WERF
Water Environment Research Foundation
Collaboration. Innovation. Results.

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

Energy

FINAL REPORT

Demonstrated Energy Neutrality Leadership: A Study of Five Champions of Change

Co-published by
IWA PUBLISHING

ENER1C12b

DEMONSTRATED ENERGY NEUTRALITY LEADERSHIP: A STUDY OF FIVE CHAMPIONS OF CHANGE

by:

Steve Tarallo, P.E.
Andrew Shaw, P.E.
Erica Zamenski
Black & Veatch

Paul Kohl, P.E.
Philadelphia Water Department

Ralph Eschborn, P.E.
AECOM

Ned Beecher
North East Biosolids and Residuals Association

2015

WERF

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

The Water Environment Research Foundation, a not-for-profit organization, funds and manages water quality research for its subscribers through a diverse public-private partnership between municipal utilities, corporations, academia, industry, and the federal government. WERF subscribers include municipal and regional water and water resource recovery facilities, industrial corporations, environmental engineering firms, and others that share a commitment to cost-effective water quality solutions. WERF is dedicated to advancing science and technology addressing water quality issues as they impact water resources, the atmosphere, the lands, and quality of life.

For more information, contact:

Water Environment Research Foundation
635 Slaters Lane, Suite G-110
Alexandria, VA 22314-1177
Tel: 571-384-2100
Fax: 703-299-0742
www.werf.org
werf@werf.org

This report was co-published by the following organization:

IWA Publishing
Alliance House, 12 Caxton Street
London SW1H 0QS, United Kingdom
Tel: +44-0-20-7654-5500
Fax: +44-0-20-7654-5555
www.iwapublishing.com
publications@iwap.co.uk

© Copyright 2015 by the Water Environment Research Foundation. All rights reserved. Permission to copy must be obtained from the Water Environment Research Foundation.

Library of Congress Catalog Card Number: 2014956956
IWAP ISBN: 978-1-78040-745-6

This report was prepared by the organization(s) named below as an account of work sponsored by the Water Environment Research Foundation (WERF). Neither WERF, members of WERF, the organization(s) named below, nor any person acting on their behalf: (a) makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that such use may not infringe on privately owned rights; or (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Black & Veatch, AECOM, North East Biosolids and Residuals Association.

This document was reviewed by a panel of independent experts selected by WERF. Mention of trade names or commercial products does not constitute WERF nor NYSERDA endorsement or recommendations for use. Similarly, omission of products or trade names indicates nothing concerning WERF's nor NYSERDA's positions regarding product effectiveness or applicability.

The research on which this report is based was funded by the New York State Energy Research and Development Authority in partnership with the Water Environment Research Foundation (WERF).

About WERF

The Water Environment Research Foundation, formed in 1989, is America's leading independent scientific research organization dedicated to wastewater and stormwater issues. Throughout the last 25 years, we have developed a portfolio of more than $130 million in water quality research.

WERF is a nonprofit organization that operates with funding from subscribers and the federal government. Our subscribers include wastewater treatment facilities, stormwater utilities, and regulatory agencies. Equipment companies, engineers, and environmental consultants also lend their support and expertise as subscribers. WERF takes a progressive approach to research, stressing collaboration among teams of subscribers, environmental professionals, scientists, and staff. All research is peer reviewed by leading experts.

For the most current updates on WERF research, sign up to receive Laterals, our bi-weekly electronic newsletter.

Learn more about the benefits of becoming a WERF subscriber by visiting www.werf.org.

ACKNOWLEDGMENTS

The research team thanks the Water Environment Research Foundation for its support of the research. In addition, the team appreciates the many facility personnel who helped capture the vital elements of their continuing journey to energy neutrality. The research team also thanks the Energy Issue Area Team members for their valuable guidance and oversight.

Research Team

Principal Investigators:
Steve Tarallo, P.E.
Black & Veatch

Paul Kohl, P.E.
Philadelphia Water Department

Project Team:
Teresa DiGenova, P.E.
Mike Elenbaas
Alok Patil
Christine Polo, E.I.T.
Yinan Qi, Ph.D., E.I.T.
Gustavo Queiroz, P.E.
Patricia Scanlan, P.E.
Andrew Shaw, P.E., ENV-SP
Erica Zamensky
Black & Veatch

Ralph Eschborn, P.E.
Kevin Frank, P.E.
Terry Goss, P.E.
Rob Pape, P.E.
AECOM

Ned Beecher
North East Biosolids and Residuals Association

Case Study Leaders

Ken Baxter
Melbourne Water, Australia

Paul Kohl, P.E.
Philadelphia Water Department

Mark McDannel
Los Angeles County Sanitation District

Susan Pekarek, P.E.
Johnson County Wastewater

Daniel Ramer
Ithaca Area Wastewater Treatment Facility

WERF Issue Area Team

Kartik Chandran, Ph.D.
Columbia University

Amit Kaldate, Ph.D.
Suez Environment (Infilco)

Michael Keleman, MSEV
InSinkErator

Barry Liner, Ph.D.
Water Environment Federation

Nicola Nelson, Ph.D.
Sydney Water

Susan Pekarek, P.E.
Johnson County Wastewater

Beth Petrillo
New York City Department of Environmental Protection

Joe Rohrbacher, P.E.
Hazen and Sawyer

Jim Smith, D.Sc.
U.S. EPA National Risk Management Research Laboratory (retired)

Yi (Eve) Zuo, Ph.D.
Chevron

Research Council Liaisons

Robert Humphries, Ph.D.
Water Corporation (Australia)

Ted McKim, P.E., BCEE
Reedy Creek Energy Services

Beverley Stinson, Ph.D., P.E.
AECOM

Agency Liaisons

Kathleen O'Connor, P.E.
New York State Energy Research and Development Authority

Jason Turgeon
U.S. EPA Energy and Climate Unit

Phil Zahreddine, M.S.
U.S. EPA Office of Wastewater Management

Water Environment Research Foundation Staff

Director of Research: Amit Pramanik, Ph.D., BCEEM
Senior Program Director: Lauren Fillmore, M.S.

ABSTRACT AND BENEFITS

Abstract:

The purpose of this report is to create an opportunity for water resource recovery facility (WRRF) energy managers to learn from the experiences of their peers. The five case studies presented in the report will aid other utilities wanting to improve their energy management programs. The "champions of change" profiled in this report all achieved high energy performance at their respective facilities.

Findings from the case studies may enable new ways of thinking about energy efficiency and recovery, and inspire and propel other WRRFs to consider approaches to move their facilities toward net-zero energy. The findings also explore opportunities to save costs and enhance sustainability, as well as provide solutions to overcome obstacles common to energy projects. All WRRFs highlighted in this report possess three over-arching qualities that contributed to their success as energy performance leaders. Those qualities are:

- Commitment to a set of long-term goals which call for sustainable energy management often before this was called net-zero.
- Ability to access their internal advocates to serve as champions for high-performance energy management.
- Demonstrated eagerness to innovate and lead, which created an environment for innovation and interest in untested strategies to move toward net-zero energy goals.

Energy management extends beyond reduced consumption and improved efficiency. Management of energy cost volatility and control of peak demand and improved reliability are also critical factors in comprehensive energy management. The leading utilities profiled in this report took several specific actions to propel their facilities to high performance in energy management. Those actions were:

- Utility-wide energy plans that incorporate strategic goals for key performance indicators and take a holistic, life-cycle approach to energy management.
- Connection with an academic institution for support and expertise.
- Use of available resources to understand energy efficiency and recovery opportunities.
- Sharing of information with other WRRFs and collaboration on policy matters to advance their energy goals.
- Exploration of new and innovative funding options for energy projects and use outside sources of capital funds.

Benefits:

- Demonstrates that energy-neutral wastewater treatment is within reach for a significant number of facilities via proven and available technologies.
- Compiles lessons learned by WRRF energy leaders.

Keywords: Energy management, energy neutrality, energy high-performance facility, net-zero energy, energy champions, case studies.

TABLE OF CONTENTS

Acknowledgments iv
Abstract and Benefits vi
List of Tables ix
List of Figures x
List of Acronyms xi
Executive Summary ES-1

1.0 Energy Neutrality Leaders 1-1
1.1 Introduction 1-1
1.2 Background 1-1
1.3 Characteristics of Energy Management Leaders 1-2

2.0 High-Performance Facility Case Studies 2-1
2.1 Case Study 1 – Northeast Water Pollution Control Plant, Philadelphia, Pennsylvania 2-1
2.1.1 Summary 2-1
2.1.2 Plant Process/Operations 2-1
2.1.3 Energy Journey 2-2
2.1.4 Challenges, Lessons Learned, and Benefits 2-6
2.1.5 Energy Profile 2-9
2.2 Case Study 2 – Los Angeles County Sanitation District, Joint Water Pollution Control Plant, California 2-10
2.2.1 Summary 2-10
2.2.2 Plant Process/Operations 2-10
2.2.3 Energy Journey 2-12
2.2.4 Challenges, Lessons Learned, and Benefits 2-14
2.2.5 Energy Profile 2-16
2.3 Case Study 3 – Melbourne Water Western Treatment Plant, Melbourne, Australia 2-17
2.3.1 Summary 2-17
2.3.2 Plant Process/Operations 2-19
2.3.3 Energy Journey 2-20
2.3.4 Challenges, Lessons Learned, and Benefits 2-23
2.3.5 Energy Profile 2-24
2.4 Case Study 4 – Johnson County Wastewater, Douglas L. Smith Middle Basin Wastewater Treatment Plant, Kansas 2-25
2.4.1 Summary 2-25
2.4.2 Plant Process/Operations 2-26
2.4.3 Energy Journey 2-28
2.4.4 Challenges, Lessons Learned, and Benefits 2-31
2.4.5 Energy Profile 2-32

2.5 Case Study 5 – Ithaca Area Wastewater Treatment Facility, Ithaca, New York.... 2-34
2.5.1 Summary.... 2-34
2.5.2 Plant Process/Operations.... 2-35
2.5.3 Energy Journey.... 2-35
2.5.4 Challenges, Lessons Learned, and Benefits.... 2-38
2.5.5 Energy Profile.... 2-39

3.0 Case Study Synthesis.... 3-1
3.1 Overview of Findings.... 3-1
3.2 General Attributes of Net-Zero Leaders.... 3-1
3.3 Key Actions Towards Energy Neutral Wastewater Treatment.... 3-2
3.3.1 Barriers.... 3-2
3.3.2 Communications.... 3-2
3.3.3 Planning and Collaboration.... 3-2
3.3.4 Resourcefulness.... 3-3
3.3.5 Financial Considerations.... 3-3
3.4 Moving the Net-Zero Energy Plan Forward.... 3-4
3.4.1 Energy Management Best Practice.... 3-4
3.5 Conclusions.... 3-5

Appendix A.... A-1

References.... R-1

LIST OF TABLES

ES-1 Case Study Utility Energy Neutrality Performance Based on Information from Facility Surveys ES-1
2-1 NE Plant Annual Average Energy Profile Before and After Energy Improvements 2-9
2-2 LACSD Capital and Operational Project Energy Savings 2-13
2-3 JWPCP Annual Average Energy Profile Before and After Energy Improvements – Theoretical 2-16
2-4 Melbourne Water West Treatment Plant Annual Average Energy Profile Before and after Energy Improvements 2-24
2-5 Middle Basin WWTP Energy Profile Before and After Energy Improvements 2-33
2-6 Ithaca Area Wastewater Treatment Facility Energy Profile Before and After Energy Improvements 2-39

LIST OF FIGURES

2-1 The Northeast Water Pollution Control Plant in Philadelphia, Pennsylvania, Captures and Uses Biogas to Meet 81% of the Electrical Demands of Facility Operations 2-1

2-2 The Biogas Cogen Facility Exemplifies PWD's Commitment to Resource Recovery and to Sustainable and Cost-Conscious Operations 2-4

2-3 JWPCP Sits on a 420-Acre Property in the City of Carson in Southwest Los Angeles County in California 2-10

2-4 Late 1930s Power Plant at the JWPCP 2-12

2-5 The Western Treatment Plant Produces 95% of its Annual Electric Needs 2-17

2-6 An Ongoing $43 Million Project to Replace WTP Lagoon Covers Will Allow Increased Power Generation..... 2-18

2-7 The Extensive WTP Lagoon Network Removes Large Amounts of Nitrogen Which Would Otherwise Flow into Port Phillip Bay 2-19

2-8 The Captured Biogas Allows Melbourne Water to Generate Electricity Onsite 2-21

2-9 The Douglas L. Smith Middle Basin Wastewater Treatment Plant Saves Johnson County Water $250,000 Annually by Meeting About 50% of the Plant's Electricity Demand.... 2-25

2-10 Upgrades to the Middle Basin Plant, Completed in 2013 Included New Digestion, Gas Management, and Cogeneration Systems..... 2-29

2-11 The Ithaca Area Wastewater Treatment Plant 2-34

LIST OF ACRONYMS

ADF	Aircraft De-Icing Fluid
ADG	Anaerobic Digester Gas
AGL	Melbourne's Electricity Provider (Formerly Australian Gas Light Company)
ARRA	American Recovery and Reinvestment Act
AWWTF	Ithaca Area Wastewater Treatment Facility
BAT	Best Available Technology
Biogas Cogen	Biogas Cogeneration Project
BNR	Biological Nutrient Removal
BOD	Biological Oxygen Demand
BRC	Biosolids Recycling Center
C	Cubic
CFD	Cubic Feet per Day
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
DA	Direct Access
DO	Dissolved oxygen
EDC	Energy Distribution Company
EE&C	Energy Efficiency and Conservation
ESCO	Energy Service Companies
ETP	Eastern Treatment Plant
FOG	Fats, Oil, and Grease
FY	Fiscal Year
GHG	Greenhouse Gas
GPD	Gallons per Day
GTI	Geomembrane Technologies Inc.
GWh	Gigawatt Hours
HRSG	Heat Recovery Steam Generator
HVAC	Heating, Ventilation, and Air Conditioning
JCW	Johnson County Wastewater
JOS	Joint Outfall System
JWPCP	Joint Water Pollution Control Plant
KCPL	Kansas City Power and Light
KPI	Key Performance Indicator
kV	Kilovolt
kW	Kilowatt
kWh/d	Kilowatt Hours per Day
LACSD	Los Angeles County Sanitation District

MARC	Mid-America Regional Council
MCF	1,000 Cubic Feet
Mg	Million Gallon
MGD	Million Gallons per Day
Middle Basin Plant	Douglas L. Smith Middle Basin Treatment Plant
MJ/d	Megajoules per Day
MMBtu	1,000,000 British Thermal Units
MOP	Manual of Practice
MOS	Mayor's Office of Sustainability
M&V	Measurement and Verification
MW	Megawatt
MWh	Megawatt Hours
N	Nitrogen
NE Plant	Northeast Water Pollution Control Plant
NEHA	National Environmental Health Association
NPV	Net Present Value
NYSEG	New York State Electric and Gas Corporation
NYSERDA	New York State Energy Research and Development Authority
P	Phosphorus
PE	Professional Engineer
PECO	Philadelphia's Electricity Provider (Formerly Philadelphia Electric Company)
PGW	Philadelphia Gas Works
PON	Program of Opportunity
PPP (or P3)	Public-Private Partnership
PWD	Philadelphia Water Department
REC	Renewable Energy Credit
RFP	Request for Proposals
RTO	Regional Transmission Organization
SCE	Southern California Edison
SCF	Standard Cubic Foot/Feet
SPE	Special-Purpose Entity
TSS	Total Suspended Solids
V	Volt
VFA	Volatile Fatty Acids
VSR	Volatile Solids Reduction
WERF	Water Environment Research Foundation
WRRF	Water Resource Recovery Facility
WTP	Western Treatment Plant

EXECUTIVE SUMMARY

The five net-zero energy case study utilities presented in this report shared their experiences in order to benefit other utility managers who wish to improve their energy management programs. The net-zero energy leaders highlighted in this document were selected from a list of 46 WRRFs located in the U.S. and Australia who completed a facility survey requested as part of this project. Of those 46 surveys, five utilities were selected as case study topics based on their innovative technology and management approaches implemented during their journey towards achieving high-performance energy management at their facilities. The case studies provide detailed examples of each facility's journey towards net-zero energy. Findings drawn from these case studies illustrate a steadfast attitude and innovative approach to operations, management, funding, and collaboration. These are the common winning attributes of these champions of change.

Table ES-1. Case Study Utility Energy Neutrality Performance Based on Information from Surveys and Interviews.

Utility	Facility	Onsite Energy Production	% Site Energy Neutrality (Reported)
Philadelphia Water Department, Philadelphia, Pennsylvania	Northeast Water Pollution Control Plant (NE Plant) (Basic Secondary Treatment Facility)	Biogas Cogeneration	54
Los Angeles County Sanitation Districts (LACSD), California	Joint Water Pollution Control Plant (JWPCP) (Basic Secondary Treatment Facility)	Biogas Cogeneration	51
Melbourne Water, Australia	Western Treatment Plant (WTP) (Basic Secondary Treatment Facility)	Biogas Cogeneration	76
Johnson County Wastewater (JCW), Kansas	Douglas L. Smith Middle Basin Water Treatment Plant (Biological Nutrient Removal Facility)	Biogas Cogeneration, uses fats, oil, and grease (FOG) from local restaurants to increase biogas production	21
City of Ithaca, Town of Ithaca, and Town of Dryden, New York	Ithaca Area Wastewater Treatment Facility (AWWTF) (Basic Secondary Treatment Facility)	Biogas Cogeneration; uses Cornell University's waste to increase biogas production	22

Despite the varied location, size, and history of each utility, the attributes which led to their successes are similar. Across the board, the staff and managers at each facility:

- Showed commitment to a set of long-term goals which call for sustainable energy management.
- Tapped internal advocates to lead the charge towards high-performance energy management. These advocates became the champions who drove the process internally and externally.
- Demonstrated eagerness to innovate and lead – creating an environment that supported piloting untested strategies to move toward net-zero energy goals.

The following four main categories of actions greatly influenced success:

1. **Communication:** Clarify the facility's energy plan to enable the education of politicians, community members, and potential sources of funding as the plan moves forward.
2. **Planning and Collaboration:** Plan for the facility's energy goals, including key performance indicators (KPIs), such as kilowatt-hours consumed per million gallons treated (kWh/MG). Identify and connect with institutions, such as universities or other WRRFs, for support and expertise.
3. **Resourcefulness:** Use available resources to understand energy efficiency and recovery opportunities to enable facility staff to become subject matter experts.
4. **Financial Considerations:** Explore funding options by reaching out to energy service companies (ESCOs), state legislature, and independent research agencies. Know the facility's energy bills and rates to identify the potential for cost reductions.

The energy champions' journey yielded several observations and recommendations which could be of benefit to their peers:

- Co-digestion was the best near-term solution to achieve significant onsite energy production at facilities with anaerobic digestion and biogas-fueled cogeneration.
- Energy managers must understand their system inside and out in order to streamline operations and reduce the risk of "overbuilding" energy projects.
- Do not overlook details during design and construction.
- Preventive maintenance is critical for energy efficiency projects.
- Spread the message of "green renewable energy" to garner support from the community and local governments.
- Encourage staff to embrace the idea of reaching net-zero energy goals, even if it means greatly increased responsibilities during the energy journey. Train staff in energy efficiency.

CHAPTER 1.0

ENERGY NEUTRALITY LEADERS

1.1 Introduction

Energy represents one of the largest controllable costs of providing wastewater services to the public; therefore, increasing energy efficiency is one of the most effective means for utilities to manage costs and help ensure long-term operational sustainability. An increasing number of water resource recovery facilities (WRRFs) integrate improved energy management into their daily operations and long-term planning. Energy management extends beyond reducing energy consumption and improving energy efficiency; it also involves measures such as managing total energy consumption, controlling peak demand for energy, managing energy cost volatility, and improving energy reliability. The primary goal of effective energy management planning is to ensure energy-related decisions are well developed (NYSERDA, 2013).

One motivation for undertaking this study was a desire among WRRF energy managers to learn from the experiences of their peers. The five facility case studies presented in this report have achieved high energy management performance. Their energy journeys are captured for the benefit of other utilities wanting to improve their energy management programs.

