Water Environment Research Foundation
Collaboration. Innovation. Results.

Energy. Innovation. Solutions.

Operations Optimization

FINAL REPORT

Barriers to Biogas Use for Renewable Energy

Co-published by

IWA Publishing

OWSO11C10

BARRIERS TO BIOGAS USE FOR RENEWABLE ENERGY

by:

John Willis, P.E.
Brown and Caldwell

Lori Stone, P.E.
Black & Veatch

Karen Durden, P.E.
Brown and Caldwell

Ned Beecher
North East Biosolids and Residuals Association (NEBRA)

Caroline Hemenway
Hemenway Inc.

Rob Greenwood
Ross & Associates Environmental Consulting, Ltd.

2012

WERF

nyserda
Energy. Innovation. Solutions.

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 wastewater utilities, 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

Library of Congress Catalog Card Number: 2011943815
Printed in the United States of America
IWAP ISBN: 978-1-78040-101-0/1-78040-101-9

Name of organizations that helped prepare this report: Brown and Caldwell, Black & Veatch, Northeast Biosolids and Residuals Association, Hemenway, Inc.

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

ACKNOWLEDGMENTS

The authors wish to acknowledge the funding support provided by the New York State Energy Research and Development Authority (NYSERDA) and the Water Environment Research Foundation (WERF), and the helpful guidance of Kathleen O'Connor, P.E. and Lauren Fillmore, Project Officers for NYSERDA and WERF, respectively.

The project team gratefully acknowledges the hundreds of utility personnel who voluntarily participated in this project. The success of the project is directly attributed to the dedication and enthusiasm of these utilities to share their experiences regarding creating biogas for renewable energy. The authors also wish to express their appreciation to the project advisory committee for its guidance in the design and conduct of the project as well as to Jennifer Aurandt, Ph.D. of Kettering University and Joseph Cantwell, P.E. of Science Applications International Corporation (SAIC).

Report Preparation

Principal Investigators:

John Willis, P.E.
Brown and Caldwell

Lori Stone, P.E.
Black & Veatch

Project Team:

Karen Durden, P.E.
Brown and Caldwell

Ned Beecher
North East Biosolids and Residuals Association (NEBRA)

Rob Greenwood
Ross & Associates Environmental Consulting, Ltd.

Caroline Hemenway
Hemenway Inc.

Bill Toffey
Mid Atlantic Biosolids Association (MABA)

Nora Goldstein
JG Press/BioCycle

Technical Review Committee

Robert Bastian
U.S. Environmental Protection Agency

David Cooley
Hampton Roads Sanitation District (HRSD)

Arthur J. Meyers, Jr., Ph.D.
University of Tennessee

David Tucker
City of San Jose

WERF Optimization Challenge Issue Area Team

John Barber, Ph.D.
Eastman Chemical

Shahid Chaudhry
California Energy Commissions

Steve Constable, P.E.
DuPont Engineering Technology

David Cooley
Hampton Roads Sanitation District (HRSD)

Robert F. Kelly, Ph.D.
Suez Environnement

Arthur J. Meyers, Jr., Ph.D.
University of Tennessee

Ali Oskouie, Ph.D.
Metropolitan Water Reclamation District of Greater Chicago (MWRDGC)

David Tucker
City of San Jose

James Wheeler, P.E., BCEE
U.S. Environmental Protection Agency

John Willis, P.E., BCEE
Brown and Caldwell

Water Environment Research Foundation Staff

Director of Research: Daniel M. Woltering, Ph.D.
Program Director: Lauren Fillmore, M.S.

ABSTRACT AND BENEFITS

Abstract:

The U.S. Environmental Protection Agency (U.S. EPA) reports that few wastewater treatment plants with anaerobic digestion beneficially use their biogas beyond process heating. Thus, there must be actual or perceived barriers to broader use of biogas to produce combined heat and power (CHP).

In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study to determine what barriers wastewater utilities face in implementing combined heat and power projects.

The project team developed an online survey to determine the most significant barriers facing utilities. This survey was distributed nationally and completed by more than 200 respondents. The survey findings were presented and discussed with dozens of utility representatives at four focus groups timed with industry conferences.

Many of the findings of the project were not surprising. Of the 10 barrier categories introduced as potential barriers at the beginning of the project, nine were deemed significant, according the broad input and testing conducted. However, it became clear that economic barriers – inadequate payback/economics and lack of available capital – were dominant. Other barriers fell into two categories: policy factors such as regulatory permitting, and human factors, such as decision making.

Benefits:

- Identifies barriers that public utilities face in implementing beneficial use of biogas.
- Consolidates responses received on barriers to biogas for renewable energy recovery from more than 200 utility participants across the United States.
- Provides specific strategies to help utilities overcome barriers to biogas use for renewable energy.
- Provides recommendations to expand the production of renewable energy from biogas.

Keywords: Biogas, renewable energy, green power, cogeneration, combined heat and power.

TABLE OF CONTENTS

Acknowledgments iii
Abstract and Benefits v
List of Tables ix
List of Figures x
List of Acronyms and Abbreviations xii
Executive Summary ES-1

1.0 Introduction 1-1
1.1 Research Context 1-1
1.2 Project Overview 1-2
1.3 Report Organization 1-2

2.0 Biogas Uses for Renewable Energy 2-1
2.1 Introduction 2-1
2.2 CHP Uses for Biogas 2-1
2.2.1 Internal Combustion Engines 2-1
2.2.2 Combustion Gas Turbines 2-2
2.2.3 Microturbines 2-2
2.2.4 Fuel Cells 2-2
2.2.5 Steam Turbines 2-2
2.3 Non-CHP Uses for Biogas 2-2
2.3.1 Biogas Addition to Natural Gas Pipelines 2-3
2.3.2 Sale of Biogas to Industrial User or Electric Power Producer 2-3
2.3.3 Biogas Used as Vehicle Fuel 2-3

3.0 Online Survey Overview 3-1
3.1 Survey Overview 3-1
3.2 Survey Methodology 3-1
3.3 Barrier Identification and Ranking 3-2
3.3.1 Development of Barrier Categories and Categorization of Barrier Statements 3-3
3.3.2 Scoring Responses and Consolidating Scores 3-11

4.0 Online Survey Results and Interpretation 4-1
4.1 Overview of Respondent and Plant Data 4-1
4.2 Barrier Analysis Results by Biogas Use Category and Role of Respondent 4-5
4.2.1 Group I 4-5
4.2.2 Group II 4-7
4.2.3 Group III 4-8
4.2.4 All Groups 4-9
4.3 Is the “Plant Too Small” Barrier for Real? 4-10
4.3.1 Group I 4-10
4.3.2 Group II 4-11
4.3.3 Group III 4-12

5.0 Focus Groups ... 5-1
5.1 Miami, FL Focus Group Meeting ... 5-1
5.2 New York City, NY Focus Group Meeting ... 5-3
5.3 Sacramento, CA Focus Group Meeting ... 5-5
5.3.1 Prioritization Exercise ... 5-7
5.4 Chicago, IL Focus Group Meeting ... 5-8
5.5 Focus Group Meetings Summary ... 5-11
5.5.1 Methodology Assessment ... 5-11
5.5.2 Discussion of Focus Group Findings ... 5-12
5.6 Relational Diagrams ... 5-14

6.0 Small-Plant Barrier Mitigation ... 6-1
6.1 Background ... 6-1
6.2 Summary of Survey Results on Small Plants ... 6-1
6.3 Strategies to Overcome Small-Plant Barriers ... 6-2
6.3.1 Use Alternative Feedstocks to Increase Biogas Production ... 6-3
6.3.2 Consolidate Solids Handling ... 6-4
6.3.3 Re-frame Economics ... 6-4
6.3.4 Investigate Alternative Sources of Funding ... 6-4
6.3.5 Simplify O&M ... 6-5
6.3.6 Highlight Risk of Status Quo to Decision Makers ... 6-5
6.3.7 Leverage Current Discussions with Third Parties ... 6-6
6.3.8 Use Chemical Precipitation of Phosphorus or Deammonification Process.. 6-6

7.0 Non-Utility Perspectives on Barriers ... 7-1
7.1 Overview of Respondent Data ... 7-1
7.2 Barrier Categorization Methodology and Results ... 7-3
7.3 Summary ... 7-7

8.0 Conclusions and Recommended Next Steps ... 8-1
8.1 Major Barriers to Biogas Use for Renewable Energy ... 8-2
8.1.1 Policy Factors ... 8-2
8.1.2 Human Factors ... 8-3
8.2 Opportunities to Mitigate or Overcome Barriers ... 8-4
8.2.1 Inadequate Payback/Economics and/or Lack of Available Capital ... 8-4
8.2.2 Complications with Outside Agents ... 8-5
8.2.3 Plant Too Small ... 8-6
8.2.4 Operations and Maintenance Complications and Concerns ... 8-6
8.2.5 Difficulties with Air Regulations or Obtaining Air Permit ... 8-6
8.2.6 Technical Merits and Concerns ... 8-7
8.2.7 Complications with Liquid Stream ... 8-7
8.2.8 Maintenance Status Quo and Lack of Community/Utility Leadership Interest in Green Power ... 8-7
8.3 Overcoming Decision-Making Barriers ... 8-7
8.3.1 Decision Theory and Analysis ... 8-8

8.3.2 Innovation Diffusion Theory 8-8
8.4 Recommended Next Steps 8-10

Appendix A: Case Studies at a Glance A-1
Appendix B: Biogas Factsheet B-1
Appendix C: Biogas Postcard Mailer C-1
Appendix D: Decision Theory and Analysis; Innovation Diffusion Theory D-1

References R-1

LIST OF TABLES

6-1 Most Significant Barriers by Plant Category for Respondents Between 1 and 5 mgd 6-2
6-2 Most Significant Barriers by Plant Category for Respondents Between 5 and 10 mgd .. 6-2
6-3 Small Plant Barriers and Mitigation Strategies 6-3
7-1 Response to Open-Ended Questions on Most Important Barriers 7-4

LIST OF FIGURES

3-1 Biogas Use Categories ... 3-2
3-2 WERF Barriers to Biogas Survey – Response Options ... 3-2
3-3 Ten Barrier Statement Categories ... 3-3
3-4 Barrier Category – Inadequate Payback/Economics ... 3-4
3-5 Barrier Category – Lack of Available Capital ... 3-5
3-6 Barrier Category – Operations/Maintenance Complications/Concerns ... 3-6
3-7 Barrier Category – Complications with Liquid Stream ... 3-6
3-8 Barrier Category – Outside Agents (Utilities, Public) ... 3-7
3-9 Barrier Category – Sustainability/Green Power Limitations ... 3-7
3-10 Barrier Category – Air Regulations ... 3-8
3-11 Barrier Category – Plant Too Small ... 3-8
3-12 Barrier Category – Technical Merits/Concerns ... 3-9
3-13 Barrier Category – Maintain Status Quo ... 3-10
3-14 Six Levels of Response Agreements ... 3-11
4-1 Responses by Respondent – Defined Role Categories ... 4-1
4-2 Responses by Plant Sizes ... 4-2
4-3 Responses by Biogas Use ... 4-2
4-4 Responses by Plant Flow ... 4-3
4-5 Responses by EPA Regions ... 4-4
4-6 Barrier Analysis Results: I–AD-no-CHP ... 4-6
4-7 Barrier Analysis Results: II – AD and CHP ... 4-7
4-8 Barrier Analysis Results: III – No AD No CHP ... 4-8
4-9 Barrier Analysis Results: All ... 4-9
4-10 Reality Check on “Plant Too Small” Barrier: I – AD no CHP ... 4-10
4-11 Reality Check on “Plant Too Small” Barrier: III – AD and CHP ... 4-11
4-12 Reality Check on “Plant Too Small” Barrier: II – No AD No CHP ... 4-12
5-1 Focus Group Participant Barrier Category and Statement Grouping Diagram – Inadequate Payback/Economics ... 5-16
5-2 Focus Group Participant Barrier Category and Statement Grouping Diagram – Lack of Available Capital ... 5-17
5-3 Focus Group Participant Barrier Category and Statement Grouping Diagram – Operations Maintenance Complications/Concerns ... 5-18
5-4 Focus Group Participant Barrier Category and Statement Grouping Diagram – Outside Agents (Non-Regulatory, Utilities, Public) ... 5-19

5-5 Focus Group Participant Barrier Category and Statement Grouping Diagram – Technical Merits/Concerns 5-20
5-6 Focus Group Participant Barrier Category and Statement Grouping Diagram – Maintain Status Quo 5-21
5-7 Summary Diagram of Relationship Among Barrier Categories 5-22
7-1 Geographic Distribution of Responses to Survey of Non-Utility Perspectives 7-2
7-2 Roles of Respondents to Survey of Non-Utility Perspectives 7-3
8-1 Ten Barrier Statement Categories 8-2

LIST OF ACRONYMS AND ABBREVIATIONS

AD	Anaerobic digestion
ADG	Anaerobic digester gas
ARES	Advanced Reciprocating Engine System
BTU	British thermal units
CHP	Combined heat and power
CHPP	Combined Heat and Power Partnership
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CWNS	Clean Watershed Needs Surveys
DO	Dissolved oxygen
EPRI	Electric Power Research Institute
ESCO	Energy service company
FOG	Fats, oils, and grease
HHV	Higher heating value
HRSG	Heat recovery steam generator
HSW	High-strength waste
kWh	Kilowatt hour
kWh/m3	Kilowatt hour per cubic meter
kWh/PE/y	Kilowatt hour per population equivalent per year
L/PE	Liters of digester gas per population equivalent
mg/L	Milligrams per liter
mgd	Millions of gallons per day
NEBRA	North East Residuals and Biosolids Association
NGO	Non-governmental organization
NOx	Oxides of nitrogen

NPV	Net present value
NYSERDA	New York State Energy Research and Development Authority
NYWEA	New York Water Environment Association
O&M	Operations and maintenance
REC	Renewable energy credit
ROI	Return on investment
RPS	Renewable portfolio standards
TPAD	Temperature-phased anaerobic digestion
U.S. EPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds
VS	Volatile solids
WERF	Water Environment Research Foundation
WRF	Water reclamation facility
WWTF	Wastewater treatment facility (wastewater treatment works that might include one or more discrete plants, conveyance systems, and/or associated operations)
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

Wastewater treatment facilities (WWTFs) are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The most common form of biogas use is to produce combined heat and power (or CHP, largely used interchangeably in this report to represent the myriad forms of biogas beneficial use). Thus, there must be actual or perceived barriers to broader use of these heat-capture or energy recovery technologies.

Known barriers to CHP were grouped into 10 major categories. These barriers, along with summary statements, include the following:

- Inadequate payback/economics – the economics do not justify the investment for beneficial use of biogas.
- Lack of available capital – there are more pressing needs for our limited dollars.
- Operations and maintenance complications and concerns – concern over a lack of expertise on staff or on call to operate a CHP system.
- Complication with liquid streams – the improvements negatively impact liquid stream compliance and operation.
- Outside agents (non-regulatory: utilities, public) – "we could not work with our power and gas utilities or the public to implement CHP."
- Lack of community and utility leadership or interest in green power – the environmental benefit provides inadequate justification for the project.
- Difficulties with air regulations or obtaining air permit – air and greenhouse gas (GHG) regulations make it too difficult to get a CHP air permit or CHP will require a Title V permit.
- Plant too small – "our facility and/or biogas production is too small to justify a CHP project."
- Technical merits and concerns – technical concerns limit willingness to implement.
- Maintain status quo – "we like things the way they are too much."

In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers wastewater utilities face in implementing combined heat and power projects.

The project team developed an online survey to determine the most significant barriers facing utilities; this survey was distributed nationally and completed by more than 200 respondents. The survey findings were presented and discussed with dozens of utility representatives at four focus groups – in Miami FL, New York NY, Sacramento CA, and Chicago IL – timed with industry conferences.

To develop the survey and discussion areas for the meetings, the project team used available baseline information about biogas uses for renewable energy and about known uses within the industry. These uses are divided into two categories:

- Uses in CHP processes, including internal combustion engines, combustion gas turbines, microturbines, fuel cells, and steam turbines.
- Non-CHP uses, including injection of biogas into natural gas pipelines, sale to third-party end users, and use as vehicle fuel.

Many of the findings of the project were not surprising. Of the 10 barrier categories introduced as potential barriers at the beginning of the project, nine were deemed significant, according the broad input and testing conducted. However, it became clear that the economic barriers – inadequate payback/economics and lack of available capital – were dominant. Other barriers fell into two categories: policy factors such as regulatory permitting, and human factors, such as decision making. The following findings became evident during this project:

- The largest, most widespread barriers to biogas use are economic, related to higher priority demands on limited capital resources or to perceptions that the economics do not justify the investment.
- Outside agents such as power utilities for CHP and gas utilities for renewable compressed natural gas can be significant barriers.
- Air permitting requirements can create an extremely significant barrier in specific geographies/permitting situations.
- Public agencies' decision-making bureaucracy/configuration can hinder biogas use. A surprisingly high percentage of our respondents from smaller-capacity facilities have found means to justify biogas use projects; as such, it seems that textbook 5- or 10-mgd lower-capacity barriers can be overcome with creative thinking. In juxtaposition, a number of mid-sized plants (10-25 mgd) identified inadequate gas production as a barrier.
- There has been considerably more interest and investment in biogas use over the past five years than in the prior years.
- There is also greater interest in enhanced efficiency, operational cost reduction, and sustainability today that supports biogas use projects.

This much-needed research has revealed the barriers that impede more widespread use of biogas as a renewable energy source and identified some mechanism for mitigating those barriers. To build on the work completed in this project, the following next steps are recommended to increase biogas-generated renewable power at WWTFs:

- Continue to quantify and define the energy generation potential from biogas at WWTFs throughout the United States.
- Develop databases, similar to that developed by U.S. EPA Region 9, of potential high-strength waste (HSW) sources that could be used to increase biogas production at WWTFs.

- Develop a consolidated database or repository of grant funding opportunities for CHP and biogas production projects.
- Update the University of Alberta Flare Emissions Calculator to include nitrogen oxides (NOx) and carbon monoxide (CO) that are often regulated by permitting agencies to document the relative performance of these non-recovery/fuel-wasting devices against CHP technologies.
- Expand outreach and information exchange between the wastewater industry and power companies and natural gas utilities.
- Further advance understanding of how decision science and innovation diffusion theory can help guide overcoming barriers to biogas use for renewable energy at wastewater treatment utilities.
- Develop a centralized database of CHP installations and continue to develop case studies on successful CHP projects.
- Develop an economic analysis tool that uses other financial evaluation methods in addition to simple payback.
- Develop an education and training course to assist in the understanding of the benefits of biogas, including a course specifically for decision makers.
- Assemble information on the barriers to anaerobic digestion.
- Move biogas to the Department of Energy (DOE) list of renewable energy.
- Identify how to pursue legislation to assist in financing CHP projects.
- Promote research to identify less costly methods to achieve anaerobic digestion and biogas production so it can become more widely applicable particularly to small WWTFs and industrial applications.

CHAPTER 1.0

INTRODUCTION

1.1 Research Context

According to the U.S. Environmental Protection Agency (U.S. EPA) Combined Heat and Power Partnership (CHPP) (2011), here are some context-setting figures to set the stage for this report:

- Only 1,351 of the 3,171-wastewater treatment facilities (WWTFs) greater than 1 mgd in the United States (43%) operate anaerobic digestion.
- Of the facilities with anaerobic digestion, only 104 WWTFs (8%) generate electrical or thermal energy using biogas as a renewable energy source representing 248 MW of capacity.

The potential to generate renewable energy from wastewater is significant. As noted by the CHPP (2011), renewable energy from biogas has the potential to supply an additional 200 - 400 MW of power that can be used on site at WWTFs or distributed back into the electric grid. Since about 4% of the electricity used in the United States moves and treats water and wastewater according to the Electric Power Research Institute (EPRI) (2002), the ability for WWTFs to generate power to offset their own demands or provide additional power to the grid is critical to reducing energy consumption.

> WWTPs have the potential to generate an additional 200 to 400 MW of power from biogas.

The advantages of anaerobic digestion coupled with CHP to generate energy are numerous. As noted by Wiser, Schettler, and Willis (2011), these advantages include the following:

- Biogas generated from anaerobic digestion is a valuable source of fuel for CHP systems.
- Electricity generated from biogas is reliable and available for immediate use.
- Electricity is often expensive and represents one of the largest costs associated with treating wastewater – generated power displaces high-priced retail purchases from power utilities.
- In some cases, biogas-generated electricity can be made available for export and sale to power utilities.
- Generated electricity is a product of biogenic carbon and is carbon neutral. The generated power displaces largely fossil-fuel-derived, electric-utility-produced power.

Biogas is a renewable energy source and a valuable commodity. So why are more WWTFs not using anaerobic digestion and CHP to generate renewable energy from biogas? That is the question this project and report addresses.

1.2 Project Overview

WERF and NYSERDA, in conjunction with Brown and Caldwell, Black & Veatch, Hemenway Inc., and NEBRA, led a research project to determine the following:

- What are the barriers to biogas use for renewable energy at WWTFs?
- Which barriers are most significant and how do they vary by size of facility and by roles and responsibilities within an organization?
- What opportunities are available for overcoming the identified barriers?

The answers to the questions above were determined by working with hundreds of utility personnel from varying sizes of facilities across the United States who have different experience levels with anaerobic digestion and CHP systems. To determine the barriers that utilities face in implementing renewable energy projects from biogas, the project team used an online survey and focus groups to gather data and develop hypotheses about the barriers. Case studies also were developed for numerous participating utilities; the information used to develop the case studies was gathered from the focus groups, survey, and telephone interviews by the project team. This report presents the findings of the project and suggests next steps for biogas generated renewable energy.

The result of the project is a report to educate the industry about the barriers – perceived or otherwise – and methods to overcome them to increase biogas-generated renewable power at WWTFs.

1.3 Report Organization

The report is divided into the following chapters:

- Executive Summary
- Introduction
- Biogas uses for renewable energy
- Online survey overview
- Online survey results and interpretation
- Focus group summaries
- Small plant barrier mitigation
- Non-utility perspectives on barriers
- Conclusions and recommended next steps
- References

Appendices include the following:

- Case studies at a glance from 21 utilities
- Biogas factsheet
- Biogas postcard invitation to survey
- Brief discussion of decision theory and analysis and innovation diffusion theory

CHAPTER 2.0

BIOGAS USES FOR RENEWABLE ENERGY

2.1 Introduction

The following chapter presents an overview of biogas uses for renewable energy. These uses are divided into two categories:

- Uses in CHP processes, including internal combustion engines, combustion gas turbines, microturbines, fuel cells, and steam turbines.
- Non-CHP uses, including injection of biogas into natural gas pipelines, sale to third-party end users, and use as vehicle fuel.

The intent of this chapter is to present a general overview of these alternatives for CHP and non-CHP uses of biogas. Performance information and advantages and disadvantages of the various uses were taken from Wiser, Schettler, and Willis (2011). Detailed information on CHP technologies can be found in this reference.

2.2 CHP Uses for Biogas

CHP systems, which simultaneously or sequentially produce mechanical and thermal energy, can be used to produce renewable energy from biogas. CHP uses for biogas include the following:

- Internal combustion engines
- Combustion gas turbines
- Microturbines
- Fuel cells
- Steam turbines

These technologies are briefly described in the next sections.

2.2.1 Internal Combustion Engines

Internal combustion engines are widely used in WWTFs for generating process heat and renewable energy from biogas. Spark-ignition internal combustion engines, including rich-burn and lean-burn types, are almost exclusively used for low-BTU gas CHP applications.

Historically, rich-burn engines, which require a higher fuel-to-air ratio, have been used at WWTFs. However, in the last 20 years, advances in engine technology as well as concerns about exhaust emissions have largely eliminated the addition of new rich-burn engines at WWTFs. Instead, lean-burn engines, with lower fuel-to-air ratios, have become more widely used. In addition to lower exhaust emissions, lean-burn engines achieve higher fuel efficiency from available biogas due to more complete fuel combustion. Engine manufacturers have recently partnered with the United States Department of Energy to decrease exhaust emissions and improve fuel efficiency in the Advanced Reciprocating Engine System (ARES) program.

2.2.2 Combustion Gas Turbines

Combustion gas turbines are used, particularly at large WWTFs, to produce renewable energy and process heat from biogas. Renewable energy is produced by the compression and ignition of atmospheric air and fuel within the combustion gas turbine. Mechanical energy is then harnessed from the expanded, high-temperature gases.

2.2.3 Microturbines

Microturbines, which are small, high speed combustion gas turbines, are frequently used for CHP, particularly at smaller WWTFs. Microturbines recover heat from exhaust, typically in the form of hot water that can be used for anaerobic digestion or other process needs. In some cases, recuperators may be used to pre-heat combustion air with exhaust. Similar to combustion gas turbines, recuperators increase overall electrical efficiency of the process but reduce heat recovery.

2.2.4 Fuel Cells

Fuel cells are a CHP technology that uses electrochemical reactions to convert chemical energy into electricity. Fuel cells use clean, pressurized methane gas from anaerobic digestion to produce hydrogen gas to power the unit. There is a range of fuel cells available for CHP applications. However, phosphoric acid-type fuel cells and molten carbonate fuel cells have been used historically or are in use currently at WWTFs.

2.2.5 Steam Turbines

Steam turbines use thermal energy to produce power. Although steam turbines do not produce power directly from fuel, they typically use steam boilers to produce power. The use of steam turbines for CHP is not widespread due to the large quantity of biogas required to operate the process. However, when used, steam turbines and their associated equipment are reliable and require minimal maintenance relative to other CHP technologies.

2.3 Non-CHP Uses for Biogas

CHP systems can be used to produce renewable energy from biogas. However, at some WWTFs, utilities may prefer to use biogas in other, non-CHP applications. Non-CHP uses for biogas include the following:

- Injection of biogas into natural gas pipelines
- Sale of biogas to an industrial user or power company
- Use of biogas as a vehicle fuel

These alternative uses are briefly described in the following sections. As noted by Wiser, Schettler, and Willis (2011), purified biogas is approximately six percent less energetic than natural gas and has a lower heating value (HHV) relative to natural gas; these characteristics may sometimes affect the use of biogas in non-CHP applications.

2.3.1 Biogas Addition to Natural Gas Pipelines

One non-CHP alternative for biogas is injection into natural gas pipelines. In this alternative, biogas must be thoroughly cleaned and pressurized prior to introduction into the natural gas supply. To achieve this, water, carbon dioxide, and hydrogen sulfide are removed from biogas so that it approaches the purity of natural gas.

> The City of Des Moines, Iowa sells excess biogas to an industrial user to generate additional revenue. The city's experience is featured in Appendix A.

2.3.2 Sale of Biogas to Industrial User or Electric Power Producer

At some WWTFs, biogas is sold to an industrial user or electric power producer. The end user then converts biogas to electrical and/or thermal energy at its facility. In this alternative, biogas pre-treatment will depend on the quality requirements of the end user. This gas pre-treatment may be done by the utility, the end user, or both.

2.3.3 Biogas Use as Vehicle Fuel

Biogas can be purified and used as vehicle fuel. In this alternative, biogas is treated (including removal of most CO_2) and compressed for use in fleet vehicles or other equipment. For utilities that already use natural gas-fueled vehicles, this alternative may be cost-effective. However, vehicle conversion, the construction of fueling stations, and biogas purification and compression equipment must be considered in when evaluating this option.

CHAPTER 3.0

ONLINE SURVEY OVERVIEW

3.1 Survey Overview

An online survey was developed by the project team to collect data on the most significant barriers to biogas use for renewable energy. In addition, the survey was used to gather data on WWTFs that have already overcome barriers to biogas use and implemented biogas renewable energy projects. The survey was distributed nationwide by the project team through several email announcements.

The survey remained open from November 17, 2010 to April 6, 2011. During that time, more than 200 survey entries were received from utility respondents around the country, as well as from some international utilities. This showed a strong commitment to and interest in collaboration with WERF and NYSERDA to help answer questions regarding biogas use for renewable energy. Many utilities completed the survey multiple times for each of their WWTFs; this was done so that barriers could be identified for each facility, since many of the barriers varied from plant to plant and because perception of barriers varies form individual to individual.

3.2 Survey Methodology

The survey was divided into three main sections:

Section I	Demographic information: General information about the respondent and the utility.
Section II	Specific treatment plant information: General information about the plant including flows and loadings, types and quantities of sludge processed, and general unit process descriptions.
Section III-IV-V	Anaerobic digestion, biogas use and barriers.

After providing general information about the utility and the plant in Sections I and II, respondents were asked to select one of three statements regarding biogas use that would guide them to a specific set of questions to pursue in Sections III, IV, or V. These biogas use categories have been relabeled I, II, and III, for simplicity throughout this report, as shown in Figure 3-1.

Figure 3-1.
Biogas Use Categories

BIOGAS USE STATEMENT	SURVEY SECTION	BIOGAS USE CATEGORY
This plant operates anaerobic digesters but does not use biogas except for process heating	Section III	I. AD no CHP
This plant operates anaerobic digesters and is using biogas (for more than process heating) or is/will be investing in biogas use in the near future.	Section IV	II. AD and CHP
This plant does not have anaerobic digestion, but is interested in considering digestion and biogas use OR has decided not to pursue digestion.	Section V	III. no AD no CHP

3.3 Barrier Identification and Ranking

Once the appropriate biogas use category was selected, respondents were asked to agree or disagree with a number of statements developed by the project team regarding biogas use barriers. Depending on whether the respondent fell into category I-AD-no-CHP, II-AD-and-CHP, or III-no-AD-no-CHP, he/she was asked to rank the level of agreement with 31, 18, or 39 statements tailored for each biogas use category, respectively. Respondents were given the option to strongly or somewhat agree or disagree, to neither agree nor disagree, or to consider the statement not applicable (N/A), as shown in the screen shot (Figure 3-2).

Figure 3-2.
WERF Barriers to Biogas Survey – Response Options

WERF Survey - Barriers to Biogas Use

13. Section III Barriers: Plants that have digesters but do not use biogas (exc...

This part of the survey is for plants that DO have digesters but DO NOT use biogas (except for process heating).

71. Please rate your agreement with the following statements based on this plant's ability to overcome barriers to implementing biogas use.

	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree	N/A
We have a good energy management program.	○	○	○	○	○	○
Utilizing biogas would reduce our dependency on purchased heat and electricity, thus reducing our operating costs.	○	○	○	○	○	○
The local natural gas utility is not willing to work with us, even if we clean the biogas to their standards.	○	○	○	○	○	○
Utilizing biogas would reduce our "carbon footprint" (greenhouse gas emissions").	○	○	○	○	○	○
Our local electricity utility prevents us from easily benefitting from sale of renewable energy credits.	○	○	○	○	○	○
The equipment is too expensive to buy.	○	○	○	○	○	○
CHP will produce more CO2 and might get us into greenhouse gas trouble.	○	○	○	○	○	○
Safety issues associated with generating biogas on-site make it undesirable.	○	○	○	○	○	○

3.3.1 Development of Barrier Categories and Categorization of Barrier Statements

The project team devised a system to interpret more than 200 different responses to 88 qualitative statements on biogas barriers. The first step was to develop barrier statements then group the statements into 10 major categories, summarized by the statements listed in Figure 3-3, taken from the survey.

Figure 3-3.
Ten Barrier Statement Categories

BARRIER CATEGORY	SUMMARY STATEMENT
A. Inadequate Payback/Economics	The economics do not justify the investment
B. Lack of Available Capital	There are more pressing needs for our limited dollars
C. Operations/Maintenance Complications/Concerns	We are concerned about operations and maintenance
D. Complication with Liquid Stream	The improvements negatively impact our liquid stream compliance/operation
E. Outside Agents (Non-Regulatory: Utilities, Public)	We could not work with our power and gas utilities or the public
F. Lack of Community/Utility Leadership Interest in Green Power	The environmental benefit provides inadequate justification
G. Difficulties with Air Regulations or Obtaining Air Permit	Air and GHG regulations make it too difficult
H. Plant Too Small	Our facility is too small
I. Technical Merits/Concerns	Technical concerns limit our appetite to implement
J. Maintain Status Quo	We like things the way they are too much

The second step interpreting survey responses was to classify the statements as either direct or inverse. Some statements were phrased in a way that if the respondent agreed, it could be understood that the barrier was an important one, whereas if the respondent disagreed, the barrier did not matter much for that plant or utility. For example, agreement to the statement "The equipment is too expensive to own/operate" indicated that barrier "A. Inadequate Payback/Economics" was important. As such, it would be classified as direct. Agreement with the statement "Our power costs justified the investment" indicated just the opposite; the plant may have been able to implement a biogas use system just because barrier "A. Inadequate

Payback/Economics" was easy to overcome. This statement would be classified as inverse. Figures 3-4 through 3-13 below show the barrier category each statement was placed in along with its classification as either direct or inverse.

Figure 3-4.
Barrier Category – Inadequate Payback/Economics

		A. INADEQUATE PAYBACK/ECONOMICS
DIR	I-2	The payback on the investment is not adequate.
INV	I-22	Utilizing biogas would reduce our dependency on purchased heat and electricity, thus reducing our operating costs.
INV	I-26	The prices of natural gas and electricity are likely to rise, and if we used biogas, we could more easily predict our operating costs.
DIR	I-28	We do not know enough about the financial merits of CHP.
DIR	I-3	Our electricity is too cheap to justify the investment.
DIR	I-8	The equipment is too expensive to own/operate.
INV	II-1	Our power costs justified the investment.
INV	II-10	We used an alternative delivery method that improved the risk profile.
DIR	III-14	The equipment is too expensive to own/operate.
INV	III-32	Less expensive anaerobic digesters have been in use in industry and agriculture for many years and are a viable option for us.
INV	III-35	Anaerobic digesters can be used to process other organic wastes, such as fats, oils, & grease (FOG), bringing in additional revenue to the utility and producing more biogas.
DIR	III-37	We do not know enough about the financial merits of CHP.
DIR	III-7	The payback on the investment in digestion is not adequate.
DIR	III-8	Our electricity is too cheap to justify the investment in anaerobic digestion and use of biogas.

