provide clean water and return treated water into the environment.

A comprehensive approach to energy reduction involves an overall evaluation of the energy use at the water or wastewater treatment facilities, with the development of a baseline to identify where, why and when energy is used. These data are then used to create performance metrics for comparison, evaluation and long-term optimization.

There are a number of methods that can be used to create an energy use baseline. The selected methodology should balance cost and complexity with the level of accuracy and granularity needed for the intended purpose. Typically, the energy use baseline is created by collecting equipment nameplate data, run time and current operation strategy, and energy use measurement (spot measurements, logging, submetering, etc.). Information is then aggregated and compiled by process type to develop the "energy use pie" and allocate energy consumption amongst the top energy users at the plant. For example, the US Environmental Protection Agency's (USEPA's) Energy Use Assessment Tool provides a good framework for the total energy use and the breakdown by process type.

Often, the energy use pie reveals many energy savings opportunities; typically, aeration, pumping and sludge handling systems offer the greatest potential. For an effective, long-term impact on energy cost savings, the utility should apply the energy efficiency evaluation to all or at least the top energy users at the facility, revisiting goals and comparing with the initial baseline, and making energy efficiency an iterative process rather than a one-time occurrence, where blowers and pumps, sludge handling and odor control systems are initially optimized and then routinely monitored against established performance indicators to maintain high levels of efficiency.

Beyond energy efficiency, utilities can also consider the economic benefits and technical feasibility of onsite renewable energy, such as anaerobic digestion of biosolids or co-digestion with high-strength waste to generate combined heat and power; photovoltaic (PV) systems; small hydrokinetic electrical generation; as well as any potential for effluent heat recovery. Regional energy pricing, incentives and utility specific drivers can all significantly influence the overall viability of demand side distributed generation.

Effective Energy Management Programs

The first step for an effective energy management program is to secure organizational commitment from a diverse group of stakeholders. Management, engineering and operations not only are important links in this collaborative approach, but also have a dramatic impact on the successful change in culture that is required to transform from "doing business as always" to "considering energy use first."

Following organizational commitment, the energy program focuses on gathering information and building a strong understanding of existing energy use and costs. It is important to undertake internal and external benchmarking, and to assess the relative efficiency at a process level, particularly for the larger energy-consuming processes. This information can be used to evaluate current energy usage and establish energy efficiency goals for future improvements and operational changes.

A technical evaluation is performed to evaluate opportunities for energy savings and energy cost reduction, using simple paybacks or return on investment calculations to prioritize the identified energy conservation measures, although other economic and non-economic variables should be considered prior to implementation.

Progress tracking and reporting is the final step in building an energy program. This step is important for monitoring and measuring the progress of the energy program, for ensuring changes align with the utility's overall energy efficiency goals, and for establishing and maintaining support for the program. ***Figure 1*** shows the basic steps involved in building an energy program *(NYSERDA 2010)*.

Figure 1 shows the basic steps involved in building an energy program *(NYSERDA 2010).*

Case Study: Toho Water Authority (TWA)

The following case study provides an overview of energy management initiatives that are being implemented by Toho Water Authority (TWA). TWA owns and operates 15 water plants, eight wastewater plants, and numerous wells and pump stations. Located in Kissimmee, Florida, it is the largest provider of water, wastewater and reclaimed water services in Osceola County.

TWA has adopted an Energy Master Plan to provide reliable, cost effective, and efficient water services to its customers through an industry-leading sustainable energy program that incorporates staff training and the application of new technologies at the lowest achievable energy consumption. The energy program was launched by bringing together directors, managers, and representatives from engineering and operations and maintenance to create the high-level goals and objectives of the energy management program. These members form the Energy Team. The group identified internal and external drivers (such as: management practices, service, asset condition, culture, rates, economy, customer satisfaction,

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regulations) and the desired key outcomes (such as: control and predictability of energy use and costs, increased efficiency, lower operating costs, reinvestment savings, more autonomy from the electric utilities, process optimization, and cultural change) to define the Energy Master Plan.

In the role of Energy Master Plan's manager, ARCADIS is performing a broad assessment of energy use at water reclamation facilities (WRFs) which are the largest energy users at TWA. Implementation of the Energy Master Plan relies on energy assessment tools to establish external and internal benchmarks and to identify processes that use more energy per unit of flow than typical. The USEPA's Energy Star Portfolio Manager Tool and the USEPA's Energy Use Assessment Tool (EUAT) were relied upon for this activity.

Electrical and flow data for TWA's WRFs were entered into Portfolio Manager, an external benchmarking tool that helps assess energy efficiency relative to similar facilities nationwide. Different Portfolio Manager tools are available from the USEPA for different space types/sectors. The Wastewater Treatment Plant tool was used for this task.

Portfolio Manager provided a first assessment of the facilities' performance compared to the national median. A sample report provided by Portfolio Manager for Water/Wastewater sites is shown in ***Table 1***. The report compares the site energy use intensity (EUI) in thousand British thermal units per gallon per day (kBtu/gpd) to the national median.

Portfolio Manager also allows the comparison of facilities in the same portfolio, as shown in ***Table 2***, making it an excellent tool for entities with a portfolio of facilities.

The rating received by TWA's wastewater facilities (below national median) highlighted some of the challenges associated with external benchmarking. These are not typical WWTPs and have additional tertiary treatment and effluent pumping that would not be reflected in the energy usage of a WWTP that discharges by gravity to a river or lake. Additionally, the largest WRF in the portfolio (WRF No.1) provides centralized biosolids treatment for other TWA facilities, therefore, it uses a proportionally larger amount of energy for solids handling and dewatering. Even so, external benchmarking was a valuable exercise. The rating that is established can be compared against future ratings to assess the effect of energy improvements that are undertaken and the process forces a facility to look more critically at its energy usage and identify the reasons why its energy usage may be different from that of others included in the USEPA database.