1.2 Background

In early 2013, the project team conducted a Utility Partner Survey of wastewater treatment facilities in North America and Australia to obtain statistics on their energy use. The survey was distributed to 49 utility partners. The team received completed surveys from 24 utilities representing 45 wastewater treatment plants and one solids handling facility. The partners were solicited and selected to provide a balanced representation of the spectrum of wastewater treatment/biosolids management practices and range of geographical differences. Several characteristics were sought in selecting the utility partners, including the following:

- *Energy Technology Pioneers* – Those facilities which have shown energy savings or are producing benefits of a new and innovative, but demonstrated, processing approach.
- *Energy Management Performance Leaders* – Facilities which have progressed well down the road to energy neutrality, and where experiences and "lessons learned" would be of interest to others just beginning to develop and execute their own energy management plans with similar goals.
- *Service-Oriented, Enthusiastic Utilities* – Those potential partners willing to commit their time and energy to sharing their experiences and helping their colleagues.

The survey was designed to provide an overview of each WRRF to identify the type of liquid and solids treatment systems used at the plant, as well as the level of treatment and energy consumption/production information. The questions were drafted specifically not only to gain information for energy modeling, but as identification of case study facility candidates and utilities' decision making and triple bottom line approaches. (This document is a companion to WERF's *A Guide to Net-Zero Energy Solutions for Water Resource Recovery Facilities*, Project No. ENER1C12. Energy modeling information obtained through the survey was used as research for the companion document.)

The survey requested the following information:

- Energy consumption/production data (e.g., electric, natural gas, fuel oil, digester gas).
- Major unit processes employed (e.g., aerobic digestion, co-digestion, incineration, disinfection).
- Type of treatment (e.g., basic secondary treatment, Biological Nutrient Removal (BNR), and Enhanced Nutrient Removal (ENR)).
- Plant capacity/level of treatment, including influent wastewater characteristics and effluent quality data (e.g., Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), nitrogen (N), and phosphorus (P)).
- Decision making process information; triple bottom line criteria and weighting.

The survey was distributed to the utilities with the option to complete it by hand (printout or interactive Portable Document Format, or PDF) or through an online questionnaire service (SurveyMonkey). The survey consisted of 113 questions, most of which were multiple-choice (Appendix A). The most recent annual average was requested relative to all collected data, such as energy, influent, and effluent. From those facilities surveyed, five were selected as subjects of case studies.

Selection was based primarily on the level to which energy neutrality had been achieved, cross-section of facility sizes, process configurations, and locations to obtain a representative list of WRRFs. Interviews were conducted with key facility staff and data documented for each of the facilities. These utilities can serve as role models for implementing best practices in energy efficiency and conservation (EE&C), innovation in approaches to energy recovery, technology development, strategic energy management, and sustainability.

1.3 Characteristics of Energy Management Leaders

The researchers found that the energy management leaders profiled in this report shared three characteristics:

1. Leaders demonstrated a commitment to a set of long-term goals centered on sustainable energy management.
2. Leaders had internal advocates to champion the collaboration and actions needed to further their journey toward energy neutrality.
3. Leaders were eager to innovate, which created an environment where inventive strategies were developed and tested as potential pathways toward net-zero energy goals.

At the heart of successful energy programs and projects was a sense of ownership and a foundation of entrepreneurial expertise among the managers and operations staff. Internal

advocates do not have to be in command, but reasonable access to those in decision making positions allows the advocate to make efficient headway towards achieving net-zero energy performance. Moreover, when the advocates work in an environment where innovation is heralded and mistakes along the way are tolerated, the advocates are emboldened to not only create opportunities for improved energy management performance, but to take action towards obtaining the highly challenging goal of energy neutrality. Chapter 2.0 presents case studies which highlight the energy journey of five energy neutrality leaders. Chapter 3.0 synthesizes those case studies to form a comprehensive summary of specific actions, approaches, and mindsets demonstrated by the leaders as they carved a path toward energy neutrality and sustainable operations at their facilities.

CHAPTER 2.0

HIGH-PERFORMANCE FACILITY CASE STUDIES

2.1 Case Study 1 – Northeast Water Pollution Control Plant (NE Plant), Philadelphia, Pennsylvania

The following case study describes the energy journey of a dynamic energy management leader, the Philadelphia Water Department (PWD).

2.1.1 Summary

The PWD, a large integrated water, wastewater, and stormwater utility, has been a leader in energy efficiency for decades. The utility's legacy led to the Northeast Biogas Cogeneration Project (Biogas Cogen), which began as an improbable initiative in 2004, and resulted in a pioneering facility that went online in 2013.

According to energy efficiency analyses (Black & Veatch, 2014), the $45 million biogas cogen system generates 134,400 kilowatt hours per day (kwh/d) of electric energy and 468,900 megajoules per day (MJ/d) of heat for the buildings and digesters, reducing purchased electricity at the plant by 81%. The biogas cogen system is expected to reduce carbon emissions by more than 32,000 metric tons of carbon dioxide equivalents per year.

2.1.2 Plant Process/Operations

Philadelphia's NE Plant, shown in Figure 2-1, receives waste from the Philadelphia metro area. The NE Plant has a design flow capacity for 210 million gallons per day (MGD) of wastewater, with a current average flow of 160 MGD. The plant produces and barges about 300 million gallons per year of anaerobically digested solids (320 barges/year). A capital improvement program began in 2011 to expand the plant's wet weather treatment capacity to 650 MGD.

Figure 2-1. The Northeast Water Pollution Control Plant in Philadelphia, Pennsylvania, Captures and Uses Biogas to Meet 81% of the Electrical Demands of Facility Operations.

The Biosolids Recycling Center (BRC) is a remote dewatering complex and pelletization process operation managed by Synagro under the title of Philadelphia Biosolids Services. The pelletized biosolids are land applied. At the BRC, Synagro operates two of the largest dryers in the world to create Class A biosolids.

The process used about 117,000 MCF (thousand cubic feet) in FY 2012 and 228,000 MCF in FY 2013 of natural gas, purchased from Philadelphia Gas Works (PGW). The new thermal drying process that went online in 2012 was expected to cut annual biosolids truck deliveries by 7,000 per year.

2.1.3 Energy Journey

The PWD has a rich heritage of energy efficiency and innovation. The Fairmount Waterworks, designed in 1812 and operated until 1909, harnessed the energy of the Schuylkill River to pump water to a hilltop reservoir to supply the city. "It was a unique engineering marvel of its time," according to Paul Kohl, PWD's Energy Program Manager.

The PWD has since remained focused on energy expenditures and conservation, mainly to control cost to the rate payer. Since the 1970s, all pumps had to be energy efficient (now a standard specification element) to effectively control power costs. Off-peak pumping, system storage, startup protocols, load shedding, and other processes also reduce operating costs.

Of the 10 major cities in the U.S., Philadelphia is the poorest, with 28.4% of the population living under the federal poverty line (U.S. Census American Community Survey, 2009-2011). "PWD must face the reality of poverty and its effect on our ability to implement rate increases, which forced PWD to find ways to save the rate payer money," Kohl says.

PWD realized long ago that energy cost control started from within. "This is a legacy of having engineers run the utility, and managers who understand electricity price structures and regulatory impacts," Kohl says. Although not a requirement, all plant managers are professional engineers (PEs), licensed by the state.

Philadelphia Water District and NE Philadelphia Water Pollution Control Plant Energy Milestones

Year	Event
1970s	All pumps energy efficient.
1997	Pennsylvania Electricity Generation Customer Choice and Competition Act passes, deregulating electricity, with rate caps ending in December 31, 2010.
2004	NE Plant engineers begin considering alternative energy sources.
2006-7	NE Plant engineers consider gas and electricity production and settle on electricity.
2008	The General Assembly of Pennsylvania enacts Act 129 which requires the Commonwealth's largest seven energy distribution companies to develop EE&C plans and adopt other methods of reducing the amount of electricity consumed.
2008	Biosolids Recycling Center operation privatized; operated and controlled by Synagro Technologies through Philadelphia Biosolids Services LLC.
2010	Electricity rate cap ends. AECOM completes design for new biogas cogeneration facility at NE Plant.
2011	January 1: Rate caps are removed, allowing electrical supply to be truly market driven. December 23: Ameresco, Inc. signs a construction and maintenance agreement with the City to design, build, and maintain the innovative wastewater biogas-to-energy CHP facility.
2012	BRC starts to produce Class A biosolids (February) using a pelletization process which requires a great deal of heat. Digester gas from nearby SW Water Pollution Control Plant is used to reduce the consumption of natural gas (April). Up to 40% of the gas used to produce pellets is biogas.
2013	Mechanical completion (lease payments start) and substantial completion achieved (maintenance payments start), the CHP facility goes online by end of year. Measurement and verification (M&V) procedure to qualify for Act 129 funding initiated December 26th.
2014	Act 129 M&V process completed in April.

2.1.3.1 Journey Towards Energy Neutral Wastewater Treatment

About half the gas generated in the NE Plant's anaerobic digester has been used beneficially for the last 35 years to heat water for the boilers, while the other half is flared. "Every five or 10 years, plant managers would ask: 'Wouldn't it be nice if we could use all of the gas?'"

While managers would occasionally muse about energy generation, it was not cost effective to pursue, as the plants purchased their energy affordably and used it wisely. PWD purchased its electricity under a block rate structure from PECO (formerly the Philadelphia Electric Company), and qualified for block rates as low as 2.34 cents per kWh (third tier). This rate made it cost prohibitive to pursue alternative energy projects centered on electricity production.

Pennsylvania energy utilities were deregulated in 1995 but, rates would remain low until 2011 when the rate caps were removed. Although the electrical supply market was open to free market forces, the reality that PECO had to keep rates at prescribed levels did not force consumers to shop around. Prior to the end of rate caps, PECO contacted its high-demand customers and informed them of the impending changes, principally that the block rate structure would no longer apply. This event opened a long-awaited opportunity for PWD to pursue alternative energy products.

Kohl reported, "At the same time we began looking at our biosolids processing options, including pelletization, PWD considered purifying the methane, *wheeling* it, and sending it to the pelletization facility. (Wheeling involves transporting gas in a series of seller/buyer stages.)

"We have a $25 million per year contract with Synagro, which is processing 60,000 dry tons per year of anaerobically digested sludge. The deal we talked about was, 'Synagro will run the facility, but PWD will have to pay for the utilities.' Then someone said, 'There's all this gas at NE…let's use that,'" Kohl says.

From 2006 to 2007, NE Plant managers evaluated purifying biogas into natural gas at pipeline quality with the intent to wheel it; however, this idea fell short due to costs, logistics, and price uncertainty. "We learned a lot from that process. We took the design of the biogas purification facility to 60% but, by that point, we determined that construction costs would have been $7-8 million, which was prohibitively expensive for the project," Kohl reports.

During that design process, PWD realized that striking an arrangement with the gas company, PGW, would be onerous. PGW used a system of gate stations, or points of connection to various natural gas pipelines, to buy the gas it imported. Kohl says the typical transactions required more volume and administrative support than the proposed facility could manage.

In retrospect, “the design and business experience allowed us to learn some valuable lessons,” Kohl relates. For example, engineers learned:

- How to conduct siloxane tests.
- About different types of biogas purification equipment (e.g., pressure swing absorber, molecular sieve), sizing, and the effect of temperature on gas measurement.
- How to recover the heat, and appreciate that the process was not always worth the cost.
- That the hydrogen sulfide concentration in the digester gas was very low due to the iron content of the incoming sewage sludge.

“The biggest lesson we learned was that once you begin to pay attention, you get interested, and so do others; a certain organizational dynamic gets going,” Kohl says. “We found that there was a higher level of monitoring, engagement, and therefore discovery; it was an informative time.”

Inspired by this period of discovery, engineers turned their attention to electricity. When the price caps expired in 2011, NE Plant managers could finally justify producing electricity at 6-8 cents/kWh and decided to pursue a combined heat and power (CHP) cogeneration facility, shown in Figure 2-2.

“It was our original hope that outside funding could be obtained,” Kohl says, but their resolve was tested when their submission for a federal grant was not selected. Kohl approached the PWD Deputy Commissioner of Operations to discuss funding; the Commissioner indicated the CHP project could not be funded without negatively impacting other PWD objectives. “Producing energy from waste was important and valuable, but it was not a core mission,” Kohl says. Despite the inherent conflict of the core mission with the development of the biogas cogen system, the pioneering efforts described were supported by the administrators, who continued to fund the design (completed by AECOM in 2010).

Figure 2-2. The Biogas Cogen Facility Exemplifies PWD's Commitment to Resource Recovery and to Sustainable and Cost-Conscious Operations.

Funding the construction of the facility proved to be a challenge. Cold calls to numerous federal agencies and even PWD's own city government yielded enthusiastic support, but no monetary gain. On the advice of PWD's Legal Affairs office, Kohl attended a legal continuing education forum on the topic of environmental (alternative energy) products. "After all, it was free and put on by a local law firm. I was surrounded by 300 lawyers," Kohl jokes. Then it clicked. "They are talking about getting investment tax credits."

Kohl needed specific tax advice. After consulting a lawyer using a contract provided by the Philadelphia Mayor's Office of Sustainability (MOS), Kohl discovered that there was an understanding between the Internal Revenue Service (IRS) and the U.S. Department of Treasury that allowed a municipality to work with a taxable entity to set up a special-purpose entity (SPE) and gain access to cost-reducing funding to produce renewable energy as long as there was a true lease." The path forward was illuminated but, the required "entities" had yet to be formed.

PWD gathered members of operations, engineering, and the city's legal department; these gathered forces issued a Request for Proposal (RFP) for facility construction and maintenance. In 2012, PWD and Ameresco entered into an agreement to design, build, and maintain the biogas-to-energy facility, with PWD functioning as operator. As such, PWD would have jurisdiction over the biogas use and electricity generation. A third partner, Bank of America, is the facility owner. These three entities formed a public-private partnership (PPP, or P3). The "taxable entity" is the limited liability corporation or LLC; the "special-purpose entity" is called BAL Green Biogas I, LLC, and the "lessee" is the City of Philadelphia. Assets retain at least 20% of their value, as required by the IRS under the definition of a true lease.

As of mid-2013, the U.S. Department of the Treasury was reviewing the pre-application grant request from Bank of America. It was expected to allow 30% of all allowable capital investment to be returned to Bank of America via check. The City of Philadelphia took the risk. Per contract, the project was completed by December 2013. Starting in FY 2014, there are 16 years of lease payments of approximately $270,000, with PWD paying Ameresco for maintenance.

"All of this is done under a business model where, if we were generating electricity, we would still use the electricity budget line. At $5.5 million per year, with a lease of $3 million, that gives us $2.5 million for maintenance. So it will cost $5.5 million a year for 16 years," according to Kohl. "The supposition is that the value of electricity will be double that at the end of the lease. Black & Veatch did the market analysis and made that projection. It should be noted that the increased supply of natural gas using shale drilling was not projected at the time of the initial market analysis."

Economic Gains of the Biogas Cogen Facility

- Reduces cost of overall energy supply to the PWD by reducing overall demand and peak load contribution.
- Reduces Philadelphia's use of non-renewable energy sources.
- Reduces the amount of energy Philadelphia purchase from commercial providers.
- Reduces exposure to volatile energy prices.
- Eligible for $3.9 million rebate under ACT 129 (construction timeline).

PWD, 2014.

The lease is based upon the bond swap rate, not the standard bond rate. (A bond swap is selling one debt instrument and using the proceeds to purchase another, more favorable, debt instrument.) The value to the project is that the lease rate is much lower than capital payments which would have been based on the bond rate, according to Kohl. The reduced cost of money

made the overall project much more affordable and, certainly avoiding the need to have cash-in-hand at the start of the project was also an advantage. It must be noted that this is a true lease and, that at the end of the lease, the asset still has value; if the city wants to own this asset, they must pay for it. It is similar to buying the car at the end of one's lease.

2.1.3.2 BRC Use of Biogas

When the BRC pelletization facility went online in 2012, digester gas at PWD's Southwest WPCP (SW Plant) was essentially converted from a liability to an asset. "We included the connection of a digester gas line from our SW Plant to the newly constructed pelletization facility. We had Synagro include a gas line in the contract. We had to pay them a premium…an incentive…to take it...about 10% of the amount that the digester gas offsets natural gas. Now they take as much as we'll give them. They'll take up to 50% of gas flow required by the pelletization process."

2.1.3.3 Looking Forward

Kohl says that even with federal tax incentives and the low cost of money, the biogas co-gen project is expensive. One way PWD justified this expense was to promote the concept that this facility would become a cornerstone upon which other energy projects and plant upgrades could be built.

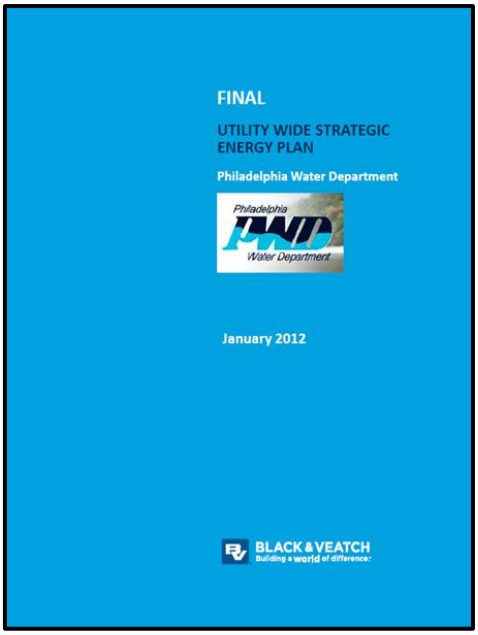
"We can now look at whether we can expand it, such as taking food waste or improving anaerobic digester pretreatment. We see biogas as valuable," Kohl says. He recalls just a handful of years ago when the value of biogas lay undiscovered. "We burned it in a boiler or flared it and had to go through the Title V air permit process. Now it's considered an actual resource! The liability of digester gas now becomes the *asset* of digester gas."

2.1.4 Challenges, Lessons Learned, and Benefits

During the course of its energy journey, PWD experienced and overcame numerous challenges, as summarized below.

2.1.4.1 Challenges/Lessons Learned

- City Council had to approve the biogas cogen system funding and construction; this political process was at times challenging to navigate and required a high degree of patience and persistence.
- In Pennsylvania, Act 129 requires the Energy Distribution Company (EDC) to buy excess alternative energy unless the power generation facility exceeds a certain size. The NE Plant biogas cogen facility was too large; therefore EDC was not required to buy back excess electrical power. The NE Plant was unable to sell its excess power. If the biogas cogen facility generates more energy than it needs in the future, it will be unable to achieve economic gain from this excess energy. The plant's only economic gain would be power cost avoidance.



- If the goal is to export power, PWD must file an application with the Regional Transmission Organization (RTO) and complete a grid analysis. A local generation station submitted this application, and it was declined. It would seem the commercial exportation of electricity is highly unlikely.
- The new technology application and large project budget invited critics, as well as opportunists, who attempted to gain a path into the energy market using the project. An open and transparent process was key to reducing unproductive intrusions.
- The PWD structure did not innately support use of a PPP arrangement as opposed to standard public works contracting, which created difficulty.
- It was critical for PWD and its project partners to establish mutual trust, use data to the ultimate advantage, and develop the political will to achieve balance between competing interests and see the project all the way through to completion.
- Exploring funding options also proved critical. ESCOs can help identify and evaluate savings, develop engineering designs and specifications, manage the project, arrange for financing, train staff, and offer guaranteed savings to cover costs. It is important to start with the state legislature, and never dismiss investors outright; many entities are ready to help launch projects that will create energy savings.
- Legal help may be needed. Access to lawyers can often be obtained through city or state governments.
- Buying agreements or interdepartmental procurement may offer benefits beyond purchasing electricity. The NE Plant did not have the legal authority to buy its own chemicals, and used the city-authorized procurement department, ultimately receiving benefits related to law, human resources, and other business functions.
- Education and forming relationships are critical steps. It is important to seek out seminars on resource recovery options and review case studies on successful energy projects, as well as reach out to existing energy partners who may share the same goals.
- It is necessary to invest in actions which produce smaller-scale savings, such as lighting contracts, zone controls, and motion controls.