Figure 3-5.
Barrier Category – Lack of Available Capital

		B. LACK OF AVAILABLE CAPITAL
DIR	I-16	Our Utility Board/Commissioners would never be willing to pay for such a costly upgrade.
INV	I-25	Some states are providing incentives for renewable energy projects, and we should be able to get a grant to help install biogas utilization systems.
DIR	I-6	There are other, more pressing needs for our limited capital dollars.
DIR	I-7	The equipment is too expensive to buy.
INV	II-11	We used an alternative delivery method that improved the cost/investment profile.
INV	II-2	We received a grant that made the investment affordable.
INV	II-5	We found cost-saving concepts that made the project cheaper to build.
INV	II-6	We found an additional revenue source/operational savings that made the payback attractive.
DIR	III-12	There are other, more pressing needs for our limited capital dollars.
DIR	III-13	The equipment is too expensive to buy.
DIR	III-24	Our Utility Board/Commissioners would never be willing to pay for such a costly upgrade.
DIR	III-25	We can't get the political support needed for this kind of project.

Figure 3-6.
Barrier Category – Operations/Maintenance Complications/Concerns

C. OPERATIONS/MAINTENANCE COMPLICATIONS/CONCERNS		
DIR	I-13	The required equipment does not work/will not last.
INV	I-24	There are many recent advances in gas treatments that have made it easier and safer to use biogas.
DIR	I-30	Safety issues associated with generating biogas on-site make it undesirable.
DIR	I-9	New equipment will require us to hire specialized operations and maintenance staff.
INV	II-12	We contracted for related service that required specialized expertise.
DIR	II-18	Safety issues associated with generating biogas on-site make it undesirable.
DIR	III-15	New equipment will require us to hire specialized operations and maintenance staff.
INV	III-31	Anaerobic digesters have been in common use around the world for decades.
DIR	III-33	We had digesters and they didn't work well.
DIR	III-39	Safety issues associated with generating biogas on-site make it undesirable.
DIR	III-34	There is a bias against anaerobic digesters in this region.

Figure 3-7.
Barrier Category – Complications with Liquid Stream

D. COMPLICATIONS WITH LIQUID STREAM		
DIR	III-2	Anaerobic digestion could make compliance with our nitrogen limits very difficult.
DIR	III-3	Anaerobic digestion could make compliance with our phosphorus limits very difficult.
DIR	III-4	Treatment of the recycled liquid from digesters will take too much effort and cost too much.
DIR	III-5	We do not have capacity/capital to implement recycle treatment.

Figure 3-8.
Barrier Category – Outside Agents (Utilities, Public)

E. OUTSIDE AGENTS (UTILITIES, PUBLIC)		
DIR	I-18	The local natural gas utility is not willing to work with us, even if we clean the biogas to their standards.
DIR	I-19	Our local electricity utility makes it too tough for us to generate power onsite for our own use.
DIR	I-20	Our local electricity utility prevents us from easily benefitting from sale of renewable energy credits.
DIR	I-21	Our local electricity utility makes it too hard for us to sell produced renewable power back to the grid.
INV	II-13	We were able to work out an agreement with the local electric utility so we could sell some electricity back to the grid.
INV	II-14	We were able to work out an agreement with the local gas utility so we could sell gas to them.
DIR	III-9	Digesters smell bad and cause odor complaints.

Figure 3-9.
Barrier Category – Sustainability/Green Power Limitations

F. SUSTAINABILITY/GREEN POWER LIMITATIONS		
INV	I-23	Utilizing biogas would reduce our "carbon footprint" (greenhouse gas emissions).
INV	II-15	We benefit from the sale of either renewable energy credits and/or carbon credits.
INV	II-16	The value of renewable energy credits and/or carbon credits is only going to increase dramatically over time.
INV	II-3	Sustainability was the primary factor in our decision to use digestion and/or biogas.
INV	II-4	The biogas use facilities are a key part to our greenhouse gas reduction strategy.
INV	II-9	We decided it was the right thing to do.
INV	III-29	Anaerobic digestion produces biogas that can be used to generate renewable energy.

Figure 3-10.
Barrier Category – Air Regulations

G. AIR REGULATIONS		
DIR	I-14	CHP will produce more CO_2 and might get us into greenhouse gas trouble.
DIR	I-15	Adding a "stationary combustion" device could subject us to greenhouse gas regulation.
DIR	I-4	We cannot obtain an air permit for CHP.
DIR	I-5	Adding CHP will push us into a having to get a federal Clean Air Act Title V permit.
INV	II-7	We were able to get support that convinced the regulators to accommodate the installation.
DIR	III-10	We cannot obtain an air permit for CHP.
DIR	III-11	Adding CHP will push us into a Title V permit.
DIR	III-20	CHP will produce more CO_2 and might get us into greenhouse gas trouble.
DIR	III-21	Adding a "stationary combustion" device could subject us to greenhouse gas regulation.

Figure 3-11.
Barrier Category – Plant Too Small

H. PLANT TOO SMALL		
DIR	I-11	Our WWTP does not produce enough gas.
DIR	I-12	Our WWTP is too small.
INV	II-8	We found ways to dramatically increase our gas production.
DIR	III-17	Our WWTP would not produce enough gas.
DIR	III-18	Our WWTP is too small.

Figure 3-12.
Barrier Category – Technical Merits/Concerns

		I. TECHNICAL MERITS/CONCERNS
DIR	I-10	Biogas treatment and/or CHP are too complicated.
DIR	I-27	We do not know enough about the technical merits of CHP.
INV	I-29	We have a good energy management program.
DIR	I-31	Our biogas is not of adequate quality for CHP use.
INV	II-17	We have a good energy management program.
DIR	III-16	Digestion, biogas treatment, and/or CHP are too complicated.
DIR	III-19	The required equipment does not work/will not last.
DIR	III-27	We incinerate our solids and recover the energy; digestion would reduce its energy value.
INV	III-28	Anaerobic digestion would reduce the amount of solids we would have to manage, thus reducing transportation and handling costs.
INV	III-30	Anaerobic digestion produces more biosolids with lower odors and is more readily accepted by farmers.
DIR	III-36	We do not know enough about the technical merits of CHP.
INV	III-38	We have a good energy management program.

Figure 3-13.
Barrier Category – Maintain Status Quo

J. MAINTAIN STATUS QUO		
DIR	I-1	Our core business objective is to produce clean water and comply with our NPDES permit. CHP is not part of our core objective.
DIR	I-17	We can't get the political support needed for this kind of project.
DIR	III-1	Our solids treatment process is extremely easy to operate.
DIR	III-22	We don't need anaerobic digestion, because we already treat our solids so we can recycle them as a soil amendment.
DIR	III-23	Farmers using the biosolids from this WWTP like the material just the way it is.
DIR	III-26	Landfilling our solids is helping generate gas at the landfill; let them deal with it there.
DIR	III-6	Our core business objective is to produce clean water and comply with our NPDES permit. Digestion with CHP is not part of our core objective.

3.3.2 Scoring Responses and Consolidating Scores

The third step in interpreting these responses was to quantify the level of agreement or disagreement. The six possible answers were assigned scores, as shown in Figure 3-14.

Figure 3-14.
Six Levels of Response Agreements

LEVEL OF AGREEMENT	SCORE
Strongly Agree	5
Somewhat Agree	4
Neither Agree Nor Disagree	3
Somewhat Disagree	2
Strongly Disagree	1
Not Applicable (N/A)	0

These scores applied to statements classified as direct statements (those where "strongly agree" responses would indicate that the barrier was significant). The scoring was reversed for "inverse statements" (those where, conversely to direct statements, "strongly agree" responses would indicate that the barrier was not significant). One can conclude then that, no matter whether the statement was phrased directly or inversely, the higher the score, the higher the significance of the barrier.

The fourth step consolidated all the responses to all statements within a barrier category to provide one number corresponding to the importance of that barrier category. Weighted scores were calculated by summing the product of each response multiplied by its related score and then dividing that sum by the number of responses. If all respondents strongly agreed to a given statement, the weighted score would be a five. If half of respondents disagreed, and half agreed, the weighted score would be a three.

A simple average of the scores of all the statements falling within one barrier category could then be calculated by adding the scores and dividing by the number of statements in each category. These averages for each of the 10 barrier categories were plotted and the results are shown in Chapter 4.0.

CHAPTER 4.0

ONLINE SURVEY RESULTS AND INTERPRETATION

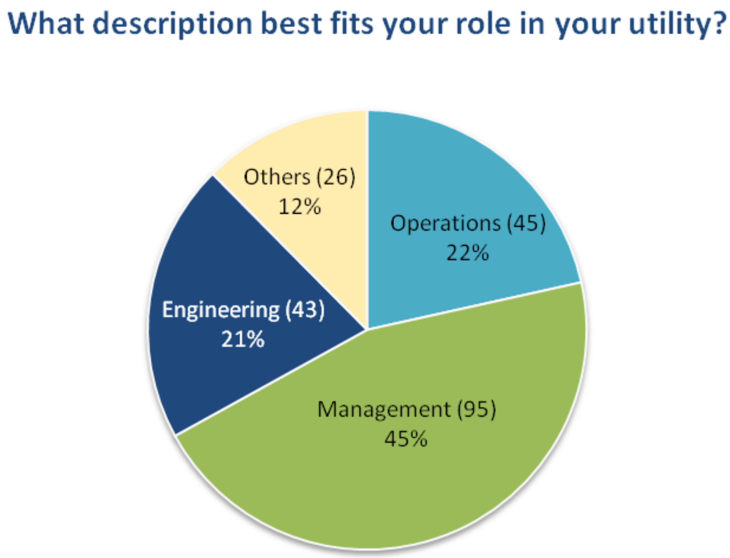
4.1 Overview of Respondent and Plant Data

At the conclusion of the online survey period, the project team analyzed and categorized the responses received based on the following information:

- Role of respondent within the utility
- Plant size
- Biogas use category
- Rated plant flow and biogas use
- EPA region and biogas use

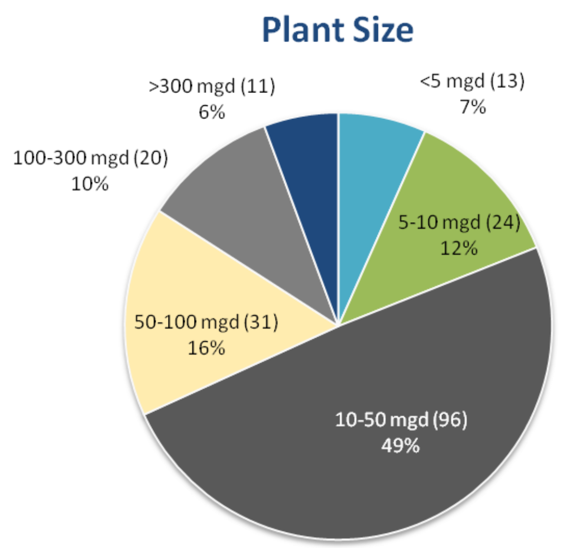
The 209 survey respondents represented a cross-section of utility personnel, represented primarily by management, engineering and operations, as shown in Figure 4-1.

Figure 4-1.
Responses by Respondent – Defined Role Categories



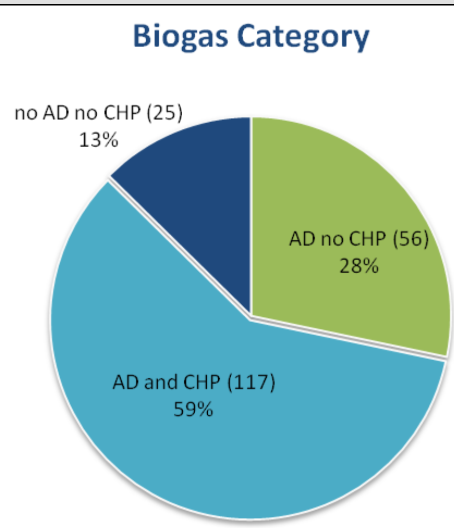
Respondents from plant sizes ranging from less than 5 mgd to greater than 500 mgd participated in the survey, as shown in Figure 4-2. Medium-sized plants predominated, with 61% of respondents from plants ranging from 5 to 50 mgd.

Figure 4-2.
Responses by Plant Sizes



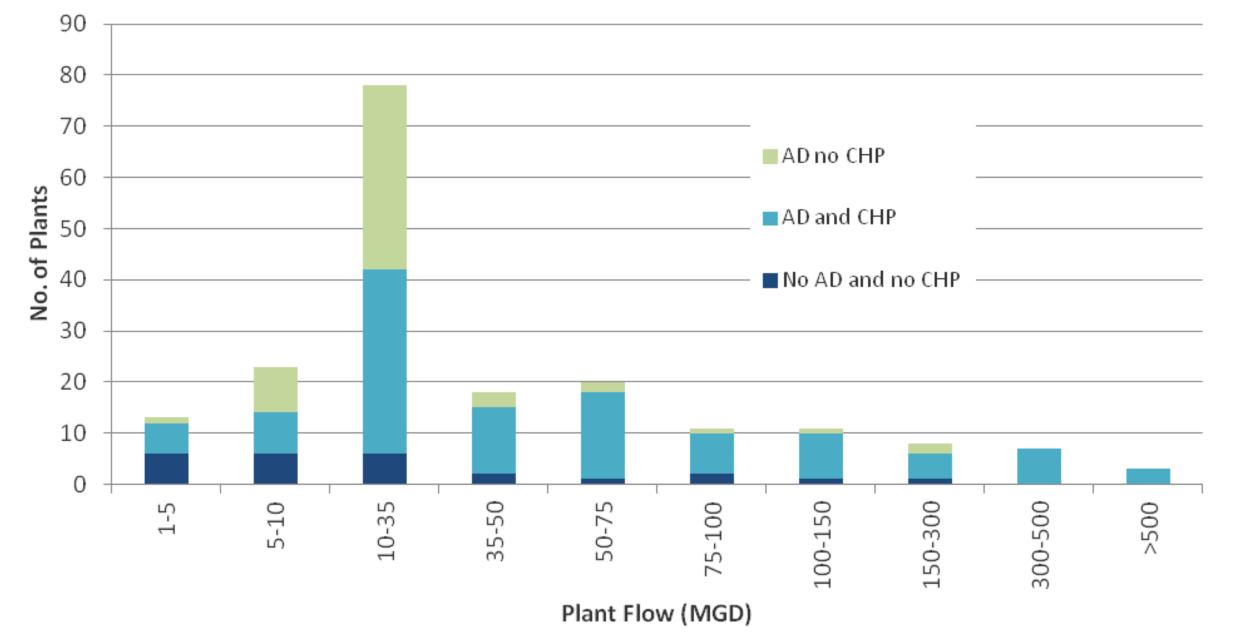
A good representation was received among the three biogas use categories, as shown in Figure 4-3. Group II-AD-and-CHP had the largest overall response; this may be because this category included not only those facilities that currently have CHP, but also those that are planning on investing in biogas use in the near future.

Figure 4-3.
Responses by Biogas Use



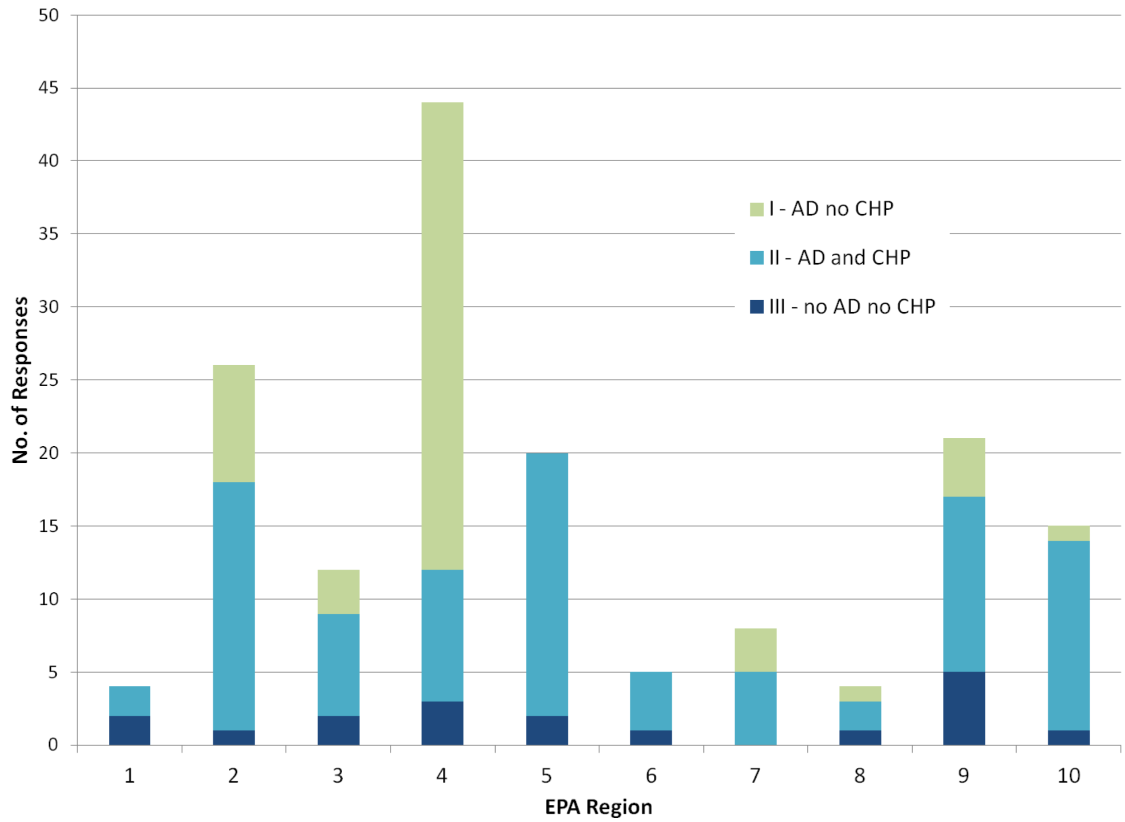
Plotting plant size and biogas use categories brings out some interesting patterns as shown in Figure 4-4. As expected, the number of responses from category III-no-AD-no-CHP decreases as plant size increases, with most of the responses from facilities less than 35 mgd. Responses from plants in category II-AD-and-CHP, that have or will be investing in biogas use, are represented across all plant sizes; and all responses from plants larger than 300 mgd fall within this group. Responses from category I-AD-no-CHP peak around the medium plant sizes, large enough to have anaerobic digesters, but whose biogas productions are not necessarily sufficient to justify investment in CHP.

Figure 4-4.
Responses by Plant Flow



Plotting EPA region and biogas use category may indicate where state subsidies or electricity costs may be driving investments in CHP. As shown in Figure 4-5, responses were received from all 10 EPA regions, with some regions more strongly represented than others.

Figure 4-5.
Responses by EPA Regions



4.2 Barrier Analysis Results by Biogas Use Category and Role of Respondent

The survey results were graphed for each biogas use category so that the relative significance of each barrier would be readily identifiable. In addition, the graphs include results according to position or role within an organization so that differences in perspectives can be discerned. These findings are presented in the next sections.

4.2.1 Group I

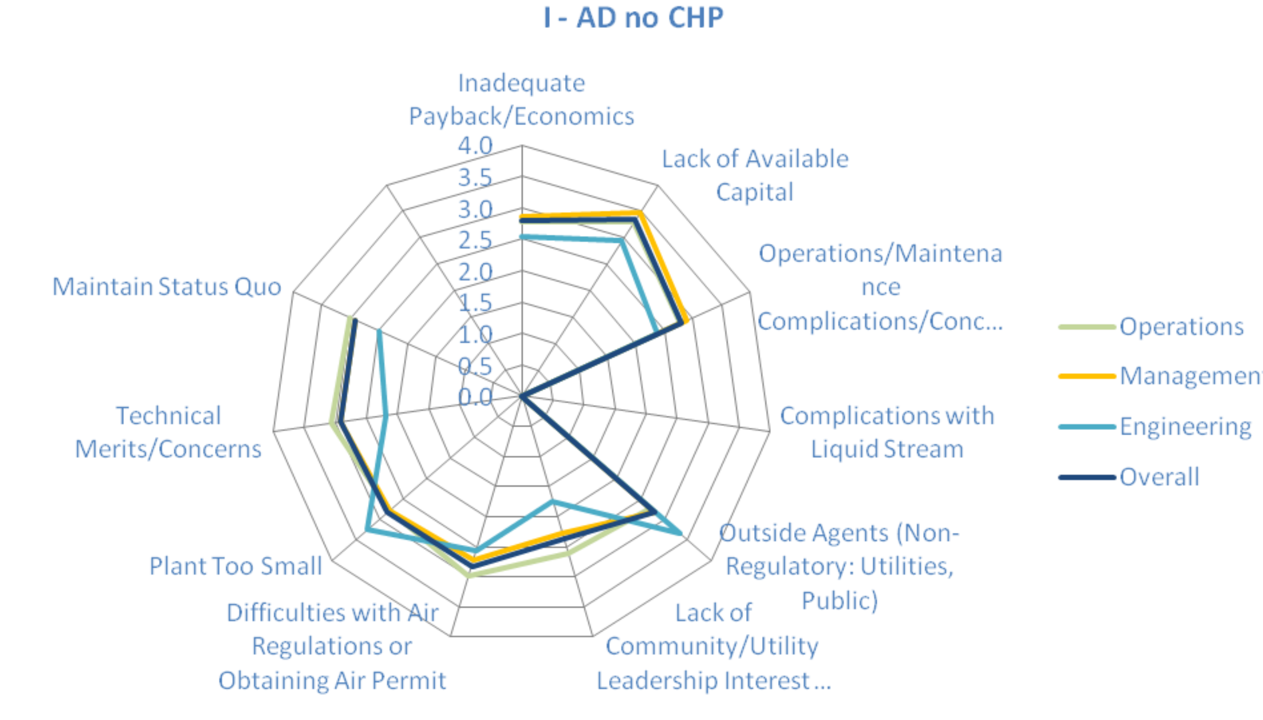
Disregarding differences in perspective among operations, management, and engineering, it can be concluded that the most important barriers for plants in Group I (AD-no CHP), are the following, as shown in Figure 4-6:

1. B) lack of available capital
2. Tie between:
   I) technical merits/concerns, and
   J) maintain status quo

Some of the interesting differences among respondent categories included the following:

1. Operators consider:
   F) lack of community/utility leadership interest in green power,
   G) difficulties with air regulations or obtaining air permit,
   I) technical merits/concerns, and
   J) maintain status quo more important compared with managers and engineers.
2. Managers consider:
   A) inadequate payback/economics,
   B) lack of available capital, and
   C) operations/maintenance complications/concerns more important compared with operators and engineers
3. Engineers consider:
   E) outside agents (non-regulatory: utilities, public), and
   H) plant too small as more important compared to operators and managers.

Figure 4-6.
Barrier Analysis Results: I–AD-no-CHP



4.2.2 Group II

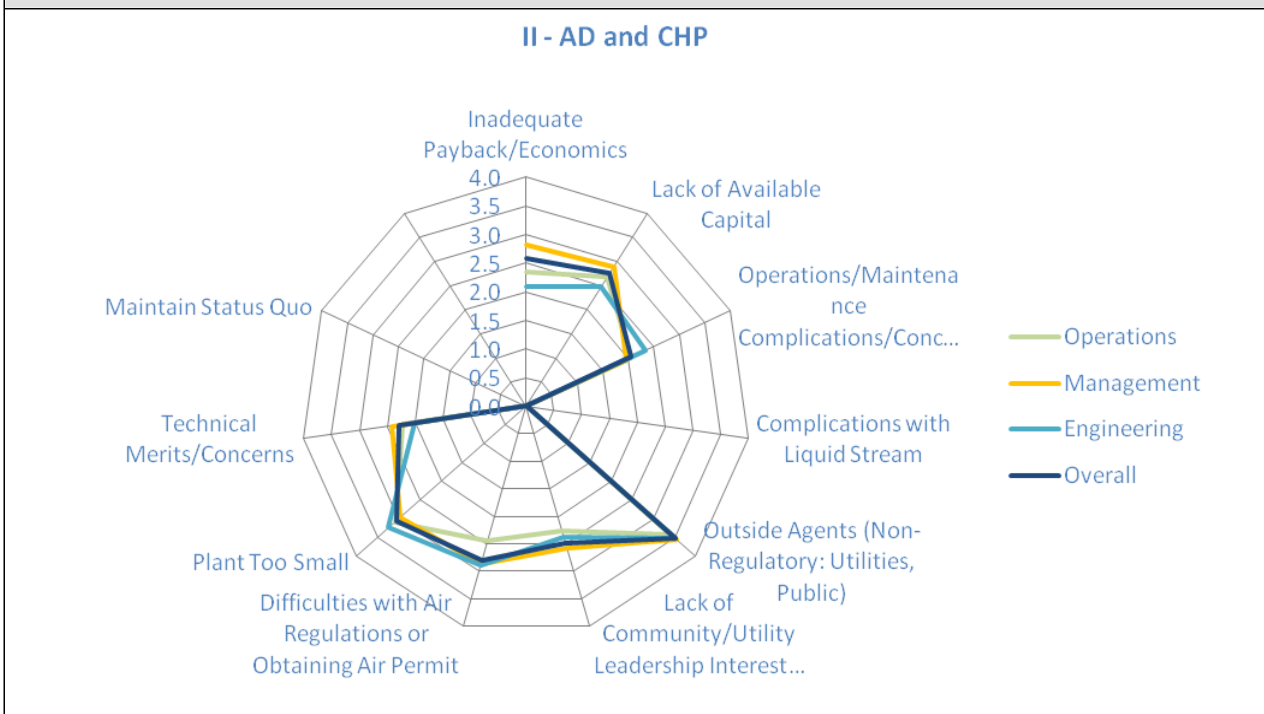
The most important barriers for plants in Group II (AD and CHP), as shown in Figure 4-7, are the following:

1. E) outside agents (non-regulatory: utilities, public)
2. H) plant too small

Discrepancies among the different perspectives included the following:

1. Operators consider every category as less important compared with managers and engineers.
2. Managers consider:
   A) inadequate payback/economics,
   B) lack of available capital,
   E) outside agents (non-regulatory: utilities, public),
   F) lack of community/utility leadership interest in green power, and
   I) technical merits/concerns more important compared with operators and engineers
3. Engineers consider:
   C) operations/maintenance complications/concerns and
   H) plant too small as more important compared with operators and managers.

Figure 4-7.
Barrier Analysis Results: II – AD and CHP



4.2.3 Group III

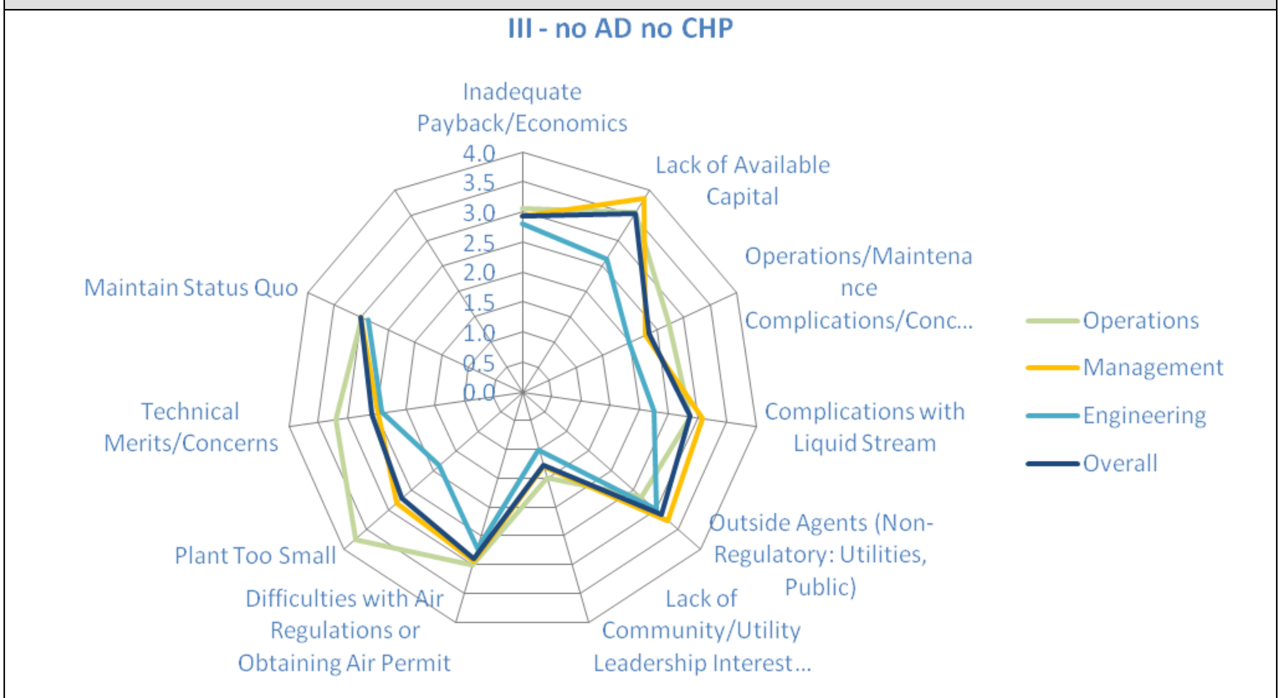
In general, it can be concluded that the most important barriers for plants in Group III (no-AD-no-CHP), as shown in Figure 4-8, are the following:

1. B) lack of available capital
2. E) outside agents (non-regulatory: utilities, public)

It is interesting to note the discrepancies among the different perspectives, including the following:

1. Operators consider:
   A) inadequate payback/economics,
   C) operations/maintenance complications/concerns,
   F) lack of community/utility leadership interest in green power,
   G) difficulties with air regulations or obtaining air permit,
   H) plant too small, and
   I) technical merits/concerns more important compared with managers and engineers.
2. Managers consider:
   B) lack of available capital,
   D) complications with liquid stream, and
   E) outside agents (utilities/public) more important compared with operators and engineers
3. Engineers consider all categories less important compared with operators and managers.

Figure 4-8.
Barrier Analysis Results: III – No AD No CHP



4.2.4 All Groups

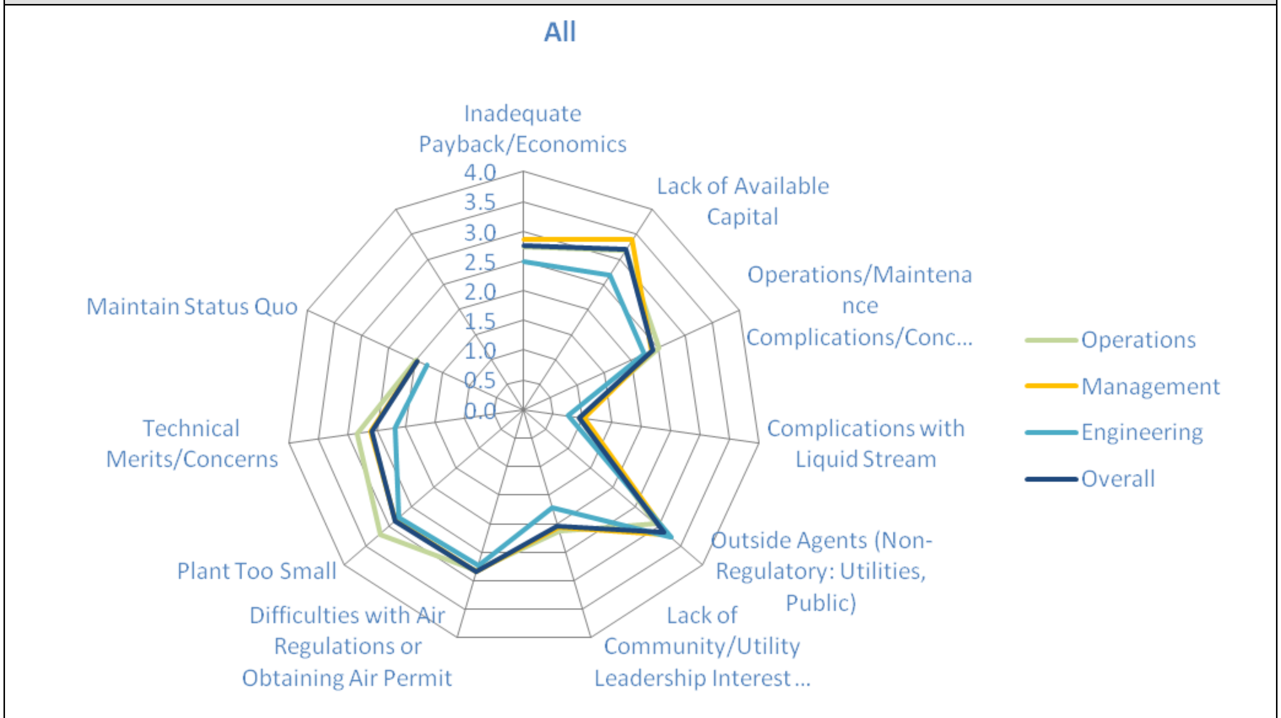
Considering all responses, it can be concluded that the most important barriers most strongly affecting all respondents, as shown in Figure 4-9, are the following:

1. B) lack of available capital
2. E) outside agents (non-regulatory: utilities, public)
3. Three other barriers are close: plant too small, difficulties with air regulations or obtaining air permit, and inadequate payback

Discrepancies among the various operational roles included the following:

1. Operators consider:
   C) operations/maintenance complications/concerns,
   H) plant too small, and
   I) technical merits/concerns more important compared with managers and engineers.
2. Managers consider:
   A) inadequate payback/economics and
   B) lack of available capital more important compared with operators and engineers
3. Engineers consider:
   E) outside agents (utilities/public) more important compared with operators and managers.