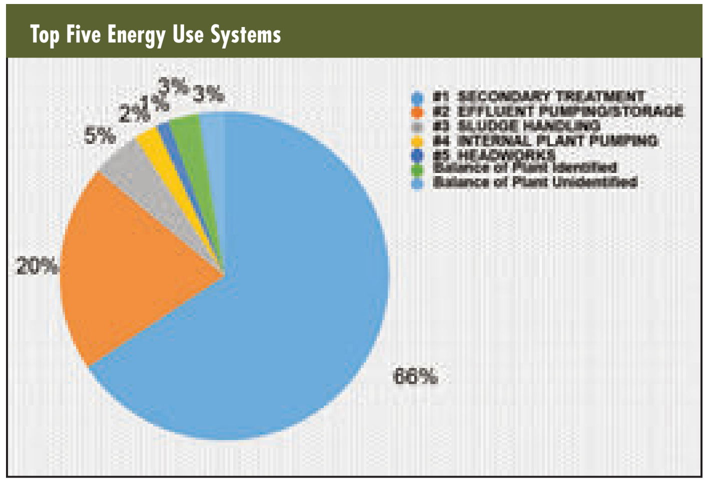

Figure 2. Distribution of Energy Use from EUAT Summary

Another valuable aspect of Portfolio Manager is that multiple facilities can be added as part of a portfolio. This way, facilities with similar treatment processes can be rated and compared to each other. The outcome of this comparison was used to identify and prioritize facilities for further evaluation through energy audits.

ARCADIS started by performing a pilot energy audit at the largest WRF, with a design flow of 13 million gallons per day (mgd). The results of this pilot audit were to be used as a baseline to extrapolate potential energy savings at similar TWA facilities and to document the process and provide training for staff. After collection of operational data, ARCADIS worked with TWA staff to set up the data review and organize data in pre-developed templates. An energy audit was performed to gather plant-wide motor inventory, equipment runtimes, and spot measurements of electrical current of significant process equipment.

Gathered data were entered into the second tool used in TWA's energy evaluation: the USEPA's Energy Use Assessment Tool (EUAT). The tool was created to assist water and wastewater utility managers and operators in the assessment of the energy use at their sites. The EUAT provides a distribution of energy use by process, as shown in ***Figure 2*** and ***Table 3***.

The table and figure were taken from the EUAT Summary Report, which highlights the top five major energy use process systems. Over 60 percent of the energy use at this WRF is due to the secondary treatment, which includes blowers, mixers and recycle pumps of the anoxic-oxic-anoxic-oxic (AOAO) systems. Twenty percent of the energy use is due to effluent pumping, including transfer, effluent, and reuse pump stations.

The table indicates the highest energy uses at the plant. Based on the top energy use systems, a technical investigation was performed on the aeration system (including blowers, air distribution and automated controls), the solids handling system (including sludge holding tank aerators, use of a dewatering centrifuge), and the effluent transfer pumps (VFDs).

A more detailed breakdown of Key Performance Indicators (KPIs) was developed by taking the energy use by process type provided by the EUAT tool and dividing it by the annual average influent

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Table 1. Portfolio Manager Report for WRF No. 2

Water Reclamation Facility	Design Flow (MGD)	National Median Water/Wastewater Site EUI (kBtu/gpd)	Facility Water/ Wastewater Site EUI (kBtu/gpd)	Percent Deviation from National Wastewater Site EUI
WRF No. 2	6	3.53	5.22	48.0%

Table 2. Portfolio Manager Report for all Facilities in Portfolio

Water Reclamation Facility	Design Flow (MGD)	National Median Water/Wastewater Site EUI (kBtu/gpd)	Water/ Wastewater Site EUI (kBtu/gpd)	Percent Deviation from National Wastewater Site EUI
WRF No. 1	13	2.70	3.81	41.2%
WRF No. 2	6	3.53	5.22	48.0%
WRF No. 3	5	3.23	3.74	15.6%


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Table 3. Top Energy Use System from EUAT

Major Process/Top Energy Use Systems	Electric Energy Use (%)	Electric Energy Use (kWh)	Electric Energy Cost ($)
#1 Secondary Treatment	65.62%	6,959,534	$728,780
#2 Effluent Pumping/Storage	20.41%	2,164,851	$226,696
#3 Sludge Handling	4.83%	512,590	$53,677
#4 Internal Plant Pumping	2.31%	245,266	$25,683
#5 Headworks	1.28%	135,726	$14,213
Balance of Plant Identified	2.99%	316,761	$33,170
Balance of Plant Unidentified	2.56%	271,308	$28,410
Total	100.00%	10,606,036	$1,110,630

flow to find the unit electric energy use per water treated. This is called the wire-to-water efficiency, or the daily energy used per volume of water treated (kWh/MG).

These ratios were compared to the theoretical energy requirements by process, as published in WEF Manual of Practice No. 32 (MOP 32). A range of -10 percent to +25 percent was included for comparison purposes to account for real conditions that might not be captured in the theoretical energy calculation included in MOP 32. The average wire-to-water efficiency at each plant was then compared to a typical WWTP of similar size and design within the comparison range. All TWA facilities appeared to use more energy than the MOP 32 baseline, however, it has to be considered that, in addition to traditional processes of a WWTP, these WRFs also include effluent pumps for storage and reuse, reuse augmentation, and centralized biosolids treatment from other facilities in the TWA area.

The KPI breakdown also highlighted additional opportunities for energy savings. When comparing actual wire-to-water use to the range of theoretical expected use for the same process type, processes that appeared to use a considerable amount of energy when compared to the expected range were flagged for further investigation.

One example is the return activated (RAS) pumping system at WRF No.1. The wire-to-water use of this system was calculated as five to seven times the typical range, normalized to flow. Typically, two of the 60-HP pumps and one of the 40-HP pumps are in operation 24 hours a day to return sludge from the four final clarifiers to the splitter box that feeds the AOAO system. The energy analysis revealed that a third 60-HP pump is currently needed in operation full time to maintain a low blanket in the clarifiers until the clarifier gaskets are replaced. Additionally, the total head that the pumps need to overcome appeared high. A preliminary hydraulic analysis of the RAS pumps configuration revealed that the last portion of the piping to the process splitter box is creating a bottleneck which increases the headloss when all the RAS flow is pumped at the same time, creating high velocity and adding considerable friction losses. Increasing the pipe size to reduce the pumps' head was recommended for energy savings.