2.1.4.2 Benefits

- Energy Management Planning: PWD has a utility-wide strategic energy plan that considers energy uses and energy conservation metrics (key performance indicators). The plan operates under a portfolio management style that is cost effective and functions to reduce exposure to volatile markets and eliminate costly risk. PWD thinks of it in terms of "making, buying, and using energy." For example, biogas cogen initially cost the NE Plant more per kilowatt-hour than for which it can be bought. But, once the plant recovers the initial investment, it more

Environmental Benefits of the Biogas Cogen Project

- The NE Plant is closer to net neutrality in energy use.
- Complies with the Clean Air Act through use of Best Available Technology (BAT) for pollution control.
- Constructed to meet ambient sound criteria so the NE Plant is a good neighbor.
- PWD, 2014

PWD, 2014.

than pays for itself. As of 2014, the department locked in the price of 15% of its electrical power for 16 years.

- CHP: PWD is generating electricity and recovering heat simultaneously.
- Better Business Case: PWD uses the net present value (NPV) analysis, which compared the status quo with the value of the PPP; the PPP showed greater value when analyzed over 20 years. Furthermore, the NPV does not quantify the value of social or environmental benefits, which add important value.
- Operational Flexibility: The facility engines perform optimally with biogas; however, they can also burn natural gas. Generally, the NE Plant should generate enough biogas (and heat through generation) to run the facility. If the plant does not have sufficient biogas, it can use natural gas with only marginal cost differences. As a utility, it is good to know that if biogas is not available for some reason, the engines can be run on 100% natural gas. This kind of built-in backup is expensive but, is worth the investment to PWD. Once an engine is operating, the maintenance cost is set, because that is a function of run time. The cost of running the engines remains the same regardless of production rates or gas used. Jenbacher engines have dual-fuel and gas blending capability (biogas or natural). This flexibility allows the plant access to the investment already made, which is an important consideration.
- Eliminate Flaring: PWD wanted to eliminate excess biogas flaring as part of their commitment to sustainability. To eliminate the flare, PWD had to specify larger engines that would consume all of the digester gas. At the same time, the plant runs the risk of operating the engines in sub-optimal conditions unless they supplement with natural gas at times when biogas quantities are low. PWD paid for dual-fuel and gas blending engines, as well as a gas supply line to the PGW system for supplementation.
- Other Energy Recovery: The system receives heat from engines through a heat exchanger in the process loop for anaerobic digester treatment. If the process and heating loads do not use all of the available heat, dedicated radiators are used to dispel excess. The heat recovery is maintained in the summer by converting steam-driven adsorption chillers to hot-water adsorption chillers. (This aspect of the project was not built when the plant went on-line in 2013.)
- Value of Latent Biogas Energy: The NE Plant could increase the digestibility of the current influent or obtain additional feed streams. For example, the SW Plant takes in aircraft de-icing fluid (ADF) from the Philadelphia International Airport. ADF runoff is collected through a gutter and stored onsite. The collected ADF is trucked to the SW Plant and fed directly into the anaerobic digesters.
- Cultural and Educational Shifts: The project was welcomed by most stakeholders as an idea whose time had come. PWD promotes the value of water in Philadelphia by making resource recovery and water quality a priority at the facility and in the community. PWD continues to seek out methods to capture more energy at the plant, as well as approaches to improve the inflow of wastewater at sources within the community. Specifically, point and non-point source nutrient loading and disposal of prescription drugs, radioactive iodide, and other undesirable substances are at the center of PWD's focus. PWD's efforts to boost the quality of water entering and exiting their plant create a process that allows for true water and energy sustainability.

2.1.5 Energy Profile

Table 2-1 provides overall facility energy consumption and production results before and after energy improvements. It is important to note that biogas cogen engines are optimized to burn biogas, but are capable of burning natural gas. The General Electric JenBacher 420 (designed for the NE Plant) produces 1,417 kW at 100% capacity with biogas, but only 1,240 kW with 100% natural gas. The basis of design is the full capture of biogas, flaring as little as possible. Using this basis of design with only 50,000 cubic feet of gas storage, the engines must be large enough to fully capture high yield days.

The table values represent an assumed volume of biogas and natural gas utilization. PWD's goal is to continue to improve and increase biogas production to reduce the need for natural gas. The before and after results must be viewed with an understanding that the biogas used prior to the production of electricity produced heat.

Table 2-1. NE Plant Annual Average Energy Profile Before and After Energy Improvements.

Energy	Unit	Before Energy Improvements	After Energy Improvements
Biogas Energy	MJ/d	1,018,000	1,018,000
Biogas Energy Flared	MJ/d	509,000	0
Electricity Supply from Grid (purchased)	kWh/d	139,700	5,300
Natural Gas Supply from Pipeline (purchased)	MJ/d	20,200	402,000
Purchased Fuel Oil	MJ/d	850	850
Electricity Produced Onsite	kWh/d	0	134,400
Percentage of Electricity Consumption Produced Onsite	%	0	96
Percent Site Energy Neutrality	%	0	54

2.2 Case Study 2 – Los Angeles County Sanitation District (LACSD), Joint Water Pollution Control Plant (JWPCP), California

The following case study describes the energy journey of another dynamic energy management leader, the LACSD.

2.2.1 Summary

LACSD has been powering wastewater operations with biogas on and off since 1939. In those early years, the JWPCP (shown in Figure 2-3) was electrically self-sufficient. However, over the years, increased wastewater treatment demands required more energy and, like other WRRFs, JWPCP consumed large amounts of purchased electricity and natural gas.

A steady, sharpened, 21st century focus on energy efficiency and energy production helped LACSD achieve dramatic savings over the years by implementing a variety of energy-saving and resource recovery options. Most recently (2013), LACSD increased electricity generation capacity at the JWPCP power plant, known as the Total Energy Facility. This success was made possible from embedded, organization-wide attention on energy which has facilitated LACSD landfill gas utilization and digester gas use at the JWPCP.

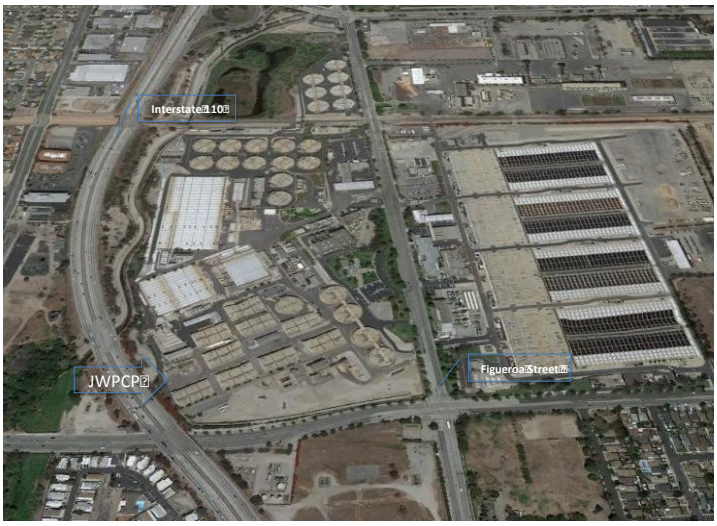


Figure 2-3. JWPCP Sits on a 420-Acre Property in the City of Carson in Southwest Los Angeles County in California.

2.2.2 Plant Process/Operations

The following sections discuss plan process and operations for LACSD.

2.2.2.1 The LACSDs

Los Angeles County is very large at over 4,700 square miles, and has a huge, diverse population of 10.2 million (2013). As noted on the Los Angeles County's website, "Los Angeles County has the largest population of any county in the nation, exceeded by only eight states" (LA County, 2014). The LACSD manages large volumes of solid waste and treats about 510 MGD of wastewater at 11WRRFs. Most of the solids are treated at the JWPCP. Of the 11 WRRFs overseen by the LACSD, seven are part of a Joint Outfall System (JOS). "The service area of the JOS encompasses 73 cities and unincorporated territory, and includes some areas

within the City of Los Angeles" (LACSD, 2014). Six of these facilities produce tertiary-treated water which is reused locally. The remaining wastewater and all of the solids are piped to the JWPCP in the southwest part of the service area. This facility removes and treats the solids before discharging cleaned water through an ocean outfall.

2.2.2.2 The JWPCP

The JWPCP began operations in 1928. Since then, the JWPCP underwent extensive improvements typical of WRRFs across the U.S., including secondary treatment, improved disinfection, and advanced solids treatment systems. All of these functions were required by increasingly stringent water pollution discharge permits, and resulted in increases in energy consumption.

Today, the JWPCP has a permitted capacity of 400 MGD and treats about 264 MGD (2013 average). As noted on the District's website, "Since 2000, the Sanitation Districts have spent, or will spend, in excess of $71.5 million in various efforts to reduce odors and air emissions from the JWPCP" (LACSD, 2014a). Energy production is centered on the Total Energy Facility (cogeneration facility) located at the JWPCP. The exhaust heat is used to heat digesters and to generate steam that powers an 8.7 MW steam turbine generator. The upgraded facility has capacity for 38 MW, and is expected to generate 20 MW on average. In 2013, 95% of the electricity needs of the JWPCP was generated in-house; this was an actual annual average of 17.3 MW or 152,000 MWh. The plant is essentially "electrically self-sufficient," according to Phil Ackman, Supervising Research Engineer. Power from the public utility grid is generally used only when the JWPCP Total Energy Facility is out of service.

LACSD Operations Focus on Resource Recovery:

- Water reuse is critical. LACSD achieves 50% water reuse through direct use for irrigation and surface water enhancement and through groundwater recharge.
- Anaerobic digestion is common.
- Energy management is increasingly important.
- Use of biogas for process heating is standard practice.
- Much of the solids generated are recycled to soils.

When necessary, electricity is purchased through Southern California Edison (SCE, transmission and delivery) and Noble Americas Energy Solutions, a third party electric service provider, through the Direct Access (DA) program rather than from the regional electric utility. In the last two years, the Districts have purchased 215 Gigawatt hours (GWh) of electricity through DA at a savings of over $2 million compared to standard utility rates. "The rate for Districts' DA accounts was $114/MW per hour, compared to $122/MW per hour for equivalent bundled SCE service. DA savings were $880,000 for Fiscal Year (FY) 2011-2012" (LACSD, 2013).

Natural gas is used to run some pumps, as well as supply the heating, ventilation, and air conditioning (HVAC) and hot water faucets throughout the plant. It is also used in a backup boiler which can provide critical process heat for the anaerobic digestion process in an emergency when steam production at the power plant and digester-fired gas boilers are unable to meet plant demand. Natural gas, purchased from the Southern California Gas Company, cost JWPCP $2,558,452 in FY 2011/2012. Biogas is used for CHP and as a backup for the effluent outfall pumps.

2.2.3 Energy Journey

In 1938, soon after it began operations, what is now the JWPCP began generating its own electricity and powering pumps (shown in Figure 2-4) by using anaerobic digestion biogas. In the 1970s, circular digesters replaced the originals, and installation of three gas turbines in 1985 set the JWPCP on the path toward net-zero-power production once again.

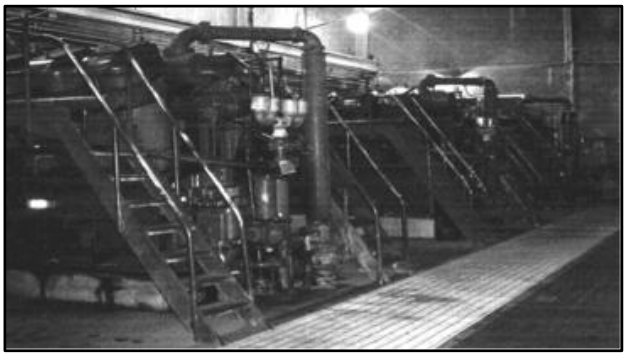


Figure 2-4. Late 1930s Power Plant at the JWPCP
(LACSD, 2012a)

In the late 1990s, LACSD formed its Energy Recovery Engineering Section, whose core functions are to:

- Develop renewable biogas resources.
- Minimize energy usage.
- Minimize energy cost.
- Demonstrate new technologies that reduce air emissions.

"In 2000, as the additional secondary treatment process trains were being built, we looked at our energy production and knew we were going to be producing additional digester gas," Ackman explains. "So we asked how we could best use that gas." Since then, two engineers worked almost exclusively on the electricity generation systems driven by landfill gas and digester gas.

JWPCP Key Energy Journey Milestones	
1938	JWPCP begins generating electricity from wastewater biogas, providing all the power needed to run the plant.
1970s	First modern circular digesters built.
1985	Three 7.5-MW gas turbines and heat recovery steam generators (HRSGs) installed. Two were generally operating and one was on standby.
1990's	Districts formalize long, ongoing focus on energy efficiency and recovery.
2000-2001	Replaced some chillers in HVAC system and used variable frequency drives (VFDs). Since then, have always installed VFDs in any projects (e.g., at the odor control center).
2001	Three new 9.9-MW gas turbines and HRSGs replace the 1985 versions.
2002	Full secondary treatment goes into operation with four new secondary treatment trains requiring a new 325 tons/day cryogenic oxygen generator, increasing electricity demand substantially. Seven new circular anaerobic digesters built. Some older anaerobic digesters were decommissioned. All older digesters from 1930s to 1950s are now out of service.
2006	Formal Energy Efficiency Management Program starts.
2010	New energy efficient lighting at the JWPCP resulted in 60% reduction in energy use for that purpose.
2012	Reduced the number of operating biological (secondary) treatment trains from seven to six. Eight of these 50 mgd biological reactor systems are in place. This reduction was possible due to a reduction in influent wastewater flow.
2012	The Energy Efficiency Management Program has documented $15.5 million in energy savings, including $4.8 million in FY 2011-2012 alone. This includes an accumulated reduction in electricity use of 3.2 MW.
2013	New drum-type heat recovery system is completed, replacing the old once-through HRSGs. New replacement steam turbine begins operations, increasing the electricity-generating capacity of the "Total Energy Facility" at JWPCP from 17 MW to 20 MW.
2014	Start of a two-year demonstration project for feeding processed food waste into JWPCP anaerobic digesters. The demonstration will help determine the potential role of food waste digestion in meeting member cities' solid waste diversion goals and the potential increase in energy production.

In 2006, LACSD created the Energy Efficiency Management Program. As a result of this program, other District facilities benefitted from an increased focus on energy conservation and utilization. Employees are encouraged to suggest energy efficiency improvements, and there is a research group that focuses considerable attention on energy management. Staff members track opportunities for grants and energy incentive programs to help pay for energy improvements. Many capital and operational projects have been implemented since 2006, which help the LACSD reduce electricity use by 3.2 MW, and claim a savings of over $15.5 million in energy efficiency savings since the start of the program. Additionally, equipment replacement and upgrades improve energy efficiency and production from year-to-year (Table 2-2).

Table 2-2. LACSD Capital and Operational Project Energy Savings.

Facility	Measure	Date Implemented	FY 11/12 Savings	Total Savings Since 2006
Energy Savings from Capital Projects				
JWPCP	VFDs on Primary Skimmings Odor Control Blowers	10/1/2008	$382,699	$1,473,043
JWPCP	Gallery Lighting Retrofit to T8 Fluorescent Lighting	1/1/2009	$115,342	$409,014
JWPCP	New Primary Sludge Pumps	3/1/2009	$13,309	$44,608
JWPCP	Four New High Speed Centrifuges	11/1/2009	$348,333	$908,434
Energy Savings from Operational Optimization				
Districts Wide	LCD Monitors	12/1/2006	$1,168	$7,161
JWPCP	VFD Turndown on Primary Skimmings Odor Control Blowers	10/1/2008	$292,531	$1,125,980
JWPCP	Operational Modifications to New High Speed Centrifuges	5/1/2010	$154,307	$324,751

"The low hanging fruit has been picked," says Ackman. The energy work at the JWPCP is driven and managed by the plant's managers and operators, including the day-to-day operations of the Total Energy Facility. The JWPCP is a natural venue for energy recovery because of the energy contained in the wastewater solids and the anaerobic digestion infrastructure. "Now, when everything works as it's designed to, we make more electricity than we need," says Ackman. The excess electricity generated is sold on the unscheduled market, which experiences price fluctuations, as the plant cannot guarantee its production.

The organization's mission statement includes energy resource recovery. Rough guidelines state that energy projects need to have a payback, generally within five years and they cannot compromise ongoing wastewater treatment operations. Occasionally the Districts will perform a demonstration project to meet other technology, research, or environmental objectives.

JWPCP views the Total Energy Facility as a way to ensure water reclamation plant reliability. By having a power plant generating all the electricity the JWPCP needs for normal operations, LACSD is assured that, in the event of a grid power failure, the facility will continue to treat wastewater in island mode (operation in isolation from the electricity distribution network). McDannel explains "their goal is to continually export at least 200 kW in order to minimize the risk of utility grid disruptions to plant operation. Power plant output varies with digester gas availability; at times, natural gas is co-fired with digester gas to maintain the target level of power export."

Like other states, California is expected to push diversion of food waste and other organics from landfills. LACSD sees yet another opportunity to increase its energy production. To test their ability to take in food waste in order to increase biogas production, LACSD developed a two-year pilot project which will take source-separated food waste in a slurry form and add it to one digester. Target feed rates are for 9% of the digester volume and 30% of the digester solids to be provided from food waste. This co-digestion pilot offers increased biogas production; however, some challenges anticipated are as follows:

"Energy efficiency is about money; we can't move on energy efficiency measures as quickly as we'd like to, because they do cost money."

Phil Ackman, Supervising Research Engineer

- Additional costs for storing and processing outside waste.
- How well the co-digestion solids will dewater.
- Possible impacts on the quality of the resulting biosolids.
- The stability of the digestion process.
- Uncertainty about how much food waste is available in the marketplace and how reliable the supply might be over time.

2.2.4 Challenges, Lessons Learned, and Benefits

Some obstacles encountered by LACSD and their ultimate, resultant benefits are detailed below.

2.2.4.1 Challenges/Lessons Learned

- Energy use cross cuts all departments and agency functions, from administration to operations. Responsibilities must be carefully delegated and, clear and frequent communication is a priority.
- Energy production and maintaining near net-zero electricity consumption relies on the flow of incoming solids. If the wastewater flow declines, as occurred in 2012 at the JWCPC, biogas production decreases and more natural gas is consumed.
- Operating a power plant like the Total Energy Facility requires capital and operating expenditures; greater operator skills; and attention to details such as cleaning the digester gas, interfacing with the utility and grid to sell electricity on the market. This increased operational complexity is a major disincentive. Employees must be encouraged to appreciate the benefits that justify the added responsibilities involved in making progress towards achieving net-zero energy consumption goals.

- Educate staff to conduct repairs and maintenance such that the experience gained remains in-house.
- Limit the number of parties involved in design, construction, and startup of new facilities and equipment.
- Understand the system inside and out to streamline operations and reduce the risk of overbuilding. For example, LACSD saved costs relating to siloxane removal by using a chiller to remove water vapor ahead of siloxane treatment.
- Do not overlook the details during design and construction. LACSD neglected to include steam flow monitoring at the power plant, which made it impossible to determine the amount of improvement in efficiency there.
- If possible, keep equipment consistent and standardized for ease of maintenance. This is difficult when public bid processes result in a variety of equipment types and brands.
- Preventive maintenance is critical, especially for energy efficiency. Follow the manufacturer's schedule for maintenance.
- Every agency, no matter their size, should employ a rate expert to understand electric bills and rates to take advantage of huge cost saving opportunities. LACSD has consistently managed to reduce energy costs by:
  - Buying power through DA.
  - Buying fixed price blocks of power.
  - Seeking out utility rebates through regional electric utilities to incentivize energy efficiency improvements.
  - Paying attention to the bills.
  - Setting goals and tracking savings.
  - Reviewing rate options to determine whether a lower rate was available.
- Smaller and mid-size water reclamation plants should be involved in industry groups and learn from the larger facilities. Sharing information between agencies and working together on policy matters is critical.

Money Lessons Learned:

- Utility rebates afforded LACSD $1.3 million in energy efficiency rebate incentives for energy efficiency projects.
- LACSD saved over $600,000 by switching to lower available billing rates.
- The Demand Response program reduces electricity usage temporarily to provide grid relief. By diverting flows to the JWPCP when needed, the LACSD saved $45,000 over the last two years for participating in this program.

2.2.4.2 Benefits

- The JWPCP can continue full wastewater treatment operations even if grid power is lost.
- Millions of dollars in annual savings have been realized through energy efficiency and renewable energy production.
- Employees are proud of their efforts to reduce net energy consumption and costs.
- LACSD employees now have extensive experience with anaerobic digestion, cogeneration, energy efficiency, and energy use.