Figure 4-9.
Barrier Analysis Results: All



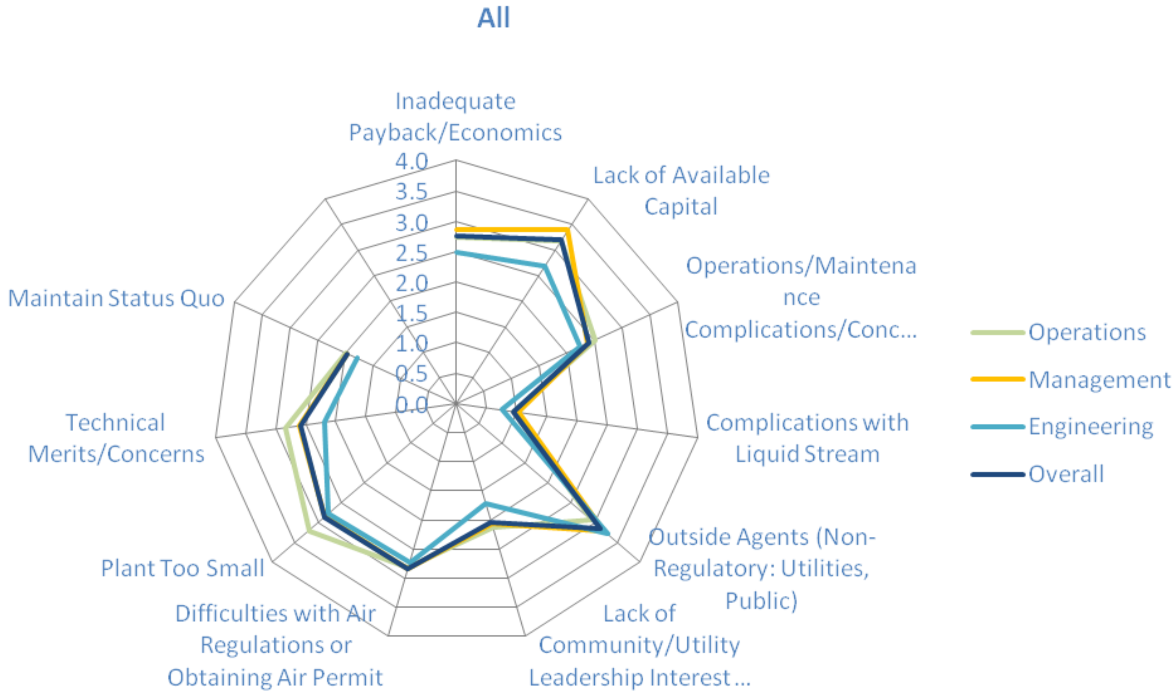
4.3 Is the "Plant Too Small" Barrier for Real?

Some particular statements related to plant size were brought outside their barrier category classification and looked at in more detail. Results were plotted versus plant size to determine if plant size is really as important as it has been hypothesized. The results from this analysis are shown below.

4.3.1 Group I

Respondents from plants between 5 and 50 mgd somewhat agree that the size of their plant and gas quantity are barriers for using CHP. Above that, plant respondents disagree that the size of their plants is a barrier, but somewhat agree that their gas production is a barrier. Note that this plot in Figure 4-10 is based on 55 responses, out of which 39 (71%) are between 10 and 35 mgd.

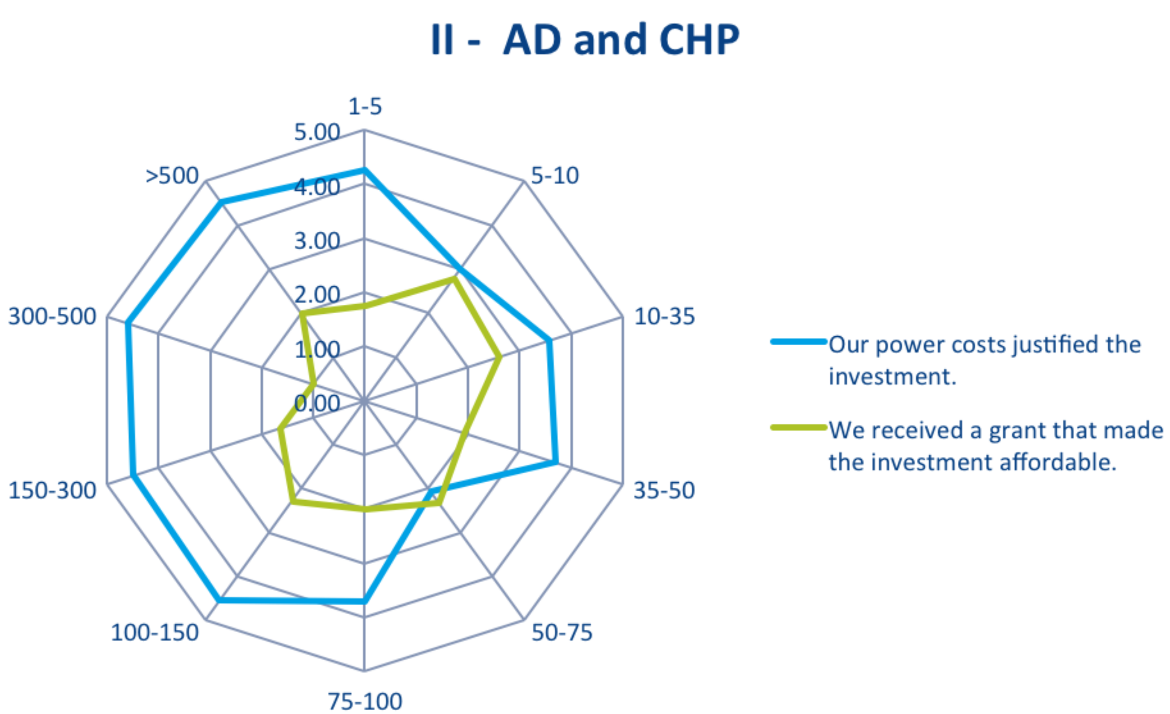
Figure 4-10.
Reality Check on "Plant Too Small" Barrier: I – AD no CHP



4.3.2 Group II

At greater than 75 mgd, respondents from plants with CHP strongly agree that their power costs justify the investment in CHP. All plants either strongly or somewhat disagree about the second statement, which indicates the infrequency of receiving CHP grants. This plot in Figure 4-11 is based on 112 responses.

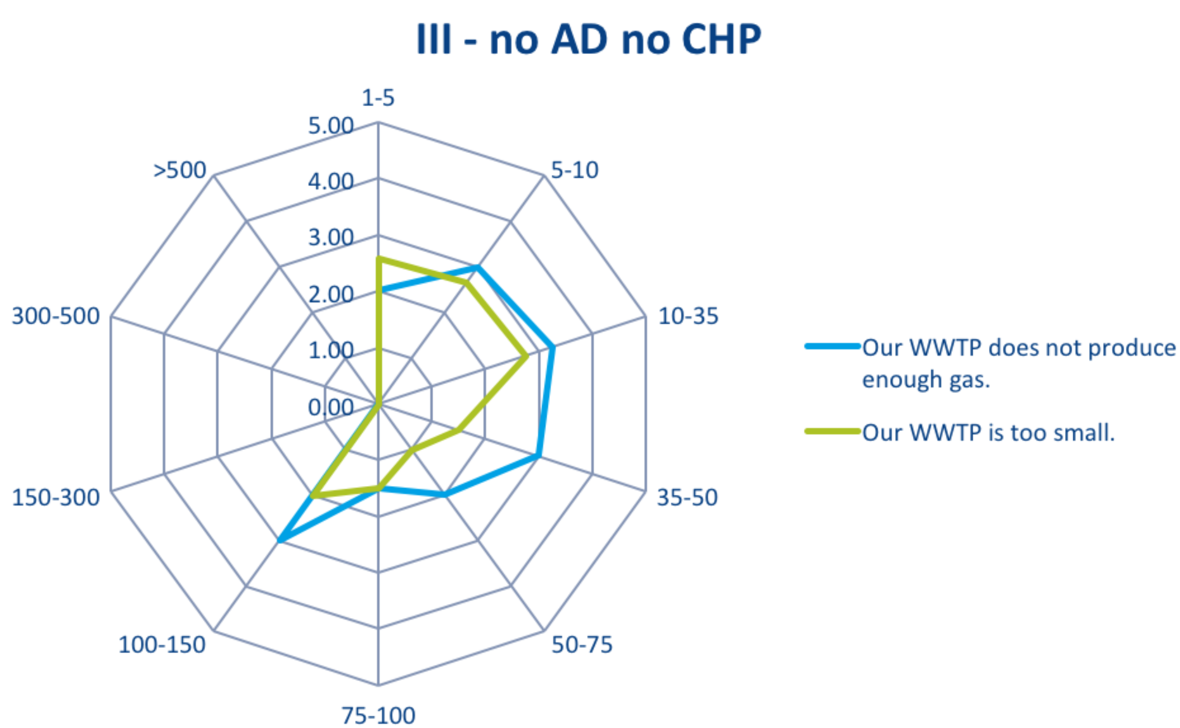
Figure 4-11.
Reality Check on "Plant Too Small" Barrier: III – AD and CHP



4.3.3 Group III

A similar pattern is observed for plants without anaerobic digesters. Respondents from plants between 5 and 50 mgd note that gas quantity is somewhat of a barrier for using CHP. However, those same respondents do not agree that their plant is too small. Note that this plot in Figure 4-12 is based on 25 responses, out of which 18 (72%) are below 35 mgd.

Figure 4-12.
Reality Check on "Plant Too Small" Barrier: II – No AD No CHP



CHAPTER 5.0

FOCUS GROUPS

A series of focus group meetings was held to gather additional data on barriers to beneficial biogas use and validate the survey findings. These meetings were held across the United States in conjunction with state or national association conference events:

- WEF Nutrient Recovery and Management 2011 in Miami, FL, 1/9/2011
- New York Water Environment Association Annual Conference in New York City, NY, 2/9/2011
- WEF Residuals and Biosolids 2011 in Sacramento, CA, 5/25/2011
- WEF Water and Energy 2011 in Chicago, IL, 8/3/2011

A summary of each focus group meeting is provided in the following sections.

5.1 Miami, FL Focus Group Meeting

The first focus group for this project was held in Miami, Florida on January 9, 2011 in coordination with the WEF Nutrient Recovery and Management Conference. One representative from each of the following four agencies participated:

- Alexandria Sanitation Authority, Virginia
- Miami-Dade County, Florida
- Tropicana/Pepsi, Florida (industrial treatment facility)
- Hampton Roads Sanitation District, Virginia

Three project team members, a WERF representative, and an engineering consultant also attended the focus group. The goal of the focus group was to delve deeper into the barriers that were deemed most significant during the initial survey data analysis.

The focus group began with a presentation of initial results from the online survey. This triggered a discussion on the meaning of the results. Economic barriers were identified as the most significant in the online survey. Discussion by the attendees reinforced that this is the most critical issue, at least on the surface. Evaluating project payback, which involves considering a variety of factors (e.g., capital costs, expected revenues, etc.) was identified as a major part of the decision-making process regarding whether to undertake an anaerobic digestion and/or CHP project. In utilities' decision making, it was found that many rely on simple payback, as opposed to more complex economic analyses.

There is often a real or perceived lack of capital and economic payback, attendees agreed, and the highest priority for spending limited resources is to meet regulatory or permit requirements. The group indicated, however, that how economics influence decisions is far more complex and involves other considerations such as consumer confidence and political significance.

Other factors, such as level of knowledge and personal bias, affect decisions about biogas use projects. Promoters and detractors of a project have been known to manipulate projections and cost estimates in favor or against a proposed project. The level of knowledge (or lack thereof) of the decision makers and their preferences is considered a strong, underlying influence, as long as the payback is reasonable.

Technical barriers were the second topic discussed at this focus group. The attendees noted that there is a wide variety of experience and knowledge regarding different technologies available for anaerobic digestion and CHP – some technologies have been successfully operated for an extended period, some are new, and some are rapidly changing. This, as well as reports and rumors of others' negative experiences, lead to a cautious approach on the part of many managers and operators. There also was concern about unexpected impacts on other parts of operations (anaerobic digestion and CHP projects often include interacting with outside agents such as power companies; CHP ownership can also be more complex and can involve high operations and maintenance costs). As with the discussion of economic barriers, this discussion pointed to the underlying concern about the level of knowledge of decision makers and the influences of their pre-conceptions, preferences, and style of management.

Operations and maintenance barriers were briefly discussed by this focus group. The most significant operations and maintenance concern was about the safety of dealing with biogas.

The "status quo" factor and inertia were mentioned by this focus group. This may be because some people in an organization – or the organization as a whole – like things to stay the way they are. The attendees agreed that at least some people see this as a barrier. It was noted that the survey data seemed to show a difference in perspective between operators and managers regarding the importance of this barrier. It was noted by one participant that the status quo for some facilities includes anaerobic digestion and CHP.

Decision making was a concern, or barrier, clearly identified by this focus group. The group identified a wide variety of factors that influence how decisions are made within any organization. These included mandates from upper management; politics; public recognition; payback and other economic considerations; how the organization manages compliance, risks, and uncertainties; the ability of technical staff to communicate the complexities of the proposed project; and the lack of compliance or consent orders as drivers for anaerobic digestion and CHP projects.

Based on feedback from the attendees, it became clear that many identified barriers were intertwined. The discussions in the Miami focus group concluded with uncovering key root-causes of barriers:

- Uncertainties – how do the people and organization deal with them?
- Communications – is there effective communication, especially of the complexities involved?

- Experience/level of knowledge – to what extent does a person's or organization's experience and level of knowledge regarding anaerobic digestion and CHP influence their decisions?

These findings informed the development of the subsequent focus groups and the initial formulation of some hypotheses.

5.2 New York City, NY Focus Group Meeting

The second focus group was held on February 9, 2011, in conjunction with the New York Water Environment Association (NYWEA) Annual Conference. Eleven utility attendees participated, representing the following seven utilities:

- New York City Department of Environmental Protection
- Binghamton-Johnson City WWTP, New York
- Narragansett Bay Commission, Rhode Island
- City of Nashua, New Hampshire
- Washington County Sewer District #2, New York
- Westchester County, New York
- Fredonia, New York

In addition, two project team members and six other interested observers attended the focus group. A brief overview of the survey responses was given and most of the session focused on gathering further feedback on barriers to biogas use from those in attendance. Following are the key barriers encountered by the utilities represented, according to participants.

No standard method is available for evaluating the economic viability of CHP projects. As previously expressed by Miami focus group attendees, it was determined that arguments about the economics of a project can be driven by motivations of the promoter or decision maker. In some cases, the threshold for payback may be three to five years, which can be difficult for CHP to meet. For other utilities, a reasonable payback may be 10, 20, or as much as 30 years or the "bond period" for the expended capital. The choice of a reasonable payback period is not purely about economics, but about the perspectives of the decision makers.

Economic targets for CHP relate inversely to anticipated risk. Working against economic viability were low electric and natural gas prices, competition for capital, and bonding requirements. According to one focus group participants, electric savings sometimes accrue to general government rather than to the utility. Participants whose utilities had anaerobic digesters and no history of CHP said they had expectations that a fast payback would overcome resistance caused by other barriers.

The group expressed concern about several uncertainties and risks created when adding AD and/or CHP, including the following:

- Increased operations and maintenance expenses
- Inadequate biogas to support desired electricity production

- AD facilities at the end of their useful life (uncertain upgrade costs)
- Additional maintenance requirements

Approaches to mitigate or offset these risks included expected revenues for taking in HSW and fats, oils, and grease (FOG), and availability of grants and state-supported financing (especially true for NY State WWTPs through NYSERDA).

Public support for CHP and biogas use can be uncertain and time-consuming to engage. Where elected officials promoted biogas programs, good support and few obstacles occurred. Getting buy-in from multiple jurisdictions and layers of bureaucracy may be difficult for regional plants. Voluntary CHP proposals may require a time-consuming public awareness campaign, which is a barrier. While public support for CHP as a recycling alternative is attainable and odor and noise issues can be successfully addressed, it was noted that any new project becomes an opportunity for the public to raise old issues.

The decision-making process for CHP is challenging because of significant uncertainties. Technologies for biogas-to-energy are complicated to assess and select. Experience with microturbines has been short, and fuel cells are a relatively new technology. Capital and operating expenditures for gas pre-treatment, gas blending, switching, and substation modifications are complex and can increase the budget.

CHP adds technical complications to utilities' missions. Biogas treatment has potential to be viewed as complicated and expensive, particularly for siloxanes. Biogas production and energy quality vary seasonally, which affects electricity production. Connections to electric grid or gas pipeline have been complicated by poor relationships with those other utilities.

Agencies may not have the manpower to handle CHP equipment, and staff may not be equipped to service equipment beyond routine maintenance. In addition, experienced staff is retiring. If agencies hire outside for operations and maintenance, the additional costs mean the payback period for the CHP project is longer.

Third-party partnerships for energy projects were considered difficult. On the other hand, the third-party model for build-own-operate of CHP at WWTFs can address capital and operating risk issues, as well as employ tax incentives unavailable to public agencies. Some agencies resist approaches that profit private firms, and successful cases are not well publicized and known. Other agencies have resisted complicated, long-term, direct relationships with power utilities and energy service companies.

Air regulations have been a high hurdle for CHP in some instances. The air regulation barrier has not been fully evaluated/addressed by this industry. Air quality in major urban areas raises health issues, and citizens often oppose new air pollution sources. Where there already is an air permit, agencies have had an easier time installing equipment. Time delay is a barrier; permitting in some states takes up to two years. Small plants have often found permitting too costly relative to project benefits. For larger plants, biogas combustion would count against Title V nitrogen oxide (NO_x) nonattainment caps and would impose reporting burdens.

CHP has, in some instances, competed poorly with the core business of wastewater treatment. Human resources within the WWTF can limit new projects, particularly outside the core mission of achieving effluent quality. WWTF managers and operators have resisted novel projects because such projects impose new workloads that they believe distract from standard procedures and risk creating compliance issues.

Since energy use has not traditionally been a high-priority performance metric at many wastewater treatment plants, utilities have not had incentives for renewable energy development. This lack of energy management as a high priority has been a strong barrier, especially where investment in CHP would compete with "state-of-good repair" maintenance projects.

Two conclusions were reached related to successful projects:

1) An impassioned champion internal to the plant has been a key factor in the success of many CHP projects.

2) Education on successful case studies has increased internal support.

5.3 Sacramento, CA Focus Group Meeting

The third focus group was held at the WEF Residuals and Biosolids conference on May 25, 2011. At this focus group, one representative from each of 11 utilities was in attendance from across the country and Canada. Ten observers and five project team members also attended. Similar to previous focus groups, the objective was to continue to collect information regarding barriers to biogas. At the end of the session, a barrier ranking exercise was performed. Representatives from the following utilities participated in the focus group:

- Sacramento Regional County Sanitation District, California
- Upper Occoquan Service Authority, Virginia
- Hampton Roads Sanitation District, Virginia
- Renewable Water Resources, South Carolina
- City of San Jose, California
- Metro Vancouver, Canada
- City of Los Angeles, California
- DC Water, District of Columbia
- City of Gastonia, North Carolina
- City of Livermore, California
- Charlotte-Mecklenburg Utilities, North Carolina

The economics of CHP were a significant part of the Sacramento focus group discussion. In areas with low electricity costs, the economics of CHP can be marginal and payback less than optimal. Some utilities have received low-interest financing that helped the projects move forward. In addition, using more aggressive power cost escalation assumptions has improved paybacks. For some of the attendees, changing the economics discussion from simple payback to annual cash flow savings has made CHP projects more attractive.

Ways to creatively finance CHP projects were discussed at this focus group, including the following:

- Instead of increasing customer rates dramatically at the beginning of a project, delayed or ballooning bond payback models have been used so that rates go up slowly at first and the larger debt service is mostly paid off during the period when the project is operational and begins to bring in revenue and save money on energy costs.
- Green power credits (e.g., renewable energy credits/RECs) were noted as not having significant value now but they could become more valuable in the future and positively impact CHP economics.
- Augmenting biosolids with high-strength wastes (such as FOG) can generate new revenue streams that improve the economics.
- Grants and incentives can improve the popularity/salability of projects but, depending on their size, may or may not improve payback significantly. For example, if a utility was to receive a grant that covers five percent of a project, it has created urgency that moved projects forward. Free money often has influenced the politics and economics of a project.

Many demands for limited capital budgets was a significant topic for this focus group . CHP has typically been seen as a discretionary project, compared with those projects required by regulatory mandates. Stronger political support has often been given to competing demands for efforts like repair of aging infrastructure that must be fixed. This has made it difficult for some agencies to even find funding to study or evaluate CHP projects, much less to design and construct them. For one utility, engineering estimates from several years prior helped convince decision makers to fund their discretionary CHP project. This, along with grant funding and low-interest financing, helped sell the project to the utility board. It was agreed by the attendees that decision makers typically are focused on the economics of the project and avoid taking risks. Utilities have to work hard to make these projects attractive to decision makers.

Operations and maintenance complications was another topic the group discussed. In general, there was concern about the skill set needed to maintain and operate CHP equipment. In addition, plant staff tend to have the outlook that they treat wastewater and don't need to be in the business of generating power. In the recent challenging economic climate, operators have to do more with less staffing; adding a new process can stretch staff even thinner. Some risk is perceived in training staff to use CHP equipment: by training staff to operate and maintain this equipment, it gives them a market skill that they may use to get a new job elsewhere with a higher salary. There was discussion regarding the considerable time demands required in operating and maintaining CHP equipment.

For several utilities, especially those in California, the biggest barrier has been air regulations. Internal combustion engines are a proven CHP technology, but they have been discouraged or, in a few instances, prohibited by air regulators. On the other hand, fuel cells are advantageous with regard to air permitting, but they do not have long, successful operating histories. Regulators have often ignored flaring as an emissions source; this oversight has often pushed utilities to simply flare (waste) the biogas, because fuel cells have not been justifiable from an economic standpoint and internal combustion engines have not been allowed. Some

CHP projects have forced utilities into Title V air permitting for the first time. It was noted that education of air permitting authorities is critical to the success of CHP projects.

Challenges working with outside or third parties – especially with power companies – was a significant topic of this focus group. In some energy service company (ESCO) contracts, the WWTFs have received little return for the value of biogas and would have received greater benefit owning the biogas use project themselves. In some areas, WWTFs cannot provide energy directly to the grid due to regulations or utility policies and can only use the energy onsite. In some jurisdictions, generation of power from biogas is not classified as "renewable." Some agencies have hoped to get the same price for energy generated from biogas as an electric utility pays for solar or wind power, but this often does not happen. Power companies have the upper hand in negotiations and are politically connected.

Making decisions based on values of sustainability was one more topic raised during this third focus group. At least two utility representatives who had championed advanced biogas use at their facilities emphasized the importance of placing value on the idea of "doing the right thing" and making decisions based on advancing sustainability. For them and others, the drive to "do the right thing" had helped surmount all barriers and bring projects to fruition.

5.3.1 Prioritization Exercise

At the conclusion of the focus group, the participants conducted an exercise to prioritize the barriers to biogas use that had been identified throughout the project. The group identified the following three barriers as being most significant:

- Economics: simple payback or return on investment
- Competing demands on capital for discretionary projects
- Operations and maintenance concerns

A brief discussion was held regarding strategies to mitigate these barriers. The following were identified by this focus group:

- Improve the economics of CHP projects by considering grants, green credits, and delayed or ballooning bond payback models
- Boost biogas production by accepting high-strength wastes and FOG that provide new revenue streams
- Create better operator training programs for CHP technologies
- Use triple-bottom-line assessments that can monetize or attribute value to non-economic environmental and/or social benefits (this is how "doing the right thing" is formally evaluated and justified)
- Outsource or create public-private partnerships with extended terms; many agencies are wary of long-term agreements, but such agreements may be needed so that private entities can recover their investments at reasonable operational costs
- Conduct additional investigations of potential electrical or energy rate structures beyond those currently in use between agencies and power utilities. For example, having on-site

power generation at a plant may allow the agency to take on a more risky rate structure because, by producing its own energy, the plant has additional flexibility to alter its demand from the outside grid at any given time of day

5.4 Chicago, IL Focus Group Meeting

On August 3, 2011, the project's fourth and final focus group meeting was held in Chicago, Illinois in conjunction with the WEF Water & Energy 2011 conference. Eight utilities participated in the focus group, as well as attendees from U.S. EPA, Focus on Energy, and other interested third parties. In total, there were 22 people in attendance at the focus group, with representatives from the following utilities:

- City of St. Petersburg, Florida
- City of New York, New York
- East Bay Municipal Utility District, California
- Western Lake Superior Sanitary District, Minnesota
- City of Sheboygan, Wisconsin
- City of Los Angeles, California
- City of Honolulu, Hawaii
- Washington Suburban Sanitary Commission, Maryland

The goal of the focus group was to validate the findings on barriers to date. This was done by presenting a series of hypotheses on barriers to CHP that were developed by the project team using survey results data and feedback from previous focus groups. At the end of session, the attendees brainstormed strategies to overcome barriers that had been discussed.

Economics (payback) and competing demands on capital. The hypotheses stating that the most significant barriers to CHP are economics and limited or competing demands for capital were confirmed by the attendees.

> DC Water found inspiration in a delayed-bond-principal model so that sewer rates rise only slightly and steadily. The utility's experience is featured in Appendix A.

As previous focus groups noted, showing that CHP projects have an acceptable payback period is often difficult. Complications include low power costs, difficult contract contexts, and high CHP maintenance costs that undermine payback. Perceived economic barriers can arise from highly conservative approaches in administrative decisions and from conservative assumptions, particularly with estimates of future power costs. With such uncertainties regarding material and power costs, decision makers may require short paybacks to hedge the risk.

It was noted that utilities most typically use simple payback as their metric for project financial feasibility, while other well-accepted financial evaluation metrics such as return on investment (ROI) and net present value (NPV) may produce a more accurate portrayal of a project's benefits.

But even for utilities that are doing so, these sophisticated analyses often are boiled down for decision makers who then evaluate projects using simple payback. The attendees noted that CHP projects suffer from demands for short paybacks that are not expected from other types of improvements.

The following strategies to overcome economic barriers to CHP were discussed:

- Use better financial comparison metrics, i.e. net present value (NPV), return on investment (ROI), as opposed to relying on simple payback. Highlight cash flow potential, especially over the long term, to decision makers. Include service life of the equipment in the economic analysis.
- Boost biogas production and, thus, revenues, by introducing alternative feedstocks, such as FOG and other HSW. Note that including alternative feedstocks can result in two financial benefits: a tipping fee for the "waste," and an increase in biogas production that results in greater reductions in purchased energy costs.
- Negotiate better contracts with power utilities and natural gas companies. The ability to produce a wastewater utility's own power allows it to mitigate risk associated with variable electricity (real-time) pricing. The potential to save costs with less predictable rate structures is real and yet nearly impossible to predict. Power utilities' complex rate structures often force assessments based purely on the average cost of power, and potential savings from demand charges and peak-rate consumption are often underestimated.
- Improve integration of risk management into the economic evaluation. For example, a WWTF with CHP will control the production and cost of some of the power it uses, which is a benefit in comparison to being completely at the mercy of the power company. Other areas of risk, such as health and safety impacts of flaring biogas, should be tied into a holistic evaluation of the costs and benefits of CHP.
- The market framework for biogas needs to be improved to help justify economics. Biogas should be classified as a high-value renewable energy source. RECs, although at low valuations currently, should be considered in financial analyses especially with renewable portfolio standards (RPS) coming into effect.
- Optimize solids processing and operations to maximize efficiencies, cut costs, and maximize return on investment.

Working with third parties (outside agents). Another hypothesis discussed by this fourth focus group is that third parties, such as power companies and natural gas utilities, are barriers to beneficial biogas use. When considering CHP or biomethane production, utilities must address agencies with which they are unfamiliar and whose drivers they do not know or understand. Many power companies are not willing to accept electricity produced from biogas due to concerns over whether the power is consistent or whether it might cause a problem for the grid. If the power companies do accept renewable energy generated from biogas, it is usually at a relatively low rate, sometimes well below the cost the utility pays to purchase electricity from the grid. It was acknowledged that power from the grid is getting less reliable in some places; reliability is particularly challenging when two independent sources of power to a wastewater treatment plant are required, as stipulated in some NPDES discharge permits. This presents wastewater utilities an opportunity to use renewable energy from biogas as an alternative, more reliable, supplemental source of power.

When it comes to the potential for converting biogas to biomethane (pipeline quality biogas), the following barriers were significant:

- Natural gas is inexpensive
- Making biogas of sufficient quality is costly
- Shifting between different gas types is challenging
- Concerns about gas quantity variability and being able to guarantee a base load

For utilities working with power companies and natural gas utilities, requirements can change frequently and managing this long-term risk and potential for contract changes is difficult.

This focus group identified the following strategies for overcoming barriers associated with working with third parties:

- Leverage existing conversations and relationships with regulators, power companies, and natural gas utilities to discuss CHP. One example suggested by utilities was to collaborate on emergency operations.
- When negotiating with power companies, present an entire portfolio of customers to improve a bargaining position. For example, industry, factories, schools, and canneries use steam, which WWTFs can provide. In addition, a WWTF can provide cooling water needed for electric power production, which can be something to offer in negotiations.
- Provide better and faster exchange of information between industries to "demystify" CHP. Use professional organizations to assist in these efforts.
- Provide better public education on the benefits of CHP.
- Convince regulators of benefits of CHP and then use regulators to convince other regulators.

Internal decision making was briefly discussed by this focus group. A key to decision making is getting beyond the simplified economics of the project and highlighting why implementation is the right thing to do. Much of the decision-making process could be improved by education. Strategies below were presented for consideration to improve the decision-making process for CHP and other biogas use projects:

- Provide holistic education on CHP, including opportunities.
- Benchmark against other utilities to improve operations.
- Emphasize cost-efficient operations.
- Engage internal stakeholders.
- Identify a strong supporter or advocate for beneficial use of biogas within the utility to promote the project.
- Appeal to the desire to "do the right thing" regarding the triple-bottom-line.

Current policy environment. Finally, another hypothesis discussed by this focus group was that the current policy environment related to biogas use – both nationally and locally – is unclear and hinders the more widespread implementation of biogas use projects. Willingness to pay for RECs associated with electricity production from biogas is currently low. In some states, renewable energy is defined by source. In Los Angeles, a resolution was passed recognizing the value of biogas as renewable energy, but at a value much less than solar energy credits that drive that industry.

5.5 Focus Group Meetings Summary

The four focus group meetings were conducted in four different locations over a period of seven months and lasted four hours each. Representatives from a total of 30 wastewater treatment utilities of very different sizes, configurations, and geographic location were involved, as well as observers who commented from their perspectives as consulting engineers, project promoters, and government agencies. Altogether, the results of the four events created an understanding of barriers to biogas. The structure, agenda, discussion, and facilitation of each succeeding focus group built on the accumulating knowledge and experience from the prior focus group(s).

5.5.1 Methodology Assessment

Focus group members covered a wide range of topics, weighing options "outside the box," and sharing stories and ideas. The issues frequently returned to economics and decision making.

By design – and as was done with the initial online survey – the focus groups primarily sought the perspectives and opinions of employees of public wastewater treatment utilities. These managers and operators are considered to be the people with the most direct experience and insight into how wastewater treatment utilities come to decisions about whether or not to develop AD, CHP, and other uses of biogas. Each of the focus groups had some "observers" – engineering consultants, regulators, WERF staff, and project team members with significant interest in the topics being discussed, but they were discouraged from engaging extensively in the conversations, and the focus was on the utility representatives.

At the beginning of each focus group, each participant introduced himself or herself and provided key information on his or her utility, WWTF(s), and implementation status regarding anaerobic digestion and CHP. This allowed the facilitator to tailor each session to the attendees and types of facilities represented. Each focus group involved presentations about the project and the initial findings from the survey of wastewater treatment utility personnel. Each also focused on discussion of key barrier topics that the project team had identified in advance and the survey had corroborated as being significant. These discussions were facilitated and statements made by participants were validated or clarified by the facilitator, as needed. Probing questions were asked to better understand any underlying attitudes in the discussion.

In addition to the survey results, the focus groups strongly supported the survey finding that economics is the most important barrier to biogas use. "Economics" is a broad topic. Of the 10 categories developed from the survey questions and used throughout this project, two were focused on economics: "inadequate payback/economics" and "lack of available capital." These two are interrelated, and they interrelate with other barrier categories, such as "plant too small."

The universe of barriers covered by "economic" factors is large and complex. In each of the focus groups, the conversation naturally swung toward and spent more time on complex details of the economics and how the economics played a part in decision making. Thus, in almost every part of the discussions summarized above, economics are mentioned, whether the topic at hand was "technical barriers" or "working with third parties (outside agents)." Therefore, any inclination on the part of the project team to emphasize economics was corroborated and supported by the focus group participants.

In an attempt to further assess the degree to which the findings were being influenced by the project team's initial concepts of the likely barriers to biogas use, team members compiled and analyzed statements by focus group participants in relational diagrams (based on the concept of "current reality tree" diagrams). For each barrier category, every related statement from the online survey and every related statement from focus group participants were grouped on a diagram (several examples are provided in Figures 5-1 through 5-6). This led to recognition of summary statements or underlying themes that could easily be represented in the relational diagram as nodes. For example, in the economics diagram, a large number of statements heard during the project clearly pointed to the question of payback / return on investment, which is shown as a central node on the diagram. The relative importance of that node is evidenced by the volume of statements pointing to it.

By compiling and diagramming all statements made by focus group participants, additional nodes were identified. All of the nodes from all of the diagrams were then compiled on one diagram that highlighted their relationship with each other. Figure 5-7 at the end of this chapter provides a visual depiction of all the barrier categories identified and introduced initially by the project team, as well as those uncovered during the focus groups.

This relational diagramming exercise provided a rough quantitative evaluation of the level of attention given by the participants in this project (project team, survey respondents, and focus group participants) to the different identified barriers to biogas use.

5.5.2 Discussion of Focus Group Findings

The economics of proposed biogas use projects creates the most important barrier to biogas use. As seen in the relational diagrams and in the focus group summaries above, this was the topic of greatest interest. It was all about the bottom line. That was what wastewater treatment utility personnel said, over and over again, in all kinds of situations. The most important economic factors about which participants spoke had to do with payback (another way of saying "the bottom line") and availability of capital.

Economics dominated the discussions. Throughout the focus group meetings there were detailed discussions about the following:

- Standardizing methods to evaluate the economic viability of CHP projects
- Economic targets for CHP being inversely related to anticipated risk
- Trying to accurately predict future operations and maintenance and/or digester upgrade costs
- Ways to tweak economic arguments to push decisions one way or the other

Even when considering other perceived barriers, such as the other categories described by the project team (see Chapters 3.0 and 4.0), many of them pointed to economic concerns, as noted here:

- Technical merits and concerns often centered around the potential that additional costs will accrue because of new kinds of technology, different operations and maintenance needs and costs, and cost uncertainties due to inherent unpredictability of new and complex systems.
- Operations and maintenance complications are concerns to decision makers because of the potential associated costs, which made paybacks (returns on investment) uncertain.
- Working with third parties (outside agents) was a barrier discussed at all of the focus groups. It, too, created uncertainty in modeling the economics of a biogas production and/or biogas use project.