Other opportunities were evaluated for energy savings and energy cost reduction, including operational changes, automated controls, and the cost effective replacement of equipment. Building systems and lighting were also evaluated and a screening level feasibility of onsite generation was performed to convert the solids handling system to anaerobic digestion with power generation, photovoltaic and wind generation. As part of the Energy Management Plan, energy efficiency and performance have also been incorporated into the asset management and capital project prioritization tools that are employed by TWA.

A new round of energy audits is currently being performed. Templates that were created for the initial pilot energy audit are currently being used by TWA to collect relevant information at three additional facilities. Data will be evaluated to identify whether measures initially identified for the pilot facility can be applied to similar processes at the new facilities being considered.

Energy Management Plans play an important role in helping water utilities identify ways to reduce energy use and costs. The case study from TWA illustrates that the utility launched its Energy Management Plan by forming an Energy Core Team in charge of the energy program, by identifying and assessing current energy performance at the facilities, by setting clear objectives and targets, and by identifying areas for improvement, prioritizing the opportunities, and developing an implementation program for the selected projects.

The utility has made effective energy management a high priority, recognizing the energy, cost and environmental benefits that can be realized, and it is well on its way to establishing, improving and maintaining the long-term energy performance of its facilities and its assets.

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Bioelectrochemical Systems – Energy from Wastewater

How can we save cost and energy for wastewater treatment?

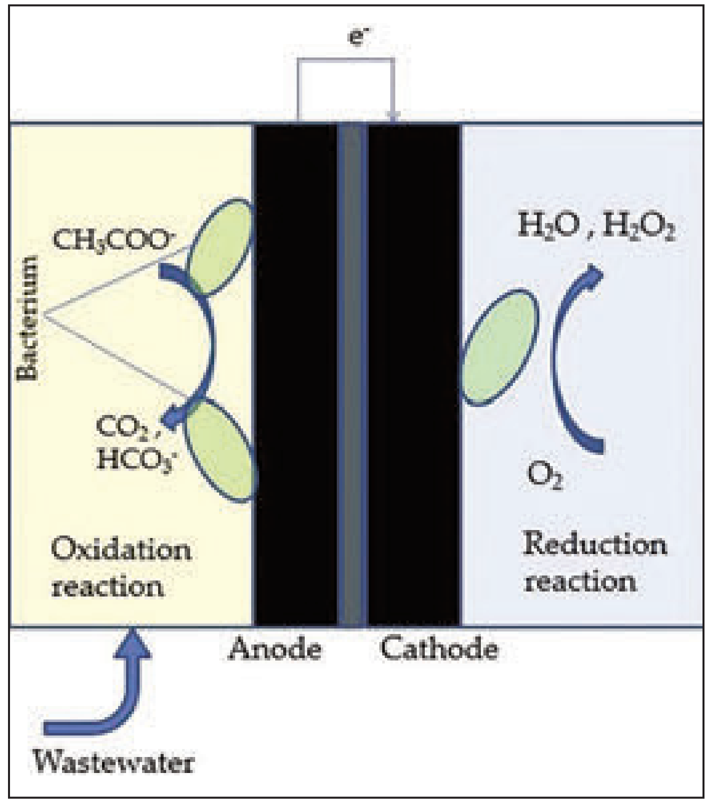
by Chenjie Wu

Bioelectrochemical systems (BESs) are an innovative approach for wastewater treatment and have received increasing attention through academic and government research and development as an alternative energy system. The Water Environment Research Foundation (WERF) identified energy from wastewater, including novel means of recovering various forms of energy contained in wastewater (e.g., chemical, thermal, kinetic), as a key research area in August 2015 *(http://www.werf.org/i/Funding/Open_RFPs/a/o/rfp.aspx?hkey=05bda2a1-23af-4891-badf-815b2960d4f3)*.

Wastewater contains a wide range of organic and inorganic materials that require treatment before its disposal to the environment. It was estimated that the annual energy demand for the water and wastewater industry in the United States is approximately 75 billion kWh, which is about 4 percent of the total electricity consumed by the nation *(USEPA 2010)*. The numerous reducing forms of organic and inorganic compounds in wastewater are a source of chemical energy. Theoretically, oxidation of one kilogram of COD to CO_2 and H_2O will produce 1.47×10^7 joules of energy. Based on an average COD concentration of 60–120 g/person/day produced in municipal wastewater, the potential energy in wastewater is estimated at $1.03–2.06 \times 10^{17}$ joules/year for the US population of 320 million, and is equivalent to 3.3–6.6 gigawatts of continuous electrical power *(Heidrich et al. 2011)*. This internal chemical energy of wastewater can be a substantial renewable energy source which can be captured by BESs. In addition to harvesting the chemical energy and reducing the need for aeration for biochemical oxidation of organics, BESs also have a distinct advantage of producing substantially less biomass than aerobic processes to achieve similar wastewater treatment objectives. In the use of BESs lies the potential of turning wastewater treatment into an energy positive industry.

How do BESs Work?

An electrochemical cell is a device that converts chemical energy into electrical energy. The basis of a bioelectrochemical system is to employ microbes to facilitate biochemical reactions. Chemical reactions are slow and sometimes require expensive catalysts such as platinum, whereas using bacteria can overcome this drawback because of their diverse metabolic functions. Through different metabolism pathways, bacteria harvest energy to live and reproduce; BESs "steal" part of that energy flow to generate electricity. In general, anode (negative electrode) and cathode (positive electrode) chambers are the two essential components of a BES, with each chamber containing an electrode. In the anode, anaerobic microorganisms are employed to facilitate organic oxidation and other metabolic functions. Electrons released from oxidation processes are intercepted by the anode electrode through extracellular electron transfer. The electrons then move across a wire to the cathode where a reduction reaction occurs. The most common reduction reaction at the cathode is oxygen reduction to water. However, to avoid additional energy input and to reduce the cost of using a noble metal such as platinum on the cathode side, biocathodes have been studied extensively. The use of biocathodes resulted in a complete biological BES with bacteria at both the anode and cathode. Bacteria with the capability of transferring electrons to electrode surface are called electrochemically active microorganisms.