2.2.5 Energy Profile

Table 2-3 provides overall facility energy consumption and production results before and after energy improvements. The results are identified as being "theoretical" because, unlike many other WRRFs, the JWPCP has produced its own energy on and off since 1939.

Table 2-3. JWPCP Annual Average Energy Profile Before and After Energy Improvements – Theoretical.

Energy	Unit	Before Energy Improvements	After Energy Improvements
Biogas Energy	MJ/d	5,320,000	5,320,000
Biogas Energy Flared	MJ/d	1,778,000	68,400
Electricity Supply from Grid (purchased)	kWh/d	383,200	23,000
Natural Gas Supply from Pipeline (purchased)	MJ/d	416,500	1,371,000
Purchased Fuel Oil	MJ/d	0	0
Electricity Produced Onsite	kWh/d	0	416,000
Percentage of Electricity Consumption Produced Onsite	%	0	95
Percent Site Energy Neutrality	%	0	51

2.3 Case Study 3 – Melbourne Water Western Treatment Plant (WTP), Melbourne, Australia

The following case study describes the energy journey of another dynamic energy management leader, the Melbourne Water WTP.

2.3.1 Summary

Melbourne Water in Australia operates two regional wastewater treatment plants: the WTP (shown in Figure 2-5) and Eastern Treatment Plant (ETP). Worldwide interest surrounds the story of how the WTP came to use biogas to meet nearly all of its electricity needs while striking a balance with the natural surroundings of each treatment plant. Melbourne Water adopted the mantra, "Do the right thing" in the late 1990s, and decisions since then have reflected both innovative operations and responsible environmental stewardship.

Figure 2-5. The Western Treatment Plant Produces 95% of Its Annual Electric Needs.
In 2014, Melbourne Water Received a Victoria Engineering Excellence Award for WTP Lagoon Cover Replacement.

Today, WTP's modernized lagoon treatment continues to feature N removal, high-quality recycled water (about 40 billion liters, or 10.6 billion gallons a year) and, according to the agency, "a network of lagoons, inter-tidal and shoreline areas that provide a haven for thousands of birds." The WTP began operating in 1897 using land and grass filtration and lagoon treatment. The three lagoon systems have 10 ponds each, staged from anaerobic to aerobic, holding about 600 million liters (160 million gallons) of water. The WTP produces almost all its onsite electricity from a 10-megawatt (MW) biogas-fueled power station owned and operated by AGL (formerly Australian Gas Light Company), the local electricity provider. Building on their success, the Utility plans to add another 4 MWs of cogeneration to its profile. Alongside their

operational success, Melbourne Water also slashed N loading into Port Phillip Bay, reduced odor and emissions, and produces high-quality recycled water.

The ETP, located across the bay from the WTP, uses biogas to generate a substantial quantity of its electricity usage and most of its heating and cooling. The plant's seven generators can run solely on biogas or with supplemental natural gas as needed. (While both plants are notable, this case study focuses on the WTP.)

The addition of lagoon covers added to the WTP's energy ingenuity, capturing the methane gas produced in the anaerobic ponds. This gas is used to generate electricity for plant operations (with a small amount for office heating and cooling). Additionally, Melbourne Water is in the process of replacing the lagoon covers (shown in Figure 2-6), which will collect more biogas to further reduce odor emissions, and increase electricity generation.

Figure 2-6. An Ongoing $43 Million Project to Replace WTP Lagoon Covers Will Allow Increased Power Generation.

2.3.2 Plant Process/Operations

The WTP is operated by Melbourne Water, owned by the Victoria state government, and overseen by a board of seven directors and a managing director. As a water resource manager, it captures, treats, and supplies drinking and recycled water, treats 58% of the city's wastewater, and manages 8,400 kilometers (5,220 miles) of waterways and 1,500 kilometers (930 miles) of underground drains in the Port Phillip and Westernport region. The plant staff is proud of their research program that guides integrated water management.

According to Melbourne Water, the WTP covers about 27,000 acres and combines lagoon and land treatment to process 132 MGD, or 58%, of the city's wastewater. Raw wastewater flows into three lagoon systems, about 230 meters (755 feet) wide by 1,500 meters (4,920 feet) long (shown in Figure 2-7). Huge lagoon covers suppress odors, halve greenhouse gas (GHG) emissions, and capture methane gas, which is used to power the aerators in successive aerobic ponds and other parts of the plant. The activated sludge system removes N from the wastewater. There are no primary tanks, and chlorine is used for disinfection following the treatment process. After 30 to 35 days in the lagoon system, the treated effluent is recycled or discharged to Port Phillip Bay, under strict EPA Victoria license requirements for Class A standards. Recycled water is supplied to a range of customers.

Figure 2-7. The Extensive WTP Lagoon Network Removes Large Amounts of Nitrogen Which Would Otherwise Flow into Port Phillip Bay.

EPA Victoria regulates biosolids production. About three million cubic meters (3.9 million cubic yards) of biosolids are stockpiled at the ETP and the WTP. Biosolids are stockpiled in drying ponds for six months or sent to a landfill. WTP has two biosolids qualities: historic stockpiles with metals and contaminants which make them unsuitable for land use, and current biosolids for use in forestry and farming.

With the entire city sewered, the WWTFs no longer accept septic tank sludge. The WWTFs do not take in solid waste or FOG either, but are considering the advantages of co-digestion, depending on possible available waste streams, such as glycerol. Melbourne Water is funding research into new markets and technologies for biosolids reuse, and is working with the University of Stockholm on nutrient recovery.

2.3.3 Energy Journey

"The unique thing with the WTP was the availability of cheap land when it was built in the 1890s," explains Ken Baxter, Energy Manager at Melbourne Water. Thus, land filtration and lagoons were easy options.

The gas-recovery journey started in the mid-1990s when the water agency "went from land and grass compression with polishing lagoons to lagoon processing," Baxter continues. "Lagoons are just a big hole in the ground, lined with natural clay at the bottom. We are relying on natural bacteria and organisms in sewage to do their work. Anaerobic digestion and biogas collection comes from them being covered. It's low tech, but the biology is off the charts in terms of intricacies. [The WTP] succeeds because of the size, shape, hydraulics, and how they laid it out. Fascinating technology."

Melbourne Water Western Treatment Plant Energy Milestones	
Year	**Event**
1982	Western Treatment Plant declared a Ramsar site, internationally recognized for its wetland habitat especially for waterfowl.
1996	Study recommends reduction in nitrogen loads to the bay.
1998	World's largest floating membrane cover system installed at WTP.
2004	Stage 1 upgrades to reduce nitrogen loads to the bay. Recycled water irrigation replaces sewage irrigation across the site. Land and grass filtration methods cease. Two power stations installed to capture biogas.
2005	Stage 2 of upgrades. Expanded WTP and simplified biogas-electricity contract with AGL.
2010	Four additional power stations installed.
2013	Stage 3 upgrades to enlarge lagoon capture system and install new covers.
2014	Stage 4 of upgrades and new power station sizes at WTP will depend on gas generation from existing system, possibly at 4 MW on top of 9.9 MWs as of 2013.
2015	Cogeneration Trial at WTP.

The road to current success was paved with many challenges. "The city was encroaching on the western treatment plant. Open anaerobic lagoons were odorous and unpopular. We had dissolved oxygen (DO) problems." In the 1990s, the WTP experimented with engine generators to eliminate flaring, driven by the cost of energy imports.

Sustainability awareness escalated at the plant and in the community. The WTP had already installed activated sludge processing to reduce N to meet new limits and was recycling wastewater. The treatment process was reduced to two lagoons. "We needed to control odor and air quality and reduce operating costs. We realized we could make some money off the gas." Lagoon covers could offer a solution, but it took several imperfect iterations over the years before they finally "struck gold."

In 1997, Melbourne Water contracted with Geomembrane Technologies Inc. (GTI) of Fredericton, New Brunswick, Canada, to design and construct the world's largest floating membrane cover system to capture the biogas (Figure 2-8), compress it and send it to odor treatment through a pipeline. The covers had to be low-maintenance, self-draining, withstand pressures from scum, and withstand rain and wind. GTI covered the inlets of two lagoons with a triple-layered floating insulated cover. The two covers, maintained under negative pressure by a vacuum, were 650 by 560 feet for the west lagoon and 700 by 650 feet for the east lagoon, capturing gas for storage and sale. The project was completed in 1998.

Figure 2-8. The Captured Biogas Allows Melbourne Water to Generate Electricity Onsite.

Baxter relates that more challenges accompanied the new covers: "The wastewater went straight into the big covered area of those lagoons and whatever settled out, settled out, and whatever floated, floated out." The remaining gas was still flared.

When the covers were installed in 1998, Melbourne Water decided that electricity generation was not a core business objective, so they contracted with AGL, who captured the gas, retained the flares, and provided the interface to the pipe flange. A third party was contracted for electricity generation. "At that time, there were about three 1 MW generators in place at each lagoon." To export to the grid, they needed a substation. The local telecom service provider owned the nearest substation, and it took six months to come to an arrangement.

Early contracts with AGL were complex; in 2005, when Melbourne Water entered Stage 2 of the upgrade, Baxter saw an opportunity to simplify the contract, expand WTP, and take full advantage of the biogas they were capturing. In short, Melbourne Water agreed to limit pressures and guarantee a certain amount of biogas, and AGL would guarantee Melbourne Water a certain amount of electricity. AGL is essentially an energy retailer attempting to be more vertically integrated at the generation end, in the natural gas market, and in electricity production. AGL accepted this opportunity, and the "commercial in confidence" contract was drawn up.

The relationship with AGL was then and is today "very, very good," Baxter observes. "It has to be because we have to interact very much. We have a lot of contracts with AGL through the tender process. We don't have a natural gas feed at the Western Treatment Plant. We're capturing the gas, but AGL is taking that out and compressing it and accepting it and turning it into electricity. They started giving us gas repayments. We are 'transmission lines,' and they are the 'interface.'" AGL coordinates maintenance and manages the feeders.

One benefit of the new relationship was an open-book arrangement, he notes, where AGL retains ownership of the renewable energy credits (RECs), but Melbourne Water could see all the transactions. An REC is a form of renewable energy currency, established in part to meet a government target of 20% renewable energy-sourced electricity by 2020. One REC is equivalent to 1 MW hour of electricity generation. An REC can be traded for cash, and the value fluctuates with market conditions.

"We can see the financial models the generator was using to underpin the project and see how the tariffs we paid were created within that model - typically extraction payments, operating and maintenance costs. The argument comes down to internal return on RECs that the service provider is retaining. It's no longer arguing about specific elements and items, but about internal rate of return in the deal."

AGL took over the engine-generators, with three in place by 2004 at the station, and two more expansions in 2010 and 2013 to total two 1.25 MW and seven 1.06 MW engines, for a total of 9.9 MWs. Stage 3 of the expansion project enlarged the lagoon gas capture system and, as of the end of 2013, one lagoon was in the process of being re-covered, which will allow more gas to be captured.

With onsite electrical generation through combustion of methane gas produced in the anaerobic lagoons, the total amount of energy consumed (excluding lagoon methane gas but including propane and natural gas) dropped by 76%.

Black & Veatch, 2014

Biogas production varies greatly from summer to winter, and Baxter admits they are still struggling with finding a balance. "In winter, we feed as much as possible to the power station. For gas safety reasons, the flare is kept running but throttled back, though we can run it at nearly zero turndown. In the summer we have lots more gas and the power station is running as hard as it can, but we're still flaring gas. There is probably some opportunity to put in small storage systems. When we go to Stage 4 [of the expansion], we will still suffer from variability and are thinking of how to manage that. One way is bringing in a natural gas feed."

Melbourne Water and AGL both know the impact of limited gas. "We both know if we don't deliver gas on a month-to-month basis, we calculate what we need to do regarding penalty payments. Once a month we sit around a table – the energy accountant, reps from plants, operational and process and asset people, and go through [corrective and preventive] goals and [look at the] future. It's useful to keep everyone on the same page."

Once Melbourne Water knows how much more biogas is captured under Stage 3, it will be time to replace the second lagoon cover. "We'll frame up the timeline to size Stage 4, then implement it so they come online together. We need to learn a lot about how to replace covers quickly." He anticipates the power station would total about 14 MWs by adding 4 MW engines to the existing 9.9 MW. There is potentially another million dollars in savings if Stage 4 can be accelerated.

2.3.3.1 Looking Forward

Climate change considerations have been significant, as with all water facilities. "At that time, we were in a drought that had lasted over a decade, with reservoirs down to their lowest levels ever recorded. In 2000, we set a target of 40% renewable energy use by 2005. All our activities went toward achieving internal targets. In 2006, at the high point of the drought, the board wanted additional GHG emission reduction.

"But having said all that, every action we took to get to renewable energy targets was still economical to do. And we will still do renewable energy where it's cheaper than grid supply." For example, Melbourne had five new hydroelectric stations in construction as of 2014 (in addition to their existing nine stations), with further expansions for another six under consideration.

Wastewater production and pollutant loads will grow concurrent to the 1.5% population growth per year in Melbourne. While increases in inflow can increase gas production, Melbourne faces ever-rising environmental standards for water and effluent quality. "We had a big jump at Eastern where we took it from primary/secondary to tertiary treatment. We're getting pressure from environmental advocacy groups to extend the output out to sea or improve quality. At Western, the effluent goes into the bay, a protected nature and wildlife reserve. We have to treat to nutrient standards and keep flow going through." Problematic elements in the effluent like cadmium and trace metals have been reduced over the years.

Melbourne Water is preparing for a 2015 co-digestion trial at the WTP. By adding organic waste, they expect to increase the biogas produced which, in turn, increases electricity available for use at the plant, while decreasing landfill waste and creating another revenue stream.

2.3.4 Challenges, Lessons Learned, and Benefits

Melbourne Water faced several challenges on its ultimately successful quest for energy neutrality leadership. Their challenges and lessons learned are summarized below.

2.3.4.1 Challenges/Lessons Learned

- When working with AGL, Melbourne Water had to be careful not to overestimate the amount of biogas they could provide, risking penalties if they could not supply as agreed.
- WTP generated appreciably more biogas in summer than in winter. Power station sizing was an economic balancing act; an evaluation of idle time in the winter when gas is limited, but processing copious amounts of produced gas in summer.
- Melbourne Water does not anticipate a great return generating electricity onsite versus importing. They use 76% of it on an annual basis, and sell the excess to the grid at times when production exceeds consumption.
- Industry partners bring great advantages, as they can share the risk while receiving a fair return.
- The open-book approach with AGL benefitted Melbourne Water. Transparency in the financial model (capital investments, operation costs, and other line items) allows both parties to calculate the percentage return on investment.

2.3.4.2 Benefits

Melbourne water continues to improve its WTP operations, which not only affords the facility continued progress towards net-zero energy, but provides the community with many benefits:

- WTP produces a large percentage of its own electricity, and also supports other Melbourne Water sites when excess electricity is generated.

- The long-term health of Port Phillip Bay will be protected using improved wastewater treatment processes, which reduce N loading to the bay.
- Capturing biogas to generate electricity has substantially reduced GHG and odor emissions.
- Innovative lagoon systems and land management have created several habitats that support diverse vegetation, wildlife, and habitats.

2.3.5 Energy Profile

Table 2-4 provides overall annual average facility energy consumption and production results before and after energy improvements.

Table 2-4. Melbourne Water's Wastewater Treatment Plant Annual Average Energy Profile Before and After Energy Improvements.

Energy	Unit	Before Energy Improvements	After Energy Improvements
Biogas Energy	MJ/d	2,018,200	2,018,200
Biogas Energy Flared	MJ/d	2,018,200	296,700
Electricity supply from Grid (purchased)	kWh/d	203,300	48,700
Propane Gas supply (purchased)	MJ/d	1,730	1,730
Natural Gas supply from Pipeline (purchased)	MJ/d	4,790	4,790
Electricity Produced Onsite	kWh/d	0	156,800
Percentage of Electricity Consumption Produced Onsite	%	0	76
Percent Site Energy Neutrality	%	0	76

2.4 Case Study 4 – Johnson County Wastewater (JCW), Douglas L. Smith Middle Basin Wastewater Treatment Plant, Kansas

The following case study describes the energy journey of another dynamic energy management leader, JCW.

2.4.1 Summary

JCW operates seven WRRFs and treats septage, returning cleaned water to area streams and producing biosolids, most of which are land applied on area farms. The Douglas L. Smith Middle Basin Treatment Plant (Middle Basin Plant, shown in Figure 2-9), which was built in 1979, underwent dramatic upgrades over the past five years, including the addition of BNR, a new liquid process train which increased capacity to 14.5 MGD, a fourth anaerobic digester, a biogas storage sphere, a biogas cleaning system, and two 1,060 kW CHP (cogeneration) engines. This plant is the focus of this case study.

As part of these upgrades, the Middle Basin Plant built a receiving system for FOG and other high-strength outside wastes. Co-digestion of these outside wastes with the solids from the Middle Basin Plant and solids from another JCW facility (Blue River) boosted biogas volumes to ~185% over pre-project production.

Figure 2-9. The Douglas L. Smith Middle Basin Wastewater Treatment Plant Saves Johnson County Water $250,000 Annually by Meeting About 40% of the Plant's Electricity Demand.

The electricity generated saves JCW approximately $250,000 per year by meeting ~50% of the Middle Basin Plant's electricity demand. Heat from the generators is used in the anaerobic digestion process and in buildings. JCW anticipates being able to generate even more energy by accepting additional outside wastes, although it has learned that the market for such wastes is becoming competitive.

In a few short years, JCW has taken dramatic steps towards energy independence. In so doing, the agency is helping meet formal Johnson County goals of reducing energy consumption and GHG emissions while saving on operational costs. This dramatic progress occurred during the Great Recession, when JCW and Johnson County were cutting budgets and staff. Those cuts might have been greater, but JCW's upgrades were "shovel-ready" when the American Recovery and Reinvestment Act (ARRA) became law in February, 2009, providing $18.3 million for the Middle Basin Plant upgrades, nearly half of which was an outright grant. In part because of the federal funding, the Middle Basin Plant cogeneration project has garnered considerable attention from regional and national agencies, political leaders, and the media. In 2013, it was honored with a National Environmental Health Association (NEHA) sustainability award. The project also received awards from NACWA and the Mid-America Regional Council (MARC).

The Middle Basin Plant is a secondary treatment facility using a modified Bardenpho process for BNR. Peak flows are managed in equalization basins. Disinfection is achieved with ultraviolet light. The plant's discharge permit includes targets of 1.5 mg/L for P and 8 mg/L for N. Kansas, like other states, is focusing on controlling P discharges, and JCW has been working toward stricter nutrient discharge limits since 2005.

2.4.2 Plant Process/Operations

The following sections discuss plant process and operations for the Middle Basin Plant.

2.4.2.1 The Middle Basin Plant Solids Treatment Process

The Middle Basin Plant treats not only the solids it produces, but also, since the 2013 upgrades, 300,000 gallons of unthickened solids from the Blue River plant, as well as other outside wastes. Because both treatment plants include biological phosphorus removal processes, their solids are high in P. The Middle Basin Plant does not use iron addition in its process, in part because it achieves 60% solids removal in the primary settling process and, because iron would interfere with the function of the biological P removal process.

2.4.2.2 Anaerobic Digestion

The solids produced by the Middle Basin Plant have been anaerobically digested at mesophilic temperatures (~98° F) since the plant began operation in the early 1980s. The digesters each have a capacity of 540,000 gallons or 47,500 pounds dry solids/day, which is mixed by solids pumping. The three primary digesters have fixed covers, while the secondary digester has a floating cover. Solids are fed equally by flow metering to the three primary digesters. Digester feed now also includes FOG and other high strength wastes. The solids retention time averages 20 days, and a volatile solids reduction (VSR) of 45% is achieved. The digesters are not designed to store biogas; biogas storage is achieved in the new dual-membrane gas storage sphere, which has a capacity of 88,000 cubic feet (about five hours during continuous operation).

The newest of the three primary digesters began operations in July of 2010. By the end of that year, total biogas production exceeded any prior production level at the Middle Basin Plant. The prior average had been about 130,000 scf/day. FOG began to be added in January 2011,

resulting in a jump to nearly 250,000 scf/day, before a foaming event in March set gas production back to 150,000 scf/day. Once that event was mitigated and, with the addition of other high strength wastes, the gas production for the remainder of 2011 averaged approximately 240,000 scf/day. That year, onsite generation of 8.8 million kWh of electricity at the Middle Basin Plant provided ~50% of the plant's needs. Some of that power production is fueled by natural gas, which continues to be used as a supplemental fuel to optimize engine generator output.