A summary diagram was prepared to illustrate the relationship among barriers. Several key challenges emerged: dealing with uncertainty, complexity, and the need for knowledge. Decision theory and innovation diffusion theory could help in understanding these.

- Complications with the liquid stream was sometimes cited as a barrier, but it was not rated as a significant barrier in the online survey and it was only minimally discussed in the focus groups. However, it too is related to economics, as the uncertainty and concerns it induces are related to the potential for additional costs needed to address proper management of return flows from anaerobic digesters.
- Other uncertainties and risks – such as the inability to predict future electricity prices – also concerned decision makers because of the potential impact on payback.
- Barriers concerning air regulations and obtaining an air permit only applied in some areas and had the effect not of stopping an AD and/or biogas use project, but of significantly changing its nature and costs. For example, in California, this barrier has forced installation of less-well-demonstrated fuel cells as opposed to long-tested, reliable engines. This barrier introduces an additional level of uncertainty and risk, making decision makers concerned about the eventual costs and payback.
- The barrier described as “plant too small” was purely an economic one. Being too small was related to the fact that not enough biogas might be produced to pay for the infrastructure required to produce and use it.
- The uncertainty about gaining public support for biogas production and use projects had a significant economic component. To develop public support costs time and money, and, if it is not eventually forthcoming, the project can end up wasting money.

There were a few topics of discussion in the focus groups that clearly did not focus on economic factors. Indeed, some of these potential barriers seem to *underlie* and/or *influence* the discussions of economics. These potential barriers, some of which were not introduced initially by the project team, rose up in all four focus groups, although they did not garner as much discussion time as the economics topics. These barriers can be summarized this way:

- **Decision making:** This topic rose up in all four focus groups. At Sacramento, discussion of decision making included the role of aiming for sustainability by "doing the right thing." The Chicago discussion of decision making focused on how it can be affected by uses of different economic modeling and accounting systems (e.g. net present value or projected future cash flow rather than simple payback) – so there was some connection to the dominant economic theme.

- **The "status quo"** barrier category came up in various but subtle ways during the focus groups. There was discussion about how developing CHP or other biogas use complicates or competes with a utility's mission and scope. There were mentions of the fact that some agencies do not like change.

- **Communication** became a topic of the later focus groups, especially as participants talked about potential ways to mitigate some barriers. There were suggestions about negotiating with power companies and regulators and informing internal staff and management more about AD and/or biogas use.

- **The levels of experience and knowledge** on the part of wastewater utility employees, management, and decision makers was a minor topic at all of the focus groups. The implication was that lack of knowledge and experience, or misinformation ("history" and rumors), have led to rejection of AD and/or biogas use projects. Several participants noted that the lack of knowledge of more thorough, complex economic analysis tools has resulted in reliance on simple payback.

- **Community and/or utility interest and leadership** was another barrier that bubbled up in discussions. The inverse of this was a commonly stated belief that many AD and/or biogas use projects have relied on one or two project champions for their success.

Some barriers appear to be deep-rooted, about which people are less aware and less willing to discuss. As was experienced in the focus groups, it was clearly easy to talk about economics, to use economics as an explanation for a decision. But the following question persistently arose: "Why has one small utility gone ahead with AD and CHP while a matching one has decided it is not cost-effective?" Given the economics of the two are the same, what barrier is the latter experiencing that the former did not?

The final three chapters explore these questions.

5.6 Relational Diagrams

For each barrier category, every related statement from the online survey and every related statement from focus group participants were grouped on a diagram. Examples of the diagrams included in Figures 5-1 through 5-6 are for the following barrier categories:

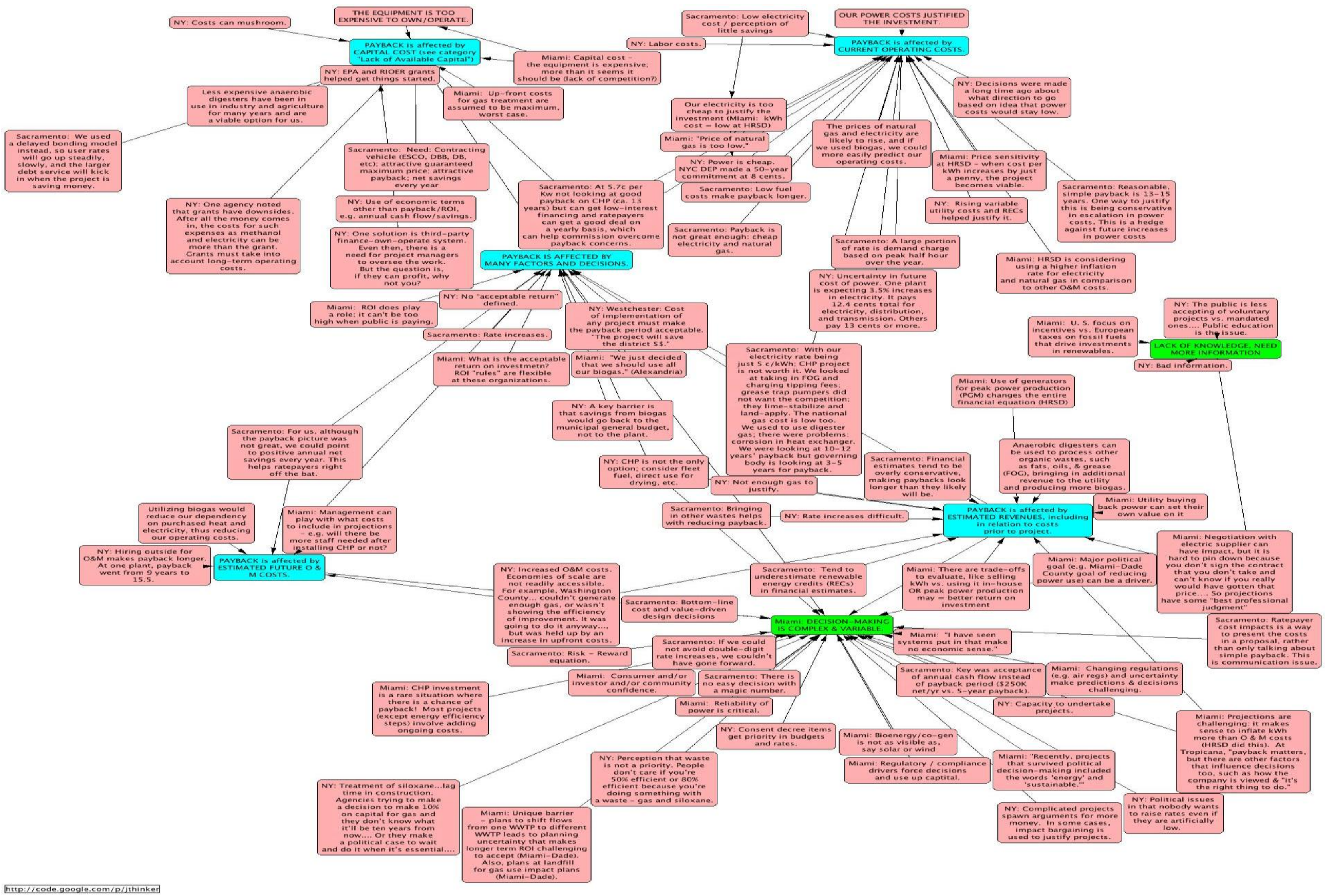
- Inadequate payback/economics
- Lack of available capital
- Operations maintenance complications/concerns
- Outside agents (non-regulatory, utilities, public)

- Technical merits/concerns
- Maintain status quo

Figure 5-7 represents a summary compilation of all of the diagrams included in Figures 5-1 through 5-6, as well as additional diagrams created for the other barrier categories. This diagram shows the interrelationships between barrier categories. It includes underlying barriers discovered during the focus groups, which seem to underlie some of the more obvious barriers. These (shown in green) include “decision making,” “lack of knowledge/need more information,” “dealing with uncertainty,” and “complexity is daunting.” The understanding represented by this diagram helped identify topics of social science research – decision theory and innovation diffusion theory (shown in cyan) – that will be helpful in addressing the underlying barriers.

Figure 5-1. Focus Group Participant Barrier Category and Statement Grouping Diagram – Inadequate Payback/Economics

For a larger view of this figure, refer to the online report pdf at www.werf.org.



WERF

Figure 5-2. Focus Group Participant Barrier Category and Statement Grouping Diagram – Lack of Available Capital

For a larger view of this figure, refer to the online report pdf at www.werf.org.

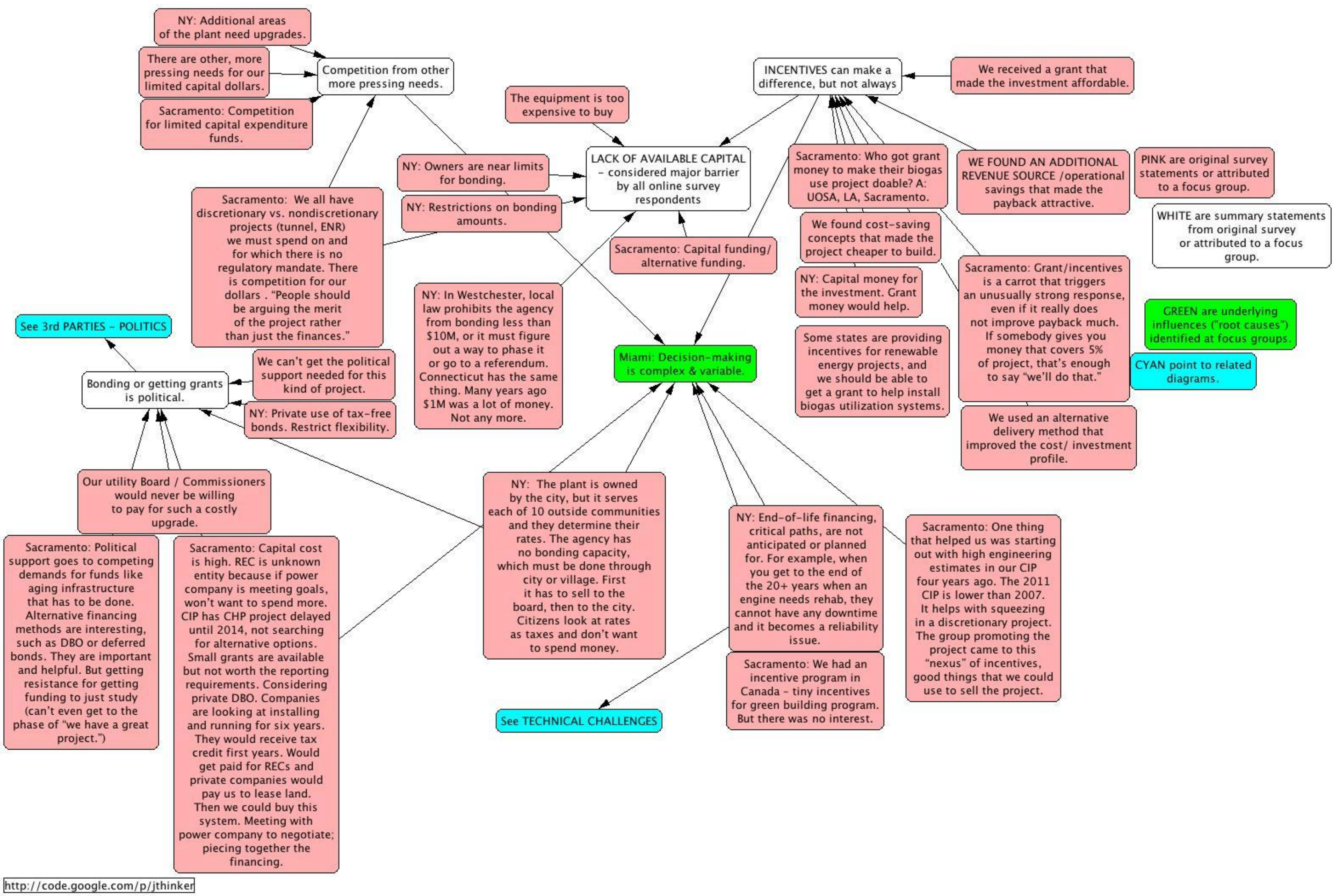
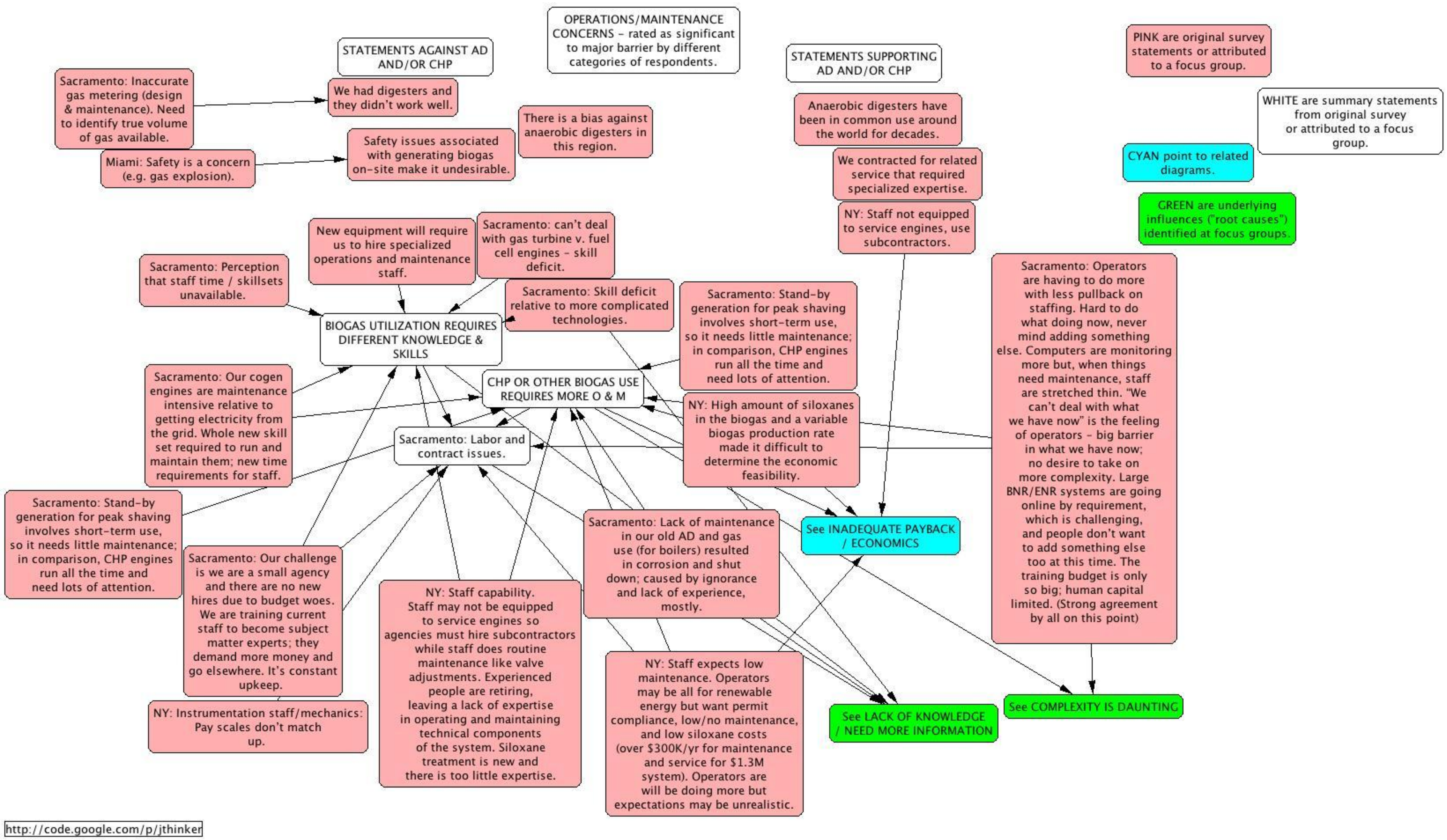


Figure 5-3. Focus Group Participant Barrier Category and Statement Grouping Diagram – Operations Maintenance Complications/Concerns
For a larger view of this figure, refer to the online report pdf at www.werf.org.



WERF

Figure 5-4. Focus Group Participant Barrier Category and Statement Grouping Diagram – Outside Agents (Non-Regulatory, Utilities, Public)

For a larger view of this figure, refer to the online report pdf at www.werf.org.

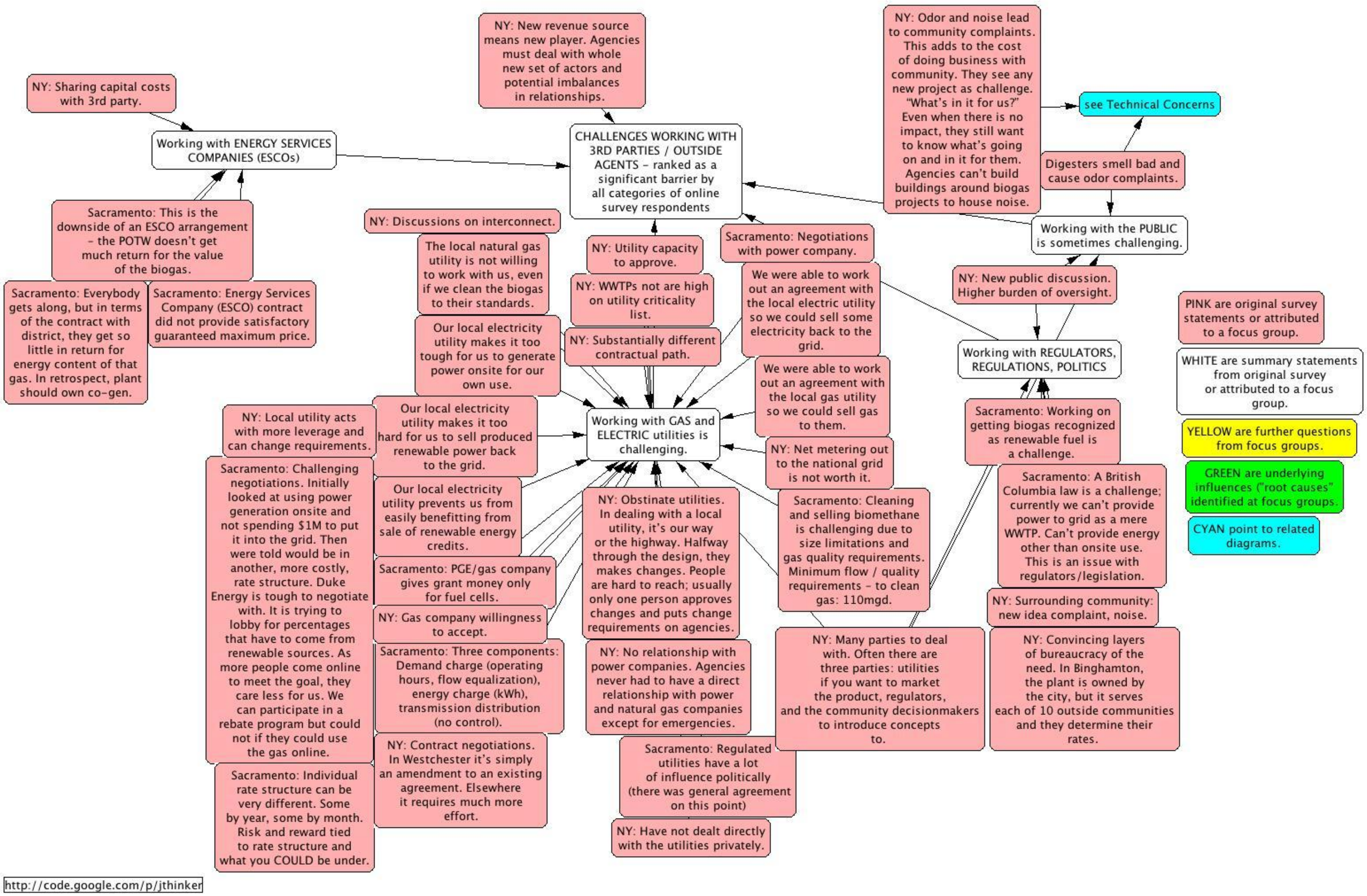
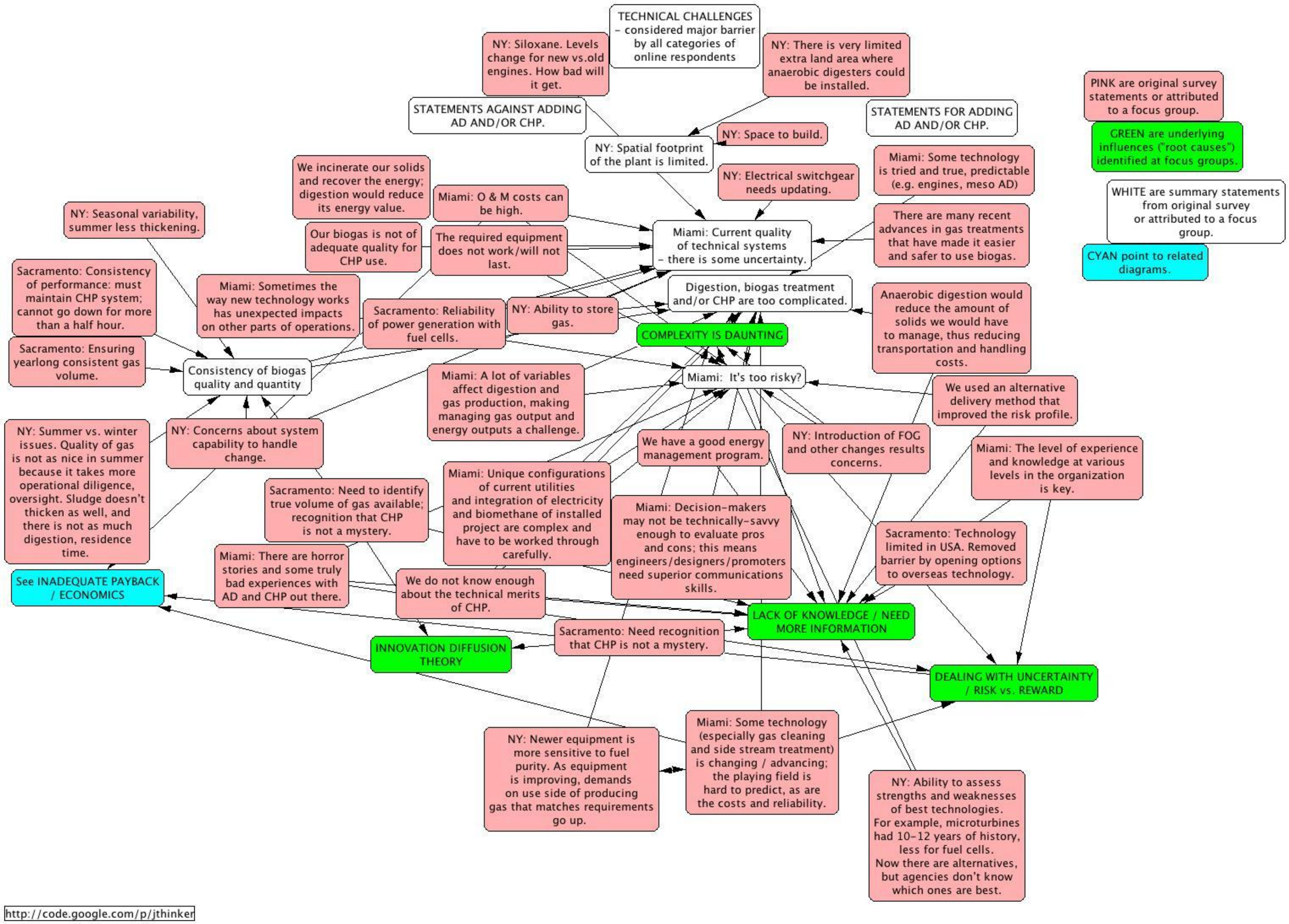


Figure 5-5. Focus Group Participant Barrier Category and Statement Grouping Diagram – Technical Merits/Concerns

For a larger view of this figure, refer to the online report pdf at www.werf.org.



WERF

Figure 5-6. Focus Group Participant Barrier Category and Statement Grouping Diagram – Maintain Status Quo

For a larger view of this figure, refer to the online report pdf at www.werf.org.

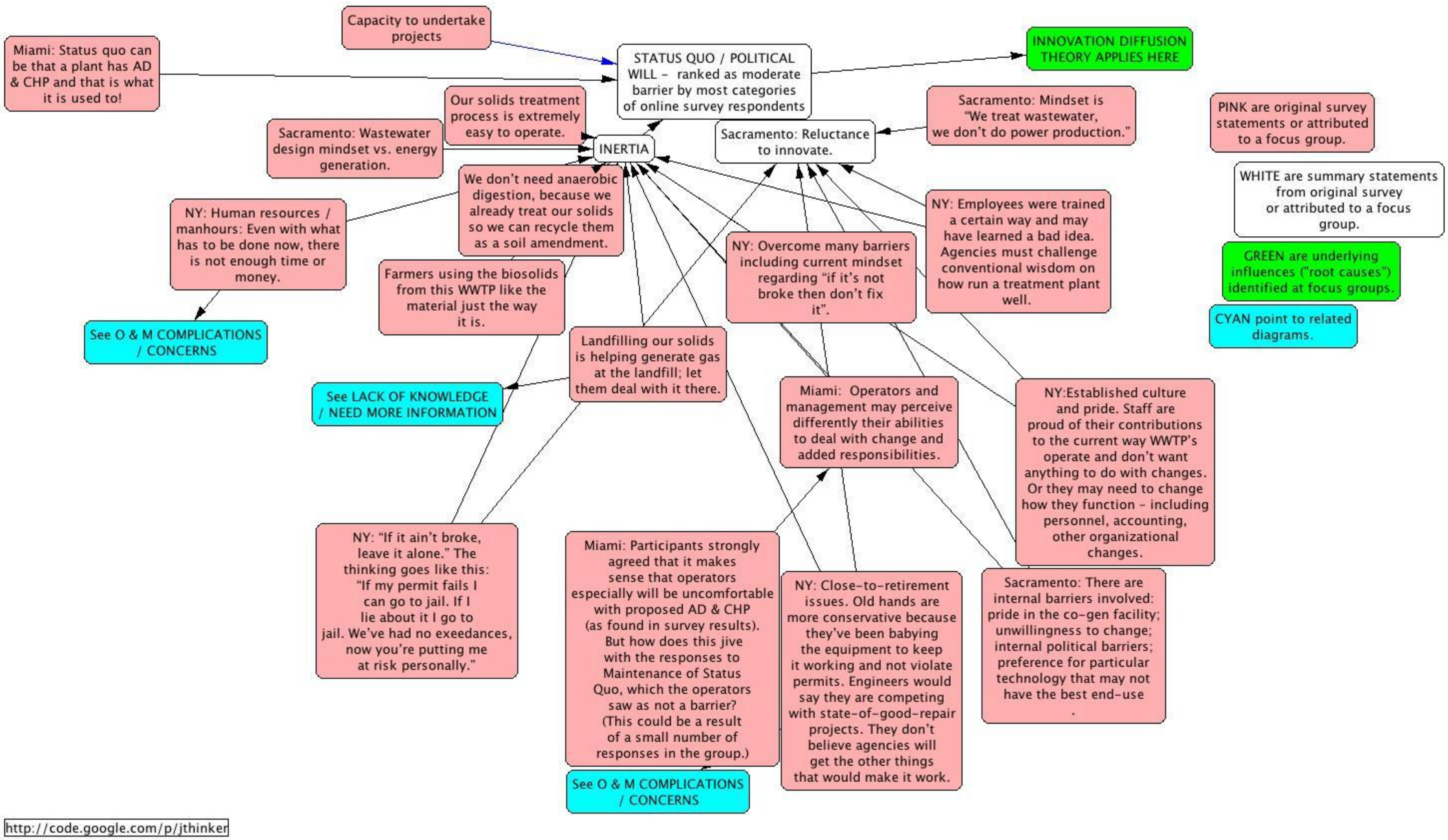
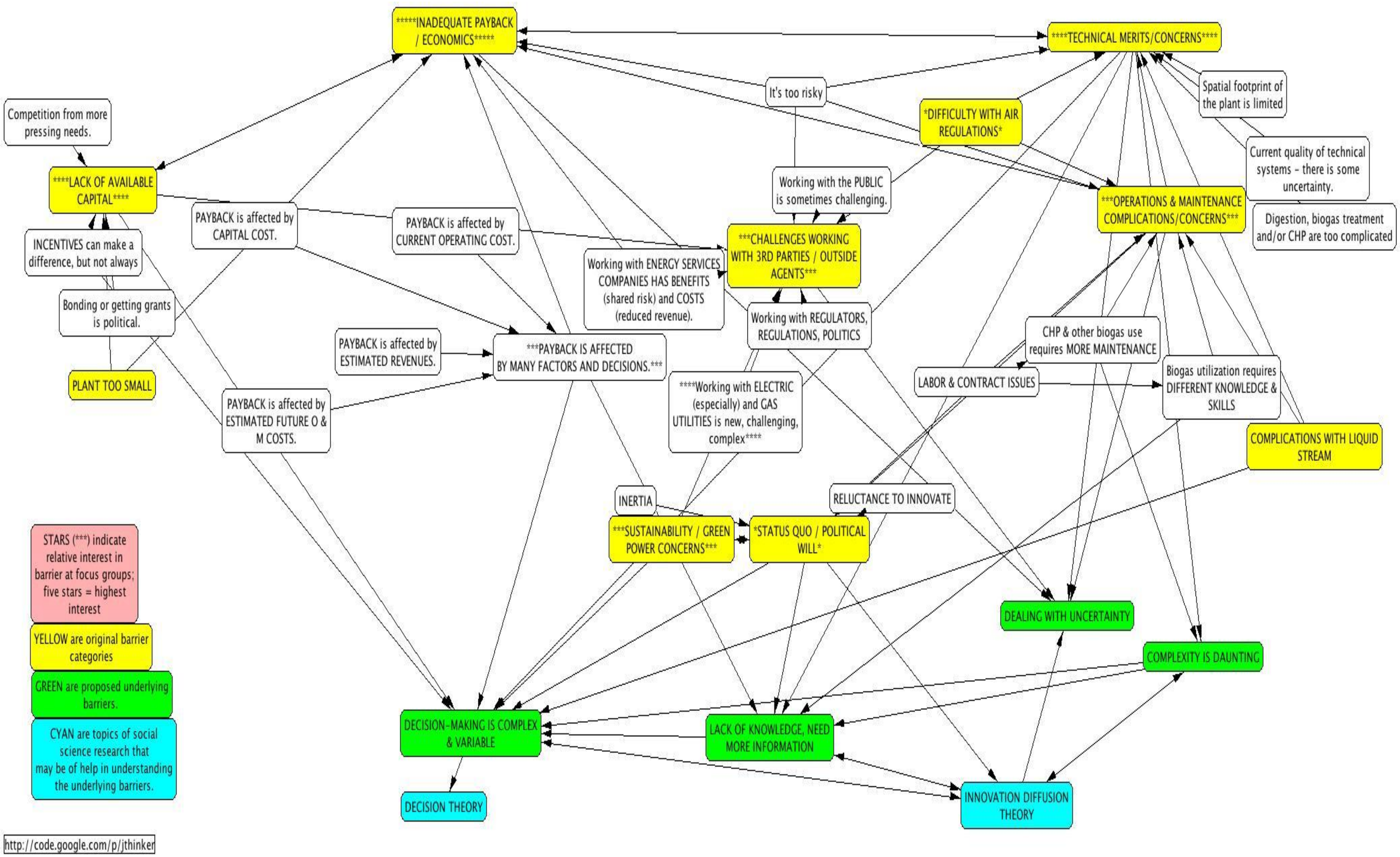


Figure 5-7. Summary Diagram of Relationship Among Barrier Categories

For a larger view of this figure, refer to the online report pdf at www.werf.org.



CHAPTER 6.0

SMALL-PLANT BARRIER MITIGATION

6.1 Background

According to the CHPP (2011), larger WWTPs use biogas to generate renewable energy more than small WWTPs do. However, several smaller WWTPs, some of whom participated in this project, have successfully implemented and operated anaerobic digestion and CHP. Why are some small utilities moving forward with CHP while others are not?

One goal of the project was to determine how small WWTPs have implemented CHP and to educate the industry about strategies to overcome the barriers faced by these plants. These mitigation techniques could also be used by medium and large WWTPs since many barriers, such as economics and challenges with third parties, apply to plants of all sizes. For this report, a small WWTP is categorized as one treating 10 mgd or less of average influent flow.

6.2 Summary of Survey Results on Small Plants

The online "Barriers to Biogas" survey received feedback from a limited number of small utilities – 13 respondents participated with WWTPs between 1 and 5 mgd and 23 respondents participated with WWTPs between 5 and 10 mgd. This represented 7% and 12%, respectively, of overall responses received.

- Of the WWTPs treating 1 to 5 mgd that responded to the survey, one facility has anaerobic digestion but does not use biogas except for process heating, six have anaerobic digestion and CHP or are planning to implement CHP, and six have neither anaerobic digestion nor CHP.
- Of the WWTPs treating between 5 and 10 mgd that responded to the survey, nine have anaerobic digestion but do not use biogas except for process heating, eight have anaerobic digestion and CHP or are planning to implement CHP, and six have neither anaerobic digestion nor CHP.

The survey data were analyzed to determine the top three barriers for each flow range and biogas use. For plants between 1 and 5 mgd, the barriers presented in Table 6-1 were the most significant. Table 6-2 shows the most significant barriers for plants between 5 and 10 mgd.