Created by Dr. Chenjie Wu

Figure 1. A two-chamber BES separated by membrane

Figure 1 shows a simple representation of a two-chamber BES with bacteria employed on both electrodes. ***Figure 2*** shows a one-chamber BES model with open air-cathode for oxygen reduction reaction. Compared to common fuel cell systems, BESs are often operated under relatively mild conditions (i.e., ambient temperature, neutral pHs and low concentrations of supporting electrolytes), and mostly do not use expensive precious metals as catalysts. The BESs typically consist of a carbon-based anode and cathode either separated by a cation/proton exchange membrane or without a membrane.

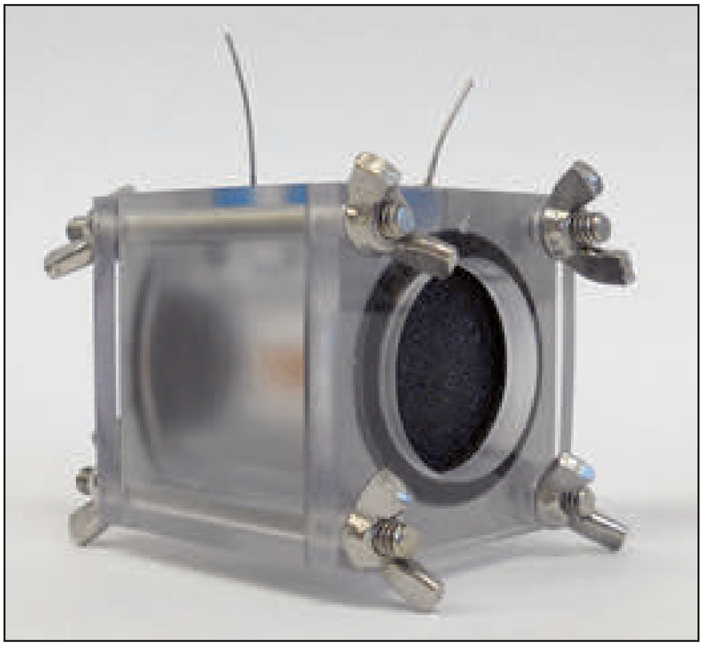
> ***"In the use of BESs lies the potential of turning wastewater treatment into an energy positive industry."***

Different Kinds of BESs

According to the types of applications or working principles, BESs can be categorized as microbial fuel cells (MFCs) for electricity generation, microbial electrolysis cells (MECs) for chemical production, or microbial desalination cells (MDCs) for desalination.

Microbial fuel cells (MFCs) are used for maximizing electricity production. Power production of typical MFCs is in the range of milliwatts per square meter of electrode surface area. The maximum power density that has been achieved so far is 1600 milliwatts/m^2 *(Logan et al. 2007)*. Microbial solar cells (MSCs) are a special kind of MFCs which utilize solar energy to produce electricity. The MSCs use photoautotrophic microorganisms or higher plants to produce organic matter which is then transferred to anode where oxidation of organic matter is achieved through electrochemically active bacteria.

Microbial electrolysis cells (MECs) are a type of BES in which net electrical power may be needed for product formation or certain designed process. The design of MECs is similar to MFCs.



Courtesy of Rachel Wagner, assistant professor at Saint Francis University

Figure 2. Lab scale air-cathode microbial fuel cell

The MECs operate under completely anaerobic conditions and, therefore, promote the growth of obligate anaerobic bacteria, such as exoelectrogenic *Geobacter spp.*, as well as nonexoelectrogenic fermentative or methanogenic microorganisms. With the presence of methanogens, methane gas can be produced through direct one-step reaction or a two-step reaction with hydrogen as intermediate product. Therefore, MECs are usually used for hydrogen/methane production. The conversion of organic compounds to hydrogen or methane yields a positive Gibbs free energy, which indicates that such a reaction will not occur spontaneously. An external power source is used to provide the energy required for driving reactions for hydrogen and methane production.

Recent studies have also shown the potential of using BESs for desalination. Such devices are called microbial desalination cells (MDCs). The theoretical minimum energy for desalination of typical seawater (35 g/L of total dissolved solids) is 1.0 kWh/m^3 (http://www.usbr.gov/research/AWT/energy_use.html). The energy in domestic wastewater ranges from 1.8 to 2.0 kWh/m^3 which is sufficient enough to power a desalination process. In an MDC, two membranes are commonly used to create a middle chamber between anode and cathode for water desalination. An anion exchange membrane is placed next to the anode, and a cation exchange membrane is placed next to the cathode. An electrical current is produced between the two electrodes which drives the cations to travel through the cation exchange membrane to the cathode compartment and the anions through the anion exchange membrane to the anode chamber, leaving the middle chamber desalinized.

What Kind of Wastewater Can BESs Treat?

Any kind of wastewater containing biodegradable organic matter can be treated using BESs, including municipal wastewater, brewery wastewater, food processing wastewater, and paper recycling wastewater. Other than wastewater, wood chips/shavings/pellets, crop residues, household vegetable, fruit and garden waste and electron sources in natural waters can all be used as fuel for BESs. The COD removal efficiency via BESs can reach up to 95 to 98 percent.

The advantages of BESs are clear:

- The chemical energy of reducing compounds can be converted to electrical energy for direct use
- Useful chemical production
- Significant reduction in greenhouse gas emission from wastewater treatment
- Produces low amounts of excess sludge
- Ambient temperature operation
- No or reduced energy input for aeration

What are the obstacles that need to be conquered before using BESs in our wastewater treatment plants?