2.4.2.3 Receiving FOG and Other Outside Wastes

The new facility for receiving FOG and other outside high-strength wastes operations includes the following:

- Trucks discharge wastes to one of three storage tanks. This new FOG receiving system has a capacity to take in an annual average of 12,400 gallons per day (gpd) (three to four trucks per day), with the potential to expand to receive up to 30,000 gpd.
- Before entering the storage tank, the FOG or other waste goes through a chopper pump and is then warmed in a heat exchanger that uses water heated in the cogeneration engines. If waste is to be in the storage tank longer than a day and risks cooling and congealing, the system allows for it to be mixed through the heat exchanger again.
- Typically, at any given time, one storage tank is receiving waste, while material from a different tank is being fed to the digesters. The third storage tank is used to store excess volumes that may accumulate during weekends or holidays.
- FOG and outside wastes from the storage tanks are pumped in equal volumes into the three primary digesters. Typically, 14% of the volume of each digester is FOG/outside waste.
- Odors associated with the outside waste receiving facility are controlled by a biotower with activated carbon, which "polishes" the air from the FOG storage tanks.

As of 2013, the facility accepts restaurant and industrial waste. JCW sized the FOG receiving facility with the assumption that 75% of all Johnson County FOG would be delivered to this facility. Additional outside wastes come from industrial facilities; these are screened to determine if they are appropriate for the Middle Basin operation by analysis of samples provided in advance of any agreement.

2.4.2.4 The Cogeneration System

Two 1,060 kW reciprocating engines are the core of the new Middle Basin Plant CHP (cogeneration) system. The engines can run on cleaned biogas, natural gas, or a blend of both. Cooling jacket water from the engines is used to heat the digesters and FOG, as well as the building. The biogas cleaning system uses a chiller to remove moisture from the gas, as well as remove hydrogen sulfide and siloxanes. Excess biogas is burned in three Groth candlestick flares mounted in a semi-enclosed structure to screen them from winds and view.

2.4.3 Energy Journey

"We probably did not start with an energy journey in mind," said Susan Pekarek, Chief Engineer at JCW. "The current Director was Operations Manager not long ago, and he brought up the idea of a FOG receiving facility. There were frequent complaints by waste haulers that pumping of grease interceptors was required, but there weren't many good places to dispose of it."

The County requires annual grease permits for food service businesses, of which there are about 800. Grease interceptors must be maintained and pumped at intervals no greater than 90 days, and records are required to be kept. The result is a need to manage 4.3 million gallons of FOG from restaurants and food processing each year.

FOG was one driver leading to JCW's recent reductions in net energy consumption. JCW designed their new FOG receiving facility assuming they would receive 75% of the available FOG, or an annual average of 12,400 gpd with a peak capacity of 30,000 gpd, if needed.

"Another driver was the fact that Johnson County leaders had started a sustainability program about a decade ago, following recommendations of the National Association of Counties. A County baseline estimate of GHG emissions was completed in 2005, and wastewater was a large part of the County baseline: 40%."

In 2007, the County Commissioners signed a resolution that included GHG goals to "reduce the amount of…GHGs…associated with energy use to zero by the year 2030 and develop and implement a plan to reduce GHG emissions by 80% by the year 2050" (CH2M HILL, 2011).

Douglas L. Smith Middle Basin WWTP Energy Milestones

Year	Event
1979-84	The Middle Basin mechanical WWTP is built and becomes operational, treating 3 MGD of Johnson County and City of Olathe wastewaters using a redwood trickling filter. This WWTP replaces a lagoon system. Anaerobic digestion in operation.
1987	Middle Basin plant is expanded to 9 MGD, including adding a primary anaerobic digester. Digester gas is used to heat buildings and solids in the digesters; the remainder is flared.
2001	Middle Basin WWTP is upgraded with UV disinfection.
2003-07	Major upgrades to the Middle Basin WWTP, again increasing its treatment capacity, including installation of activated sludge process for a portion of the treatment process.
2005	Johnson County completes GHG inventory baseline; wastewater treatment accounts for 40% of total County energy use. Electricity costs ~$0.05/kWh.
2009-10	In response to a violation due to shortage of treatment capacity, the Middle Basin WWTP is expanded to include a fourth liquid treatment train, building the capacity from 12 to 14.5 MGD. This upgrade includes BNR using a modified Bardenpho process.
2011	Middle Basin WWTP begins operating a fourth primary anaerobic digester, a FOG and other high-strength waste receiving system, and a cogeneration facility.
2013	Middle Basin WWTP completes installation of three new 2-meter belt filter presses for solids dewatering.

"At that same time," said Pekarek, "JCW was studying the increasing wastewater discharge in its service area and beginning to plan an increase in treatment capacity."

The Great Recession soon followed. Johnson County, like other governments, had to cut costs and reduce ambitions. But, momentum carried forward the upgrade of the Douglas L. Smith Middle Basin facility, increasing the capacity from 12 to 14.5 MGD and improving nutrient (nitrogen and phosphorus) removal. With $18.3 million in funding from ARRA, nearly half of which was an outright grant, JCW broke ground in May 2009 on a multi-faceted

improvement of solids treatment (Johnson County, 2014; HDR Inc., 2009, illustrated in Figure 2-10), including:

- A plant-wide SCADA system.
- Primary solids degritting equipment.
- A fourth anaerobic digester (thus meeting the need for more solids treatment capacity).
- New recirculation pumps and mixing systems.
- The planned FOG receiving facility.
- A membrane digester gas holding facility.
- Two biogas/natural gas fired boilers.
- Biogas storage.
- Gas cleaning equipment for removal of moisture, hydrogen sulfide, and siloxanes.
- Two 1,060-kilowatt (kW) CHP cogeneration units.

Even as the national economy collapsed and county priorities changed, JCW managed to leap forward in its energy journey. Anticipated benefits of the upgrade included reductions in GHG emissions "by 9,700 metric tons in CO_2 equivalent emissions annually." In addition, the new facility reduced the average miles traveled by FOG waste haulers by at least 40,000 miles annually, resulting in an estimated savings of 8,000 gallons/year of fuel and a reduction of 80 metric tons CO_2/yr emissions" (CH2M HILL, 2011).

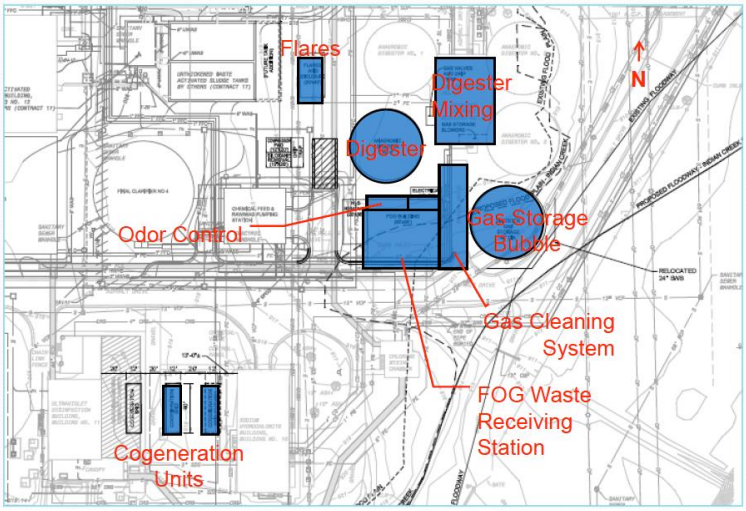


Figure 2-10. Upgrades to the Middle Basin Plant, Completed in 2013 Included New Digestion, Gas Management, and Cogeneration Systems (in blue).

During a recent economic downturn, the greater focus was on cost savings through sustainable projects. The challenge for JCW is that the current staff is overloaded, and simply does not have the adequate time needed to devote to all the energy work begun. JCW desires to bring in more waste, and hopes to devote more effort to finding those resources. Pekarek explained that, "as we continue to move forward, we use the words 'energy recovery' and 'energy reduction' more, emphasizing the cost savings we can achieve."

2.4.3.1 Energy Use

Energy demands at the Middle Basin Plant require electricity, natural gas, and biogas. Electricity currently costs about 9 cents/kWh. The Middle Basin Plant presently requires an average of about 1,800 kW of electricity. In 2011, with the new biogas and cogeneration systems just beginning operations, the Middle Basin Plant consumed 16.15 million kWh, 7.01 (43%) of which was generated onsite.

Natural gas is used to optimize the consistent operation of the two 1,060-kW engines as backup fuel sources in boilers that provide heat to the digestion process and building heat. (There is also another small, stand-alone boiler in the Headworks Building that uses natural gas. Natural gas is supplied by Constellation Energy (formerly OneOk), with final transportation to the Middle Basin Plant by Atmos Energy. In 2013, the price was $5.40/MMBtu and the Plant used 64,309 MMBtu totaling $347,270.

Biogas from the anaerobic digesters is used to power the two 1,060-kW engines to produce CHP; heat from the engines is used to heat the digestion process and buildings. After FOG and other outside wastes began to be added in early 2011, biogas production increased into the range of 160,000 cubic feet per day (cfd) to more than 260,000 cfd.

JCW does not have available or engage in any power purchase agreements or energy management programs such as peak shaving or RECs. Kansas City Power and Light (KCPL) determines electricity rates, and natural gas pricing is determined in the open market. “That is about as close to negotiated pricing as we get,” said Pekarek.

2.4.3.2 Energy Production and Efficiency

In developing the new CHP system, JCW opted for two 1,060-kW engines having a shorter payback period (18.2 years) compared to the option of one 848-kW engine (20.1 years). This choice minimized flaring of digester gas, minimized GHG emissions, and maximized electricity output, while providing the best coverage for the expected range of digester gas output.

In 2011, part of the ARRA funding was used to complete an energy audit, which identified many opportunities for energy and money savings. A similar audit had not been done for 20 to 25 years. Now that the major energy production upgrade at the Middle Basin Plant has been completed, JCW is turning its attention to a variety of efficiency projects, which are being considered.

2.4.3.3 Looking Forward

An energy efficiency plan has not been completed; therefore, this plan will be one of the first tasks undertaken by JCW staff as their limited work schedule allows. Pekarek expects that report will show more ways to save on natural gas, electricity, and water purchases, “but we’ve already attacked the low-hanging fruit.” Potential projects being considered include replacing HVAC systems and installing efficient lighting and motors (they have been doing this in the new projects). “First, we want to establish goals and figure out how to best track energy use. At the Middle Basin Plant, we now track power purchased and produced, but we don’t have that capability yet anywhere else.”

Other potential projects considered include:

- The energy audit raised the consideration of cogeneration at the Myron K. Nelson complex but, without more outside waste available there to boost biogas production, it did not make operational or economic sense.

- Johnson County has received a grant for the purchase of compressed natural gas (CNG) vehicles. JCW has to complete an evaluation of whether or not it would be economical for them to produce additional biogas for a county fleet of CNG vehicles.
- The Mill Creek WRRF is close to a landfill with installed gas wells. JCW has considered whether they might benefit from generating electricity from the landfill gas, even though it is more challenging to use.

Finally, affecting all potential energy production projects is the fact that JCW's electricity suppliers are seeking ways to shave peak demand. If JCW can negotiate a favorable price for reducing its peak grid electricity demand, it may realize cost savings which can justify some of the possible additional investments in energy production.

2.4.4 Challenges, Lessons Learned, and Benefits

JCW faced various challenges on its journey as a champion of change, gaining invaluable knowledge and operating expertise.

2.4.4.1 Challenges/Lessons Learned

JCW staff spent two years fine-tuning the operations of the new and upgraded systems at the Middle Basin Plant. As is common, there have been startup challenges, including technical difficulties, staffing and training needs, and increased interactions with stakeholders and the public.

- A lack of technical resources and example projects resulted in the JCW staff having to navigate operations on their own or reach out to their consultants. Tours of similar facilities and discussions with their operations staff proved very helpful.
- The most prominent technical difficulties seem to derive from adding FOG and other outside wastes. These difficulties show up in both the anaerobic digestion process and in the cogeneration system. JCW staff did not anticipate how quickly FOG was becoming a valued resource targeted by other users. Having built its operations with enough capacity to take 75% of the FOG produced in the county, JCW suddenly found itself short on supply, competing for this resource, which was no longer a waste.
- Soon after introducing the new feedstocks, the digesters experienced foaming and rapid expansion, with overflows out of the digester boxes. In response, JCW operators reduced the mixing energy applied to the digestion process. The mixing system now runs just a few minutes at a time, rather than continuously. In addition, JCW added more relief piping to manage volume expansions. "We have not had upsets for some time," said Pekarek.
- Operators began by fueling the new cogeneration engines with all of the biogas being produced and supplementing with natural gas. The chiller was sized for a particular anticipated volume of biogas but, the facility was just not producing that much. "We haven't figured out exactly why," said Pekarek. "It may be because the strength of the waste we are receiving is not as high as expected." The lower loading on the gas chiller made it inoperable. Thus, at times, uncleaned biogas is flared and the engines are run on natural gas alone. "But mostly now we run one engine at a time on 200,000 cfd of biogas and use natural gas for the other half. Natural gas is cheap right now, so it works out," Pekarek said,
- Achieving the correct carbon balance is an ongoing operational challenge. JCW staff has considered bringing in volatile fatty acids (VFAs) to help the process. Adding ferric for P removal is another commonly used option. But adding chemical iron reduces the

effectiveness of biological P removal. "To figure this out, we may need to be looking at a mass balance," explained Pekarek.

- The Middle Basin Plant is staffed 24 hours per day, seven days per week. The Great Recession and its accompanying staffing cuts compounded the increased demands on staff as they learned new systems, leading to a "brain drain" of sorts.
- KCPL "does not like working with small generators of electricity, such as JCW," said Pekarek. JCW finds it most practical and cost-efficient to limit the electricity production at the Middle Basin Plant to no more than the plant consumes. Because of the challenges discussed above, in late 2013, only one engine generator was operating at any one time, thus meeting between 50 and 60% of the plant's electricity need.
- The Middle Basin Plant and other JCW operations continually strive to be good neighbors. Odors and other nuisance issues are mitigated with a variety of controls and standard operating procedures. The public issued concerns about the gas storage bubble and safety concerns about biogas. "We hosted an open house with neighbors," said Pekarek, "…and now the County has created and hired several people for a rebranding effort, in which wastewater is featured. We realize now that we have to educate Board members as well as the community in general."

2.4.4.2 Benefits

"There are few facilities like this around the country," Pekarek noted. "JCW should be proud of the Middle Basin Plant and its energy production." Not only is it cost-effectively generating at least half of its own electricity, the plant is also:

- Reducing the demand from the local utility's coal-fired power plant, thus reducing JCW's GHG emissions substantially.
- Treating solids from another JCW facility, thereby reducing transportation costs and the landfill disposal of those solids.
- Reducing the miles driven by transporters of FOG and other outside wastes, which reduces fossil fuel consumption and GHG emissions.
- Reducing the amount of biogas / methane being flared (a waste of a resource).
- Providing a convenient outlet for FOG and other high-strength wastes, a benefit to the broader community.

2.4.5 Energy Profile

Table 2-5 lists the overall facility energy consumption and production results before and after energy improvements. The energy profile at the Middle Basin Plant is significantly affected by two factors:

1. *The reuse of carbon for biological treatment.* The Middle Basin Plant ferments its primary solids and sends about 26,600 MJ/d of the fermentate to the secondary system for biological phosphorous removal. The remaining fermentate is sent to the head of the plant, resulting in the high recycle concentration of energy. This practice is an energy conservation measure, because it reduces both the energy to produce a carbon source (such as methanol) and the energy used in transportation of that external carbon source.
2. *The use of natural gas as a supplemental fuel to operate the cogeneration engines*. The cogeneration engines, along with biogas, are currently fed approximately 154,800 MJ/d

of natural gas. Natural gas is used because the cogeneration engines can consume more gas than is currently being produced by the anaerobic digesters. These large-capacity engines were installed not only because it was fiscally viable, but also because they provide for the potential for utilization of increased biogas production resulting from population growth and increasing processing of FOG and other high strength wastes.

Table 2-5. Middle Basin WWTP Energy Profile Before and After Energy Improvements.

Energy	Unit	Before Energy Improvements	After Energy Improvements
Biogas Energy	MJ/d	101,600	101,600
Biogas Energy Flared	MJ/d	9,500	46,000
Electricity Supply from Grid (purchased)	kWh/d	42,000	24,300
Natural Gas Supply from Pipeline (purchased)	MJ/d	0	154,800
Purchased Fuel Oil	MJ/d	0	0
Electricity Produced Onsite	kWh/d	0	17,600
Percentage of Electricity Consumption Produced Onsite	%	0	42
Percent Site Energy Neutrality	%	0	21

2.5 Case Study 5 – Ithaca Area Wastewater Treatment Facility (AWWTF), Ithaca, New York

The following case study describes the energy journey of another dynamic energy management leader, AWWTF.

2.5.1 Summary

When AWWTF was built in 1987 (Figure 2-11 shows an aerial view of the facility), it included two Caterpillar 100-kW cogeneration engines and heat recovery systems. “We also have a pretty extensive trucked waste collection program, which is segregated so it can be discharged directly to the anaerobic digesters. We’ve always had a history of using biogas for boilers and in the Caterpillar engines,” says Daniel Ramer, Chief Operator.

By mid-2013, the facility was in the middle of a multi-year, $8 million, energy performance upgrade. Ramer reports that the buildings were weather-sealed, and energy-efficient lighting and photovoltaic solar panels had been installed. The two aging 100-kW cogenerators had been replaced by four state-of-the-art 65-kW micro-turbines. “One of our hot water boilers was replaced with two smaller, more efficient units,” he says. “The anaerobic digesters received more efficient mixers and a new biogas storage bubble was installed.” The trucked waste receiving facility upgrade was completed in late spring 2014. The original trucked waste facility had two storage tanks (40,000 gallons total), with manually raked screens and propeller mixers in a pole barn type building. The new facility includes an additional 20,000-gallon tank, a food receiving tank, JWC Honey Monsters® to screen garbage, Vaughan chopper pump mixing systems, and odor control in a high bay metal building.

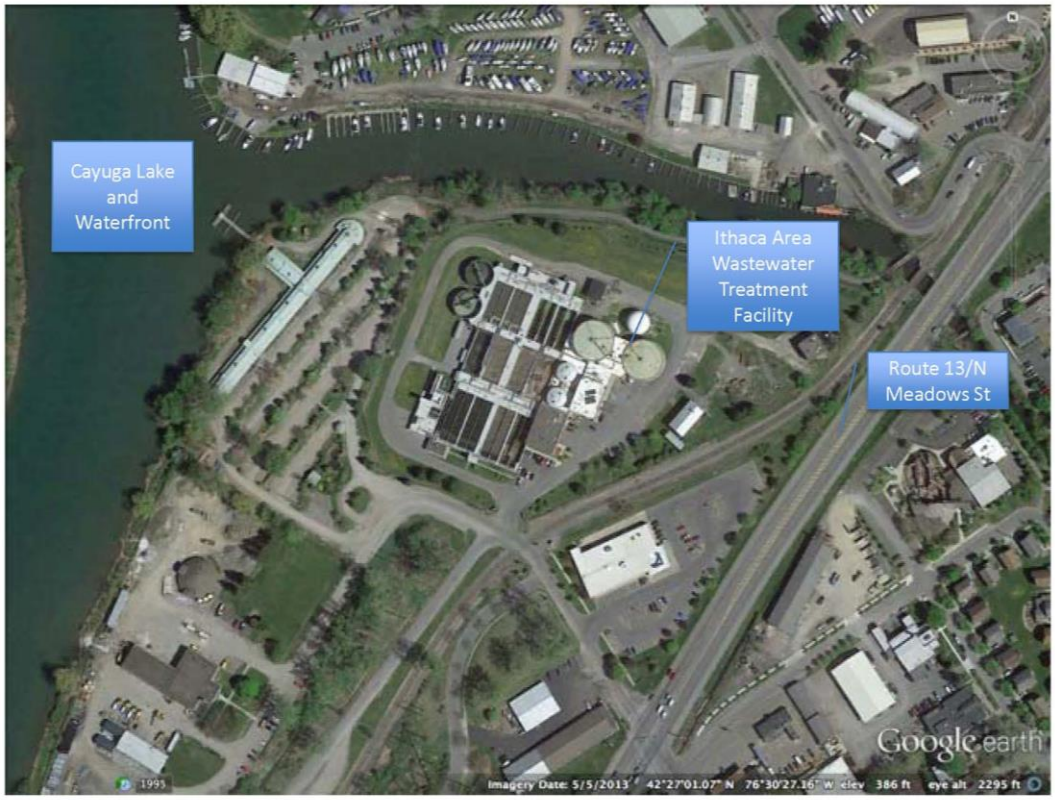


Figure 2-11. The AWWTF.