Table 6-1. Most Significant Barriers by Plant Category for Respondents Between 1 and 5 mgd		
I – AD no CHP	II – AD and CHP	III – No AD no CHP
Plant Too Small	Complications with Outside Agents	Lack of Available Capital
Lack of Available Capital	Technical Merits and Concerns	Complications with Outside Agents
Maintain Status Quo	Plant Too Small	Plant Too Small

Table 6-2. Most Significant Barriers by Plant Category for Respondents Between 5 and 10 mgd		
I – AD no CHP	II – AD and CHP	III – No AD no CHP
Plant Too Small	Plant Too Small	Lack of Available Capital
Lack of Available Capital	Complications with Outside Agents	Complications with Liquid Stream
Inadequate Payback/Economics	Technical Merits and Concerns	Maintain Status Quo

As shown in the tables, for plants without anaerobic digestion and with anaerobic digestion but without CHP, capital and economic concerns ranked highly, followed closely by maintaining the status quo. For those plants that had implemented CHP, complications with outside agents and technical merits and concerns were top barriers. Concerns about plant size relative to biogas production also ranked highly among survey participants in all three classifications.

6.3 Strategies to Overcome Small-Plant Barriers

Strategies have been developed by small WWTFs, many of which are also used by plants of larger size, to overcome barriers to biogas use for renewable energy. Often, multiple approaches are used in combination to circumnavigate the barriers. Mitigation strategies used by small WWTFs participating in the project are presented in Table 6-3 for the barriers identified as most significant. Participants from small WWTFs in the focus groups and case studies identified these strategies during discussion and interviews.

Table 6-3. Small Plant Barriers and Mitigation Strategies	
Barrier	**Mitigation Strategy**
Plant Too Small	• Use alternative feedstocks to increase biogas production. • Consolidate solids handling with other small plants or at a larger, centralized facility.
Lack of Available Capital	• Investigate alternative sources of funding.
Inadequate Payback/Economics	• Investigate alternative sources of funding. • Re-frame economics to something beyond simple payback. • Use alternative feedstocks to increase biogas production and provide a source of revenue associated with tipping fees.
Complications with Outside Agents	• Leverage current discussions/relationships with third parties.
Maintain Status Quo	• Highlight risk of status quo to decision makers. • Involve potential blockers in decision-making process.
Technical Merits and Concerns	• Simplify O&M. • Visit successful sites to improve familiarity/acceptance.
Complications with Liquid Stream	• Use chemical precipitation of phosphorus or deammonification process • At small plant scale, liquid biosolids program can avoid recycled nutrient issues.

Further descriptions of the methods used by small utilities' participating in this project to justify their CHP and/or anaerobic digestion project are provided below.

6.3.1 Use Alternative Feedstocks to Increase Biogas Production

Several small WWTFs, realizing that their current solids loading would not produce sufficient biogas to economically justify CHP, use co-digestion of FOG, food wastes, and/or HSW to increase biogas production. For small WWTFs, the additional power that can be generated from FOG or HSW can significantly improve project economics and, in many cases, be the tipping point for moving ahead with their CHP project. Furthermore, additional revenue generated by receiving FOG and HSW improves the utility's operating savings considerably.

The City of Sheboygan, Wisconsin increased biogas production at its 10-mgd facility by introducing HSW directly to their anaerobic digesters, including whey and cheese processing waste and thin stillage from ethanol manufacture. Sheboygan encouraged HSW to be discharged at the facility by lowering tipping fees for industrial waste streams. A 5-mgd WWTF in Massachusetts uses co-digestion of food, beverage, brewery, and dairy waste to increase biogas production.

The Village of Essex Junction, Vermont has added FOG, brewery waste, and oily waste by-product since 2007 in measured amounts directly to the digester, which has improved biogas production and volatile solids reduction. The 2-mgd WWTF has reduced its electricity costs by 30% and is receiving RECs for the electricity it generates.

At the City of St. Petersburg's Southwest WRF (currently treating 10 mgd), a tipping station will be constructed to receive HSW to boost biogas production and generate a new revenue stream for the city of approximately $500,000 per year.

More details on these facilities are given in Appendix A.

6.3.2 Consolidate Solids Handling

In some instances, CHP projects can become more economically favorable by consolidating solids handling from several smaller treatment plants at one larger facility. This strategy can be implemented by plants that are large enough to have anaerobic digestion but believe they do not have sufficient biogas for CHP as currently configured.

For example, the City of St. Petersburg, Florida operates a total of four small-to-medium WWTPs, each treating less than 10 mgd. The city is closing one of the four WWTPs and pumping its influent wastewater to the Southwest WRF for treatment. In addition, the city plans to convey all WAS from its remaining facilities to the Southwest WRF for solids handling. By consolidating solids handling and treatment at one WWTP, the city was able to justify construction of new anaerobic digestion and CHP processes and save $800,000 per year in operations and maintenance effort. This approach was more affordable and achieved greater economies of scale compared with constructing multiple, smaller digestion and CHP upgrades.

6.3.3 Re-Frame Economics

As noted in the survey and focus groups, economics and competing demands for limited capital are major barriers to biogas projects. Decision makers sometimes take a narrow approach to evaluating CHP projects, which are often viewed as discretionary in nature, that focuses on simple payback period. Although what is considered an "acceptable" payback period varies, some utilities require that potential CHP projects meet a three- to seven-year payback. Small WWTFs have had some success re-framing the economics of CHP by focusing on alternative financial criteria, such as net present worth and reduced operational costs, to move their CHP projects forward. In addition, some facility managers, such as those at Essex Junction, Vermont, recognize that wastewater treatment plants are likely forever and can be managed for the very long term, opening up the possibility to see payback periods measured in decades.

> Two Rivers Utilities owned by the City of Gastonia, NC, at 8.3 mgd with three plants considers itself too small to invest in biogas without grants, adequate payback, or political support. But it has a strong interest in green power and is pursuing this opportunity. Its case study is in Appendix A.

The City of St. Petersburg used net present worth and operational savings to justify construction of anaerobic digestion and CHP. The city's digestion and CHP project has a 20-year present worth $33 million less than continued Class-B land application under future rules. In addition, the project will save some $3 million per year in operating costs. A 5-mgd facility in Massachusetts estimated that its CHP project would save $300,000 annually in electricity and sludge disposal costs. By focusing on economic criteria other than simple payback, the argument for CHP can oftentimes be more compelling.

6.3.4 Investigate Alternative Sources of Funding

Pursuing and securing alternative sources of funding, such as grants, low-interest loans, or capital purchase agreements with third parties, is another strategy to implement biogas projects at small WWTFs. As noted in the Sacramento, California focus group, grants and incentives can not only improve project economics, but they also can create a sense of urgency and importance around a project. Depending on the size of the award, payback for projects can be significantly improved. Grants from organizations such as Focus on Energy and NYSERDA, one of the sponsors of this project, as well as federal and state governments are available to utilities for CHP projects.

For example, Essex Junction, Vermont, grants and incentives helped make the simple payback acceptable to the board. The City of Sheboygan, Wisconsin pursued several alternative funding arrangements, including grants, low-interest loans, and capital cost-sharing partnerships with a local utility for their CHP projects. For the original project, the local power utility purchased and owns the microturbines and biogas treatment equipment while the city owns the heat recovery system and has the option to purchase the microturbines and biogas treatment equipment after six years of operation for a price of $100,000.

The total cost to develop and construct the original CHP system was $1.2 million, of which Sheboygan paid only $200,000 for the heat recovery equipment. For the CHP expansion project, the city used a $1.2 million low interest loan, which will be paid back in five years with funds saved by operating the CHP system and offsetting a portion of the WWTP's energy costs. In addition, Focus on Energy provided a $205,920 grant for expansion of the CHP system. As such, the city only had to cover the remaining $100,000 from its own finances for the CHP expansion project.

6.3.5 Simplify O&M

For both small and large WWTFs, the technical and operations and maintenance challenges associated with CHP as well as biogas treatment equipment can be complex. Utilities have been successful overcoming this barrier by breaking their CHP projects into their most basic components, such as prime mover, heat exchanger, and gas conditioning system. O&M staff is then educated on each of the components prior to education on the entire CHP process. By using a systematic, step-by-step approach, the staff recognizes that the process is not as complex as it might have been previously believed.

Equipment maintenance contracts with outside parties, although they may be more expensive and need to be evaluated with respect to project economics, can also be used to overcome this barrier if inter-utility maintenance expertise is not available or practical. In some cases, utilities have found it advantageous to enter into maintenance contracts for one to two years prior to taking over maintenance responsibilities; this allows time for plant staff to become more familiar with the process prior to leading these activities.

For Essex Junction, Vermont, increased complexity associated with operations and maintenance of CHP technology was its most significant barrier. Moving the project forward required a project champion and educating staff, which took significant time and research. Continued education was required after the system was constructed. In addition, for Essex Junction and other small WWTFs in relatively isolated areas, there was not a lot of expertise nearby for some CHP technologies. In the future, this may lead to maintenance contracts being issued for the equipment.

6.3.6 Highlight Risk of Status Quo to Decision Makers

For some utilities, the risk of "doing nothing" is higher than the risk associated with beneficial use of biogas. Discussing this risk with decision makers can be a key way to overcome this barrier. For example, several utilities performed a holistic review of their current biosolids management practices, which included land application, and determined that the risk and cost associated with continuing to operate as they had in years past was untenable in the future. Land application of Class-B biosolids in some states, including Florida, is becoming more costly and burdensome. If the City of St. Petersburg were to continue with the "status quo," more farms/application sites would be necessary and permitting requirements, nutrient management plans, and risks to farmers would result in considerably higher costs. It was less risky and costly for the city to implement Class-A anaerobic digestion and CHP than to continue with land application of Class-B biosolids.

Another area of risk for utilities is associated with rising power costs. Use of biogas to generate renewable energy can greatly reduce the risk of energy volatility and operating budget costs. For many utilities, power is their most significant operating expense. For a small WWTP in Massachusetts paying $0.16/kWh and more than $300,000 annually in power costs, controlling the risk of rising energy costs on its bottom line was essential in implementing its anaerobic digestion and CHP project.

6.3.7 Leverage Current Discussions with Third Parties

Another barrier to biogas projects for renewable energy involves complications gaining approval for the projects from outside agents, such as regulators, power companies, and the public. At the Chicago, Illinois focus group, small and large utilities discussed strategies to overcome this barrier. Several attendees recommended that current relationships, particularly with power companies and natural gas utilities, be used as a springboard to discuss the potential for CHP. It was agreed that more information must be exchanged between utilities and third parties for CHP to become more widely accepted.

Essex Junction, Vermont, faced initial challenges working with the electrical utility on interconnection of its CHP system to the grid, but these became been easier to overcome in recent years.

In the case of regulators, one strategy discussed at the focus group is to partner with a regulator who is knowledgeable about the benefits of CHP or can be convinced of the benefits; the regulator can then serve as an advocate for the project in outreach efforts to other regulators and even within the wastewater utility itself.

6.3.8 Use Chemical Precipitation of Phosphorus or Deammonification Process

For those facilities with anaerobic digestion, the addition of CHP should not cause any new complications with liquid stream treatment. This barrier applies to small plants that do not currently have anaerobic digestion.

For plants that must meet low phosphorus limits, ferric salts or alum can be used for chemical precipitation of phosphorus at relatively low cost. Furthermore, iron present in primary sludge or WAS from chemical precipitation of phosphorus can aid the anaerobic digestion process. For WWTFs that must meet low ammonia or total nitrogen limits, a deammonification process, such as DEMON, could be used to remove nitrogen from the recycle streams. However, these processes can be expensive for even medium-to-large-sized WWTFs and would need to be evaluated for small facilities on a case-by-case basis.

A final option for smaller plants with stringent nutrient limits is to not dewater the finished biosolids, keeping the nutrients in the biosolids rather than returning them to the liquid stream. There are many successful liquid-land application programs (usually associated with smaller WWTFs - less than 10 mgd). At smaller scale, the costs of one or two tankers per day of liquid biosolids may be very cost effective when compared with the capital expenditures that may be required to adjust the plant process.

CHAPTER 7.0

NON-UTILITY PERSPECTIVES ON BARRIERS

This project focused on understanding the perspectives of public wastewater treatment utility employees and managers. They are the ones that ultimately make the decisions regarding AD and biogas use projects. However, they are influenced by many others, including consulting engineers and promoters of biogas use from the public and private sectors. What are the perspectives of these non-utility personnel regarding AD and biogas use? Do they see the same barriers?

A second, short, online survey was developed for non-utility personnel to answer these questions. The survey methodology and results are presented below.

7.1 Overview of Respondent Data

Invitations to participate in the non-utility survey were distributed via email networks. Thirty-six (36) responses were received. The responses came from throughout the United States and Canada, with the greatest number of responses from the northeast, upper midwest, and west coast of the US. Overall, the response rates from each region roughly mirror the population densities of the various regions (Figure 7-1).

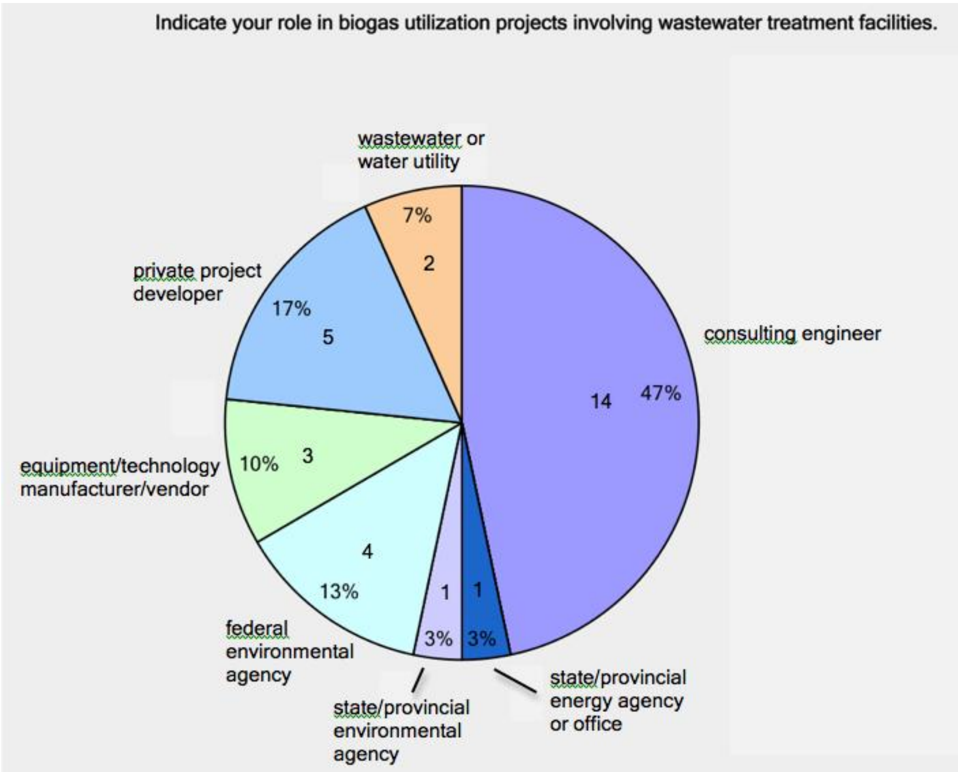
Figure 7-1.
Geographic Distribution of Responses to Survey of Non-Utility Perspectives

2. In what region(s) of North America do you promote, develop, and/or work on biogas utilization projects involving wastewater treatment facilities? Create Chart Download

	Response Percent	Response Count
EPA Region 1: New England	17.1%	6
EPA Region 2: NY, NJ, P.R., V.I.	34.3%	12
EPA Region 3: DC, DE, MD, PA, VA, WV	22.9%	8
EPA Region 4: AL, FL, GA, KY, MS, NC, SC, TN	14.3%	5
EPA Region 5: IL, IN, MI, MN, OH, WI	22.9%	8
EPA Region 6: CA, LA, NM, OK, TX	14.3%	5
EPA Region 7: IA, KS, MO, NE	14.3%	5
EPA Region 8: CO, MT, ND, SD, UT, WY	8.6%	3
EPA Region 9: AZ, CA, HI, NV	22.9%	8
EPA Region 10: AK, ID, OR, WA	28.6%	10
Canada: Maritime Provinces	5.7%	2
Canada: Quebec	8.6%	3
Canada: Ontario	17.1%	6
Canada: Central Canadian Provinces	8.6%	3
Canada: Alberta and/or British Columbia	11.4%	4
	answered question	35
	skipped question	1

Consulting engineers dominated the responses to this survey. However, a little more than 50% of responses were from other perspectives: government agencies, project developers, and technology vendors (Figure 7-2).

Figure 7-2.
Roles of Respondents to Survey of Non-Utility Perspectives



Almost all of the respondents (83%) had been involved in promoting, developing, and/or working on biogas use projects over the prior three years; most (25 of 36) had considerable experience, having been involved in from one to 10 projects, while another five had been involved in more than 10 projects.

7.2 Barrier Categorization Methodology and Results

At the beginning of the survey, an open-ended question was used to identify the most important barriers to the respondent. This question was posed early in the survey to avoid bias about suggested barriers or hypotheses.

The self-directed, open-ended written responses provided by these non-utility personnel were then grouped into the same categories as were used in analysis of the survey of wastewater treatment utility personnel and in the focus groups. Any response that included language referring to one of the barrier categories was added to that group; some responses were added to more than one group. For example, the following written response was considered to address three barrier categories (economics/payback, lack of available capital, and decision making): "Prioritization of energy production as a use of municipal capital, even with a simple payback period of five years." In contrast, the following statement was applied to only one category (technical merits/concerns): "Co-digestion substrates - Insufficient volume of WWTP residuals (i.e., not enough VS)."

Placing statements into categories required interpretation of the intent of the respondent. Thus, for example, the following statement was added to both the experience and knowledge and operations/maintenance complications/concerns categories: "Education of client regarding the reliability of a modern anaerobic digester in comparison to maintenance requirements and inefficiencies of older gas-mixed (poorly mixed) versions."

Table 7-1 shows the number of times a particular barrier category was identified by these open-ended, self-directed responses. One barrier mentioned did not fit well into any of the established categories, although it was counted under "communications:" "lack of communication or relationships between solid waste industry and WWTP personnel and different world views."

Table 7-1.
Response to Open-Ended Questions on Most Important Barriers

Barrier Statement Category	No. of Mentions in Self-Directed Responses
Inadequate Payback/Economics	37 (7 mention low cost of electricity specifically)
Lack of Available Capital	17
Operations/Maintenance Complications/Concerns	9
Complication with Liquid Stream	0
Outside Agents (non-regulatory, utilities, public)	2
Lack of Community/Utility Leadership, Interest in Green Power	13
Difficulties with Air Regulations	6
Plant Too Small	0
Technical Merits/Concerns	35 (14 focused on biogas quality and cleaning
Maintain Status Quo	8
Decision Making	2
Communications	1
Experience and Knowledge	22

The final two substantive questions of the survey asked respondents to rate the degree to which they found various statements to be true. The first of these questions asked them to rate many of the same barriers statements that had been rated by respondents to the utility perspective survey.

The respondents to this first question clearly felt the following potential barriers were *not* significant:

- Safety issues associated with generating biogas make it undesirable
- CHP will produce more CO2 and might get a WWTF into greenhouse gas trouble
- WWTFs' biogas is not of adequate quality for CHP use
- The required equipment does not work/will not last
- Many WWTFs cannot obtain air permits for CHP

The respondents to this survey were self-selected; they chose to take the survey and as a group, they do not constitute a random sample. They likely were very involved in this topic and came to the survey with a great deal of knowledge and experience regarding details of biogas use, including technical details. It made sense that they would discount the five potential barriers listed above.

These respondents also clearly felt that the following were major barriers (listed in order, with most significant barrier at the top, according to responses of the non-utility personnel completing this survey):

1. There are other, more pressing needs for a WWTF's limited capital dollars
2. The payback on the investment is not adequate
3. The equipment is too expensive to own/operate
4. The cost of electricity for most WWTFs is too cheap to justify the investment
5. The local electricity utility makes it too hard for a WWTF to sell produced renewable power back to the grid
6. The equipment is too expensive to buy
7. Many WWTFs are too small (<5 mgd) for biogas use projects
8. A WWTF's utility Board / Commissioners would never be willing to pay for such a costly upgrade
9. Most WWTFs do not produce enough biogas
10. Biogas treatment and/or CHP are too complicated
11. The local electricity utility prevents a WWTF from easily benefiting from sale of renewable energy credits (RECs)

These data corroborated the findings from the surveys and focus groups with utility staff. The most significant barriers were inadequate payback/economics and lack of available of capital – the economic concerns. Interestingly, interactions with outside agents, including electricity utilities, was seen as a major barrier in responses to this question, but was not a barrier that this group identified on its own in the initial, open-ended survey question.

The last question in this survey of non-utility perspectives asked respondents to state their level of agreement with various hypotheses developed by the project team through analysis of the results from the utility perspective survey and the focus groups.

The following hypotheses, listed in order by strength of agreement, were strongly supported by the non-utility respondents:

1. Biogas use projects only happen when driven forward by one or more committed proponents/advocates. (Note: This statement had a high amount of *very strong agreement*.)
2. Without additional mechanisms and incentives geared towards diverse biogas use and management models, biogas use will continue to struggle to grow.
3. The most important, widespread barriers to biogas use are economic, related to either limited capital resources or perceptions that the economics do not justify the investment. (Note: This statement had a high amount of *very strong agreement*.)
4. Currently, there is great interest in cost efficiency, renewable energy, and sustainability – all of which support biogas use projects.
5. If the wastewater treatment plant management and staff are used to dealing with a lot of complex technologies, systems, and people, they are more likely to proceed with biogas use projects.
6. Climate change, carbon regulations, air regulations, renewable energy credits (RECs), and renewable portfolio standards (RPS) present a complex and confusing regulatory environment that discourages utilities from getting into biogas use.
7. Producing biogas (and/or other energy) from wastewater should be part of the responsibility of public wastewater treatment plants. (Note: There was a fairly high amount of *strong disagreement* with this statement by some respondents.)
8. Reducing the uncertainty about future electricity and other energy costs would greatly help decision makers decide on whether or not to proceed with AD and CHP, or other uses of biogas.
9. Creative thinking can make it possible for even small agencies (< 5 mgd) to benefit from biogas use projects.
10. Air permitting can create a major barrier in specific geographies and/or permitting situations. (Note: This statement was the one that did not apply for some respondents. This makes sense since air permitting issues are not important in some parts of the continent.)

The greatest level of *disagreement* was expressed for the following hypothesis: “the current policy environment at the federal and state level does not recognize the renewable resource potential from biogas and, thus, creates a barrier.”

Most respondents (20 of 36) agreed with the statement that “if the simple paybacks on biogas use projects were reduced to five years or less, there is no question that every wastewater treatment plant would proceed with biogas use projects;” only four mildly disagreed with it.

7.3 Summary

In summary, non-utility personnel and utility personnel agree that economic factors – lack of available capital and inadequate payback – are the most significant barriers to biogas use. There is no doubt from this project that this is the most important barrier on people's minds.

However, the non-utility perspective survey corroborated the importance of some of the more subtle – but significant – underlying barriers, such as "leadership" and "experience and knowledge." The respondents to this survey – self-selected proponents of biogas use – appreciated arguments regarding incentives and policy support for biogas production and use. Most of them expressed fairly strong support for the radical statement that producing biogas or other energy should be a responsibility of WWTFs. They agreed with the idea that, if the payback is reasonable, the decision should be made to develop anaerobic digestion and use biogas.

CHAPTER 8.0

CONCLUSIONS AND RECOMMENDED NEXT STEPS

During this project, responses were sought from wastewater treatment utility and other participants regarding barriers to biogas use for renewable energy. Furthermore, the project sought to weigh and rank these barriers relative to significance and importance. This was accomplished using an online survey that was distributed nationally and completed by wastewater utility staff, by conducting four focus groups at major conferences throughout the country, through analysis and discussion in the project team, and by conducting a survey of non-utility personnel with experience in developing biogas use projects. The project also identified some opportunities to mitigate or overcome barriers to biogas use for renewable energy.

From this work, a number of conclusions were developed regarding barriers. These conclusions and opportunities to overcome barriers are presented below.

8.1 Major Barriers to Biogas Use for Renewable Energy

Many of the findings of the project were not surprising. Of the 10 barrier categories introduced at the beginning of the project, nine were deemed significant (Figure 8-1).

Figure 8-1.
Ten Barrier Statement Categories

CONFIRMED	BARRIER CATEGORY	SUMMARY STATEMENT
√	1. Inadequate Payback/ Economics	"The economics do not justify the investment."
√	2. Lack of Available Capital	"There are more pressing needs for our limited dollars."
√ Impacts payback, decision making	3. Operations/Maintenance Complications/Concerns	"We are concerned about operations and maintenance."
X Not a major barrier by itself; a subset of technical merits barrier; impacts payback, decision making	4. Complication with Liquid Stream	The improvements negatively impact our liquid stream compliance/operation
√ Impacts payback, decision making	5. Outside Agents (Non-Regulatory: Utilities, Public)	"We could not work with our power and gas utilities or the public." Outside agents like power utilities for CHP and gas utilities for renewable compressed natural gas are significant barriers.
√ Impacts decision making	6. Lack of Community/Utility Leadership Interest in Green Power	"The environmental benefit provides inadequate justification." However, there is recognition that There is greater interest in enhanced efficiency, operational cost reduction, and sustainability today that supports biogas use projects.
√ Impacts payback, decision making	7. Difficulties with Air Regulations or Obtaining Air Permit	"Air and GHG regulations make it too difficult." Air permitting can create an extremely significant barrier in specific geographies/permitting situations, like California. Climate change, carbon regulations, air regulations, RECs, and RPS present a complex and confusing regulatory environment. Wastewater utilities need a more consistent picture for decision making and CIP recommendations.
√ Impacts payback, decision making	8. Plant Too Small	"Our facility is too small." Textbook 5- or 10-mgd lower-capacity barriers can be overcome with creative thinking.
√ Impacts payback, decision making	9. Technical Merits/Concerns	"Technical concerns limit our appetite to implement."
√ Impacts decision making	10. Maintain Status Quo	"We like things the way they are too much."

However, it became clear that the economic barriers – inadequate payback/economics and lack of available capital – were dominant. As discussed in Chapter 5.0, most of the other barriers were less significant; given sufficient funding, these barriers can be overcome.

In addition to the barriers confirmed above, several other factors that influence barriers became evident during the project. These include both policy factors and "human" factors, which are described below.

8.1.1 Policy Factors

A few of the barriers identified during the project involved policy. One such factor identified at the beginning by the project team was air permitting, which has particularly strong impacts in some regions, such as California. There are other policies at the federal, regional, and state level that create disincentives to biogas projects. Policy barriers can make projects more difficult and influence the bottom line, although they tend to be less significant than the economics barriers. However, given enough time and money, policy disincentives can be overcome. Policy factors include the following:

- In some states, there is a lack of government policy recognition of biogas as a valuable renewable energy source in renewable energy credit (REC) programs, renewable portfolio standards (RPSs), etc. This results in biogas use projects being ineligible for incentives for which other, competing renewable energy projects are eligible.
- In comparison to European countries and Canada, the U.S. has not developed significant federal policies on greenhouse gas (GHG) emissions. At the time of this report, only California had significant GHG-related incentives to avoid use of fossil fuels and reduce releases of fugitive methane, both of which are possible with biogas use.
- Similarly, in the U.S., fossil fuel and electricity prices are relatively low compared with those in Europe and Canada, where government policies, such as taxes, have raised the price of non-renewable fuels, creating better opportunities for biogas use.

8.1.2 Human Factors

What became clear through the focus group work is that there is another group of barriers that do not directly impact the *objective* economics of the project. Rather, these barriers affect *subjective* perspectives on the economics. These barriers seem to *underlie* and/or *influence* the discussions of economics. These are the “human” factors that include the following:

- **Decision making** that requires integrating economics with many complexities, uncertainties, perceived risks, and values (“doing the right thing”). During the focus group meetings, it became clear that decision making as an activity itself was a factor in whether and how biogas use was considered.
- **Inertia,** human dislike for change, and the status quo (which the project team had identified as a barrier at the beginning of the project).
- **Communication,** such as negotiations with electric utilities that are required to address the complexities of AD and biogas use projects.
- **Experience and knowledge** on the part of people involved in a potential project, especially decision makers. Biogas use requires focus and skills outside the traditional scope of wastewater treatment utilities.
- **Leadership** (which the project team had identified, to some extent, at the beginning of the project) and is related to the clear finding that successful marginal AD and biogas use projects have been advanced by one or two influential proponents.

There are two areas of social science research that can provide helpful insights into the human factors that create or enhance barriers to biogas use: decision science and innovation diffusion theory. The project team explored these superficially, but it was beyond the scope of this project to apply them thoroughly to the particular challenge at hand. However, these schools of thought may provide useful insights into advancing use of biogas at wastewater treatment plants. This is described further in Appendix D.

8.2 Opportunities to Mitigate or Overcome Barriers

During the focus group sessions, opportunities to overcome barriers were discussed by utility participants. In many cases, these mitigation strategies have been used successfully by utilities to overcome barriers to CHP and implement CHP projects.

8.2.1 Inadequate Payback/Economics and/or Lack of Available Capital

The following opportunities to overcome economic-related barriers to CHP were discussed:

- Use better financial comparison metrics, i.e., net present value, net revenue, and operational savings, as opposed to relying on simple payback period. Highlight cash flow potential, especially over the long term, to decision makers. Tie payback into the service life of the equipment, which for engines and combustion turbines can be quite long.
- Consider delayed bonding models so that customer rates go up slowly at the beginning of a project and the larger debt service will only be paid off once the project begins to save money.
- Increase biogas production by introducing alternative feedstocks, such as FOG and HSW. These also have the opportunity to provide a utility a new or improved revenue stream in the form of tipping fees.
- Negotiate better contracts with power utilities and natural gas companies.
- Improve tie-in of risk management to the economic evaluation. For example, for WWTFs with CHP, the utility vs. the power company controls power production and costs. Other areas of risk, such as health and safety of flaring biogas, should be tied into a holistic evaluation.
- Use triple-bottom-line assessments that can monetize or attribute to value to non-economic environmental or social benefits.
- Evaluate the possibility that the construction of anaerobic digestion and CHP may allow avoidance of other solids-handling costs, e.g., replacement or rehabilitation of older equipment and processes.
- Consider RECs (at low valuations currently) in financial analyses especially with RPS coming into effect.
- Consider a third-party model for build-own-operate of CHP and/or anaerobic digestion to address capital and operating risk issues. These models can access tax incentives that are unavailable to public agencies.

- Consider partnering with a third-party that can fund the initial capital and ongoing O&M costs associated with CHP. Utilities then enter into long-term contracts to buy back generated electricity from the third-party.

- Optimize solids processing and operations. Evaluate anaerobic digestion processes, such as TPAD, that will increase the amount of biogas produced. Assess the potential for increased biogas production rather than focusing on current biogas production. Maximize organic loading to anaerobic digestion to produce additional biogas and fully utilize the capital investment.

- Investigate alternative sources of funding, such as grants, low-interest loans, and state-supported financing, to improve economics.

- Identify and recognize how conservative assumptions and the level of knowledge by decision makers influence the economics of a project.

- Track energy use and benchmark energy usage internally and against other WWTFs. Use energy use as a performance metric and incentive for renewable energy development.

> Western Lake Superior Sanitary District in Duluth, MN (40 mgd) faces challenges selling biogas as a fleet fuel because extensive inter-organizational agreements would be needed to create a market with a reasonable price incentive. It continues to evaluate biogas options. See the case study in Appendix A.

- Review potential electrical or energy rate structures beyond those currently paid by the utilities. Having on-site power generation at a plant may allow an agency to take on more risky rate structures because of the additional flexibility provided by the added ability to reduce power consumption either routinely or as needed.

- Recognize that CHP projects often suffer from demands for very short paybacks that are not expected from other types of improvements.

- Maximize non-cost benefits of CHP programs, including maximum renewable energy production and greenhouse gas emissions reduction.

- Select construction and procurement methods that help keep construction costs lower yet deliver the project quickly.

8.2.2 Complications with Outside Agents

Strategies discussed for overcoming barriers associated with third parties included the following:

- Leverage existing conversations and relationships with regulators, power companies, and natural gas utilities to discuss CHP. One area of potential collaboration includes coordination and discussion on emergency operations.

- Present an entire portfolio of customers to improve bargaining position with power companies. Industry, factories, schools, and canneries use steam which WWTFs can provide. In addition, utilities provide cooling water needed for electric power production which can be used as an advantage.

- Don't take "no" for an answer; power companies that do not want to cooperate can be moved by persistence and research/facts on actual regulatory requirements; stick to it and keep trying when talking to outside parties.
- Provide better and faster exchange of information between industries to "demystify" CHP. Use professional organization to assist in these efforts.
- Provide better public education on the benefits of CHP.
- Convince regulators of benefits of CHP and then use regulators to convince other regulators.
- Use the stipulation in NPDES discharge permits for two independent sources of power as leverage for renewable energy from biogas.
- Promote and encourage the classification of biogas as a renewable energy source.

8.2.3 Plant Too Small

Methods to overcome the barrier of WWTFs that consider themselves too small for CHP to be feasible or practical include the following:

- Use alternative feedstocks, such as FOG, HSW, or other industrial wastes, to increase biogas production.
- Consolidate solids handling with other small plants or at a larger, centralized facility.
- Consider a regional approach to CHP projects among multiple utilities.

8.2.4 Operations and Maintenance Complications and Concerns

Strategies to overcome operations and maintenance complications and concerns include the following:

- Provide better training programs for operators on CHP technologies and anaerobic digestion.
- Educate staff on safety issues associated with biogas.
- Break down the CHP process into its basic components – engine generator, heat exchanger, and gas conditioning system – to reduce complexity of the process.
- Consider third-party maintenance service contracts for the CHP system.
- Visit successful sites to improve familiarity/acceptance.

8.2.5 Difficulties with Air Regulations or Obtaining Air Permit

In some jurisdictions, air permitting barriers can be significant. Strategies to overcome this barrier include the following:

- Educate air permitting authorities on the benefits of CHP.
- Convince regulators of benefits of CHP and then use regulators to convince those regulators with jurisdiction for the site in question.

- Select a CHP system with low levels of exhaust emissions.
- Highlight potential emissions issues associated with biogas flaring.