Because BESs are a relatively new technology, to fully develop them for large scale requires additional time and effort. The power production of BESs is still low compared to other energy sources and scale-up of the technology would enlarge the problem. Further studies are also necessary to understand the effect of different parameters (operating potential, bacteria community, etc.) and electron transfer steps that aim to optimize the performance of BESs. Finally, in order to be economically efficient, new electrode and membrane materials need to be developed to reduce the cost for large scale applications without sacrificing the performance of BESs. The scale-up development of BESs has been challenging. Before finding a solution for better energy harvest from BESs, the public may still need to wait 50 years or more before seeing them in US wastewater treatment plants.

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Operator Spotlight:

A Passion to Pass on Professional Knowledge

Don't doubt 28-year-old **Kristofer Gushlaw** when he says, "I fell in love with wastewater." Just look at what he has accomplished in four years since starting work at the Plattsburgh Wastewater Treatment Plant.

"I never thought I would have entered the field I'm in now, but how many others have said that before?" he commented. "It's been an incredible career for me."

Kris joined the staff as an operator trainee in 2011with a BS degree in biology and minor in chemistry from SUNY Plattsburgh – well prepared for the science and laboratory duties his work would entail. "This career not only uses most of my college background, but has expanded my knowledge of microbiology and chemistry, which I enjoy."

Initially placed in the lab to learn the water resource chemist duties, Kris was immersed in the plant's cross-training program with management deciding to take full advantage of his many talents. In addition to plant chemist, Kris' abilities in computer systems, plant processes and science would be best applied if he were groomed for the position of assistant chief plant operator.

Kris steadily climbed the state licensing ladder for operators (2A, 3A, 4A certifications), earning the 4A credential in 2014. Kris was promoted to assistant chief plant operator later the same year.

Recognizing the importance of maintaining institutional knowledge, Kris has another passion – that of learning all he can about plant operations and passing on what he learns to other operators. He knows that the demand for water and wastewater operators not only is predicted to increase, but that the industry will lose over 40 percent of the current workforce to retirements within this decade.

Kris decided to take a leadership role on the issue of succession by volunteering on the statewide NYWEA Operators of the Future Taskforce, and assisting with facility tours and other public educational outreach for his plant.

"I think the position of wastewater operator is a highly overlooked career because it is often considered a 'dirty job.' I'm an advocate for increasing public knowledge of the kind of responsibilities and the complicated work the operator faces each day. I've helped to publish brochures about our plant and promote plant tours. Getting the public to understand more about wastewater operations will increase not only good public relations, but recruit more job seekers with higher skills and knowledge for job openings."

An area at work in which Kris is passing on his knowledge is one of his own personal interests – computer troubleshooting. When he joined the plant he learned everything he could about the SCADA system, which monitors the plant processes, alarms and pump stations.

"I've become the go-to guy when it comes to set points, troubleshooting or new installations involving our plant's SCADA system," he said. "I'm teaching other operators this, so should a problem arise they can solve the problem without my assistance. Expanding operators' knowledge in advanced systems really helps the operations of the plant as a whole and I feel is a very important thing to do."

Photo by Sandra Geddes

Kristofer Gushlaw, assistant chief plant operator of the Plattsburgh Wastewater Treatment Plant, is also a member of the NYWEA Capital Chapter's Young Professionals Committee and the statewide Operators of the Future Taskforce.

"I would advise others who are entering the field to learn all they can about their plant. When an operator can run the plant with his or her eyes closed, then help to expand knowledge in areas which lack personnel with experience, or specialize in an area of personal interest that further helps benefit the plant."

Kris has also completed a number of continuing education workshops, including nitrification/denitrification, nutrient removal and DMR (discharge monitoring reports).

Long-term, his professional goals are "to learn as much as I can from the veterans of the plant so when they retire, their knowledge won't be lost. I'd also like to become the chief plant operator."

Born and raised in Plattsburgh, he's there to stay. Kris has been married four years to Maria, and "we have two beautiful children – Elena and Nicholas."

"I highly enjoy my career," he added. "It's very dynamic, with new challenges every day to overcome, keeping you on your toes. Wastewater forces you to think about how you can solve problems in many different ways. The most rewarding part of the job is assisting with the plant's process control to make a high quality effluent and protect the public health."


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Plattsburgh Plant's Major Staff Transition is Team Success

by Jonathan Ruff

In the not too distant past, the City of Plattsburgh Wastewater Treatment Plant had a staff of 24 – nine certified operators, five maintenance workers, five laboratory technicians, plus some management and support staff running a 24/7 operation. Only three of those staff members now remain: the chief plant operator, water resource chemist, and a lab technician who transferred into operations. Needless to say, an 80 percent staff turnover in a relatively short amount of time had the potential to be catastrophic.

During the turnover transition, new technology was implemented and work plans and scheduling were made more efficient, which allowed the number of employees to be reduced by attrition from 24 to 12 (50 percent) without compromising safety or performance. Operations and maintenance of the facility are now accomplished by a team of water quality professionals comprised of just six certified operators, one maintenance worker, a CPO (certified plant operator), ACPO (assistant certified plant operator), water resources chemist, storekeeper, and typist – all working one staggered 0800–1600 shift, seven days per week, 356 days per year.

Certified operators are now performing a much larger diversity of tasks than in the past. Impressively, despite the staff reductions, productivity and performance have increased significantly. These changes that occurred could not have happened without the collaboration of all plant employees in a remarkable team effort.

Plattsburgh's Environmental Manager Jon Ruff demonstrates on the whiteboard how operators calculate different wastewater equations, such as for SVI (sludge volume index).

Plant History and Staff Strategy

The City of Plattsburgh has a combined collection system. The wastewater treatment plant is permitted at 16 mgd dry weather flow and 50 mgd wet weather flow. To accommodate loads from the Plattsburgh Air Force Base and several papermills, the plant was rated for 48,000 lb/day BOD (biochemical oxygen demand) and 36,000 lb/day. The air force base and a papermill have since closed and the remaining mills have scaled back production, resulting in a present average daily flow of only about 6 mgd and just fractions of the historic BOD and TS (total solids) loads. The rain has not decreased, so the wet weather instantaneous peaks still reach the 50 mgd capacity. The size of the facility has not changed, so there is the same, if not more, maintenance work.