At the time this report was written, installation of the aeration component of the project was not complete. Electrical wiring for valve control, DO monitoring, and other control parameters were being performed, with commissioning of the system planned for early December 2014.

"The guaranteed result of these improvements," Ramer says, "will be in long-term cost savings. These results come from decreasing our energy usage while increasing our renewable energy production, generated primarily from increased biogas production along with some solar electric. Plans to also include food waste from Cornell University are near fruition and, that in conjunction with the blower upgrades, should get us to near 60% energy neutral or better."

The project was expected to save $9.8 million through 2031, while reducing about 997 tons of GHG emissions. Some of the implemented measures were supported by funds from the New York State Energy Research and Development Authority (NYSERDA) and the American Recovery and Reinvestment Act of 2009.

Johnson Controls performed an energy audit at the Ithaca facility, which convinced officials to approve the upgrade and issue a contract. "Slowly but surely we came up with a list of facility improvement modifications. That became what they used to come up with a performance contract, always based on energy," he says.

2.5.2 Plant Process/Operations

Three municipalities own the Ithaca facility: The City of Ithaca, the Town of Ithaca, and the Town of Dryden. Each municipality has their own water and sewer division. Part of Dryden has a sewer district that runs to the Ithaca facility. Nearby Cornell University has its own water supply, but uses the Ithaca facility for sewer. "It's a strange set of boundaries," Ramer notes.

Emerson Power Transmission Corporation is the only significant industrial user; the remaining users are residential. Discharge from Cornell University varies based on the school academic schedule; it increases as the campus population increases in late August and decreases again for summer break.

2.5.3 Energy Journey

The partnership with Johnson Controls involved an energy services performance contract, and a bond for the project "We were able to use the energy savings as fuel for paying off the bond," Ramer says. The project included ancillary facility improvements, such as installation of a membrane-based gas storage system and conversion of a dual-fuel burner boiler to use biogas. These improvements did not contribute to the energy payback, but they did support future biogas production.

Electric power is fed into the system at 13.2 kilovolts (kV), stepped down to 480 volt (V) three phase. The electric energy demand is 450 kW average. The plant has one 800 kW standby diesel generator, enough to power the entire plant if needed.

When considering upgrade options, AWWTF and Johnson Control staff "spent a lot of their time at WEFTEC, over a two-year span, really looking at the alternatives. That kind of collaboration was great," remembers Ramer. In addition to the relationship with Johnson Controls, the AWWTF considers NYSERDA a key partner in their energy journey. NYSERDA worked with plant managers to assess its energy profile, identify improvements, and obtain grant

funding for research and development. “NYSERDA gave us $480K for improvements,” Ramer relates.

New York State Electric and Gas Corporation (NYSEG) run the Ithaca facility’s electrical transmission system. Ramer says they have an electrical interconnect agreement in place with NYSEG, and have received their first incentive payment for anaerobic digester gas (ADG) capacity through NYSERDA’s program of opportunity (PON).

Ithaca AWWTF Energy Milestones	
Year	**Event**
1987	Ithaca AWWTF established.
2000	New belt filter press installed.
2001	Fifth influent pump installed, VFDs installed on 13 different pumps, boiler rebuilt.
2013 and 2014	• Weather-sealing existing buildings. • Installation of energy efficient lighting fixtures and bulbs. • Installation of 7.5-kW photovoltaic solar panels on a roof. • Improvements to the air handling HVAC equipment. • Two aging 100-kW cogenerators have been replaced by four state-of-the-art 65-kW micro-turbines. • One hot water boiler has been replaced with two smaller, more efficient units. • The anaerobic digesters received more efficient mixers, and a new methane storage bubble has been installed. • New aeration blowers, DO control system, and air diffusion equipment will be installed during spring and summer 2014.
2014	• Upgraded trucked waste receiving building (mainly for organic waste).
2015	• Clean primary digester to compare accumulation to that of previous years.

2.5.3.1 Waste Streams

The facility handles a variety of wastes, and considers them as potential revenue streams. Ramer says, “We have always been the regional truck waste receiving center.” Ithaca has collected FOG over the last 25 years, in addition to high-strength dairy processing waste and sludges and wastes from Cornell’s Animal Research Institute, which are major biogas producers. Most of Ithaca’s biogas is generated from wastes received at the truck waste facility. About 20 gallons a month comes from Cornell University, while septage tank waste and grease-trap waste provides the rest. Regional truck waste receivers in the rural areas also provide a quantity of biogas. The Utility has considered accepting grease beyond the county borders where dairies are located but, trucking costs would probably preclude that venture.

“Because the county doesn’t have a landfill, it is a high priority to extract the tonnage from [local] food waste and get it out of the stream.” Ramer says.

2.5.3.2 Energy Upgrades

The AWWTF was fortunate to start out as a “green”-focused plant. “Our engineers originally included a CHP system and digesters. Our two 1.4 million-gallon digesters are one of our best assets. We included biogas use from the start, using a small boiler that could burn just methane at 1 MBtu, and adding a larger unit at 3 MBtu that could burn natural gas and methane.” The facility ran on two 100-kW Caterpillar reciprocating engines from 1987 to 2011.

“These [engines] were removed when we began the new project. We sold the engines to a local dairy farmer who had digesters with Caterpillar engines, so they will have a second life. Once we stripped them out, we began the Johnson Controls project.”

Part of the project was implementing building envelope and HVAC improvements, funded in part by ARRA money, which also paid for new lighting. The project was completed in 2012.

The digester component includes the following upgrades, according to Ramer:

- Installed Ovivo® linear motion mixers in each digester to replace the existing biogas lance rotary mixer PERC system. "We chose those mixers, along with implementing computational flow dynamics, for the improved mixing energy efficiency, ease of installation, and lower maintenance."
- Added a 35,000 cubic foot Ovivo® membrane storage dome for biogas storage.
- Installed a Unison biogas cleanup skid. "We can go to the boiler or microturbines without cleaning the biogas; they are optimized to run that way." The Unison system dehumidifies the biogas and pulls out siloxanes and organic chemicals. There is a mass flowmeter for each supply. A 75% reduction in contaminants from incoming gas from gas sampling is achieved.
- Added two new natural gas boilers which can be used to help heat the digesters, if necessary.
- Added a completely renovated heat recovery system to offset natural gas boiler-supplied heat with heat off of the cogeneration system.
- Added a solar panel on the 7.5-kW solids handling building (funded through ARRA).
- Added new light sensors to conserve electricity.

The system does not use UV treatment for disinfection, so Ithaca depends on chlorine. "We wanted to include the embedded energy in chlorine, as well as supplemental carbon for denitrification, and lime, as part of our energy profile. We aren't using the full palette of chemical alternatives that tend to reduce energy use."

2.5.3.3 Funding, Savings, and Rates

As of mid-2013, data are being collected on energy use by and savings from the upgrades. This M&V are part of the energy performance contract. Data from raw electric numbers indicate that Ithaca is generating between 85,000 and about 130,000 kWh a month from biogas production alone.

Ithaca buys electricity at a blended rate of 11 cents per Kwh, and receives a transmission charge from NY SEG. Ithaca acts as an aggregator, so the energy bill is "bundled" with other bills, which Johnson Controls monitors. Three municipalities bill for services, which include charges for the treatment plant, collection system, and the actual sewer rate. Rates have risen modestly at 2 to 3% a year. "Because we've been saving money through process changes, lowered chemical, energy usage, and other operational efficiencies, we have been using the fund balance to keep the rate stable. But we tend to save more than what we have in the fund balance, which should be 10 to 20% to protect rate payers. While we're increasing the debt service each year, the rates aren't going up as much as we've increased the budget."

Contracts are subject to "Wicks Law," which requires that construction projects greater than $500,000 outside certain areas must issue separate plumbing, HVAC, and electrical contracts. Ramer says, "It makes contract management a nightmare. A performance contract allowed us to avoid all that. Johnson Controls did it as design-build contract. We saved a lot of money because of collaboration. We could stop and redesign something without it becoming a change-order paper chase." The utility could do this because certain energy laws allow it. The incentive is that if Johnson Controls "doesn't meet savings, they have to write us a check."

2.5.3.4 Looking Forward

The completed aeration project should result in the plant coming closer to meeting 60% of its energy needs if the food waste supply remains consistent. “We may have to buy a couple more microturbines to get to net-zero,” says Ramer. Additionally, in 2015, the primary digester will be cleaned to compare accumulation to last year’s quantity to determine whether additional digester capacity is needed.

Additionally, Ithaca is collaborating with the community to create a district energy facility to supply biogas, heat, and/or electricity for community needs. The AWWTP has also applied for a $2 million New York State Department of Environmental Conservation grant for vehicle fueling equipment so the AWWTP can recover additional biogas.

2.5.4 Challenges, Lessons Learned, and Benefits

The AWWTF, on its course to achieving energy neutrality, was prompted to evolve into the success it is today by facing several challenges and completing a fair degree of operational troubleshooting, as detailed below.

2.5.4.1 Challenges/Lessons Learned

- Successful projects require internal champions.
- Conduct outreach activities to get rate payers on board. It is important to know your public and educate them on potential “green” projects like resource recovery.
- Variable imported organic waste quantities and characteristics affect energy production. Energy demand is also highly variable (increases during wet weather events and when the Cornell students return to campus).
- Finding the right “recipe” for co-digesting various organic waste streams.
- Odors can be a problem unless tankers pull fully into the bay and close the door.
- Thorough research into state laws regarding the state bid processes would have saved contracting time and effort.
- A mixer should be added in the secondary digester tank for redundancy and future capacity.
- Put a cover on open-top tanks to contain odors.

2.5.4.2 Benefits

- All carbon processed at the AWWTF and converted to useful forms of energy (biogas fuel, electricity, heat) benefits the rate payers.
- All local communities have strong “green” programs, which include the collection of food waste and the recovery of renewable energy derived from these wastes.

2.5.5 Energy Profile

Table 2-6 provides overall facility energy consumption and production results before and after energy improvements.

Table 2-6. AWWTF Energy Profile Before and After Energy Improvements.

Energy	Unit	Before Energy Improvements	After Energy Improvements
Biogas Energy	MJ/d	59,500	59,500
Biogas Energy Flared	MJ/d	30,600	7,100
Electricity supply from Grid (purchased)	kWh/d	13,000	9,300
Natural Gas Supply from Pipeline (purchased)	MJ/d	16,600	16,600
Purchased Fuel Oil	MJ/d	0	0
Electricity Produced Onsite	kWh/d	0	3,800
Percentage of Electricity Consumption Produced Onsite	%	0	29
Percent Site Energy Neutrality	%	0	22

CHAPTER 3.0

CASE STUDY SYNTHESIS

3.1 Overview of Findings

The case studies create an opportunity for WRRF energy managers to learn from the experiences of their peers. The five energy leaders presented shared their energy journeys to benefit other utilities improving their energy management programs. These champions of change have made significant progress towards energy neutral wastewater treatment.

Findings drawn from these case studies guide facilities toward energy neutrality and enable new ways of thinking about energy efficiency and recovery. They illustrate opportunities to save costs and enhance sustainability, provide both solutions to overcome obstacles common to energy projects and actionable strategies adopted by WRRFs as they planned projects to move toward energy neutral operation.

3.2 General Attributes of Energy Leaders

All WRRFs highlighted in this report possess three exceptional qualities which contributed to their success as energy leaders::

1. Showed commitment to a set of long-term goals that call for sustainable energy management.
2. Accessed internal advocates to lead the charge towards energy neutrality. These advocates became the champions who drove the process internally and externally. The internal advocate does not have to be “in charge,” but, they must have connections to those who are.
3. Demonstrated eagerness to innovate and lead. Created an environment that supported trialing untested strategies to move toward net-zero energy goals.

The researchers found that at the core of successful energy programs and projects is a staff with a sense of ownership and an entrepreneurial skill set. Energy program leaders seek, recognize, and seize opportunities which serve the utility and the broader community. The process of reaching energy goals involves multiple, diverse stakeholders. Utility employees; energy program, legislative, and municipal decision makers; residents; and businesses create both support and momentum towards energy efficiency which can lead to change.

As an example, an employee who is allowed to take prudent risk and fail can generate innovative ideas which lead to optimized operations or energy-efficient approaches. Champions of change consider ideas from all areas of the organization, knowing that an energy management idea will not always originate from the assigned energy person or team.

3.3 Key Actions Toward Energy Neutral Wastewater Treatment

Energy represents the largest controllable cost of providing wastewater services to the public; therefore, increasing energy efficiency is one of the most effective ways for utilities to manage costs and help ensure the long-term operational sustainability. WRRFs are increasingly integrating improved energy management into their daily operations and long-term planning. Energy management extends beyond reducing energy consumption and improving energy efficiency; it also involves measures such as managing total energy consumption, controlling peak demand for energy, managing energy cost volatility, and improving energy reliability. The primary goal of effective Energy Management Planning is to ensure energy-related decisions are carefully planned and executed (NYSERDA, 2013).

3.3.1 Barriers

The energy champions highlighted in this report had to overcome significant barriers during their continuing journey towards energy neutral wastewater treatment. These barriers were primarily economic (justifying the investment in capital and human resources) and organizational (resistance to change and any level of risk-taking; department silos).

The energy champions overcame the economic barriers to a great degree by educating themselves and the stakeholders on the myriad ways of helping finance energy projects, including using government grants and incentives as well as partnership arrangements with private firms, such as investment banks and ESCOs.

The research team found that overcoming organizational hurdles required strong, committed leadership, which is the hallmark of the champions of change highlighted in these case studies. These leaders were strategic and persistent in educating their colleagues of the long-term economic, environmental, and societal benefits of their journey to energy neutrality. Each utility took similar steps along the road to energy neutrality. Their key steps fell into four main categories of actions that greatly influenced their success:

3.3.2 Communication

Energy use impacts all departments and agency functions, from administration to operations. Successful organizational leaders recognized that responsibilities must be carefully delegated; clear and frequent communication is a priority. Most utilities, especially those for larger organizations, addressed communications by forming an “energy committee” which included representatives from major departments. The committee set objectives and action items and met routinely to review progress.

Similarly, the leaders also organized external communication efforts. They educated politicians, board members, and their community about their goals and planned actions in order to garner support. As noted by the Ithaca Area Wastewater Treatment Plant chief operator, “if your board or authorities don’t grasp the concepts or they don’t understand how energy financing options work, then you can’t sell them on a big-ticket project.”

3.3.3 Planning and Collaboration

The WRRF energy champions in this study developed utility-wide energy plans that incorporate strategic goals for key performance indicators. Energy management includes a holistic, life-cycle approach. WRRF energy champions connected with academic institutions for support and expertise. Practical know-how, coupled with a vision of operational possibilities and

academic discipline, often led to creative advancement. WRRF energy champions found that sharing information with other WRRFs and collaborating on policy matters was critical to advance their energy goals. Specifically, JCW benefited greatly from having their operations staff tour facilities similar to theirs.

Energy champions recommend WRRFs act as a reliable resource to their community and support their staff's professional networking on the topic of energy. Like innovative ideas, helpful relationships can spring from any corner of the industry.

3.3.4 Resourcefulness

WRRF energy champions use available resources to understand energy efficiency and recovery opportunities. They encouraged their staff to become subject matter experts on various aspects of energy recovery and efficiency at their facilities, from process engineering to learning specialized operation and maintenance skill sets.

Energy champions took advantage of energy management resources, including opportunities to obtain outside funding, and used available guidance (i.e., NYSERDA, Wisconsin Focus on Energy, U.S. EPA, and WEF). Using existing resources not only provides guidance, but it leverages organizational investments and increases a utility's network of energy professionals.

3.3.5 Financial Considerations

The energy champions consistently explored innovative funding options for energy projects and took advantage of outside sources of capital funds (i.e., NYSERDA, CEC, ARRA). Several leaders found that ESCOs can help identify and evaluate savings, develop engineering designs and specs, manage the project, arrange for financing, train staff, and offer guaranteed savings to cover costs. PWD suggests that many financial entities and investors are ready to help launch projects that will create energy savings. The state legislature is a great starting point for funding and, the utility may be eligible to receive legal advice or contract interpretation through city or state governments. For example, PWD developed a cost-effective plan with additional goals to reduce exposure to volatile markets and mitigate risk. Risk mitigation costs money, but it is money well spent. The premium paid for alternative or renewable energy development can be considered similar to paying insurance premiums. When energy prices become volatile, the cost portion of one's portfolio is already accounted for, making those energy projects a type of energy hedge.

Energy champions often use a rate expert to analyze their energy bills and rates to take advantage of cost saving opportunities available to major power users like WRRFs. The leaders in this study developed a cooperative relationship with their electric company.

Electric utilities often avoid working with small generators of electricity, making it necessary for both parties to work at creating a cooperative relationship. Leaders wisely avoided creating an adversarial relationship with the electric distribution company because there is an interdependence that must be maintained to foster a beneficial relationship to both entities. WRRF leaders understand that their electric power generation, at least for the present time, may be limited to the electric power used to offset onsite demand with little chance of generating revenue from sale to the grid. Despite this current reality, opportunities do exist for significant power savings and cost-reduction for WRRFs.

The energy champions used life-cycle financial metrics, such as the NPV metric, to compare the new energy project and the cost of status quo. This information helped business case decision making and enabled more energy projects to move forward. These champions realized that life cycle analysis, while useful, did not quantify the value of social or environmental benefits, which add important value to an energy project that cannot be readily monetized.

3.4 Moving the Energy Plan Forward

The leaders recommend creating local interest in proposed energy projects. They suggest that WRRFs be visible and participate in local outreach opportunities to promote their projects and showcase expected outcomes. The message of "green renewable energy" resonates in many communities. WRRFs who undertake energy efficiency and recovery projects should proudly promote their energy project's benefits to the community, such as reduced demand from the local power plant; electric grid protection; reduced overall cost of the electric supply; and positive impacts to air quality and greenhouse gas emissions. Energy champions and their staff understood and referenced guiding legislation when promoting renewable energy projects. These laws include the President's Climate Action Plan (the White House, 2013), the proposed Clean Power Plan (U.S. EPA, 2014), and Section 111 of the Clean Air Act, which is focused on reducing carbon pollution from the power sector.

It is important to show that energy recovery projects can beneficially impact a community because they:

- Divert organics from landfill disposal to energy recovery through co-digestion of organic wastes.
- Reduce the miles driven by transporters of wastes, thus reducing fossil fuel consumption and greenhouse gas emissions.
- Reduce the amount of biogas flared (a waste of a valuable resource).
- Provide a convenient outlet for high-strength wastes, a benefit to the broader community.
- Create sustainable operations through energy efficiency, particularly energy recovery, to further ensure water reclamation plant reliability. In the event of a grid power failure, LACSD noted that WRRFs which produce their own power continue to reliably treat wastewater.

Power generation by WRRFs requires capital and operating expenditures, greater operator skills, and attention to details to sell electricity on the market. WRRF management must encourage employees to embrace the idea of reaching net-zero goals, even if it translates to greater responsibilities and operational complexity during the energy journey. As an extension of this goal, it is important to train staff in energy efficiency in order for them to understand the cost (environmental and financial) of grid power. A staff that understands the WRRF's energy goals can best support the activities that enable net-zero energy programs and upgrades.

3.4.1 Energy Management Best Practice

The energy champions' journeys yielded several observations and recommendations which are of benefit to their peers. First, for WRRFs with anaerobic digesters and a local supply of high-strength waste, co-digestion is an attractive near-term solution to achieve significantly improved energy performance. WRRFs note that once an entity realizes their waste has value,

they will market it accordingly. Recommendations for WRRFs with anaerobic digesters and additional capacity are to:

- Seek out local organic waste feedstocks and partner with local industry to enable co-digestion.
- Advance the understanding of co-digestion to improve digester performance without unintended side effects.
- Support the development of a Manual of Practice (MOP) for co-digestion of organics with wastewater solids to advance the understanding and use of co-digestion by WRRFs.