8.2.6 Technical Merits and Concerns

Methods to overcome the barrier related to technical merits and concerns include the following:

- Clearly define impacts on other parts of operations.
- Provide better training programs for operators on CHP technologies.
- Visit successful sites to improve familiarity/acceptance.
- Break down the CHP process into its basic components – engine generator, heat exchanger, and gas conditioning system – to reduce complexity of the process.

8.2.7 Complications with Liquid Stream

Strategies to overcome concerns and complications about the impact of anaerobic digestion on liquid stream treatment include the following:

- Recognize that this barrier does not apply to those that already have anaerobic digestion or are solely adding CHP.
- Use chemical precipitation of phosphorus or a deammonification process.
- For small plants, liquid biosolids programs can avoid recycled nutrient issues.

8.2.8 Maintain Status Quo and Lack of Community/Utility Leadership Interest in Green Power

Because the opportunities to overcome these barriers are similar, the following strategies could be used to overcome either of these barriers:

- Highlight risk of status quo to decision makers.
- Involve potential blockers and engage internal stakeholders in the decision-making process.
- Identify a strong supporter or advocate for beneficial use of biogas within the utility to promote the project.
- Provide holistic education on CHP and biogas technologies, including opportunities.

8.3 Overcoming Decision-Making Barriers

Decision making as an activity itself is a factor in whether and how biogas use is considered. Decision theory and analysis, further discussed in Appendix D, can be used to help advance the use of biogas because it provides insights into how to integrate uncertainties and risks into decisions.

8.3.1 Decision Theory and Analysis

Using decision theory and analysis, the following strategies can be taken to overcome decision-making barriers:

- Use a decision matrix to assess risks of decisions made under “certainty,” under “risk,” “uncertainty,” or “ignorance.” Probabilities of factors are estimated and then multiplied to estimate an outcome.
- Use tools to better define the scope and critical factors of decisions around biogas use. For example, benefits such as improving community sustainability and receiving FOG to prevent sanitary sewer overflows can be integrated into the economic models and decision-making process. These benefits often are left out of the analysis.
- Consider “real options valuation” which emphasizes keeping options open as decisions are made and steps forward are taken. The real-options approach asks this question in the decision-making process: “Will the next step open up more options and increase the value of options, or not?” This approach can also enable digesters to be built as an initial phase with the potential for adding biogas use at a later time.

8.3.2 Innovation Diffusion Theory

Although use of biogas from WWTFs is not new, it is reasonable to argue that the focus on biogas use over the past several years, driven by new demands for renewable energy and greenhouse gas reductions, is similar to an innovation. This is further supported by the fact that technologies have advanced considerably since anaerobic digestion and uses of biogas were initiated decades ago. There is a strong, rising tide of interest in biogas use, making this phenomenon an innovation that is diffusing into the marketplace.

Following are examples of how the concepts of innovation diffusion theory can be applied to biogas use at WWTFs.

- During this project, a common observation by participants is that biogas use systems are unfamiliar to wastewater treatment managers and operators and they are complex in terms of technology and in terms of interactions with different people and organizations (e.g. electric utility) and policies (e.g. air regulations). For some wastewater utilities, this complexity is daunting and drives them from serious consideration of biogas use, even if the economics are favorable. On the spectrum of those who range from “innovators” and “early adopters” to “laggards” in embracing innovation, such utilities may tend to be “laggards” anyway, but they are driven in that direction by the perceived complexities involved in biogas use.
- The project team had continual discussions about complexity, hypothesizing that a utility that already had what it considered complex systems would be more likely to see addition of biogas use systems as less challenging.
- Because they are stewards of public funds, wastewater treatment utilities and designers of systems have long tended to be conservative in their approaches to anything new. This systemic pressure could discourage and slow early adoption and diffusion of innovations.

- When focusing on the qualities of the innovation itself – in this case biogas use – there are many things that could be done to promote relative advantage, compatibility, simplicity, trialability, and observability of the practice, including the following:

  – Stress improvements in recent technologies. This message is especially important in some areas of the country (e.g., New England) where there is a legacy of embedded negativism about the reliability and manageability of anaerobic digesters.

  – Eliminate or reduce incompatibilities within treatment plant systems and outside agents, such as the electrical grid.

  – Simplify the user interface for biogas use systems through refined and consistent systems and technological interfaces and through having operations, maintenance, and other services provided by technical specialists contracted by the wastewater utility (e.g., ESCOs). Try giving the utility a "plug and play" experience.

    One non-utility person stated it this way: "Agencies need to create public private partnerships that allow the public sector to access capital and then possibly operate and partner on the revenue gains from biogas production. Several wastewater treatment plants are separating the digestion and biosolids management and attracting private vendors to operate these systems. without accessing capital sources, reducing technical risk through contract and proven operating capabilities."

  – Simplify the regulatory structures and outside party interactions to make biogas use more user-friendly. For example, using biogas-generated electricity generated only in the WWTF is simpler than dealing with interconnection to the grid and should be considered for this reason, even if it is not as cost effective.

  – When first getting into anaerobic digestion and biogas use, take smaller and less disruptive steps (consistent with the "real options approach" mentioned above) so that it appears simpler. For example, have the digesters operating well before adding outside waste. As one non-utility person stated: "Many WWTPs will not work to import more high BOD products because of the hassle and disconnect between solving a solid waste problem at the same time as focusing on their core, which is to provide wastewater treatment for sewage." The most complex scenarios, including conversion to biomethane, while beneficial, should probably be put off until after initial digestion and biogas use systems are familiar and running smoothly.

  – Provide information to address the perceived technical barriers and financial complexities so that utilities no longer see biogas use as an unusually complex and challenging undertaking.

  – Provide opportunities for wastewater operators and managers to "test drive" biogas use systems by visiting existing operating systems or perhaps through computer-assisted simulations.

  – Similarly, conduct economic simulations for managers and other decision makers to give them experience in what it means to have a revenue stream from energy production that reduces ongoing operations costs over the long term.

– Increase tours and demonstrations of modern operating systems and make them more visible in the industry.

A detailed discussion of innovation diffusion theory is in Appendix D.

8.4 Recommended Next Steps

To build on the work completed in this project, the following next steps are recommended to increase biogas-generated renewable power at WWTFs:

- Continue to quantify and define the energy generation potential from biogas at WWTFs throughout the United States.
- Develop databases, similar to that developed by U.S. EPA Region 9, of potential HSW sources that could be used to increase biogas production at WWTFs.
- Develop a consolidated database or repository of grant funding opportunities for CHP and biogas production projects.
- Update the University of Alberta Flare Emissions Calculator to include nitrogen oxides (NOx) and carbon monoxide (CO) that are often regulated by permitting agencies to document the relative performance of these non-recovery/fuel-wasting devices against CHP technologies.
- Expand outreach and information exchange between the wastewater industry and power companies and natural gas utilities.
- Further advance understanding of how decision science and innovation diffusion theory can help guide overcoming barriers to biogas use for renewable energy at wastewater treatment utilities.
- Develop a centralized database of CHP installations and continue to develop case studies on successful CHP projects.
- Develop an economic analysis tool that uses other financial evaluation methods in addition to simple payback.
- Develop an education and training course to assist in the understanding of the benefits of biogas, including a course specifically for decision makers.
- Assemble information on the barriers to anaerobic digestion.
- Support the WEF renewable energy statement to move biogas to the DOE list of renewable energy.
- Identify how to pursue legislation to assist in financing CHP projects.
- Promote research to identify less-costly methods to achieve anaerobic digestion and biogas production so it can become more widely applicable, particularly to small WWTFs and for industrial applications.

APPENDIX A

CASE STUDIES – AT A GLANCE

Barriers to Biogas Use

Alexandria Sanitation Authority, Alexandria, Virginia

Case Study at a Glance

UTILITY OVERVIEW

The Alexandria Sanitation Authority (ASA) operates one wastewater treatment plant (WWTP), which provides wastewater services to about 350,000 customers in the City of Alexandria and part of Fairfax County in Virginia, densely populated suburbs to the west of Washington, DC on the Potomac River.

Alexandria Sanitation Authority WWTP

The ASA WWTP operates anaerobic digesters and uses biogas for building and process heating. The plant has a total capacity of 54 mgd and treats approximately 36 mgd of flow on average. Sludge is stabilized through pasteurization followed by mesophilic anaerobic digestion and is dewatered using centrifuges. The product is a Class A exceptional-quality biosolid that is land applied.

The biogas production of more than 300,000 standard cubic feet per day (scfd) is used in boilers after moisture removal to generate steam. The steam then flows through a plant-wide loop, providing process heating and building heating or cooling where and when needed.

Heating the sludge to the relatively high temperatures of the pasteurization process requires high-quality heat (i.e., steam), and takes up most of the biogas production during winter months. To use the biogas during summer months, when the steam demand of the pasteurization process is low, ASA recently added an adsorption chiller that uses steam to cool buildings.

ASA has identified biogas as an opportunity for renewable energy and has researched federal and state grants. However, a number of factors have prevented ASA from implementing combined heat and power (CHP) at its WWTP.

Alexandria Sanitation Authority Service Area By the Numbers

- 350,000 customers
- 1 plant
- 54 mgd permitted capacity
- 36 mgd average flow treated
- Power cost: $0.058/kWh

Alexandria Sanitation Authority By the Numbers

- Operating since 1956
- > 300,000 scfd biogas
- 80 percent of digester gas is used through the year

What barriers were encountered and how were they overcome?

Major barriers encountered included the following:

- **Inadequate payback/economics using only excess gas.** As an alternative to use of the full digester gas production for CHP, ASA has evaluated the possibility of using only the excess gas for CHP, but the cost of the project (including gas cleaning) was shown to be too high for the amount of electricity that would be generated using just the excess gas.

- **Low electrical rates, high natural gas rates.** Electrical and natural gas rates have been an important factor driving ASA to preferentially use digester gas where it can replace the plant's natural gas consumption (i.e., in boilers) rather than to generate electricity. Historically, ASA's electrical rates have been low, while their natural gas rates have been high.

ASA has developed a strategy for taking advantage of the volume of digester gas produced, resulting in a digester gas use of more than 80 percent throughout the year. Long-term planning includes consideration of CHP coupled with increased gas production.

For more information, contact:

James Sizemore, ASA quality manager, at jim.sizemore@alexsan.com.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Charlotte-Mecklenburg Utilities, Charlotte, North Carolina

Case Study at a Glance


Mallard WRF

UTILITY OVERVIEW

Charlotte Mecklenburg Utilities (CMU) operates five wastewater treatment plants (WWTP), which provide wastewater services to some 776,000 customers in Charlotte, North Carolina. The plants have a permitted capacity of 123 mgd and treat an average flow of 83 mgd. Of the five wastewater treatment plants, four have anaerobic digesters, but none has combined heat and power (CHP). CMU is considering CHP at the McAlpine wastewater management facility (WWMF), which has the largest gas production.

CMU Service Area By the Numbers

- 776,000 customers served
- 123 mgd permitted capacity
- 83 mgd average flow
- 5 plants
- Power cost: $0.065/kWh

What barriers were encountered and how were they overcome?

The primary barriers identified by CMU include the following:

- **Capital funding/alternative funding.** Capital costs are fairly high, and a reasonable payback can only be accomplished if the plant can sell renewable energy credits (RECs).
- **Negotiations with power company.** Like most utilities, CMU would like to use the power generated by CHP on-site, since it would cost about $1 million to build a power line back to the substation. However, this would mean that it would lose its eligibility for lower power rates and rebate programs.
- **Buy-in by upper management.** Upper management will only approve projects if they are comfortable with the benefits, costs, and risks. It is important for these decisionmakers to be familiar with the technology, potential savings, and RECs related to CHP.
- **Capital funding/alternative funding.** The main barrier is funding. Capital costs are fairly high, estimated at $7 to $10 million, depending on whether a fat, oil, and grease (FOG) receiving station is included.
- **A combination of power savings and RECs** is required to make the payback less than 10 years and get a return of at least $0.10/kWh. The REC portion depends on whether the power company has met its renewable energy goal. In accordance with state law, the power companies need to meet specific goals with solar, biogas, and other renewables. Two NC companies, Duke Energy and Progress Energy, merged, resulting in a combined renewable energy capacity that exceeds the state's renewable energy goal. This may change in coming years as states' renewable energy goals continue to increase.

CMU had no funding set aside for this project as of the end of 2011. In fact, the CHP project was delayed to 2014 and was searching for alternative financing options. Grants were not available. CMU is interested in an alternative delivery method, such as design build operate transfer (DBOT), where a private company funds the capital and installs and operates the equipment for about six years. DBOT companies receive a tax credit for this period and can sell RECs to the power company. Then CMU would buy the system and get the benefits from power savings and REC sales. CMU is also looking at other financing options such as ESCOs. Working through an ESCO would reduce its burden on use of capital dollars. In 2011, CMS was working on a request for proposals (RFP) for the McAlpine CHP project.

Mallard Water Reclamation Facility

The Mallard Water Reclamation Facility (WRF) has a treatment capacity of 12 mgd. It is an activated-sludge plant with travelling bridge filter and ultraviolet (UV) disinfection. The driving effluent criteria are carbonaceous biological oxygen demand (CBOD) and ammonia limits of 4.2 and 1.2 mg/L, respectively. Solids are stabilized in mesophilic anaerobic digesters and are centrifuge-dewatered. The Mallard WRF produces about 6,000 wet tons of Class B biosolids per year, which are land applied. Some of the biogas is used for process heating; excess biogas is flared.

Mallard WRF By the Numbers

- 12 mgd average flow
- 6,000 wet tons/yr
- CBOD: 4.2 mg/L
- NH3: 1.0 mg/L

McAlpine WWMF

The McAlpine WWMF has a treatment capacity of 64 mgd. It is a biological/chemical nutrient removal plant with tertiary treatment. Processes include a small anaerobic zone followed by several aerobic zones, rapid-sand filters, and chlorine disinfection. When needed, phosphorus is further removed via precipitation with ferric chloride (FeCl3). The driving effluent criteria are total phosphorus (TP) daily and monthly limits of 1,067 and 826 lb/d, respectively, BOD limit of 4.0 mg/L and ammonia limit of 1.0 mg/L.

The McAlpine WWMF receives and processes solids from another plant. Solids are thickened in centrifuges or by gravity, stabilized in anaerobic digesters, and centrifuge-dewatered. The plant produces about 70,000 wet tons of Class B biosolids per year, which are land-applied. Some of the biogas is used for process heating; excess biogas is flared.

McAlpine WWTP By the Numbers

- 64 mgd average flow
- 70,000 wet tons/yr
- BOD: 4.0 mg/L
- NH3: 1.0 mg/L

Irwin Creek WWTP

The Irwin Creek WWTP has a treatment capacity of 15 mgd. It is an activated-sludge plant with tertiary treatment and UV disinfection. The driving effluent criteria are CBOD and ammonia limits of 5.0 and 1.2 mg/L, respectively. Solids are thickened in belt filter presses, stabilized in mesophilic anaerobic digesters, and dewatered in belt filter presses. The plant produces some 10,000 wet tons of Class B biosolids per year, which are land-applied. Some of the biogas is used for process heating; excess biogas is flared.

Irwin Creek WWTP By the Numbers

- 15 mgd
- 10,000 wet tons/yr
- CBOD: 5.0 mg/L
- NH3: 1.2 mg/L
- 23 plant staff

For more information, contact:

Jackie Jarrell, PE, Environmental management division superintendent, at jjarrell@ci.charlotte.nc.us; or Shannon Sypolt, environmental auditor, at ssypolt@ci.charlotte.nc.us.

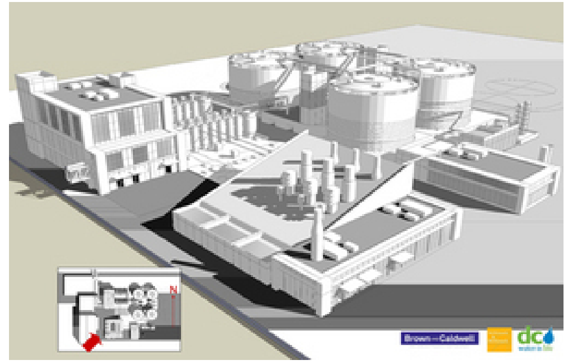
About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

DC Water, Washington DC

Case Study at a Glance



UTILITY OVERVIEW

The District of Columbia Water and Sewer Authority (DC Water) serves more than 2 million people from the greater metropolitan Washington, DC area, including Prince Georges and Montgomery Counties in Maryland; Fairfax, Arlington, and Loudoun Counties in Virginia; and the District of Columbia. DC Water owns and operates one wastewater treatment plant, the Blue Plains Advanced Wastewater Treatment Plant (AWTP).

DC Water Service Area By the Numbers

- Over 2,000,000 sewer customers
- 300 mgd average flow treated
- 1 WWTP
- Power cost: $0.08/kWh

Blue Plains Advanced Wastewater Treatment Plant

The Blue Plains AWTP treats about 300 mgd to advanced treatment levels and produces about 1,200 wet tons per day of biosolids. The plant's average daily capacity is 370 mgd – the world's largest AWTP. The liquid treatment process reduces total nitrogen and phosphorus to low levels prior to discharge to the Potomac River, which is part of the Chesapeake Bay estuary. Lime stabilization is used to produce Class B biosolids, which are trucked and primarily land-applied on farms, forests, and reclamation sites. About 5 percent of the biosolids is composted to Class A standards.

Although the current solids processing system has worked well for many years, DC Water will be installing anaerobic digestion to improve the sustainability of the current biosolids reuse program, to improve the product characteristics, to broaden beneficial reuse opportunities, and to take advantages of the energy benefits. DC Water is the largest consumer of electricity and has the largest carbon footprint in the District of Columbia.

The new 450-dry-ton-per-day Class A solids processing system began construction in 2011 and will include four thermal hydrolysis process trains and four, 3.8-mg anaerobic digesters, plus new final dewatering that will use belt filter press technology. Combined heat and power (CHP) facilities will use combustion gas turbines with heat-recovery steam generators. The medium-pressure steam generated is needed for the thermal hydrolysis process.

The $400+ million biosolids program, including the CHP processes, is expected to be online in 2015. It is estimated that CHP will produce 13 MW (net 10 MW) of renewable electricity by 2015, nearly half the AWTP's total power demand. Production of this renewable energy source will reduce the DC Water carbon footprint by 40 percent. In addition, the anaerobic digestion process will produce Class A biosolids and reduce biosolids volumes by more than 50 percent.

Blue Plains AWTP By the Numbers

- Operating since 1938
- 260 operations and maintenance plant staff
- 370 mgd average treatment capacity
- Old digester complex shut down in year 2000 (torn down in 2011)
- 4 combustion gas turbines with heat-recovery steam generators (by 2014)
- 33-percent of total plant power demand will be supplied by CHP
- 13 MW of power production by 2014
- Reduces carbon footprint by 40-percent compared with traditional energy forms

What barriers were encountered and how were they overcome?

Major barriers encountered included the following:

- **Economics.** Of primary importance was developing a biosolids program (including biogas use) that would be affordable to rate-payers.

- **Limited capital funding for discretionary projects.** DC Water management and board members questioned the need to proceed with a biosolids (and biogas program) as a discretionary project (not regulation-mandated).
- **Potential technology limitations.** There were limited anaerobic digestion and biogas use options that would satisfy the objectives and constraints for the program.
- **Air permitting concerns.** The metropolitan DC area is a non-attainment zone for ozone and any CHP process implemented would need to be permitted.

The following strategies were used to overcome the identified barriers:

- **Creative financing to reduce the impact on rate-payers.** DC Water used a delayed bond-principal model so that sewer rates rise only slightly and steadily; DC Water will pay interest only during construction, and pay the larger debt service once the project begins to save money (after start-up). The use of conventional financing with immediate, major debt service would have been much more difficult to sell to the board due to rate impacts.
- **Thinking outside the box and exploring innovative digestion and processing alternatives.** More cost-effective technology was used to construct both the digestion and CHP facilities for $400 million and produce Class A biosolids. It was estimated that conventional anaerobic digestion would cost $600 million and would not be acceptable to DC Water due to the impacts on rate-payers. DC Water is spending $50 million on an innovative thermal hydrolysis pre-digestion process (which reduces required digester volume) and will save $200 million on digester vessels.
- **Keeping construct costs down and project delivery quick.** This comes from selecting digestion tank construction and procurement methods such as concrete tanks and design/build delivery.
- **Using new digestion (and pre-digestion) technology.** This provides greater gas production than traditional digestion, thus creating more methane/energy for beneficial use.
- **Selecting new gas turbine technology.** This provides higher-than-normal power efficiency (38 to 39 percent), as well as high heat efficiency, combining to achieve at least 70-percent overall power/heat efficiency of the system.
- **Selecting a CHP system with low levels of exhaust emissions.** Combustion gas turbines produce low levels of NOx and therefore minimize the project's air permitting risks.
- **Maximizing the non-cost benefits of the program.** These include maximum renewable energy production, major greenhouse gas emissions reduction for DC Water, major reduced trucking of biosolids from the plant, and much greater potential for expanding biosolids reuse markets because of improved product characteristics.

"DC Water chose to implement an innovative technology and is building a thermal hydrolysis system that will be the first in North America and the largest in the world," said Chris Peot, PE, biosolids manager at DC Water. "This decision, along with a choice to go with a design-build model to compress the schedule and the calculated future savings ($28M/yr) has given our board the confidence to fund this discretionary project and set a precedent for renewable energy production, resource recovery, and sustainability."

For more information, contact:

Chris Peot, PE, DC Water biosolids manager at Christopher.Peot@dcwater.com.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

WERF • NYSERDA • Brown and Caldwell • Black & Veatch • Hemenway Inc. • NEBRA

Barriers to Biogas Use

Des Moines Metropolitan Wastewater Reclamation Authority, Des Moines, Iowa

Case Study at a Glance

UTILITY OVERVIEW

The Des Moines Metropolitan Wastewater Reclamation Authority (WRA) owns and operates one wastewater treatment plant that serves metropolitan Des Moines, Iowa. The Authority provides wastewater collection and treatment services to approximately 500,000 people in 17 municipalities, counties, and sewer districts in the region

Des Moines Water Reclamation Facility (WRF)

The Des Moines Water Reclamation Facility (WRF) is located in southeast Des Moines and treats an average of 70 mgd of wastewater. The WRF is an advanced secondary treatment facility whose driving effluent limitation is ammonia-nitrogen. Solids handling at the WRF includes rotary drum thickening for WAS, anaerobic digestion of thickened WAS, and primary sludge using six, 2.7-mg digesters, belt press dewatering, and land application. The WRF produces Class B biosolids.

Originally, the city installed combined heat and power (CHP) at the WRF for electricity peak shaving. The WRF has three internal combustion engine-generators, each with a capacity of 600 KWh. In the past, biogas was not produced in sufficient quantities to operate the engine-generators exclusively on biogas. However, the WRF began adding dairy waste directly to the anaerobic digesters, which greatly increased biogas production. Des Moines has since added more industrial waste streams to further boost biogas production, described in more detail below.

A plate-type heat exchanger recovers heat from the engine-generators' jacket water for use in boilers to heat plant buildings and the anaerobic digesters. Biogas is chilled to lower the temperature of the gas prior to sale to an industrial user. This has improved biogas quality by removing moisture and siloxanes and has resulted in longer maintenance intervals and greater efficiency of the engine-generators. The CHP system is 65- to 70-percent efficient during colder months; during warmer months, the system is approximately 40-percent efficient.

In addition to generating power for use onsite and for process heating, the WRF sells excess biogas to an industrial user, Cargill Oilseed Processing Facility, for use in its process boilers. A biogas delivery system was constructed in 2007 that includes a chiller for conditioning and a pipeline between the WRF and the Cargill facility. While the Authority was responsible for the cost of the biogas conditioning system, the cost of the

Des Moines Service Area By the Numbers

- 500,000 population served
- 1 WWTP
- 70 mgd average flow treated
- Power cost: $0.045/kWh

Des Moines WRF By the Numbers

- Operating since mid 1980s
- 134 mgd average wet weather permitted capacity
- 50 mgd average dry weather permitted capacity
- 200 mgd maximum wet weather permitted capacity
- 100 plant staff
- 3 engine-generators with 600 kWh capacity each
- Excess biogas sold to an industrial user
- Power Cost: $0.045/KWh

pipeline was split between Cargill and the Authority. Cargill is billed monthly based on the cost of natural gas and the ratio of methane in biogas (62 percent).

In 2011, the WRF's anaerobic digesters and biogas treatment and CHP systems were being updated to handle more organic loading and biogas. The Authority also considered using biogas as a fleet fuel. However, the Authority did not have funding to convert vehicles to accept compressed biomethane fuel. In addition, the Authority approached the local natural gas utility about purchasing biogas from the WRF but as of mid-2011 the utility had not expressed interest in this alternative.

What barriers were encountered and how were they overcome?

The biggest barriers that the Authority encountered with its CHP project included the following:

- **Need for more organic load for digestion and biogas production** to operate CHP on 100 percent biogas.
- **Need to upgrade the anaerobic digesters to accept this larger organic load.** The current gas mixing system was being replaced in a multi-year upgrade project.

These factors enabled implementation:

- **Increasing the amount of hauled waste to provide sufficient organic load and biogas.** The Authority contacted industries that were pre-treating waste prior to discharging to the influent of the WRF. It also reduced disposal rates, particularly for regional industries, for concentrated waste that did not damage the anaerobic digesters. This approach considerably increased the volumes of septage,. brown grease from restaurants, whey and cleaning wastes from dairies and food processors, and high-concentration biodegradable wastes from chemical processing industries. Not only did these high-strength wastes increase biogas production, they provided an improved revenue stream – from $50,000 in 2001 to $250,000 annually in 2010.
- **Updating and re-designing the hauled waste and digestion facility** twice to more-efficiently accept this waste and generate biogas. This was done to keep up with demand from industrial dischargers.
- **Partnering with and selling excess biogas to an industrial user.** In 2007, the WRF generated approximately $460,000 in revenue by selling biogas to the Cargill Oilseed Processing Facility. By selling excess biogas, the WRF was also able to meet its goal of no more than five percent wastage of biogas.

"We're always looking for new technologies and strategies to make the best use of our biogas at the lowest cost," said William G. Stowe, director, Des Moines WRA.

For more information, contact:

Steve Moehlmann, Des Moines WRF training and safety consultant, at semoehlmann@dmgov.org.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Village of Essex Junction WWTP, Essex Junction, Vermont

Case Study at a Glance

UTILITY OVERVIEW

The Village of Essex Junction WWTP serves a suburban area just to the east of Burlington, VT, with about 30,000 customers. Its wastewater treatment plant processes wastewater from the village and from the nearby towns of Essex and Williston. Treated water is discharged into the Winooski River.

Village of Essex Junction WWTP

The WWTP's two mesophilic anaerobic digesters (one primary, one secondary: 350,000 gallons each) were built decades ago, and the biogas was used for digester heating. Essex Junction land-applies bulk, digested, Class B liquid and cake biosolids on two nearby farms.

In 2003, two 30-kW Capstone dual-fuel (biogas and natural gas) microturbines for combined heat and power (CHP) were installed. Biogas is treated to remove moisture and siloxanes and then is fed directly to the microturbines, where heat is recovered to provide digester heating and some space heating. Since 2007, fat, oil, and grease (FOG), brewery waste, and oily waste by-product have been added in measured amounts directly to the digester, which has improved biogas production and volatile solids reduction.

The WWTP has reduced its electricity costs by 30 percent per year and is receiving renewable energy credits (RECs) for the electricity it generates.

Biogas use facilities are a key part of the village's greenhouse gas reduction strategy. Current challenges include increasing costs of chemicals, increasing energy costs, and less funding availability. Facility staff plans to expand CHP over the three years after 2011.

What barriers were encountered and how were they overcome?

Initial barriers that had to be overcome included the following:

- **Dealing with increased complexity, which creates uncertainty** about many aspects of a potential biogas use project.
- **Early versions of technology** posed problems working with the electrical utility on interconnection with the grid. These were easier to overcome in recent years.
- **No RECs were available** at the time of the initial project.

Essex Junction Service Area By the Numbers

- >30,000 sewer customers
- 2 mgd average flow treated
- 1 WWTP
- Power cost ~$0.12/kWh

Essex Junction WWTP By the Numbers

- Operating since 1964
- 1 primary and 1 secondary mesophilic AD
- Advanced secondary conventional activated sludge process
- Relatively high BOD
- P removal to 0.8 mg/L, seasonal nitrification
- Solids production: <1 dry ton /day
- 25-30 day solids retention time
- ~70% VS destruction
- CHP system capital cost for pre-construction and construction: $489,000
- Grants / incentives: $100,000
- Simple payback required: 7 years
- CHP system ownership and maintenance: Essex Junction

- **Gaining approval from the board** was done with creative financing, which included grants and incentives to make the simple payback acceptable to the board, but because WWTPs last so long, longer paybacks should be acceptable, operations staff argue.
- **The age of the digesters** makes it a challenge to keep them running optimally.

The decision to proceed with CHP was based on a return on investment, and the following incentives:

- **Getting support that convinced regulators to accommodate the installation** (because the village was a relatively early adopter of modern CHP, obtaining regulatory buy-in was a significant barrier).
- **Using an alternative delivery method** that improved the cost/investment and risk profile.
- **Finding ways to dramatically increase gas production.**

Although construction and start-up of the CHP system went smoothly, there were some operational issues that required further adjustments, including the following:

- **A decrease in the power factor rating** after the CHP system went online reduced the economic benefit for the WWTP and lengthened the payback time somewhat.
- **Initially, the biogas contained enough moisture to cause maintenance issues** for the methane compressors. An upgraded moisture removal system eliminated this problem.
- **The digesters continue to age,** and a major maintenance upgrade is pending, which requires new pipes, pumps, controls, and meeting current electrical codes, whether or not CHP were in place. The microturbine system needs $150,000 in planned or code-required maintenance. These pending costs have required careful analysis of ways to optimize the digestion and CHP systems. For example, expanding biogas production might make a central heat plant a good option. Nonetheless, CHP was expected to remain at the site in some form.
- **Lack of available expertise on microturbine operations and potential reciprocating engines**. Because of the village's relatively remote location, this issue that must be considered.

"The technology has developed and any uncertainty is easier to deal with," noted James Jutras, WWTP superintendent. "The quickly-evolving market does not spook me any more. Once you get on the other side of trying it, there is a whole different perspective – it becomes manageable. The capacity for biogas use is higher. There are more specialists in the field. Energy is now part of training for wastewater design; expectations and the bar have gone higher - especially for smaller facilities. One last important barrier: at a small plant, you have got to do it all, and often, there are not enough hours in the day." His advice is: "Do your homework, and continue with the homework after the system is constructed. Wastewater – including biogas use – is about customized systems to fit your process needs and objectives. There is no simple plug and play." Then focus on communication and advocacy. "You need to convince people. It takes a project champion."

For more information, contact:

James Jutras, Essex Junction WWTP superintendent, at ejctwwtf@sover.net

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Village of Fredonia, New York

Case Study at a Glance

UTILITY OVERVIEW

The Village of Fredonia, NY is located mid-way between Buffalo, NY and Erie, PA, near the shore of Lake Erie. Its wastewater treatment plant was built in 1978 and is permitted to treat 3.3 mgd of sewage from the Village, local food processors, the State University of NY at Fredonia, and neighboring areas.

Village of Fredonia WWTP

The Fredonia WWTP configuration includes no primary clarifiers and a three-zone aeration process that achieves biological nutrient removal. The solids are treated in one mesophilic anaerobic digester (AD), which was upgraded in the late 2000s to include a gas-holder system and high-rate mixing. The plant has another digester that was not upgraded and is used as a storage digester. The load to the treatment plant is increased with septage fed into the headworks, which helps boost Fredonia's revenues.

Biogas from the AD system is not treated and is used in boilers, which also run on natural gas. In mild temperatures, the digester produces enough gas to heat not only the digestion process, but also domestic hot water and the plant building. Use of the biogas for these purposes has reduced the annual cost for natural gas from $40,000 to $11,000.

Fredonia is developing plans for installing combined heat and power (CHP) for greater use of the biogas; which type of system was still being decided as of October 2011. As part of the new system, the gas will be scrubbed and dried. In addition, the WWTP plans to install some form of solids pre-treatment system (e.g. hydrolysis) to break down cell walls prior to digestion, which will increase biogas production. This is especially important because only secondary solids are being digested.

What barriers have been encountered and how were they overcome?

In the survey for this project, Fredonia staff noted the following top three challenges for its WWTP:

- **Increasing costs of aging infrastructure**
- **Increasing costs of energy**
- **Availability of funding**

City of Fredonia By the Numbers

- Population ~10,700
- 1 WWTP
- 2.5 mgd average flow treated
- 3.3 mgd design flow
- Power cost: $0.073/KWh (without demand charges), $0.103 (with demand charges)

Fredonia Regional WWTP By the Numbers

- Began operation in 1978
- No primary clarifiers
- Secondary aeration with 3 zones: stabilization, selector (anoxic), and contact
- Septage is received & treated in the plant
- Plan to accept and dry fats, oils, and grease (FOG)
- 1 mesophilic anaerobic digester
- 10-15 day retention time
- 50-60% VS destruction
- Biogas production ~40,000 scfd, consistent measurement is challenging
- Biogas used for process and building heating
- Biogas use has saved ~$30,000/year
- Plans to install CHP

As it contemplated adding CHP, it was experiencing challenges finding grants or other funding and working out an interconnection agreement with the local electric utility. Because of its long experience managing biogas, it does not consider the safety of biogas use to be an issue.

After the upgrade to the one digester, Fredonia staff had to work through a particular technical issue: biogas was being vented to the atmosphere due to improper settings based on faulty information about the gas volume.

But **"**the main barrier is cost," noted Chief Operator Betsy Sly.

The following strategies were being used to overcome the barriers:

- **Power costs are high enough to justify the investment.** Operational savings will help make the payback acceptable.
- **Sustainability** is important, and biogas use is part of greenhouse gas reduction.

"We have been in discussion with an engineering firm to begin an energy performance contract with the hope to utilize grants and low-interest loans to complete projects, including the conversion of our second digester to a gas holder style," said Sly.