The transition was a good model of succession planning, change management, staff development, cross training, and continuous improvement. But most of all, it was a comprehensive employee collaboration, without which, success would not have been achieved.

The reduction in staff and coverage was only possible by consolidating work, cross training staff and implementing technology. The result is an operations group composed of individuals with diverse backgrounds and skills sets, each of whom traveled different paths to become certified operators. They also perform different roles depending on plant needs and their individual knowledge, skills and abilities (KSAs), as well as preferences.

The operations team members are listed below, in order of their years of service:

David Powell is 4A certified and the chief plant operator at the Plattsburgh WWTP with over 35 years of experience. He holds a BS degree in geology from Syracuse University. He also is a NYWEA Capital Chapter member who serves on the Pretreatment/Industrial Wastewater Committee.

"With a large turnover of staff due to retirements, this presented an opportunity to train and develop the staff and instill in them the importance of doing a good job, keeping safe, and promoting our work. When I retire, my goal is to be sure that the operation and direction of the plant will not falter and my successors will be knowledgeable and dedicated. I advise operators or those thinking about entering the field to keep an open mind about it. There are many challenges and new technologies that make it more demanding, while some basics will never change. So be a student of your plant to understand how it operates, but also be open to change."

–Chief Plant Operator Dave Powell

Photo by Kristofer Gushlaw

Vash Eagelson (left) shows Eric Bertrand how to operate the PLC, aka SCADA system, to include clearing alarms and viewing incoming data.

Steve LaFaive has 28 years of experience as a lab technician, first starting in operations, for a total of 33 years at the plant. He holds a BA degree, and was trained and promoted into a 3A certified operator seven years ago. A true hybrid, he works about 50/50 in operations and the lab.

Rich Montroy is predominantly a lead operator who had worked in private sector management and manufacturing for 20 years before entering the plant in maintenance 12 years ago. Promoted to a 3A certified operator three years ago, he also initiates a variety of maintenance and special projects. Rich helps lead the development of new trainees.

Vash Eagelson, who primarily serves as a lead operator, had 15 years in operations and maintenance for a contract operator at a sludge composting plant before he came to work at this plant 10 years ago as an operator trainee. He brought with him a variety of skills and work experiences that quickly translated into becoming a 3A certified operator. Vash also leads the development of trainees and some special projects.

Adam Lucas came to the plant five years ago after 10 years in the private sector doing heavy rigging and millwrighting. He holds an AAS degree, and became a 2A certified operator who now leads all maintenance activities for the plant while continuing in operations as needed.

Scott Pierce's varied career includes 30 years in private sector grounds and maintenance, some adjunct college instruction, and then research science and quality control in a pharmaceutical company. Starting as an operator trainee four years ago, he is a 3A certified operator now working primarily in the lab, and helping in operations as needed. He holds a master's degree in biology-ecology from SUNY Plattsburgh, and also is a NYWEA member.

Kris Gushlaw joined the plant about four years ago with a BS in biology. He now holds 4A certification and is the assistant chief plant operator *(read more about Kris as our Spotlight Operator on page 57).*

Eric Bertrand worked in the private sector, including construction, for over five years and joined as a trainee two years ago. Eric has a BA in geography and was named the "Most Outstanding Graduating Senior." He is a 2A certified operator, working mostly in operations.

Photo by Kristofer Gushlaw

Scott Pierce, 3A operator/lab technician, runs a suspended solids test on the mixed liquor.

Cross Training

Operator cross training has been the foundation of the transition's success. These are the general cross training program components:

- Consolidation
- Balanced Recruitment
- Required Active KSA Development
- Voluntary KSA Development

Consolidation: Consolidation is a staffing philosophy of developing as many certified operators as possible and assigning them lab duties, maintenance, and other work as needed. As certified operators departed, existing lab technicians and maintenance workers were provided the opportunity and encouraged to move into operations. New workers are hired as operator trainees unless there is a specific set of KSAs that need to be fast tracked. They are then encouraged to develop operator proficiency and obtain certification when time permits.

Balanced Recruitment: Balanced recruitment is a hiring practice to obtain varied backgrounds. During a recent round of operator trainee additions, hires included a 55-year-old research scientist from a pharmaceutical company that was laying off people, a 32-year-old millwright with an environmental AAS degree, and an underemployed 27-year-old with a BS in science who also worked for Best Buy's Geek Squad (scored some IT help by accident!).

Required Active KSA Development: This is a practice that develops reliability, redundancy, resiliency, and robustness as an organizational priority. A gap analysis of knowledge, skills and abilities (KSAs) in employees is routinely performed and weaknesses identified, especially for mission critical tasks (see process listed below). Mandatory assignments are then made to strengthen these areas.

- Management rates each employee's KSAs in different areas.
- Each employee is asked to rate themselves.
- Gaps and weaknesses are identified.
- KSA assignments are made.

Specific examples of required active KSA development:

- The *water resource chemist* is the only person who historically performed a number of mission critical and inter-related tasks. One operator was assigned also to learn all of these tasks to provide redundancy.
- The *chief plant operator* is the only person who administers a number of discrete programs and tasks. There is an initiative underway to spread backup responsibility for these individual responsibilities to a variety of operators.
- Through attrition and transfer, the Plattsburgh plant no longer regularly hires *laboratory technicians.* All operators are required to be proficient in most process control and compliance sampling and testing. Operators who prefer the lab are assigned there as often as possible. Others are assigned into the lab periodically as a "tour of duty" to maintain their proficiency so they are ready and able to help, if needed.
- All operators are encouraged to cycle into a *lead operator* role which is like a shift supervisor. This develops their supervision, awareness, decision making, and emotional skills.