Energy champions recommend that energy managers understand their system comprehensively to streamline operations and to reduce the risk of overbuilding energy projects. They offer some key observations:

- Do not overlook details during design and construction.
- Preventive maintenance is critical for energy efficiency projects.
- Invest in actions that produce smaller-scale savings, such as lighting contracts, zone controls, and motion controls.

3.5 Conclusion

Energy champions who have travelled the furthest on the road to energy neutrality have demonstrated that net-zero goals are realistic and achievable. A shift in the organization's approach to energy management may be all that is needed to solidify a net-zero energy vision. Communication with both staff and the larger community, often overlooked by water utilities, is a key aspect of energy management planning. Energy champions have emerged from the water sector to overcome barriers and develop actions toward net-zero energy goals. While these leaders successfully pursued and retained available funds and creative financing, it is clear that greater access to capital would advance WRRF net-zero energy goals considerably.

APPENDIX A

UTILITY PARTNER SURVEY

WERF ENER1C12 Utility Partner Survey

Instructions

Thank you for agreeing to be a Utility Partner for the Water Environment Research Foundation (WERF) project on "Energy-Neutral Wastewater Facilities and Triple Bottom Line (TBL) Research". The project is a joint effort of WERF, the New York State Energy Research Development Authority (NYSERDA), Black & Veatch, AECOM, American Water, Hemenway Inc., and the North East Biosolids & Residuals Association (NEBRA).

The project will address the following questions:
• What are typical and best practice energy requirements for a representative set of wastewater processing configurations?
• Where am I on the "road to neutrality" (benchmarking) and what "routes" (alternate or innovative processing options) are worthy of consideration as I map my own path to neutrality?
• What are the TBL impacts (environmental, social and economic) of biosolids processing options?

More information about the project can be found at:
http://www.werf.org/c/KnowledgeAreas/Energy/Links/09142012_Energy_Production_Efficiency_Kick-Off.aspx

Our Utility Partners will play a significant role in achieving these objectives by providing "real world" wastewater experience and perspectives on traveling the road to neutrality. To better interact with you and facilitate identifying individual roles, we're conducting this survey to flesh out and update our profiles of your operations.

Note: Any information that would specifically identify you or your utility will remain confidential and will not be shared outside of the project team, without your prior consent.

This survey will take 20 to 30 minutes to complete. You may return to any question to modify your answer during the survey.

Please complete the survey in one sitting, if you leave before completing it, you will need to return and start from the beginning.

Please fill out this survey by January 31, 2013. We recognize that this is a request for a quick turnaround, but the survey shouldn't take long and we would be happy to assist you over the phone with filling out, if you'd like. For assistance, contact Rob Pape, PE, AECOM, 732-564-3940, robert.pape@aecom.com, or Yinan Qi, PhD, PE, Black & Veatch, 913-458-3299, qiy@bv.com.

Facility Location

1. Please tell us your name. This information will remain confidential within the project team.

Page 1

WERF ENER1C12 Utility Partner Survey

2. Please tell us your title. This information will remain confidential within the project team.

- Operator
- Engineer
- Management
- Other (please specify)

The next two sections, Section 1 and Section 2, are provided in both US units and metric units. You only need to fill out one set. Choose the set that you are more comfortable with."

***3. Is the facility you are completing this survey for located in the United States?**

- Yes
- No

Section 1 - Demographic Information (U.S.)

Please provide the following demographic information. This information will allow us to analyze data appropriately and contact you if we have any questions. It will be kept confidential within the research team.

4. Utility information. "Utility" applies to the entire set of wastewater treatment operations, not a particular wastewater treatment plant (WWTP).

Utility Name:

Address:

Address 2:

City/Town:

State:

ZIP:

Country:

Email Address:

Phone Number:

Page 2

5. Wastewater treatment plant information (if your utility has more than one WWTP, please complete this survey for one of them and then complete separate surveys for each of the others)

Facility Name:

Address:

Address 2:

City/Town:

State:

ZIP:

Country:

Email Address:

Phone Number:

Section 2 - Specific Treatment Plant Information (U.S.)

The next a few questions ask for the following three pieces of data:

Max Month Design - the maximum month value used to design this facility
Annual Average Design - the annual average value used to design facility
Annual Average Actual - the actual annual average value

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

6. What is the capacity of this facility in million gallons per day (mgd)?

Max Month Design

Annual Average Design

Annual Average Actual

7. What is the influent biochemical oxygen demand (BOD) concentration (mg/L)?

Max Month Design

Annual Average Design

Annual Average Actual

8. What is the influent total suspended solids (TSS) concentration (mg/L)?

Max Month Design

Annual Average Design

Annual Average Actual

WERF ENER1C12 Utility Partner Survey

9. What is the influent total Kjehldahl nitrogen (TKN) concentration (mg/L)?

Max Month Design

Annual Average Design

Annual Average Actual

10. What is the influent ammonia concentration (mg/L)?

Max Month Design

Annual Average Design

Annual Average Actual

11. What is the influent phosphorus concentration (mg/L)?

Max Month Design

Annual Average Design

Annual Average Actual

12. What is the influent temperature in fahrenheit (F)?

Annual Average

Monthly Maximum

Monthly Minimum

13. What is the effluent temperature in fahrenheit (F)?

Annual Average

Monthly Maximum

Monthly Minimum

14. What is the liquid stream process temperature in fahrenheit (F)?

Annual Average

Monthly Maximum

Monthly Minimum

15. Please add any comment you think would help us better understand your input on this page

Section 1 - Demographic Information (Metric)

Please provide the following demographic information. This information will allow us to analyze data appropriately and contact you if we have any questions. It will be kept confidential within the research team.

Page 4

16. Utility information. "Utility" applies to the entire set of wastewater treatment operations, not a particular wastewater treatment plant (WWTP).

Utility Name:	
Address 1:	
Address 2:	
City/Town:	
State/Province:	
ZIP/Postal Code:	
Country:	
Email Address:	
Phone Number:	

17. Wastewater treatment plant information

Facility Name:	
Address 1:	
Address 2:	
City/Town:	
State/Province:	
ZIP/Postal Code:	
Country:	
Email Address:	
Phone Number:	

Section 2 - Specific Treatment Plant Information (Metric)

The next a few questions ask for the following three pieces of data:

Max Month Design - the maximum month value used to design this facility
Annual Average Design - the annual average value used to design facility
Annual Average Actual - the actual annual average value

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

18. What is the capacity of this facility in cubic meters per day (m3/d)?

Max Month Design	
Annual Average Design	
Annual Average Actual	

WERF ENER1C12 Utility Partner Survey

19. What is the influent biochemical oxygen demand (BOD) concentration (mg/L)?

Max Month Design	
Annual Average Design	
Annual Average Actual	

20. What is the influent total suspended solids (TSS) concentration (mg/L)?

Max Month Design	
Annual Average Design	
Annual Average Actual	

21. What is the influent total Kjehldahl nitrogen (TKN) concentration (mg/L)?

Max Month Design	
Annual Average Design	
Annual Average Actual	

22. What is the influent ammonia concentration (mg/L)?

Max Month Design	
Annual Average Design	
Annual Average Actual	

23. What is the influent phosphorus concentration (mg/L)?

Max Month Design	
Annual Average Design	
Annual Average Actual	

24. What is the influent temperature in celsius (C)?

Annual Average	
Monthly Maximum	
Monthly Minimum	

25. What is the effluent temperature in celsius (C)?

Annual Average	
Monthly Maximum	
Monthly Minimum	

26. What is the liquid stream process temperature in celsius (C)?

Annual Average	
Monthly Maximum	
Monthly Minimum	

27. Please add any comment you think would help us better understand your input on this page

Section 3 - Decision Making Process

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

28. Do you use triple-bottom-line (TBL) or some other multi-criteria decision-making process for evaluating new projects or upgrades at this facility?

- Yes
- No

Comment

29. Are you willing to provide details about your TBL or other decision-making process to this WERF project team?

- Yes
- No

Section 4A - Effluent Limitations - BOD & TSS

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

30. What is the permitted effluent BOD5 limitation (mg/L)?

31. What is the actual average effluent BOD5 concentration (mg/L)?

32. What is the permitted effluent TSS limitation (mg/L)?

33. What is the actual average effluent TSS concentration (mg/L)?

WERF ENER1C12 Utility Partner Survey

34. Please add any comment you think would help us better understand your input on this page.

Section 4B - Effluent Limitations - Ammonia

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

35. Does this facility have a permitted effluent ammonia nitrogen (NH3-N) limit?

- Yes
- No

Section 4B - Effluent Limitations - Ammonia

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

36. What is the lowest permitted effluent ammonia nitrogen (NH3-N) limitation (mg/L)? If seasonal, list months in which it applies.

The lowest NH3-N limitation	
If seasonal, list months that in which it applies	
If seasonally tiered, what is the relaxed NH3-N limitation	

37. What is the actual average effluent ammonia nitrogen (NH3-N) concentration (mg/L)?

38. Please add any comment you think would help us better understand your input on this page

Section 4C - Effluent Limitations - Total Nitrogen

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

Page 8

39. Does this facility have an effluent total nitrogen (TN) limit?

- Yes
- No

Section 4C - Effluent Limitations - Total Nitrogen

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

40. What is the permitted effluent total nitrogen (TN) limitation (mg/L)? If limit is a mass load, indicate amount and time.

TN limitation

Amount (mass load only)

Time (mass load only)

41. What is the actual effluent average total nitrogen (TN) concentration (mg/L)?

42. Please add any comment you think would help us better understand your input on this page

Section 4D - Effluent Limitations - Total Phosphorus

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

43. Does this facility have an effluent total phosphorus (TP) limit?

- Yes
- No

Section 4D - Effluent Limitations - Total Phosphorus

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

WERF ENER1C12 Utility Partner Survey

44. What is the permitted effluent total phosphorus (TP) limitation (mg/L)? If limit is a mass load, indicate amount and time.

TP limitation

Amount (mass load only)

Time (mass load only)

45. What is the actual effluent average total phosphorus (TP) concentration (mg/L)?

46. Please add any comment you think would help us better understand your input on this page

Section 5 - Energy Usage and Production

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

47. How much electricity does the facility purchase annually (kWh)?

Average last 3 years

Last 12 months

Please email or fax one year of monthly electric bills for this facility to Yinan Qi. Email: qiy@bv.com, Fax: 913-458-3626 (please include "WERF energy survey" and the facility name in the title)

48. How much natural gas does the facility purchase annually? (Fill in either the first 2 boxes or the second 2 boxes).

Average last 3 years, therm (or ccf)/year

Last 12 months, therm (or ccf)/year

Average last 3 years, m3/year

Last 12 months, m3/year

49. How much fuel oil does the facility purchase annually? (Fill in either the first box or the second box).

Gallons/year

Liters/year

Page 10

50. How much high pressure steam does the facility purchase annually? (Fill in either the first box or the second box).

Pounds/year

Kg/year

51. How much low pressure steam does the facility purchase annually? (Fill in either the first box or the second box).

Pounds/year

Kg/year

52. How much propane does the facility purchase annually? (Fill in either the first box or the second box).

Gallons/year

Liters/year

53. Please add any comment you think would help us better understand your input on this page

Section 5 - Energy Usage and Production

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

***54. Does this facility produce electricity on-site?**

- Yes
- No

55. Please add any comment you think would help us better understand your input on this page

Section 5 - Energy Usage and Production

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

WERF ENER1C12 Utility Partner Survey

56. How much electricity does the facility produce annually (kWh)? Please fill in both if possible.

Average last 3 years

Last 12 months

57. Is the electricity produced used on-site or sold to grid? Please check boxes that apply, or fill in "other" when needed.

- [ ] Used on-site
- [ ] Sold to grid
- [ ] Other (please specify)

***58. Does this facility produce heat on-site?**

- ○ Yes
- ○ No

59. Please add any comment you think would help us better understand your input on this page

Section 5 - Energy Usage and Production

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

60. How much heat does the facility produce annually? (Fill in either the first 2 boxes or the second 2 boxes).
(1 therm = 100,000 BTU)

Average last 3 years, therm/year

Last 12 months, therm/year

Average last 3 years, MJ/year

Last 12 months, MJ/year

Page 12

61. Is the heat produced used on-site or sold? Please check boxes that apply, or fill in "other" when needed.

- [ ] Used on-site
- [ ] Sold
- [ ] Other (please specify)

62. Please add any comment you think would help us better understand your input on this page

Section 6 - Process Configuration: Primary Treatment

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

63. What primary treatment technologies does this facility have? Please check boxes that apply, or fill in "other" when needed.

- [ ] Influent Pumping
- [ ] Primary Clarification
- [ ] Chemically Enhanced Primary Treatment (CEPT)
- [ ] Other (please specify)

64. What is the average head/lift of influent pumping? (Fill in either the first box or the second box).

foot

meter

65. Please add any comment you think would help us better understand your input on this page.

Section 7 - Process Configuration: Secondary Treatment

WERF ENER1C12 Utility Partner Survey

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

***66. Does this facility have secondary treatment processes?**

- ○ Yes
- ○ No

Section 7 - Process Configuration: Secondary Treatment

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

67. Is the secondary treatment with or without nitrification?

- ○ With nitrification
- ○ Without nitrification

68. What secondary treatment technologies does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ Complete mixed activated sludge (AS)
- ☐ Oxidition ditch/vertical loop reactor
- ☐ Sequencing batch reactor (SBR)
- ☐ Step feed AS
- ☐ Membrane bio-reactor (MBR)
- ☐ Lagoon
- ☐ Trickling filter
- ☐ Moving bed bio-reactor (MBBR)
- ☐ Integrated fixed-film activated sludge (IFAS)
- ☐ Rotating bio-contactor (RBC)
- ☐ Biologically active filter (BAF)
- ☐ Other (please specify)

69. What is the average solids retention time (SRT) of the secondary treatment process (days)?

Page 14

70. What is the aeration method for the secondary treatment process? Please check boxes that apply, or fill in "other" when needed.

- ☐ Surface aerators
- ☐ Brush/disk
- ☐ Mechanical
- ☐ Coarse bubble
- ☐ Fine bubble
- ☐ Manual DO control
- ☐ Closed loop automatic DO control
- ☐ High purity oxygen
- ☐ Other (please specify)

71. What type of blowers does the secondary treatment process have? Please check boxes that apply, or fill in "other" when needed.

- ☐ Positive displacement (PD)
- ☐ Multi-stage centrifugal
- ☐ Turbo blower
- ☐ High speed turbo blower
- ☐ Other (please specify)

Section 8 - Process Configuration: Tertiary Treatment

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

72. What type of filtration technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ This facility does not have filtration process
- ☐ Sand filter (conventional backwash)
- ☐ Continuous backwash filter
- ☐ Cloth media
- ☐ Other (please specify)

73. What type of disinfection technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ This facility does not have disinfection process
- ☐ Gaseous chlorine
- ☐ Liquid chlorine (hypochlorite)
- ☐ UV
- ☐ Ozone
- ☐ Other (please specify)

74. How is the effluent discharged? Please check boxes that apply, or fill in "other" when needed.

- ☐ Pumped discharge
- ☐ Gravity discharge
- ☐ Effluent aeration
- ☐ Other (please specify)

Section 9 - Process Configuration: Nutrient Removal

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

75. What is the configuration of the nitrogen (N) removal process? Please check boxes that apply, or fill in "other" when needed.

- ☐ This facility does not have a nitrogen removal process
- ☐ Modified Ludzack-Ettinger (MLE)
- ☐ Step feed oxic/anoxic
- ☐ 4-stage Bardenpho
- ☐ Tertiary denitrification (Denite) filters
- ☐ Other (please specify)

Section 9 - Process Configuration: Nutrient Removal

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

76. What is the external carbon source added to the nitrogen (N) removal process? Please check boxes that apply, or fill in "other" when needed.

- ☐ No external carbon source
- ☐ Methanol
- ☐ Micro-C
- ☐ Other (please specify)

77. What type of phosphorus (P) removal technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ This facility does not have a phosphorus removal process
- ☐ Ferric addition
- ☐ Alum addition
- ☐ Biological phosphorus removal
- ☐ Other (please specify)

Section 9 - Process Configuration: Nutrient Removal

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is

required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

78. Is the bio-P process with or without a fermenter?

- With a fermenter
- Without a fermenter

79. What is the configuration of the biological phosphorus (P) removal process? Please check boxes that apply, or fill in "other" when needed.

- [ ] 5-stage Bardenpho
- [ ] UCT/modified UCT
- [ ] Johannesburg
- [ ] Other (please specify)

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

80. Does this facility have solids handling processes?

- Yes
- No, liquid solids are pumped/hauled to another facility for processing
- Other (please specify)

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

81. What solids handling processes does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ Gravity thickening
- ☐ Mechanical thickening
- ☐ Aerobic digestion
- ☐ Anaerobic digestion
- ☐ Dewatering
- ☐ Lime stabilization
- ☐ Composting
- ☐ Drying
- ☐ Incineration
- ☐ Other (please specify)

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

82. Gravity thickening is used to thicken

- ○ Primary sludge only
- ○ Primary/secondary sludge (WAS) co-thickening

83. Mechanical thickening is used to thicken

- ○ Primary sludge only
- ○ Primary/secondary sludge (WAS) co-thickening
- ○ Secondary sludge (WAS) only

84. What mechanical thickening technologies does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Rotary drum thickener (RDT)
- ☐ Dissolved air floatation (DAF)
- ☐ Gravity belt thickener (GBT)
- ☐ Centrifuge
- ☐ Other (please specify)

85. What aerobic digestion technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Mesophilic
- ☐ Thermophilic
- ☐ Autothermal thermophilic (ATAD)
- ☐ Other (please specify)

86. What aeration technology is used to aerate aerobic digesters?

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

87. What anaerobic digestion technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Mesophilic
- ☐ Thermophilic
- ☐ Temperature phased
- ☐ Acid-gas
- ☐ Other (please specify)

88. What type of dewatering technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Centrifuge
- ☐ Belt filter press (BFP)
- ☐ Frame and plate press
- ☐ Rotary press
- ☐ Screw press
- ☐ Other (please specify)

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

89. What type of drying technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Belt dryer
- ☐ Disk dryer
- ☐ Rotary drum dryer
- ☐ Other (please specify)

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

90. What fuel does the dryer use? Please check boxes that apply, or fill in "other" when needed.

- ☐ Biogas
- ☐ Natural gas
- ☐ Fuel oil
- ☐ Purchased heat
- ☐ Other (please specify)

91. What is the amount of supplemental fuel (other than biogas) purchased for dryer use? Please fill in all that applies. Fill in either imperial unit or metric unit for the same fuel, but not both.

Natural gas, therm (or ccf)/year	
Fuel oil, gallons/year	
Purchased heat, therm (or ccf)/year	
Natural gas, m3/year	
Fuel oil, liters/year	
Purchased heat, MJ/year	
Other (please specifiy)	

92. Please add any comment you think would help us better understand your input on this page.

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

93. What type of incineration technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Mutiple hearth incinerator (MHI)
- ☐ Fluidized bed incinerator (FBI)
- ☐ Other (please specify)

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

94. What fuel does the incinerator use? Please check boxes that apply, or fill in "other" when needed.

- ☐ Biogas
- ☐ Natural gas
- ☐ Fuel oil
- ☐ Other (please specify)

95. What is the amount of supplemental fuel (other than biogas) purchased for incinerator use? Please fill in all that applies. Fill in either imperial unit or metric unit for the same fuel, but not both.