For more information, contact:

Betsy Sly, Fredonia WWTP chief operator, at fwwtp@verizon.net

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

WERF • NYSERDA • Brown and Caldwell • Black & Veatch • Hemenway Inc. • NEBRA

Barriers to Biogas Use

Gastonia, North Carolina

Case Study at a Glance

UTILITY OVERVIEW

Two Rivers Utilities, which is owned by City of Gastonia, NC, operates three wastewater treatment plants (WWTPs). Both the Crowders Creek WWTP and the Long Creek WWTP operate anaerobic digesters, while the Eagle Road WWTP uses aerobic digestion. Wastewater services are provided to about 86,000 people in and around Gastonia, NC. The plants have a permitted capacity of 26 mgd and treat an average flow of 8.5 mgd.

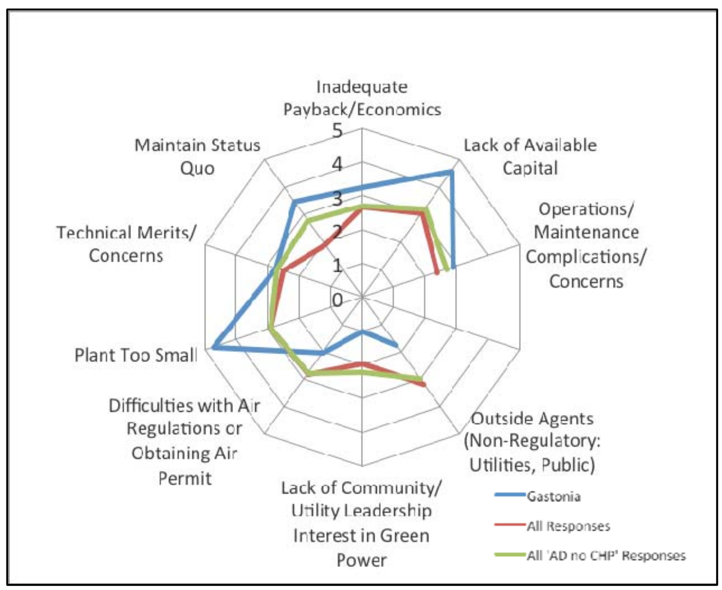
Two Rivers Utilitie Service Area By the Numbers

- 86,000 customers served
- 8.5 mgd
- 3 plants
- Power cost:$0.05/kWh

What barriers were encountered and how were they overcome?

Major barriers encountered included the following:

- **Lack of available capital.** Biogas use is not an immediate need, and so it faces strong competition for the already limited capital expenditure funds.
- **Inadequate payback.** The return on investment (ROI) period is very long for several reasons including the relatively small size of the plants and the low cost of electricity and natural gas.
- **Lack of political support.**



The spider graph to the right shows how Two Rivers' ranking of the most important barriers to biogas use compares with more than 200 other survey responses, of which more than 50 are, like the Crowders Creek and Long Creek WWTPs, plants that have anaerobic digesters but do not use the biogas except for process heating.

Note that "plant too small" and "lack of available capital" are important considerations for Two Rivers relative to other utilities. On the other hand, Two Rivers has a strong interest in green power relative to other utilities. In fact, Two Rivers has identified biogas as an opportunity for renewable energy, and has researched federal and state grants for renewable energy. As the regulations are stated, however, it is unclear whether electricity generation from biogas will be eligible for renewable energy credits.

To proceed with a combined heat and power generation (CHP) project, the city would need to obtain the necessary funding, which, with the right political support, could be in the form of federal and state grants. Clarifying whether or not biogas use would be eligible for renewable energy credits in North Carolina would be a good first step.

Crowders Creek WWTP

Crowders Creek WWTP By the Numbers

- 6 mgd permitted
- 2.1 mgd average

The Crowders Creek WWTP has a permitted capacity of 6 mgd and treats an average flow of 2.1 mgd. The driving effluent criteria are total nitrogen (TN) and total phosphorus (TP). Liquid stream processes include primary clarifiers, biological nutrient removal (BNR) (alternating ANA, OX, ANOX), secondary clarifiers, polishing ponds, and chlorine disinfection. A mixture of primary sludge and dissolved air flotation (DAF)-thickened waste-activated sludge (WAS) is stabilized in mesophilic anaerobic digesters, producing Class B biosolids that are beneficially used in land application. All the biogas generated is flared.

Long Creek WWTP

Long Creek WWTP By the Numbers

- 16 mgd permitted
- 6.0 mgd average

The Long Creek WWTP has a permitted capacity of 16 mgd and treats an average flow of 6.0 mgd. The driving effluent criteria are TN and TP. Liquid stream processes include primary clarifiers, BNR (alternating ANA, OX, ANOX), secondary clarifiers, tertiary filters, and chlorine disinfection. A mixture of primary sludge and DAF-thickened WAS is stabilized in mesophilic anaerobic digesters, producing Class B biosolids that are beneficially used in land application. All the biogas generated is flared.

For more information about Two Rivers Utilities, contact:

Stephanie Scheringer, assistant wastewater division manager – operations, Two Rivers Facilities, at stephanies@cityofgastonia.com.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Gloversville-Johnstown, New York

Case Study at a Glance

UTILITY OVERVIEW

Gloversville and Johnstown are cities in Fulton County, New York, known together as the "Glove Cities." They are about 45 miles west of Albany on Cayadutta Creek, in the foothills of the Adirondacks. The joint wastewater treatment facility serves a population of about 24,000 from one plant with two anaerobic digesters (ADs).

Gloversville-Johnstown Joint Wastewater Treatment Facility

The Gloversville-Johnstown Joint Wastewater Treatment Facility (GJJWTF) is a 11 mgd plant with mesophilic anaerobic digestion (AD) and combined heat and power (CHP) fueled with biogas.

Its unique position arises from the large feed of high-strength organic wastes, specifically 90,000 gallons per day of dairy whey, contributing to high yields of biogas. The anaerobic digestion system is a two-stage, high-rate anaerobic digestion system, with a 1.5-million-cubic-foot primary sludge digester and a 1.3-million-cubic-foot digester for secondary sludge, each with confined gas mixing systems. Digester gas is stored in a dual-membrane gasholder located directly behind the digester complex.

Biogas is fed to two internal combustion (IC) engine generators with an installed rating of 700 kW. The engines can also run on natural gas, though biogas is adequate to keep the engines running 24/7. The electricity is used to power all of the WWTP electrical needs, and waste heat is used for heating the primary and secondary digester and for building heat.

Whereas the loading rate to digesters is nearing a practical upper limit, recuperative thickening of the digester sludge in the primary digester has been added to increase the sludge retention time and thereby overall volatile solids destruction, and is also fully operational.

What barriers were encountered and how were they overcome?

Major barriers encountered included the following:

- **Shortage of qualified workforce**
- **Availability of funding**
- **Compliance with regulations**

Gloversville-Johnstown Service Area By the Numbers

- 24,000 customers
- 11 mgd average flow
- 1 WWTP
- Power cost: ~$0.12/kWh

Gloversville-Johnstown WWTF By the Numbers

- Operating since 1972
- 1 primary and 1 secondary mesophilic AD
- 80% of flow is from industry
- Significant upgrades in 1990s included ADs
- Secondary conventional activated sludge process
- Solids production: ~2 dry tons /day
- ~15 day solids retention time
- 40-50% VS destruction
- Installed generating capacity: 700 kW
- Savings from AD and CHP on annual O & M: $750,000/year
- Grants / incentives: $3.2M
- Simple payback required: 14 years, without grants
- CHP system ownership and maintenance: GJJWTF

Gloversville-Johnstown also noted the importance of the following in ensuring a successful CHP program:

- **Achieving sustainability goals.**
- **Adapting to changed industrial users** in its service area.
- **Equalizing incoming loads** to avoid overloading the digesters.
- **Training** existing personnel to manage new equipment.
- **Grants and other incentives.** These included $2.2 million in grants from the US Economic Development Administration to support improvement for accepting whey, and a $1.0 million grant from the New York State Energy Research and Development Authority (NYSERDA) to support CHP, plus $6.0 million from the American Recovery and Reinvestment Act (ARRA.) If there had been no grants, a simple payback of 14 years would have been required.

Gloversville-Johnstown has nearly 20 years' experience operating an AD and CHP system, although the upgraded digester, generator, and thickening systems increase system complexity. Initial barriers that had to be overcome included the following:

- **Insufficient biogas** to operate CHP economically, in part due to reduced organic loadings to the plant, which was overcome by accepting trucked-in waste to the digesters.
- **Insufficient heat available** from CHP to provide for digester heating; the larger engines running on the biogas supplemented with dairy whey have led to adequate heat for process and buildings.
- **Inadequate mixing** in the digesters and biogas storage capabilities.
- **Inadequate facilities for equalizing organic wastes** before feeding to digesters.

Although the upgraded digesters and CHP system installation went smoothly and enabled GJJWTF to become nearly energy self-sufficient, several operational issues that required further adjustments included the following:

- **Dewaterability of the biosolids has continued to be an issue**, and GJJWTF continues to search for technologies to improve solids content of the cake.
- **Excessive loading rates** caused deterioration of digester function on one occasion, due to high volatile fatty acid (VFA) build-up and reduction in methanogen activity. The digester was restored over a period of six weeks, after pH stabilization and recuperative thickeners removed VFAs.
- **The recuperative thickening system has been slow** to reach its operational goal for allowing the digesters to meet the goal of longer than 15 days sludge retention time.

For more information, contact:

George Bevington, GJWWTF manager, at gbev@frontiernet.net or 518-762-3101

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Gwinnett County, Georgia

Case Study at a Glance

UTILITY OVERVIEW

The Gwinnett County Department of Water Resources (GCDWR) owns and operates three wastewater treatment plants in northeast metropolitan Atlanta, Georgia. Gwinnett County was one of the fastest growing counties throughout the 1980s and 1990s. In 2009, it treated a total of about 63 million gallons per day (mgd) of flow on average and generated about 35 dry tons per day of biosolids.

F. Wayne Hill Water Resources Center (WRC)

The F. Wayne Hill WRC has a permitted capacity of 60 mgd; it treats about 30 mgd to advanced treatment levels. Primary sludge and thickened waste-activated sludge are anaerobically digested to Class B standards in five mesophilic, egg-shaped digesters. Digested solids are then transferred to a sludge storage tank and dewatered using centrifuges. Cake is disposed of in a landfill. Prior to implementation of its combined heat and power (CHP) project, biogas was used for process heating and was flared.

Energy costs at the F. Wayne Hill WRC account for 25 percent of its annual operating expenses. Gwinnett County considered it important to control this escalating cost as well as improve the sustainability of its operations, mitigate the revenue impact of reduced water sales due to drought and conservation, and minimize the impacts to rate payers. As a result, Gwinnett County initiated the Gwinnett POWER (Processing Organic Waste for Energy Recovery) project in 2009.

This project will supply up to 40 percent of the F. Wayne Hill WRC power demand and will recover about 7.5 million Btu as heat. One 2.1-megawatt (MW) internal combustion engine will be used for energy recovery. Non-hazardous high-strength wastes (HSW), such as fats, oil, and grease (FOG), will be used to increase biogas production at the WRC.

The Gwinnett POWER project was implemented using two, design-build contracts. The first contract, with a value of $5.2 million, was awarded in October 2009 for the engine-generator, gas- conditioning, and heat-recovery systems. A second contract, at $3.2 million, was awarded in June 2010 for the FOG and HSW receiving facilities. The CHP contract was completed in May 2011; the FOG and HSW facilities were scheduled to be completed in September 2011.

Gwinnett County By the Numbers

- 140,000 sewer customers
- 220,000 retail water customers
- 53 mgd average flow treated
- 3 WWTPs
- Power cost: $0.075/kWh

F. Wayne Hill WRC By the Numbers

- Operating since 2000
- 40 plant staff
- 30 mgd average flow treated
- 40-percent of power demand will be supplied by CHP
- One, 2.1-MW engine-generator
- 7.5 million Btu recovered as heat

What barriers were encountered and how were they overcome?

The major barriers at the WRC were economic. The original concept for the project (smaller engine generators) had an unacceptably long, 20-year payback period for current biogas production. The economics of the project were improved by employing the following strategies:

- **Increasing biogas production.** This was accomplished by constructing a larger CHP system supplemented with biogas generated through co-digestion of FOG and other HSW. Additional biogas will be generated by improvements to the WRC's primary clarification process and sludge transfers from another Gwinnett County WRC. This reduced the payback period to nine years.
- **Constructing a FOG and HSW receiving facility.** Although this increased the capital cost of the project, it also created a new revenue stream, estimated at over $500,000 per year, in the form of FOG and HSW tipping fees. Other benefits of accepting FOG waste included reducing sewer blockages and sanitary sewer overflows (SSOs).
- **Emphasizing the annual cost savings of the project rather than simply project payback.** It was estimated that the project would reduce the WRC's electricity costs by $1 million per year. In addition, it would eliminate the need for natural gas for process heating needs. This would reduce the impact of energy volatility and costs on Gwinnett County's operating budget.
- **Applying for and receiving grant funding**. Gwinnett County won a $5 million American Recovery and Reinvestment Act (ARRA) grant (60 percent) and loan (40 percent) administered through the Clean Water State Revolving Fund (CWSRF) and a $3.5 million ARRA grant from the US Department of Energy.

Other advantages, such as the potential for renewable energy credits (RECs) for future trading and improved sustainability and reduced GHG emissions, also were used as selling points for the Gwinnett POWER project.

"We're making good use of a renewable, previously wasted resource to help cut operating costs and keep water rates low for Gwinnett residents," said Lynn Smarr, acting director of water resources.

For more information, contact:

Tyler Richards, PE, GCDWR deputy director at Tyler.Richards@gwinnettcounty.com
Robert Harris, GCDWR operations process engineer at Robert.Harris@gwinnettcounty.com

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Hampton Roads Sanitation District, Hampton Roads, Virginia

Case Study at a Glance

UTILITY OVERVIEW

The Hampton Roads Sanitation District (HRSD) was formed in 1940 and serves 1.6 million customers in coastal, southeast Virginia. The service district encompasses 17 jurisdictions over 3,100 square miles. HRSD operates 13 wastewater treatment plants (WWTPs) with a total capacity of 249 mgd.

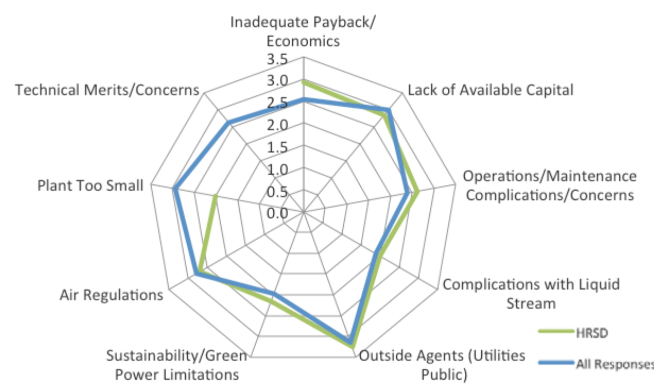
HRSD By the Numbers

- 1.6 million people served
- Operating since 1940
- 13 plants, 9 large and 4 small
- 4 plants have anaerobic digestion
- 249 mgd capacity
- 160 mgd average flow
- Power cost: $0.055/kWh

Hampton Roads Saniatation District (HRSD)

The 13 HRSD plants treat an average flow of 160 mgd. Of the nine large HRSD plants, five have incinerators and four have anaerobic digesters, including the Atlantic, James River, Nansemond, and York River WWTPs. The stabilized biosolids go to diverse end uses, including Class B land application, composting, and incineration.

A biogas-to-energy project was under design in 2011 at the Atlantic WWTP after improvements to the anaerobic digestion process. If economically viable, the combined heat and power (CHP) project was to be evaluated for implementation at the James River, Nansemond, and York River WWTPs, where biogas is flared.



HRSD identified biogas as an opportunity for renewable energy, and researched and pursued federal and state grants for renewable energy. Four survey responses received from HRSD managers and operators indicate that imnplementing CHIP is important. The graph to the right shows how HRSD's ranking of the most important barriers to biogas compares with more than 200 other survey responses collected. Note that inadequate payback/economics, operations/maintenance concerns, and sustainability were important considerations for HRSD relative to other utilities. But size of the treatment plants was not a significant barrier.

What barriers were encountered and how were they overcome?

The primary barriers identified by HRSD included the following:

- **Low cost of electricity** made financial justification of project difficult. The cost was too low to financially justify the investment, although the project is moving forward. Cost of electricity was about $0.055/kWh. If this were to increase by even one penny, CHP would be more easily justified.
- **Uncertainty associated with biogas treatment** required to meet the gas quality requirements for the engine generators.
- **The cost of equipment and lack of competition** among equipment suppliers.

HRSD was evaluating the addition of fat, oil, and grease (FOG) to the digesters at the Atlantic plant to boost biogas production, and with future additional gas storage and generation capacity, peak power generation also could be considered.

York River WWTP

The York River WWTP has a treatment capacity of 15 mgd with flows ranging from 10 to 12 mgd. It provides nitrification and denitrification and added deep bed post-denite filters to reduce total nitrogen levels in the effluent. The plant removes phosphorus via precipitation with ferric chloride (FeCl3). Solids are digested in mesophilic anaerobic digesters, centrifuge dewatered, and hauled offsite for composting. Biogas is flared.

James River WWTP

The James River WWTP operates a mesophilic anaerobic digestion system. The plant has a treatment capacity of 20 mgd with flows from 13 to 14 mgd. An integrated fixed-film in activated sludge (IFAS) system in a four-stage Bardenpho configuration is used for nutrient removal. Phosphorus is removed via precipitation with FeCl3. Solids are anaerobically digested, centrifuge dewatered, and hauled offsite for composting. Biogas production of 50,000-100,000 scfd is used in boilers for process and building heating; excess biogas is flared. This plant does not have gas storage.

It was difficult to justify the high capital investment and added operational costs of a CHP system despite electricity savings.

Nansemond WWTP

The Nansemond WWTP operates a mesophilic anaerobic digestion system. The plant has a treatment capacity of 30 mgd. Average flows range from 15 to 18 mgd with about 30 percent coming from industry. A five-stage Bardenpho system is used for nitrogen and phosphorus removal. The Ostara installation recovers nutrients by adding magnesium to precipitate struvite from the dewatering filtrate. Solids are anaerobically digested, centrifuge-dewatered, and hauled to another HRSD-owned facility for incineration. The biogas production of 50,000 to 100,000 scfd is used in boilers after moisture removal for process and building heating; excess biogas is flared.

Identifying a proven, cost-effective technology for gas cleaning was a serious barrier still to be overcome for Nansemond WWTP to invest in CHP.

Atlantic WWTP and the Biogas-to-Energy Project

The Atlantic WWTP was expanded from 36 mgd to 54 mgd with provisions for a build-out capacity of 72 mgd. The conventional high-rate anaerobic digestion process was converted to a two-phase, mesophilic acid/gas process. A new 300,000 gallon acid-phase digester was constructed to provide a 23-hour solids retention time (SRT). Six digesters were converted to gas-phase reactors to provide an 18-day SRT. With the digestion improvements, volatile solids destruction was predicted to increase to 59%, and save $190,000 in dewatering and land application costs. Biogas production of 250,000-300,000 scfd is used in boilers for process and building heating; excess biogas is flared.

In 2011, the biogas-to-energy project was under design. The goal was to maintain firm (minimum ½ hour) peak-power production using three, 800-kW internal combustion engine generators. One of the generators will be placed in standby mode. The generators will use exhaust and water jacket heat recovery and have extensive gas treatment upstream. If successful, the process will be evaluated for implementation at other WWTPs.

The biogas-to-energy project is estimated to cost $8.7 million. After obtaining Virginia Clean Water Revolving Loan Funding of $3 million (at 2.93% interest and 40% principal forgiveness) and selling bonds to cover the remainder of the project cost, the annual debt service of the project was expected to be $406,000 over 20 years.

HRSD has a relatively low power cost of $0.055/kWh. With a fuel rider of $0.034/kWh, the annual electrical power savings are estimated to be $715,000. Net operating savings using 2009 data were estimated to be $384,000. Every $0.01 increase in the fuel rider would result in an 18% increase in net power savings to HRSD, significantly improving the financial attractiveness of the project.

For more information, contact: Charles Bott, HRSD chief of special projects, at cbott@hrsd.com.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

WERF • NYSERDA • Brown and Caldwell • Black & Veatch • Hemenway Inc. • NEBRA

Barriers to Biogas Use

Lewiston-Auburn Water Pollution Control Authority, Maine

Case Study at a Glance

This engineered aerial view shows the existing LAWPCA WWTP in the lower 2/3rds and the to-be-built digester complex at the top.

UTILITY OVERVIEW

The Lewiston-Auburn Water Pollution Control Authority (LAWPCA) was created by the state legislature in 1967. It owns and operates one wastewater treatment plant (WWTP) that serves a population of 59,000 in the Twin Cities of Lewiston and Auburn, in south central Maine.

Lewiston-Auburn Water Pollution Control Authority

The LAWPCA WWTP treats an average of 12 mgd of wastewater and discharges to the Androscoggin River. The plant employs a conventional secondary activated sludge treatment process. Most of the resulting solids are composted or lime-stabilized for Class B land application, although about 10 percent are landfilled in some years.

In 2009, LAWPCA began to assess the potential for anaerobic digestion, and a feasibility study was conducted that year. This led to preliminary design, a feasibility study, and a final design, which was completed in June 2011. The construction contract was signed September 1, 2011 for an estimated cost of about $12 million. The new system will include two 70,000gallon, 65-foot-diameter circular digesters, a 50-foot-diameter solids holding tank with 30,000-cubic-foot capacity for digester gas, and two 220/230 kW reciprocating engine generators. Operations were expected to begin in early 2013. It is expected to be the only operating municipal anaerobic digestion facility in Maine and the first to use digester gas for CHP.

What barriers were encountered and how were they overcome?

Major barriers encountered included the following:

- **Costs of biosolids management.** A major driver in recent decisionmaking has been the increasing cost of solids management through the existing composting operation and lime-stabilization and land application. This challenge helped create the opportunity to pursue anaerobic digestion and CHP, since digestion will dramatically reduce the volume of solids to be managed.

Lewiston-Auburn Service Area By the Numbers

- 59,000 sewer customers
- 1 WWTP
- 12 mgd average flow treated, including 30%+ industrial input and 1 million gals./yr. septage
- 14 mgd design capacity
- Power cost: $0.118/kWh
- Natural gas cost: $0.017/cf

Lewiston-Auburn Water Pollution Control Authority By the Numbers

- Treatment began in 1967
- 18 plant staff
- Activated sludge process with selector/contact stabilization
- Construction of two 70,000 gal anaerobic digesters began in fall 2011
- CHP planned – 2 reciprocating engine generators at a cost of $817,000
- $330,000 grant for CHP from Efficiency Maine Trust
- $900,000 principal loan forgiveness from state revolving-loan fund
- $12 million total project cost

- **Limited capital dollars were available to fund the project.** The board allows for payback periods from six to ten years. Figuring out how to make the economics work was a major challenge.
- **Increasing costs of aging infrastructure**. The WWTP and biosolids composting facility need regular upgrades because of aging equipment; this places considerable demand on available capital. Improvements to the composting facility may not be as critical if the volume of solids are reduced, which will happen with anaerobic digestion.
- **Skepticism and inertia.** Getting the LAWPCA commissioners to see the value of investigating and pursuing the option required considerable communication and education.
- **Technical concerns.** Figuring out the right configuration of digesters and the potential combined heat and power (CHP) system, as well as the possibility of receiving high-strengh wastes – all these technical details had to be put together in a way that made the most sense in terms of economics. For example, egg-shaped digesters were rejected due to their greater capital cost, and a study was commissioned to determine that it is likely that the proposed anaerobic digestion system will be able to attract high-strength outside wastes, generating additional revenues (tipping fees) and biogas.

"The board voted to proceed with the anaerobic digestion and to set aside money for the CHP system," explained Mac Richardson, Superintendent. "This allows for a step-by-step approach that gives us time to refine the details of the CHP system. For example, we won't build a receiving station for outside wastes right away, but that will be an option we keep open for the future."

For more information, contact:

Clayton "Mac" Richardson, superintendent, at mrichardson@lawpca.org.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Narragansett Bay Commission, Providence, Rhode Island

Case Study at a Glance

UTILITY OVERVIEW

The Narragansett Bay Commission (NBC) serves 360,000 people in north central Rhode Island. It owns and operates two wastewater treatment facilities, the Bucklin Point WWTF (BPWWTF) and the Fields Point WWTF (FPWWTF), and treats 70 mgd of flow on average. In 2010, about 7.3 dry tons per day of biosolids were generated. In total, the Commission spent $4.2 million on energy in 2010 to provide wastewater services that included conveyance, treatment, maintenance, inspection, laboratory, and administrative services.

Narragansett Service Area By the Numbers

- 360,000 customers
- 70 mgd average flow treated
- 2 WWTPs
- Employs staff of 246
- 2010 power cost: $0.121/kWh
- 2010 natural gas cost: $1.39/therm
- Total annual energy costs: $3.8 million

Bucklin Point WWTF

The BPWWTF is a secondary, biological nutrient removal (BNR) plant treating wastewater and stormwater from the communities of Pawtucket, Central Falls, Lincoln, Cumberland, and portions of Smithfield and East Providence. The BPWWTF is designed for a maximum daily secondary flow of 46 mgd. The average daily flow is 22 mgd.

The digester system consists of three primary anaerobic digesters (ADs) and one secondary AD, fitted with a floating cover, and serves as a storage tank for biosolids and biogas. The system was designed to provide a minimum detention time of 15 days to achieve Class B stabilization. The facility uses the biogas to fuel three hot water boilers that are used for process heating and some building heating systems. Excess digester gas is burned using two waste gas flares.

When the total cost for electricity at the BPWWTF increased from $630,000 in 2004 to $1,143,000 per year in 2006 after construction of the BNR and ultraviolet disinfection processes, the NBC evaluated the feasibility of combined heat and power (CHP) at the facility to reduce energy expenditures. As a result, the Commission is implementing CHP at the BPWWTF using one, 600-kW reciprocating engine generator as well as biogas conditioning systems and switchgear. The project was expected to be bid in 2012 with CHP online in 2014.

Bucklin Point WWTF By the Numbers

- Operating since 1952
- 32 plant staff
- 22 mgd average flow treated
- One, 600-kW engine-generator is currently being designed

Fields Point WWTF By the Numbers

- Operating since 1901
- 56 plant staff
- 48 mgd average flow treated
- Initiating a utility-scale wind energy project

What barriers were encountered and how were they overcome?

Major barriers at the BPWWTF included the following:

- **The economic feasibility** of a CHP project was difficult to determine because of high amounts of siloxanes in the biogas and a variable biogas production rate.

- **Challenges selecting a CHP prime mover** (microturbine or internal combustion engine) while considering impacts on air emissions, maintenance, and project payback.

These barriers were overcome by employing the following strategies:

- **Improving the quality of biogas and providing effective biogas conditioning systems.** The major source of siloxanes in BPWWTF's biogas closed in 2008. This helped reduce costs associated with pre-treatment of biogas. A biogas conditioning system consisting of iron sponge for hydrogen sulfide removal, gas chilling for moisture removal, and activated carbon scrubbing for siloxane removal was to be provided.
- **Applying for and receiving grant funding.** EPA and Rhode Island Office of Energy Resources (RIOER) grants of $35,000 and $25,000 were used to complete renewable energy studies that ranked biogas use as a high priority and showed that generating renewable electricity from highly contaminated biogas was more feasible using an engine generator rather than a micro-turbine. These studies facilitated early progress toward the ≈$2 million capital project that was being designed in 2011.
- **Considering rising, variable utility costs and renewable energy credits (RECs) in the economic analysis.** This made the economics of the project more favorable.

Fields Point WWTF

The FPWWTF is a secondary wastewater plant providing wastewater and stormwater treatment for Providence, North Providence, Johnston and a small section of Cranston. The FPWWTF is designed for a maximum daily secondary flow of 77 mgd. The average daily flow was 48 mgd.

Biosolids treatment at the FPWWTF includes gravity thickening and centrifuge dewatering. Anaerobic digestion is not provided. Dewatered biosolids are then land-applied or incinerated by an independent contractor. New BNR processes are being constructed and were expected to be online in 2013. The annual energy use at the FPWWTF was expected to double due to BNR.

What barriers were encountered and how were they overcome?

The Narragansett Bay Commission did not have plans to construct either anaerobic digestion or CHP at the FPWWTF as of 2011. The major barriers impeding this implementation included the following:

- **Space limitations.** There is very limited extra land area where ADs and CHP could be installed.
- **Contract constraints for biosolids disposal.** A long-term contract is in effect to manage biosolids by land application and incineration. It would be difficult to modify this contract to account for a change in biosolids quantity and quality resulting from anaerobic digestion.
- **Limited resources and concerns over impacts of the liquid stream on solids operations.** The FPWWTF is being upgraded to BNR and the impact of digestate ammonia on final total nitrogen concentration is unknown.

The Narragansett Bay Commission's mission: "To maintain a leadership role in the protection and enhancement of water quality in Narragansett Bay and its tributaries by providing safe and reliable wastewater collection and treatment services to its customers at a reasonable cost."

For more information, contact:

Jamie Samons, Narragansett Bay Commission public relations manager (JSamons@Narrabay.com)

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

City of Nashua, New Hampshire

Case Study at a Glance

UTILITY OVERVIEW

The City of Nashua is New Hampshire's second largest city in the far southeast of the state on the Merrimack and Nashua Rivers. It owns and operates one wastewater treatment plant that serves a population of 100,000, including customers in the Town of Hudson. In 1999, it installed anaerobic digestion (AD) with combined heat and power (CHP).

Nashua WTF

The Division of Public Works Wastewater Treatment Facility (WTF) treats an average daily flow of 13 mgd at its anaerobic digester (AD) complex, which went online in 2000. Only wastewater solids and scum are fed to the digester; though offsite solids are being considered. Biogas is treated to remove hydrogen sulfide (H_2S) and moisture and is then fed to a 12-cylinder internal combustion (IC) engine generator, which has an installed rating of 380 kW. The engine can also run on natural gas, although that has not been necessary, as there has been enough biogas to keep the engine running 24/7 at the current 110 kW rate.

The electricity produced is used to power all of the digester complex and portions of the WWTP, although Nashua does have an interconnection with the electrical grid and was expected to be net-metering (selling back to the grid) in the future. Heat is recovered from the engine to provide all digester heating during summer months, space heating of the new combined sewer overflow (CSO) sedimentation facility, and some other space heating. Additional process heating is provided with natural gas.

The WWTP has reduced the volume of solids by 50 percent through use of AD, resulting in nearly $1 million in savings for solids end use, which is conducted by a contracted company that land applies the Class B biosolids to area farms. The digesters also process scum, which previously had to be landfilled at a cost of $22,000/year and is now saved.

What barriers were encountered and how were they overcome?

Nashua faced the following top three challenges when it began its CHP program:

- **Increasing costs of aging infrastructure**
- **Availability of funding**
- **Shortage of qualified work force**

Nashua Service Area By the Numbers

- 100,000 population served
- 1 WWTP
- 12.5 mgd average flow treated
- Power cost ~$0.10/kWh

Nashua WTF By the Numbers

- Operating since 1959
- WWTP: secondary conventional activated sludge process
- Solids production: ~7 dry tons /day
- 1 primary and 1 secondary mesophilic AD
- ~24 day solids retention time
- 40-50% VS destruction
- Grants / Incentives: 20% state grant & State Revolving Fund (SRF)
- Simple payback required: 6-10 years
- Savings from AD and CHP on annual O & M: $750,000/year
- CHP system ownership: Nashua
- CHP system maintenance: contractor

Initial barriers that had to be overcome included the following:

- **Start-up and operational challenges.** Engine sometimes needed help with natural gas for start-up, but has been generally running well, 24/7. An engine failure in 2008 after the engine warranty expired was fixed.
- **The electric utility introduced an additional safety equipment requirement** late in the project, which led to the need for a change-work order.
- **Interfacing older analog equipment** with newer digital equipment led to issues, which were addressed.
- **An air permit from the state was required** for the IC engine and methane flare.

Construction and start-up of the CHP system went smoothly, but there were some operational issues that required further adjustments, including the following:

- **IC engines use more oil and are more maintenance intensive** than other WWTP equipment, requiring oil changes, rebuilds, etc. This technology has become somewhat outdated. Nashua has been considering turbines and other, more recent, technology.
- **The road to the WWTP is through a residential neighborhood, so trucking in outside waste to boost biogas production was politically unacceptable.** However, a mayor's office energy assessment and planning effort led to identification of an alternative option for bringing outside waste in through an industrial park. This led to further consideration of expanding digestion and CHP.

As of 2011, Nashua WTF had more than 10 years' experience operating a modern AD and CHP system. As it expands chip over the three years after 2011, it considers greenhouse gas reduction as part of its existing good energy management program, but the following are seen as more important:

- Power costs need to justify the investment
- Biogas production and use is "the right thing to do"
- Contracting for related service require specialized expertise
- Safety issues associated with generating biogas on-site make it less desirable

"Because of the large up-front capital costs for CHP, [Nashua] is considering private-public partnerships for future projects," reports Mario Leclerc, Nashua WWTP superintendent.