Voluntary KSA Development: All operators are provided the opportunity to volunteer for focused KSA development in areas of their choice. These voluntary "sectors" are:

- Super Operations
- Programs and Administration
- Maintenance and Major Projects

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- Lab and Data Management

Specific voluntary KSA development cases:

- A certified operator who has an extensive background as a millwright worked with a retiring maintenance supervisor to learn his duties. He now leads the maintenance efforts.
- Several operators volunteered to engage with engineering during planning and design of capital improvement projects and also learned to help manage construction projects by performing onsite inspections and assisting with startup.
- One operator worked extensively in the lab managing data and developing compliance reports.
- Two operators requested formal training in SCADA management and PLC programming, which is now in progress.

Organizational Culture Development

There has also been a cultural shift by the group. Employees have participated in "whole person" training that includes personal and professional development such as:

- The Art of Working with Difficult People
- Becoming a Better Supervisor
- Best Year Yet
- The Compound Effect

Staff is focused on getting better at what they do and being proud of it. Mistakes are now shared as learning opportunities. Conflict is seen as an opportunity to communicate better. Employees are recognizing each other for demonstrating initiative and going above and beyond. Employees are showing they care about their work.

Last year, a consulting engineer who was onsite inspecting a recent installation commented, "I don't know what you guys are doing, but keep it up. I've never seen a group of municipal employees who are so actively engaged and caring about what they do."

Best of all, one of the veteran operators here who happens to be the resident cynic and critic, recently took me aside and observed: "We have a problem. I've noticed too many happy people walking around here smiling and whistling. We need to do something about that."

He then smiled and walked away, whistling a happy tune.

Now those are the kinds of problems to have!

The City of Plattsburgh operations group is the essence of the word "team." The term family also applies because there are sometimes arguments and gnashing of teeth. There were certainly growing pains during the transition. But in the end, this group is made up of consummate professionals who consistently pull together for the common good and their relationships rise above the conflict. Plattsburgh is blessed and honored to have them.

Jonathan Ruff, PE, is the Environmental Manager for the City of Plattsburgh, under whose supervision falls the wastewater treatment plant. He may be reached at ruffj@cityofplattsburgh-ny.gov.

This edition's Operator Spotlight (page 54) was written by Lois Hickey, editor of Clear Waters magazine, with assistance from Kristofer Gushlaw. Kris also provided the photography for Jon Ruff's plant staff article. Photos of Kris in his spotlight and on the cover were by Sandra Geddes, the City of Plattsburgh Promotions and Special Events Coordinator.

Resources

To advertise or to become a member, contact Rebecca Martin at 315-422-7811 ext. 5 or e-mail her at rebecca@nywea.org.

Visit www.nywea.org for information or see us on Facebook.

Massachusetts Clean Energy Partnership for Drinking Water and Wastewater Facilities

by Madeline Snow and Aimee Powelka

The Massachusetts Clean Energy Partnership for Wastewater and Drinking Water Facilities works with drinking water and wastewater facilities to address energy use, costs, greenhouse gas emissions and air and water quality tradeoffs.

The Partnership consists of the Massachusetts Department of Energy Resources, the Massachusetts Department of Environmental Protection, the USEPA's Office of Wastewater Management, USEPA Region 1 New England, the University of Massachusetts Lowell and the Mass Save® energy efficiency program administrators.

The collaboration evolved from parallel interests by federal and state agencies in addressing the water/energy nexus. For over eight years, this partnership has worked to promote energy performance improvements with a goal of "zero net energy" facilities. These included energy efficiency, energy reductions and the generation of onsite energy.

This collaboration has (1) reduced energy use and associated greenhouse gas emissions; (2) increased the onsite generation of renewable energy; and (3) supported a shift in the wastewater sector's identity from treatment and disposal to "water resource recovery" facilities.

This experiment to gauge the potential for significant energy improvements in the water sector has been successfully replicated across New England and in 15 other states and US territories.

The Partnership has been recognized by the Harvard Kennedy School's Ash Center for Democratic Leadership as one of five finalists in the 2015 "Innovations in American Government" national competition. The Partnership has also recently won a "Leading by Example Award" from the Commonwealth of Massachusetts for outstanding energy and environmental efforts in the state agency category.

Convening Opportunities for Peer-to-Peer Learning

An initial Innovative Energy Management Workshop in 2008 attracted over 100 participants. The workshop, based on the USEPA's *Ensuring a Sustainable Future: An Energy Management Guidebook for Wastewater and Water Utilities,* was followed by four rounds of highly interactive roundtable meetings for over 70 "Energy Leader" facilities interested in working on their energy improvements over time. A typical roundtable agenda included discussions with operators about their experiences with process energy audits/evaluations and their successes (and challenges) implementing the recommendations. The meetings also included an emphasis on using a "plan-do-check-act" approach to energy improvements, technical presentations on equipment and emerging technology, practical presentations on how to understand energy bills or use SCADA to monitor energy use, and facility tours to see the equipment and process improvements.

The series of meetings were supported by:

- Onsite visits and technical assistance
- Software to analyze energy use
- Energy audits that included evaluations of the process, not just lights and equipment
- Increased awareness of and access to grants, loans, energy utility incentives
- Creation of new funding and financing mechanisms

Lessons Learned

Partnerships between the drinking water and wastewater facilities meant building trust in a new, technical assistance role for the regulatory agencies. Keys to success for the agencies and the partnership in fulfilling this new role included a strong inter-agency planning team, senior management support, nimbleness to experiment and change, and a deep respect for the experience and expertise of facility operators. The following, broadly applicable common themes emerged during the roundtable meetings:

1. Significant energy improvement opportunities exist at drinking water and wastewater facilities. Operators and directors are increasingly implementing better ways to reduce or avoid energy costs and optimize operations while signaling to their rate-payers that they are good stewards of financial and natural resources.
2. It's not just about buying new equipment – it's about behavior and operational process changes as well as equipment and technology.
3. The more that employees are involved, the more successful the energy savings results.
4. Hearing about and learning from real-life experiences from one's peers is effective.
5. Tracking energy use and conducting energy audits are crucial.
6. Providing access to free or cost-shared audits increases success.
7. Energy audits can vary greatly in terms of scope and focus. Audits that look at opportunities for process improvements are the most informative and effective.