Natural gas, therm (or ccf)/year	
Fuel oil, gallons/year	
Natural gas, m3/year	
Fuel oil, liters/year	
Other (please specify)	

96. What heat recovery technology does the incinerator have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Hot windbox
- ☐ Steam
- ☐ Hot water
- ☐ Other (please specify)

97. Please add any comment you think would help us better understand your input on this page.

Section 10 - Process Configuration: Solids Handling

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

98. How is the sludge/biosolids used/disposed off? Please check boxes that apply, or fill in "other" when needed.

- ☐ Class B liquid biosolids land application
- ☐ Class B cake land application
- ☐ Class B cake landfill
- ☐ Class A solids land application
- ☐ Class A solids landfill
- ☐ Raw cake landfill
- ☐ Incinerator ash landfill
- ☐ Incinerator ash utilization
- ☐ Raw liquid sludge transfered to other plant
- ☐ Raw cake transfered to other plant
- ☐ Other (please specify)

Section 11 - Energy Production

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

99. How is biogas used at this facility? Please check boxes that apply, or fill in "other" when needed.

- [ ] This facility does not produce biogas
- [ ] Flare only
- [ ] Boiler
- [ ] Combined heat and power (CHP) generation (engine, turbine, fuel cell, etc.)
- [ ] Other (please specify)

Section 11 - Energy Production

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

100. What is heat produced from the boiler/CHP used for? Please check boxes that apply, or fill in "other" when needed.

- ○ None
- ○ Digester heating only
- ○ Digester and building heating
- ○ Other (please specify)

101. What type of CHP technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- [ ] None
- [ ] Internal combustion (IC) engine
- [ ] Turbine - single cycle
- [ ] Turbine - combined cycle
- [ ] Microturbine
- [ ] Fuel cell
- [ ] Other (please specify)

WERF ENER1C12 Utility Partner Survey

Section 11 - Energy Production

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

102. Is the CHP system operated with biogas only?

- ○ Biogas only
- ○ Dual-fueled (biogas/natural gas)
- ○ Other (please specify)

Section 12 - "Pioneering" Process Modules

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

A key part of this phase of WERF wastewater energy research is to identify and profile innovative technologies that have the potential to make quantum improvements in energy conservation, demand reduction, or energy production. The study team is particularly interested in any innovative processing steps ("modules") that you may be operating at full scale. Please indicate any operations that you may have of this nature.

103. What pioneering wastewater treatment modules does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Upflow Anaerobic Sludge Blanket (UASB)
- ☐ Anaerobic MBR (AnMBR)
- ☐ Ultrafine Bubble Aeration
- ☐ Other (please specify)

Page 26

104. What nutrient recovery technologies does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Sidestream P Recovery (OSTARA or equivalent)
- ☐ Sidestream N Removal (Deammonification or equivalent)
- ☐ Mainstream Two-Sludge (A/B) Activated Sludge
- ☐ Mainstream Simultaneous Nite-Denite (SND)
- ☐ Mainstream Deammonification
- ☐ Other (please specify)

Section 12 - "Pioneering" Process Modules

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

105. What type of sidestream P recovery technology does this facility have?

- ○ None
- ○ OSTARA
- ○ Other (please specify)

106. What type of sidestream N recovery technology does this facility have?

- ○ None
- ○ Deammonification
- ○ Other (please specify)

Section 12 - "Pioneering" Process Modules

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

107. What pioneering solids handling technologies does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Pre-digestion WAS conditioning
- ☐ Bio-Augmentation
- ☐ Advanced anaerobic digestion
- ☐ Gasification
- ☐ Other (please specify)

Section 12 - "Pioneering" Process Modules

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

108. What WAS conditioning technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Thermal hydrolysis process (THP)
- ☐ Chemical conditioning
- ☐ OpenCELL
- ☐ Microsludge
- ☐ Sonication
- ☐ Microwave
- ☐ Other (please specify)

109. What advanced anaerobic digestion technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Acid-gas
- ☐ temperature phased (TPAD)
- ☐ Three-phased digestion
- ☐ Other (please specify)

110. What pioneering energy production/recovery technology does this facility have? Please check boxes that apply, or fill in "other" when needed.

- ☐ None
- ☐ Co-digestion (outside wastes added into anaerobic digesters)
- ☐ CHP waste heat for refrigeration
- ☐ Process Waste Heat Power Production – Organic Rankine Cycle (ORC)
- ☐ Wastewater Heat Recovery – Water-Sourced Heat Pumps (WSHPs)
- ☐ Wastewater Hydraulic Energy Power Production – Hydro-turbine
- ☐ Other (please specify)

Section 12 - "Pioneering" Process Modules

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

WERF ENER1C12 Utility Partner Survey

111. What type of outside waste is added for co-digestion? Please check boxes that apply, or fill in "other" when needed.

- [ ] None
- [ ] Fats, oils, and grease (FOG)
- [ ] Food waste - pre-consumer
- [ ] Food waste - post-consumer, institutional
- [ ] Food waste - post-consumer, residential
- [ ] Food waste - in-sink disposer
- [ ] Other (please specify)

Section 12 - "Pioneering" Process Modules

Answer to the best of your knowledge; if you do not know the answer, you may skip the question unless an answer is required. Answer(s) is(are) required if there is an asterisk (*) in front of the question.

112. What type of pre-consumer food waste is accepted for co-digestion?

Thank You!

113. What else can you tell us to help us better understand energy use/production at this facility?

Thank you for completing this survey, if you would like to complete a new survey for another facility, please close the browser and start a new survey by clicking the link in the email or copy the link below to your browers:
https://www.surveymonkey.com/s/BQ8899C

Please email or fax one year of monthly electric bills for this facility to Yinan Qi. Email: qiy@bv.com, Fax: 913-458-3626 (please include "WERF energy survey" and the facility name in the title)

Page 30

REFERENCES

Black & Veatch (2014) *Internal Report for Philadelphia Water Department*.

CH2M HILL (2011) http://www.ch2mhillblogs.com/water/2011/05/23/startup-of-johnson-county-ks/.

HDR Inc. (2011) http://www.hdrinc.com/portfolio/douglas-l-smith-indian-creek-middle-basin-wwtp-solids-processing-improvement

Johnson County Wastewater (2012) http://www.jocogov.org/deptpage/wastewater/engineering-projects-dlsmb-cogeneration.

Johnson County Wastewater (2014) http://www.jocogov.org/dept/wastewater/about-us/overview, http://www.jocogov.org/dept/wastewater/about-us/overview#VitalStatistics, http://www.jcw.org/eng-DLSMB-Factors.htm#menu.

Los Angeles County Sanitation District (2012) *2012 Grand Prize – Operations Management: Innovative Energy Management Proves That It Pays to Be Green.* http://www.aaees.org/e3competition-winners-2012gp-operationsmanagement.php

Los Angeles County Sanitation District (2013) *Annual Energy Report: Fiscal Year 2011/2012.*

Los Angeles County Sanitation District (2014a) http://www.lacsd.org/aboutus/default.asp.

Los Angeles County Sanitation District (2014) http://www.lacitysan.org/index.htm#LASewers.

Los Angeles County (2014) http://lacounty.gov/wps/portal/lac/residents/.

Melbourne Water (2014) http://www.melbournewater.com.au/waterdata/Pages/waterdata.aspx

New York State Energy Research and Development Authority (2013) *Renewable Portfolio Standard, Main Tier 2013 Program Review Volume 1 – Program Review Introduction, Final Report.*

Philadelphia Water Department (2014) *Biogas Cogeneration Fact Sheet*. http://www.phillywatersheds.org/doc/Energy/BiogasCogenerationFactSheet.pdf.

State of Pennsylvania, *House Bill No. 2200 Session of 2008, Act 129*. Accessible at: http://www.puc.pa.gov/electric/pdf/Act129/HB2200-Act129_Bill.pdf.

U.S. Census Bureau (2012) *American Community Survey, 2009-2011*, American Community Survey Office Data Products.

Water Environment Research Foundation (2015) *A Guide to Net-Zero Energy Solutions for Water Resource Recovery Facilities* (ENER1C12).

WERF Subscribers

WASTEWATER UTILITY

Alabama
Montgomery Water Works & Sanitary Sewer Board

Alaska
Anchorage Water & Wastewater Utility

Arizona
Avondale, City of
Peoria, City of
Phoenix Water Services Department
Pima County Wastewater Reclamation Department
Tempe, City of

Arkansas
Little Rock Wastewater

California
Central Contra Costa Sanitary District
Corona, City of
Crestline Sanitation District
Delta Diablo
Dublin San Ramon Services District
East Bay Dischargers Authority
East Bay Municipal Utility District
Encino, City of
Fairfield-Suisun Sewer District
Fresno Department of Public Utilities
Irvine Ranch Water District
Las Gallinas Valley Sanitary District
Las Virgenes Municipal Water District
Livermore, City of
Los Angeles, City of
Montecito Sanitation District
Napa Sanitation District
Novato Sanitary District
Orange County Sanitation District
Sacramento Regional County Sanitation District
San Diego, City of
San Francisco Public Utilities, City and County of
San Jose, City of
Sanitation Districts of Los Angeles County
Santa Barbara, City of
Santa Cruz, City of
Santa Rosa, City of
Silicon Valley Clean Water
South Orange County Wastewater Authority
Stege Sanitary District
Sunnyvale, City of
Thousand Oaks, City of

Colorado
Aurora, City of
Boulder, City of
Centennial Water & Sanitation District
Greeley, City of
Littleton/Englewood Wastewater Treatment Plant
Metro Wastewater Reclamation District
Platte Canyon Water & Sanitation District

Connecticut
Greater New Haven WPCA

District of Columbia
DC Water

Florida
Hollywood, City of
JEA
Miami-Dade County
Orange County Utilities Department
Orlando, City of
Palm Beach County
Pinellas County Utilities
Reedy Creek Improvement District
St. Petersburg, City of
Tallahassee, City of
Toho Water Authority

Georgia
Atlanta Department of Watershed Management
Augusta, City of
Clayton County Water Authority
Cobb County Water System
Columbus Water Works
Gwinnett County Department of Water Resources
Macon Water Authority
Savannah, City of

Hawaii
Honolulu, City & County of

Idaho
Boise, City of

Illinois
Greater Peoria Sanitary District
Metropolitan Water Reclamation District of Greater Chicago
Sanitary District of Decatur

Indiana
Jeffersonville, City of

Iowa
Ames, City of
Cedar Rapids Water Pollution Control Facilities
Des Moines, City of

Kansas
Johnson County Wastewater
Lawrence, City of
Olathe, City of
Overland Park, City of

Kentucky
Louisville and Jefferson County Metropolitan Sewer District

Louisiana
Sewerage & Water Board of New Orleans

Maine
Bangor, City of
Portland Water District

Maryland
Anne Arundel County
Howard County Bureau of Utilities
Washington Suburban Sanitary Commission

Massachusetts
Boston Water & Sewer Commission
Upper Blackstone Water Pollution Abatement District

Michigan
Ann Arbor, City of
Gogebic-Iron Wastewater Authority
Holland Board of Public Works
Saginaw, City of
Wayne County Department of Public Services
Wyoming, City of

Minnesota
Metropolitan Council Environmental Services
Rochester, City of
Western Lake Superior Sanitary District

Missouri
Independence, City of
Kansas City Missouri Water Services Department
Metropolitan St. Louis Sewer District

Nevada
Henderson, City of

New Jersey
Bergen County Utilities Authority

New York
New York City Department of Environmental Protection

North Carolina
Cape Fear Public Utilities Authority
Charlotte-Mecklenburg Utilities
Durham, City of
Metropolitan Sewerage District of Buncombe County
Old North State Water Company Inc.
Orange Water & Sewer Authority
Raleigh, City of

Ohio
Avon Lake Municipal Utilities
Columbus, City of
Dayton, City of
Metropolitan Sewer District of Greater Cincinnati
Northeast Ohio Regional Sewer District
Summit County

Oklahoma
Oklahoma City Water & Wastewater Utility Department
Tulsa, City of

Oregon
Bend, City of
Clean Water Services
Gresham, City of
Lake Oswego, City of
Oak Lodge Sanitary District
Portland, City of
Water Environment Services

Pennsylvania
Philadelphia, City of, Water Department
University Area Joint Authority

South Carolina
Beaufort - Jasper Water & Sewer Authority
Charleston Water System
Greenwood Metropolitan District
Mount Pleasant Waterworks
Spartanburg Water
Sullivan's Island, Town of

Tennessee
Cleveland Utilities
Murfreesboro Water & Sewer Department
Nashville Metro Water Services

Texas
Austin, City of
Dallas Water Utilities
Denton, City of
El Paso Water Utilities
Fort Worth, City of
Houston, City of
San Antonio Water System
Trinity River Authority

Utah
Salt Lake City Department of Public Utilities

WERF Subscribers

Virginia
Alexandria Renew Enterprises
Arlington County
Fairfax County
Fauquier County
Hampton Roads Sanitation District
Hanover County
Hopewell Regional Wastewater Treatment Facility
Loudoun Water
Lynchburg Regional Wastewater Treatment Plant
Prince William County Service Authority
Richmond, City of
Rivanna Water & Sewer Authority

Washington
Everett, City of
King County Department of Natural Resources & Parks
Puyallup, City of
Seattle Public Utilities
Sunnyside, Port of

Wisconsin
Green Bay Metro Sewerage District
Kenosha Water Utility
Madison Metropolitan Sewerage District
Milwaukee Metropolitan Sewerage District
Racine Water & Wastewater Utility
Sheboygan, City of
Stevens Point, City of
Wausau Water Works

Canada
Calgary, City of
EPCOR
Lethbridge, City of
Metro Vancouver
Toronto, City of
Winnipeg, City of

Denmark
VandCenter Syd

STORMWATER UTILITY

California
Monterey, City of
San Diego County Department of Public Works
San Francisco Public Utilities, City & County of
Santa Rosa, City of
Sunnyvale, City of

Colorado
Aurora, City of

Florida
Orlando, City of

Iowa
Cedar Rapids Water Pollution Control Facilities
Des Moines, City of

Kansas
Overland Park, City of

Kentucky
Sanitation District No. 1

Pennsylvania
Philadelphia, City of, Water Department

Tennessee
Chattanooga Stormwater Management

Washington
Bellevue Utilities Department
Seattle Public Utilities

Wisconsin
Stevens Point, City of

STATE AGENCY

Connecticut Department of Energy and Environmental Protection
Harris County Flood Control District
Urban Drainage & Flood Control District, CO

CORPORATE

AECOM
Alan Plummer Associates Inc.
American Cleaning Institute
American Structurepoint, Inc.
Aqua-Aerobic Systems Inc.
Atkins
Black & Veatch Corporation
Brown and Caldwell
Burns & McDonnell
Carollo Engineers, P.C.
CDM Smith
CH2M HILL
Clear Cove Systems, Inc.
CRA Infrastructure & Engineering
D&B/Guarino Engineers LLC
Effluential Synergies LC
ElectroCell Technologies, Inc.
EMA Inc.
ENVIRON International Corporation
Environmental Operating Solutions Inc.
Evoqua Water Technologies
Gannett Fleming Inc.
GeoSyntec Consultants
GHD Inc.
Global Water Advisors Inc.
Greeley & Hansen LLC
Hazen & Sawyer P.C.
HDR Inc.
Holmes & McGrath Inc.
Infilco Degremont Inc.
Jacobs Engineering Group Inc.
KCI Technologies Inc.
Kelly & Weaver P.C.
Kennedy/Jenks Consultants
KORE Infrastructure, LLC
Larry Walker Associates
LimnoTech
Malcolm Pirnie, the Water Division of ARCADIS
McKim & Creed
MWH
NTL Alaska Inc.
PICA Corporation
Pure Technologies Ltd.
Ross Strategic
Stone Environmental Inc.
Stratus Consulting Inc.
Synagro Technologies Inc.
Tata & Howard Inc.
Tetra Tech Inc.
The Cadmus Group Inc.
The Low Impact Development Center Inc.
URS Corporation
Versar, Inc.
Wright Water Engineers Inc.
Zoeller Pump Company

Austria
Sanipor Ltd.

Canada
Associated Engineering

Norway
Aquateam Cowi AS

INDUSTRY

American Water
Bill & Melinda Gates Foundation
Chevron Energy Technology Company
DuPont Company
Eastman Chemical Company
Eli Lilly & Company
General Electric Company
InSinkErator
Johnson & Johnson
Merck & Company Inc.
Procter & Gamble Company
United Water Services LLC
Veolia Water North America
Water Services Association of Australia

List as of 2/10/15

WERF Board of Directors

Chair
Kevin L. Shafer
Metro Milwaukee Sewerage District

Vice-Chair
Glen Daigger, Ph.D., P.E., BCEE, NAE
One Water Solutions, LLC

Secretary
Eileen J. O'Neill, Ph.D.
Water Environment Federation

Treasurer
Brian L. Wheeler
Toho Water Authority

Rajendra P. Bhattarai, P.E., BCEE
Austin Water Utility

Paul L. Bishop, Ph.D., P.E., BCEE
University of Rhode Island

Scott D. Dyer, Ph.D.
The Procter & Gamble Company

Catherine R. Gerali
Metro Wastewater Reclamation District

Philippe Gislette Degrémont,
Suez-Environnement

Julia J. Hunt, P.E.
Trinity River Authority of Texas

Douglas M. Owen, P.E., BCEE, ENV SP
ARCADIS U.S.

Jim Matheson
Oasys Water

Ed McCormick, P.E.
Water Environment Federation

James Anthony (Tony) Parrott
Metropolitan Sewer District of Greater Cincinnati

Rick Warner, P.E.
Washoe County Community Services Department

Interim Executive Director
Lawrence P. Jaworski, P.E., BCEE

WERF Research Council

Chair
Rajendra P. Bhattarai, P.E., BCEE
Austin Water Utility

Vice-Chair
Art K. Umble, Ph.D., P.E., BCEE
MWH Global

Donald Gray (Gabb), Ph.D., P.E., BCEE
East Bay Municipal Utility District

Robert Humphries, Ph.D.
Water Corporation of Western Australia

Terry L. Johnson, Ph.D., P.E., BCEE Water Consulting, LLC

Mark W. LeChevallier, Ph.D.
American Water

Ted McKim, P.E. BCEE
Reedy Creek Energy Services

Carol J. Miller, Ph.D., P.E.
Wayne State University

James (Jim) J. Pletl, Ph.D.
Hampton Roads Sanitation District

Michael K. Stenstrom, Ph.D., P.E., BCEE
University of California, Los Angeles

Elizabeth Southerland, Ph.D.
U.S. Environmental Protection Agency

Paul Togna, Ph.D.
Environmental Operating Solutions, Inc.

Kenneth J. Williamson, Ph.D., P.E.
Clean Water Services

WERF
Water Environment Research Foundation

WERF Product Order Form

As a benefit of joining the Water Environment Research Foundation, subscribers are entitled to receive one complimentary copy of all final reports and other products. Additional copies are available at cost (usually $10). To order your complimentary copy of a report, please write "free" in the unit price column. WERF keeps track of all orders. If the charge differs from what is shown here, we will call to confirm the total before processing.

Name _____ Title _____

Organization _____

Address _____

City _____ State _____ Zip Code _____ Country _____

Phone _____ Fax _____ Email _____

Stock #	Product	Quantity	Unit Price	Total

Postage & Handling	
VA Residents Add 5% Sales Tax	
Canadian Residents Add 7% GST	
TOTAL	

Method of Payment:

(All orders must be prepaid.)

- ❑ Check or Money Order Enclosed
- ❑ Visa ❑ Mastercard ❑ American Express

Account No. _____ Exp. Date _____

Signature _____

Shipping & Handling:

Amount of Order	United States	Canada & Mexico	All Others
Up to but not more than:	Add:	Add:	Add:
$20.00	$7.50*	$9.50	50% of amount
30.00	8.00	9.50	40% of amount
40.00	8.50	9.50	
50.00	9.00	18.00	
60.00	10.00	18.00	
80.00	11.00	18.00	
100.00	13.00	24.00	
150.00	15.00	35.00	
200.00	18.00	40.00	
More than $200.00	Add 20% of order	Add 20% of order	

* minimum amount for all orders

Make checks payable to the Water Environment Research Foundation.

To Order (Subscribers Only):

Log on to www. werf.org and click on "Publications."

Phone: 571-384-2100
Fax : 703-299-0742

WERF
Attn: Subscriber Services
635 Slaters Lane
Alexandria, VA 22314-1177

To Order (Non-Subscribers):

Non-subscribers may order WERF publications either through WERF or IWAP (www.iwapublishing.com). Visit WERF's website at www.werf.org for details.

Water Environment Research Foundation
635 Slaters Lane, Suite G-110 ▪ Alexandria, VA 22314-1177
Phone: 571-384-2100 ▪ Fax: 703-299-0742 ▪ Email: werf@werf.org
www.werf.org
WERF Stock No. ENER1C12b

Co-published by

IWA Publishing
Alliance House, 12 Caxton Street
London SW1H 0QS
United Kingdom
Phone: +44 (0)20 7654 5500
Fax: +44 (0)20 7654 5555
Email: publications@iwap.co.uk
Web: www.iwapublishing.com
IWAP ISBN: 978-1-78040-745-6

March 2015