Results

Keys to success included a strong inter-agency planning team, senior management support, nimbleness to experiment and change, and a commitment to recognize and support the experience and expertise of facility operators.

Since 2010, the Clean Energy Partnership has:

- Resulted in drinking water and wastewater facilities saving over $35 million in energy costs
- Reduced electricity consumption by approximately 240 million kWh
- Reduced 100,000 tons of carbon dioxide.

The total onsite renewable energy generation at drinking water and wastewater facilities has increased from 16 to 43 MW, an increase of 173 percent. A product of the Partnership, a $1.7 million state "gap" investment grant program effectively moved over $11 million of municipal energy saving projects forward in 2014, saving 22 facilities $1.2 million per year.

In summary, the Clean Energy Partnership created an innovative model that broke down walls between regulators and facilities. It leveraged technical assistance, public grants, state revolving funds, and private energy efficiency and renewable energy incentives to support facility operators and directors in their efforts to get clean energy results.

For more information about the Clean Energy Partnership and how the model might be applied in other states or regions, see the author contacts below.

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Operator Quiz Test No. 110 – Rotating Biological Contactor

The following questions are designed for trainees as they prepare to take the ABC wastewater operator test. It is also designed for existing operators to test their knowledge. Each issue of *Clear Waters* will have more questions from a different section of wastewater treatment. Good Luck!

1. Use the following data to determine the organic loading rate of a trickling filter: rock media 5' deep, 160' diameter, 8.0 mgd, 110 mg/L BOD primary effluent:
   a. 73 lbs/day/1000 ft^3
   b. 9.17 lbs/day/1000 ft^3
   c. 875 lbs/day/1000 ft^3
   d. 11.7 lbs/day/1000 ft^3

2. A trickling filter with a hydraulic loading rate of 75 gal/day/ft^2 would be considered what type of trickling filter?:
   a. High rate filter
   b. Roughing filter
   c. Standard rate filter
   d. Tertiary filter

3. Determine the hydraulic loading rate of a trickling filter using the following specifications: 6,250 gallons per minute, 140' diameter, 6' deep:
   a. 1585 mgd/ft^2
   b. 585 gpd/ft^2
   c. 975 gpm/ft^2
   d. 115 gph/ft^2

4. All of the following are types of drive assemblies used to rotate an RBC, except:
   a. Motor with chain drive
   b. Motor with direct shaft drive
   c. Air drive
   d. Magnetic drive

5. What is the organic loading rate on a rotating biological contactor with the following data: 50,000 gpd, 125 mg/L influent BOD, surface area of 28,000 ft^2?:
   a. 0.0019 lbs/day/1000ft^2
   b. 1.86 lbs/day/1000ft^2
   c. 0.0019 lbs/day/1000ft^3
   d. 1.86 lbs/day/1000ft^3

6. When the temperature of the influent to a trickling filter is warmer than ambient air, the air will:
   a. Flow down through the media
   b. Flow up through the media
   c. Recirculate throughout the media
   d. Air temperature compared to influent temperature has no bearing on air flow

7. What is the purpose of the under drain system in a trickling filter?:
   a. Controls wastewater flow to the filter media
   b. Distributes flow evenly to the filter media
   c. Collects untreated wastewater and distributes it to top of filter
   d. Collects treated wastewater and permits air flow to filter media

8. Voids between the filter media in a trickling filter:
   a. Must be kept open to allow sloughing of biology and proper air flow
   b. Must be kept plugged to allow proper detention time of wastewater
   c. Must be kept plugged to allow for retention of biology in the filter
   d. Must be kept open to allow for visual inspections of filters

9. By controlling the organic strength of wastewater into a trickling filter, an operator can directly control:
   a. The amount of filter flies breeding
   b. The thickness of biological buildup
   c. The amount of wastewater flow into the filter
   d. The amount of inorganic materials treated

10. Of the following, which describes the best rotating speed in a rotating biological contactor (RBC):
   a. 10 rpm and is adjusted based on media diameter
   b. A speed rate which shears off growth allowing for constant hungry growth to develop
   c. A speed which coincides with incoming flow; higher flow means faster speed
   d. A slow to nearly stopped speed which allows biomass to stay submerged in wastewater

11. The best observed characteristic of biomass in an RBC can be described as:
   a. Being white in appearance denoting special bacteria are treating sulfur compounds
   b. Being black in appearance denoting biomass effectively using dissolved oxygen in treatment
   c. Being brown to grey in color, shaggy in appearance and uniformly covering the media
   d. Being brown to grey in color, smelling of sulfide and sloughing off, exposing many bare spots

12. A small community has a wastewater plant with an RBC system and experiences a high flow during the day and very low flow during the night. Which of the following is the most true statement describing the best operational parameters?:
   a. High loading during the day provides the biomass food, RBC experiences sloughing due to low loading at night. Influent flows should be throttled during the peak times making use of an equalization tank, and secondary flows should be recycled at night.
   b. High flows during the day provide a diluted influent and low flows during the night provide a concentrated influent. Secondary flows should be recycled at a high rate during the day and reduced during the night.
   c. These flow parameters are normal flows for an RBC system. The operator should make very small adjustments throughout the day and night
   d. A flow equalization tank should be installed in the plant and only used when flows are consistent throughout the day and night.

This quiz material was compiled from Vol. 17 of Operation of Wastewater Treatment Plants, OWP. **Answers on page 62.**

For those who have questions concerning operator certification requirements and scheduling, please contact Tanya May Jennings at 315-422-7811 ext. 4, tmj@nywea.org, or visit www.nywea.org/OpCert.

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New York Water Environment Association, Inc.

Answers from page 61: 1 A, 2 C, 3 B, 4 D, 5 B, 6 B, 7 D, 8 A, 9 B, 10 B, 11 C, 12 A