For more information, contact:

Mario Leclerc, Nashua WWTP superintendent, at leclercm@nashuanh.gov

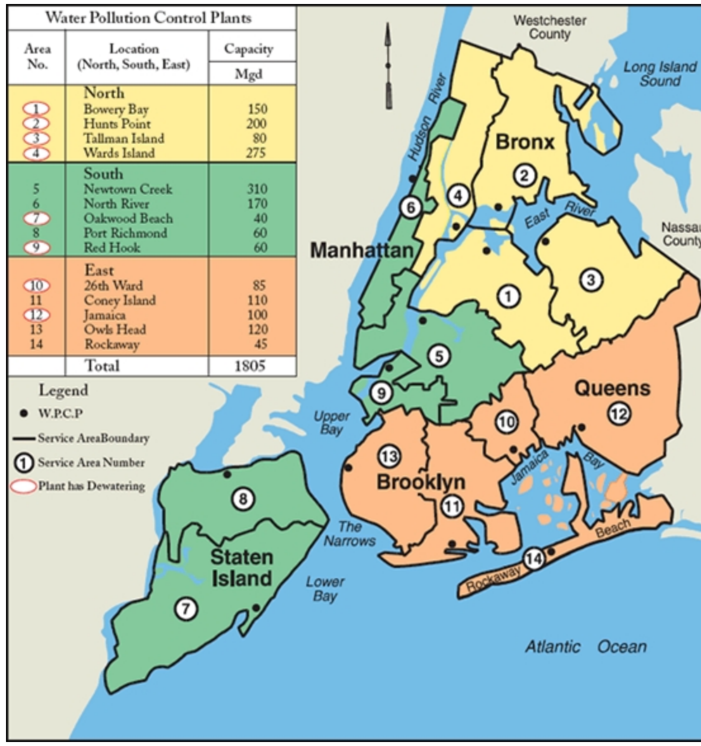
About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

New York City Department of Environmental Protection, New York

Case Study at a Glance



UTILITY OVERVIEW

The New York City Department of Environmental Protection (DEP), Bureau of Wastewater Treatment (BWT) provides wastewater services to eight million people throughout the five boroughs of NYC. BWT operates 14 wastewater treatment plants (WWTPs) with a total dry weather capacity of 1,800 mgd. The plants treat approximately 1,200 mgd of flow on average and generate about 550 dry tons per day (dtpd) of biosolids, all of which are dewatered. Of the 14 WWTPs, eight have dewatering facilities and the remaining six transport their sludge for dewatering either through force mains or sludge vessels.

NYC DEP Service Area By the Numbers

- 7.8 million customers served
- 1,800 mgd dry weather capacity
- 14 plants, 8 with dewatering

For the last 20 years DEP has committed some or all of its biosolids to beneficial use. Treatment techniques have included thermal drying, alkaline stabilization, composting, and direct land application. The beneficial use of biosolids includes nutrient-rich fertilizer or soil conditioner for parks, farms, lawns, and golf courses, and production of clean energy. Potential applications include use in asphalt-paving mixes. The DEP continues to monitor cost-effective methods for using its biosolids beneficially.

What barriers were encountered and how were they overcome?

The DEP has been a pioneer in some areas of renewable energy and greenhouse gas emissions management. Traditionally, the WWTPs have been designed to use anaerobic digestor gas (ADG) as a primary fuel source in boilers and engines that produce electricity or directly drive equipment (i.e., main sewage pumps, air blowers). However, beginning in the late 1970s local economic conditions and the cheap cost of electricity moved the department away from ADG use toward electricity as its main power source.

Today, while all of the WWTPs use ADG in their boilers, only four of the 14 WWTPs still have continuous-duty engines. The department is now looking at reinvigorating its conventional culture of energy conservation by employing proven methods and exploring novel ideas for reducing its carbon footprint. More recently, the DEP has had experience with fuel cells at the Red Hook, Hunts Point, 26th Ward, and Oakwood Beach WWTPs. But because of problems with conveying digester gas to the fuel cells and low quality waste heat, these units have failed to achieve expected results. In addition, the required near-term major capital maintenance and the speed of the technology evolution complicate continued operation.

Sustainability is an important factor affecting DEP's decisions. Concerns about aging infrastructure and the need to invest in a major overhaul of the digester system to optimize gas production and use must be addressed when considering the economics of biogas use.

Ever-increasing air permitting regulations with their direct (additional treatment technologies) and indirect (time and money related to permit requirements) impacts are a major impediment. This is compounded by the fact that the air and water side of the regulatory arenas are disconnected. That is, the regulatory authorities do not take a systematic approach in setting permit requirements, and those associated with water are often conflicted with those for air.

Other barriers include staffing requirements (i.e., some technologies require new skill sets), space constraints, high upfront capital, and coordination with third parties. Low power costs are additional drivers, further affecting decisionmaking and investment in CHP.

New York City has illustrated a strong commitment to sustainability and greenhouse gas reduction goals with the release of PlanNYC and Strategy 2001-2014. These plans challenge DEP to reduce its greenhouse gas emissions from its 2006 baseline by 30 percent by 2017, at the same time that new water and wastewater treatment facilities come on-line. These facilities are projected to increase annual electricity consumption by more than 53 percent by the end of the decade.

Some of the challenges to be overcome include the following:

- Making investments in sludge handling processes while maintaining a state-of-good repair for critical wastewater treatment equipment
- Finding a solution that bridges the gap between air and water and getting the support of regulators
- Finding cost-saving concepts that make the project less expensive to build

The department is working on a project, in cooperation with National Grid, the local natural gas utility, to process the ADG and inject it into the local distribution system for the benefit of local customers – about enough to heat 2,500 homes. This project extends the beneficial use of ADG beyond the fence line and leverages the capital and expertise of a third party to finance the upfront costs and manage the construction of a technology that is part of its core business. National Grid will finance the initial capital investment and in return DEP will provide a base volume of gas to it at no cost. This will allow National Grid to recoup its capital and operating expenses over the term of the agreement and provide a levelized cost to its customers, which is expected to be competitive with traditional supply sources.

It is expected that this project will reduce greenhouse gas emissions by some 15,000 metric tons – the equivalent of removing almost 3,000 cars from the road – by offsetting more traditional, carbon-intensive production methods. DEP officials hope this project will serve as a national and international model on how to incorporate renewable energy into a dense urban environment at cost-competitive rates.

For more information about the NYC DEP, contact:

Anthony J. Fiore, chief of staff – operations, NYC DEP, at afiore@dep.nyc.gov

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Renewable Water Resources, Greenville, South Carolina

Case Study at a Glance

UTILITY OVERVIEW

Renewable Water Resources (ReWa) provides wastewater collection, treatment and reuse for 400,000 people in metropolitan Greenville, SC. ReWa owns and operates nine WWTPs that treat a total average flow of 28.5 mgd. Seven of the nine WWTPs have anaerobic digestion (AD); in total, 18 dry tons per day of biosolids are produced.

ReWa By the Numbers

- 400,000 customers served
- 28.5 mgd average flow treated
- 9 WWTPs
- 7 WWTPs with anaerobic digestion
- Nominal power cost: $0.07/kWh
- Effective power cost: $0.055/kWh

Mauldin Road WWTP

The Mauldin Road WWTP is the largest of ReWa's WWTPs and has a permitted capacity of 70 mgd; it treats 19 mgd and produces 6,000 dry tons of biosolids per year. The WWTP uses enhanced biological phosphorus removal process and deep-bed filtration to meet a 1.3 mg/L monthly average phosphorus limit. Primary sludge and thickened waste-activated sludge (WAS) are digested to Class B standards using three, 1.27-million-gallon (mg) mesophilic digesters (two in parallel and one standby). Following digestion, solids constantly overflow to a solids holding tank and are thickened with gravity belt thickeners and land-applied at agronomic rates by contract haulers. An average of 240,000 cubic feet per day of biogas is produced at the WWTP; about 30 percent is used for process heating and the remainder is flared.

Mauldin Road WWTP By the Numbers

- Operating since 1928
- 70 mgd permitted capacity
- 19 mgd average flow treated
- 13 plant staff
- 800 kW engine generator project currently being designed and constructed

As the result of an evaluation begun in 2009, a combined heat and power (CHP) system for the Mauldin Road WWTP was scheduled to be completed in December 2011. This project will use an advanced internal combustion engine and will produce up to 800 kW of power that will be used at the plant to reduce the amount of power that ReWa purchases from the local power utility. The energy produced by the CHP system will be metered; ReWa will sell renewable energy credits (RECs) to the local utility provider and/or other interested parties. The CHP design will facilitate future connection to the local utility provider's power grid through a future capital project should ReWa find the economics favorable. ReWa was also evaluating the addition of CHP at four other WWTPs.

What barriers were encountered and how were they overcome?

The major barriers that ReWa encountered while considering CHP included the following:

- **Low electricity cost and perception of minimal savings.** ReWa has a nominal power cost of $0.07/kWh and an effective power cost of $0.055/kWh.
- **Inaccurate gas metering.** Measurement of digester gas flow is notoriously difficult; it is often desirable to compare measured values with calculated estimates based on measured digester influent loadings and solids destruction. It was difficult to get accurate values for digester feeds because there was no flow meter on the primary sludge feed line from the clarifiers.
- **Perception of inadequate staff time and skill sets** to operate and maintain a CHP process.

The barriers were overcome by employing the following strategies:

- **Identification of actual biogas volume.** In October 2009, the digester gas flow meters were calibrated. In November 2009, a new magnetic primary sludge flow meter was installed, replacing the existing positive displacement pump stroke counter. Making these changes allowed for better estimates of the digester gas produced, which allowed for a more accurate assessment of the CHP project economics. ReWa studied alternatives to increase biogas production, such as installation of a fats, oils, and grease (FOG) receiving and feed station or incorporating one of several possible thermophilic digestion process strategies; however, these alternatives were not included in the project.
- **A full cost/benefit analysis.** Key to this process was acceptance of annual cash flow instead of a payback period. For the Mauldin Road CHP project, it was estimated that the net yearly savings would be $250,000. This was more attractive to ReWa decision-makers than the projected five-year payback for the project.
- **Education of staff on the CHP process.** This was done by breaking down the CHP process into its basic components – engine generator, heat exchanger, and gas conditioning system. As a result, staff recognized that the process was not as complex as they had perceived. Additionally, ReWa elected to include a two-year maintenance service contract with the pre-purchase of the CHP system.

According to ReWa officials, "Renewable Water Resources continuously places emphasis on operational efficiency, using data to drive down costs and optimize operations by eliminating wasted efforts and resources, and leveraging new technology and processes to modernize the organization."

For more information, contact:

Joey Collins, ReWa solids manager, at joeyc@re-wa.org
Glen McManus, ReWa director of operations, at glenm@re-wa.org

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Sheboygan, Wisconsin

Case Study at a Glance

UTILITY OVERVIEW

The City of Sheboygan (City) owns and operates one wastewater treatment plant (WWTP) in eastern Wisconsin along Lake Michigan. The city provides wastewater collection and treatment to about 68,000 people in the region.

Sheboygan Regional WWTP

The Sheboygan Regional WWTP treats an average of 10.5 mgd of wastewater. The plant is a biological nutrient removal (BNR) facility whose driving effluent limitations are ammonia-nitrogen and total phosphorus. Solids-handling at the WWTP consists of three primary anaerobic digesters and one secondary anaerobic digester. Anaerobic digestion yields about 490,000 cubic feet of digester gas per day (scfd) on average.

In 2002, the city began to evaluate ways to reduce energy consumption and power costs at the WWTP. Increasing the amount of digester gas available to produce renewable energy was considered an alternative. At the time, the digesters were producing about 200,000 scfd of digester gas, which was used primarily to fuel three boilers for digester heating. A portion of the digester gas also was used to power an engine-driven, influent wastewater pump. The excess digester gas was flared. After the plant-wide evaluation, the City of Sheboygan elected to implement combined heat and power (CHP) at the WWTP. Digester gas production increased significantly with the addition of alternative feed stocks to the digesters.

The city's original CHP system was installed in 2006 and consisted of ten Capstone microturbines, each with a power generation capacity of 30 kW. At its full rated capacity, the ten microturbine-based CHP system produced up to 300 kW of renewable energy. Because of the successful operation of the original microturbines and the dramatic increase in biogas production from high-strength wastes, the WWTP installed two new Capstone microturbines, each with a power generation capacity of 200 kW, with startup in December 2010. The expanded CHP system also included new and dedicated heat recovery and biogas treatment systems.

The total full rated capacity of the expanded CHP system is 700 kW. Digester cover and digester gas piping improvements were scheduled for completion during the fall of 2011. The WWTP generates between 90- and 115 percent of electrical energy, and 90 percent of heating energy onsite.

City of Sheboygan By the Numbers

- 68,000 sewer customers
- 1 WWTP
- 10.5 mgd average flow treated
- Power cost: $0.048/kWh (without demand charges), $0.081 (with demand charges)

Sheboygan Regional WWTP By the Numbers

- Operating as a secondary WWTP since 1982
- 18.4 mgd permitted capacity
- 10.5 mgd average flow treated
- 16 plant staff
- 12 microturbines with full rated capacity of 700 kW
- Generates 90 to 115 percent of electrical energy and 90-percent of heating energy onsite

What barriers were encountered and how were they overcome?

The major barriers encountered included the following:

- **Organizational skepticism** regarding whether the amount of biogas produced would be sufficient to operate the microturbines, boilers, and reciprocating engine.
- **Technical concerns** about CHP technology and biogas treatment. Others' experiences with microturbines negatively affected the perception of CHP within the organization.
- **Limited capital dollars** were available from the city to fund the project.

The following strategies were used to overcome the barriers:

- **Increasing biogas production by introducing high-strength wastes**, including whey and cheese processing waste and thin stillage from ethanol, directly to the anaerobic digesters. One strategy the WWTP used to encourage high-strength wastes to be discharged at the facility was by lowering the tipping fees for industrial waste streams.
- **Collaboration with the local electric utility** to fund 80 percent of the project. This reduced the city's risk associated with negative experiences with microturbines. The local privately owned power utility had purchased some 100 30-kW Capstone microturbines several years earlier and were looking for a biogas supply to add the electrical output to their renewable portfolio. In addition, gas conditioning technology had improved to address removal of siloxane compounds from biogas.
- **Teaming with a local power utility** to fund the original CHP project. The local power utility purchased and owned the ten 30 kW microturbines and the digester gas treatment equipment that were part of the original CHP project. The WWTP owned the heat recovery system and had the option to purchase the microturbines and digester gas treatment equipment after six years of operation for $100,000. The total cost to develop and construct the original CHP system was $1.2 million, of which Sheboygan only paid $200,000 for the heat recovery equipment.
- **Applying for and receiving energy grants** for the recent $1.5 million CHP expansion project. The CHP expansion project was funded, in part, by a $1.2 million low-interest loan, which was to be paid back in five years with funds saved by operating the CHP system and offsetting a portion of the WWTP's energy costs. Because of its increased electric power generation potential, Focus on Energy provided a $205,920 grant for expansion of the CHP system. The City of Sheboygan covered the remaining $100,000 out of pocket.

"With energy costs increasing each year, we were actively looking at different ways to reduce our total energy cost," said Dale Doerr, wastewater superintendent with the City of Sheboygan. "Since we were wasting excess biogas produced at the wastewater treatment plant, it became evident that we could use the excess biogas as fuel for the Capstone MicroTurbines and reduce our energy cost."

For more information, contact:

Dale Doerr, Sheboygan Regional WWTP wastewater superintendent at DaleD@SheboyganWWTP.com.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

City of St. Petersburg, Florida

Case Study at a Glance

UTILITY OVERVIEW

The City of St. Petersburg, Florida owns and operates three water reclamation facilities (WRFs) in the metropolitan St. Petersburg area. The city provides wastewater collection and treatment to about 317,000 people in the region with a total average flow treated of 35 mgd. The city also operated the Albert Whitted WRF, but this facility, which treats approximately 6.2 mgd, was being closed and all flows were being transferred to the Southwest WRF for treatment.

City of St. Petersburg Services Area By the Numbers

- 317,000 sewer customers
- 3 WRFs
- 35 mgd average flow treated
- Power cost: $0.0935/kWh

Northeast WRF, Northwest WRF, and Southwest WRF

The city owns and operates the Northeast, Northwest, and Southwest WRFs. Each WRF treats an average of 8.4 mgd, 10 mgd, and 10 mgd of wastewater, respectively. The WRFs are advanced secondary facilities whose driving effluent criteria include chlorine residual, turbidity, pH, fecal coliform, total suspended solids, carbonaceous biochemical oxygen demand (cBOD), and chlorides. The WRFs use complete-mix-activated sludge, filtration, and disinfection with sodium hypochlorite to treat influent wastewater. Effluent is reused in the community and any excess flows are discharged to deep injection wells; the facilities do not discharge effluent to any surface waters. Biosolids handling at the WRFs consists of gravity belt-thickening of waste-activated sludge (WAS), mesophilic anaerobic digestion (AD), and dewatering using screw presses to meet Class-B biosolids standards. Biogas is flared.

Southwest WRF By the Numbers

- Operating since 1953
- 10 mgd average flow treated
- Will begin to receive consolidated solids from the Northeast and Northwest WRFs
- TPAD and 1.2-MW internal combustion engine
- Digestion and CHP project will save $2 - $3 million per year compared with current operation

In 2010, the city began to evaluate solids management practices at the WRFs when new state standards were imposed for increasingly stringent and cost-prohibitive Class B land application requirements; the effective date is January 1, 2013. More than 25 alternatives were considered by the city. The one chosen will consolidate biosolids treatment at the Southwest WRF and include the addition of primary clarification, Class-A temperature-phased anaerobic digestion (TPAD), and dewatering using new screw presses. The WRF will produce a Class-AA cake that is certified as a fertilizer. One, 1.2-MW internal combustion engine will be added to produce renewable energy from biogas and provide sufficient power for the WRF to be energy-independent. It was estimated that these improvements would be completed in 2013 or 2014. The city will evaluate the feasibility of adding a thermal process, such as fluid bed combustion or gasification, to convert yard waste and possibly biosolids to additional renewable energy.

What barriers were encountered and how were they overcome?

The major barriers encountered included the following:

- **Producing sufficient biogas to make CHP cost-effective.**
- **Convincing decisionmakers to make significant changes** to a Class-B land application program that had been operating successfully for many years.

The following strategies were used to overcome the barriers:

- **Consolidating solids handling** by conveying WAS produced at the city's plants to the Southwest WRF for treatment. By constructing new digestion and CHP processes at the Southwest WRF instead of at all three facilities, it was more affordable and achieved greater economies of scale.
- **Adding primary clarification at the Southwest WRF.** Primary sludge had a higher energy value compared with WAS when anaerobically digested, and produced more biogas than a similar mass of WAS. This allowed the city to reduce its overall energy expenditures by avoiding costs that would have resulted by treatment of conveyed WAS and settleable raw wastewater solids in the Southwest WRF's biological process.
- **Upgrading the digestion process to TPAD.** TPAD would produce more biogas, and therefore more energy, relative to the current mesophilic digestion process.
- **Constructing a fat, oil, and grease (FOG) tipping station** at the Southwest WRF. The co-digestion of high-strength wastes would increase biogas production and also generate a new revenue stream for the city of some $500,000 per year.
- **Highlighting the risks and costs of the current operation** and Class B-land application. Land application of Class-B biosolids in Florida was becoming more costly and burdensome. In addition, more farms/application sites would be necessary and permit requirements, nutrient management plans, and risks to farmers would result in considerably higher unit costs for land application.
- **Using present-worth analysis to evaluate alternatives.** The selected digestion and CHP project had a 20-year present worth $19 million less than the city's current operation did, and $33 million less than continued Class-B land application under future rules. In addition, the project would save between $2 and $3 million per year in operating costs.

"The business of wastewater treatment is changing rapidly," said Director of Water Resources George Cassady "Increased regulatory requirements rarely present an opportunity to reduce O&M costs. However, through this evaluation, we were able to meet new requirements and realize a substantial cost savings in our operations."

For more information, contact:

George Cassady, St. Petersburg director of water resources, at George.Cassady@stpete.org.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Upper Occoquan Service Authority, Centreville, Virginia

Case Study at a Glance

UTILITY OVERVIEW

The Upper Occoquan Service Authority (UOSA) owns and operates the Millard H. Robbins Water Reclamation Plant (WRP), which provides wastewater services to about 277,000 people in the cities of Manassas and Manassas Park and the western portions of Fairfax and Prince William Counties in Virginia. UOSA has been successful in obtaining funding and board approval for an engine generator combined heat and power generation (CHP) project, which was expected to be brought online in 2012.

UOSA Service Area By the Numbers

- 0.3 million customers served
- 1 plant, 54 mgd
- > 250,000 scfd biogas
- Power cost $0.057/kWh

Millard H. Robbins WRP By the Numbers

- Operating as a secondary WWTP since 1982
- 54 mgd permitted capacity
- 32 mgd average flow treated
- Three 1mg mesophilic ADs with IDI gas cannon mix systems
- One gas-powered, internal combustion generator with a rated capacity of 650 KW.

Millard H. Robbins Water Reclamation Plant

The Millard H. Robbins WRP has a capacity of 54 mgd, and treats an average of 32 mgd. The plant discharges upstream of a water supply reservoir for a major portion of the Washington, DC suburbs. It is designed to provide advanced treatment, including post-secondary lime addition and recarbonation, and both sand and activated carbon filtration.

The solid-stream treatment includes three mesophilic anaerobic digesters that produce more than 250,000 standard cubic feet per day (scfd) of biogas. The gas is used for building and process heating, and to make steam for carbon regeneration. The carbon-dioxide-rich exhaust gases from the boilers are captured and used to adjust the pH in the high-lime process. After anaerobic digestion, biosolids are centrifuge-dewatered, dried, and beneficially used via land application.

The plant has worked internally to reduce operating costs, with a special emphasis on reducing energy usage. Even with these efforts, an analysis by plant staff comparing energy usage with comparably sized neighboring facilities indicated that the Millard H. Robbins WRP had among the highest energy usages based on kilowatt-hour per million gallons treated. Though most of the difference could be explained by the unique treatment processes used at the plant, staff identified the need for additional efforts to control energy usage.

In 2008, UOSA initiated an energy performance contract (EPC) to identify and implement energy conservation measures (ECMs) throughout the plant process. UOSA and the selected energy service company (ESCO) conducted a comprehensive review of plant facilities and operations, with the express goal of reducing operating costs. More than 50 potential ECMs were identified, ranging from lighting and building HVAC improvements to blower replacement needs and CHP. The ECMs were screened to a final list of 19 based on technical feasibility, and the likelihood of working within UOSA's financial goals.

After completion of the technical energy audit, UOSA determined that a more phased approach would be most appropriate, so the first phase of the project was reduced to two ECMs: the digester gas cogeneration and the aeration blowers.

What barriers were encountered and how were they overcome?

Major barriers to approving project have included the following:

- **Wastewater design mindset.** The wastewater design mindset often incorporates double and triple redundancies. UOSA had to switch from this mindset to one in which design considerations were more value-driven and based on bottom-line costs.
- **Technology uncertainties.** UOSA has identified internal combustion engines as the technology of choice. Reliably measuring the concentration of siloxanes in digester gas was problematic as was the determination of whether expensive gas-cleaning technologies were necessary to incorporate into the project. UOSA ultimately chose to include gas cleaning and was able to retain favorable lifecycle cost estimates for CHP.
- **The EPC delivery method was chosen, but it was controversial.** The EPC delivery method has advantages and disadvantages. In this case, the EPC method allowed the owner to initiate a speculative energy investigation with low initial cost, the potential to use operations and maintenance funds to finance improvements, and a guaranteed return on investment. Additionally, the EPC process aligns owner and contractor interests toward a common goal of developing project designs that minimize scope creep and optimize return on investment. Set against these difficult-to-quantify advantages was the higher cost arising from the ESCO's overhead and profit. The UOSA board ultimately chose to proceed with the ESCO process but to secure its own financing through state low-interest loans and principal forgiveness.

Barriers yet to be overcome by mid-2011 included the following:

- **Finding the right delivery method.** UOSA was unable to reach contractual terms with the original ESCO firm that satisfactorily balanced project price, guaranteed payback and performance guarantee terms. UOSA subsequently negotiated a satisfactory contract with Johnson Controls, Inc. Construction of the cogeneration system and replacement of the blowers was scheduled to begin by the end of 2011.

"A clear and concise measurement and verification plan that is easily understood by the decisionmakers is essential for ESCO project support and approval," according to Tom Appleman, UOSA regulatory affairs coordinator. "That's because guaranteed savings is a difficult concept for some to accept. They liken it to putting your arms around a column of smoke and then trying to measure how much you've captured. It needs to be very clear who is responsible if you fail to capture the guaranteed amount."

For more information about UOSA, contact:

Tom Appleman, UOSA regulatory affairs coordinator, at thomas.appleman@uosa.org.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Metro Vancouver, Burnaby, British Columbia, Canada

Case Study at a Glance

UTILITY OVERVIEW

Metro Vancouver operates five wastewater treatment plants (WWTP), which provide wastewater services to more than 2 million customers in the Greater Vancouver, Canada area. The plants treat a total average flow of 320 mgd. The four largest plants have anaerobic digesters (ADs) and beneficially use biogas in a number of ways:

- Annacis Island and Iona Island WWTPs use biogas in engine generators for combined heat and power generation (CHP).
- Lions Gate WWTP uses biogas to run the engine driven influent pumps.
- Lulu Island WWTP uses biogas in boilers for process and building heating.

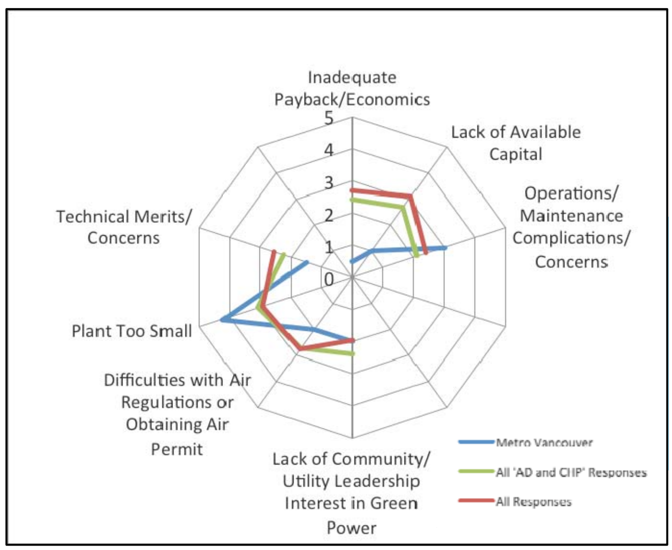
Metro Vancouver By the Numbers

- >2 million customers served
- 320 mgd average flow
- 5 plants, 4 with anaerobic digestion
- Power cost: $0.055/kWh

What barriers were encountered and how were they overcome?

Metro Vancouver's optimized use of biogas as an energy resource is exemplar, with engine generators using biogas at three of its WWTPs. Metro Vancouver considers flared biogas a wasted resource. Purchased power comes from hydroelectric generation at low unit cost and with low associated GHG emissions.

The business case for small plants has been a barrier for full installation of CHP. The opportunity to do something else with biogas is approached by trying to find the highest-value use for this recovered resource. Metro Vancouver continues to explore multiple on- and off-site uses for the biogas produced at its four AD treatment plants.



The spider graph to the right shows how the region's ranking of the most important barriers to biogas use compares with a that of more than 200 other survey responses, of which more than 100 have, like four of Metro Vancouver's WWTPs, anaerobic digesters and are using the biogas for more than process heating.

Lack of significant capital and inadequate payback are minor barriers for Metro Vancouver relative to other utilities. Funding availability and a realistic business case have aligned to allow for successful installations of engine generators using biogas at three Metro Vancouver WWTPs.

Annacis Island WWTP

The Annacis Island WWTP provides secondary treatment of wastewater from one million customers. In addition, the plant receives five to ten wet tons per day (wtpd) of outside waste including fat, oil, and grease (FOG), and portable toilet waste. In 2006, it processed an average flow of 130 mgd and produced about 13,000 dry tons of Class A biosolids via thermophilic anaerobic digestion.

Some storage is provided for the more than 1,400,000 standard cubic feet per day (scfd) of biogas produced to reduce pressure and flow fluctuations. Following moisture removal, the biogas is used to drive engine generators for CHP generation, resulting in an average electricity generation of 1,780 MWh per month. Recovered heat is used for digester and building heating.

Iona Island WWTP

The Iona Island WWTP provides primary treatment of wastewater from 0.6 million customers. In addition, the plant receives less than 1 wtpd of outside waste including septage, FOG, food waste, and industrial waste. In 2006, it processed an average flow of 160 mgd and produced about 5,500 dry tons of Class B biosolids via mesophilic anaerobic digestion.

Some storage is provided for the over 992,000 scfd of biogas produced to reduce pressure and flow fluctuations. Following moisture removal, the biogas is used to drive engine generators for CHP generation, resulting in an average electricity generation of 1,290 MWh per month. Recovered heat is used for digester and building heating.

Lions Gate WWTP

The Lions Gate WWTP provides primary treatment of wastewater from 174,000 customers. In 2006, it processed an average flow of 24 mgd and produced about 740 dry tons of Class B biosolids via thermophilic anaerobic digestion. The biogas produced, which ranges between 150,000 and 200,000 scfd, is used to drive engine driven influent pumps. Recovered heat is used for digester and building heating.

Lulu Island WWTP

The Lulu Island WWTP provides secondary treatment of wastewater from 180,000 customers. In 2006, it processed an average flow of 21 mgd and produced about 2,000 dry tons of Class B biosolids via mesophilic anaerobic digestion. It produces between 250,000 and 300,000 scfd of biogas that is used to fuel boilers for process and building heating. Metro Vancouver plans to upgrade and sell the biogas from this plant.

For more information, contact:

Laurie Ford, PE, LEED AP, senior engineer, project contracts, Wastewater Secondary Treatment Upgrades, Metro Vancouver, at laurie.ford@metrovancouver.org.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Annacis Island WWTP By the Numbers

- 1 million people
- 130 mgd average
- 13,000 dry tons

Iona Island WWTP By the Numbers

- 0.6 million people
- 160 mgd average
- 5,500 dry tons

Lions Gate WWTP By the Numbers

- 175,000 people
- 24 mgd average
- 740 dry tons

Lulu Island WWTP By the Numbers

- 180 ,000 people
- 21 mgd average
- 2,000 dry tons

Barriers to Biogas Use

Western Lake Superior Sanitary District, Duluth, Minnesota

Case Study at a Glance

UTILITY OVERVIEW

The Western Lake Superior Sanitary District (WLSSD) owns and operates one wastewater treatment plant (WWTP) in Duluth, MN. The District provides wastewater collection and treatment for 17 municipalities (totaling about 111,000 people) and five industrial customers in the region.

WLSSD Service Area By the Numbers

- 111,000 sewer customers
- 1 WWTP
- 40 mgd average flow treated
- Power cost: $0.068/kWh

WLSSD Regional WWTP

The District's WWTP treats 40 mgd of flow on average and receives flow from both industrial and residential sources through a 70-mile network of sanitary sewer interceptors and 16 pumping stations. The facility receives a significant volume of high-temperature influent waste from some of its industrial dischargers. The WWTP is a high purity oxygen-activated sludge facility with tertiary filtration.

WLSSD Regional WWTP By the Numbers

- Operating since 1978
- 40 mgd average flow treated
- 105 District staff
- 2 existing 70-kW microturbines are offline
- The District is evaluating future options for CHP

Solids handling at the WWTP consists of dissolved air flotation thickening, two-phase anaerobic digestion (AD), and dewatering using centrifuges. The final biosolids product, Field Green®, is land-applied year-round by District staff on nearby agricultural fields.

The District uses biogas to heat plant buildings and for process heating of the anaerobic digesters. In winter, biogas is supplemented with natural gas at a cost of $250,000 to $300,000 per year. The District has intermittently used one-third of its excess biogas to operate two, 70-kW microturbines to generate renewable energy at the WWTP. These microturbines were installed as a pilot project with grant assistance from the local power utility. During warmer weather, excess biogas is flared. The plant's electric demand is supplied by purchased energy. It spends about $1.9 million annually on electricity for wastewater treatment plant operations.

In recent years, the District has sought to reduce overall consumption of purchased fuels at the facility. With that goal in mind, the District evaluated alternative technologies and approaches to use biogas and waste heat. Several biogas use technologies were evaluated, including combined heat and power (CHP) with internal combustion engines and biogas conditioning for fleet fuel sale. As of 2011, the District had not implemented CHP, for reasons described below.

What barriers were encountered and how were they overcome?

While WLSSD continues to evaluate options for biogas use to produce renewable energy, the following barriers were impeding implementation of a CHP project:

- **Lack of available capital funds.** Capital funds were limited and it was an ongoing challenge to keep up with essential rehabilitation projects of aging facilities, which was necessary to maintain the District's mission. Financing alternatives were essential for CHP or other high-payback energy improvement projects to be initiated in the short term.
- **Unacceptable payback period.** The CHP and fleet fuel alternatives had paybacks between 20 and 30 years at current heat loads. Therefore, they did not meet the District's financial targets for payback at current electrical costs. The payback period for the internal combustion engine alternative was negatively impacted by the need to purchase natural gas for heating in the winter since the engine would generate less heat than the existing boilers.
- **Low electricity costs and standby-fees imposed by the local power utility and uncertain regulatory climate.** The WWTP pays about $0.068/kWh for electricity. However, if CHP were implemented, Minnesota Power would consider the cogeneration system a "distributed generation" facility, in contrast to typical centralized, utility-owned power generation facilities. Minnesota Power applies standby fees to facilities with distributed generation to cover the cost of providing power in the event of an outage of the distributed generation facility. These fees further eroded the potential savings and attractiveness of the engine generator alternative. The economics of the District's potential CHP projects would be improved if the future value of RECs were greater than current market conditions. It was unknown whether the Minnesota's renewable portfolio standard (RPS) would affect REC pricing to significantly affect project economics.
- **Challenges with selling biogas as a fleet fuel.** Since there were no compressed natural gas (CNG) vehicles in the Duluth area, the District would have to pursue agreements with local agencies to create a market for compressed biomethane fuel. Extensive inter-organizational agreements would be necessary to arrange fleet procurement, establish sales conditions, and address logistical details. Without a reasonable price incentive, it would be difficult to gain acceptance for compressed biomethane as vehicle fuel, particularly with concerns about engine damage and fueling location. Selecting a biogas conditioning system appropriate for this application and matching supply and demand for the fuel were expected to be challenging issues.

"We look forward to proceeding with this project," said Marianne E. Bohren, WLSSD executive director. "We recognize it is a move in the right direction and necessary to control operating costs. It is a matter of determining the best long term alternative and how to finance it."

For more information, contact:

Carrie Clement, WLSSD supervisory engineer, at Carrie.Clement@wlssd.com.

About this project

Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

Barriers to Biogas Use

Yonkers Joint WWTP, Westchester County, New York

Case Study at a Glance

UTILITY OVERVIEW

The Westchester County Department of Environmental Facilities (DEF) owns and operates seven wastewater treatment facilities north of New York City. The DEF organization also includes 42 pump stations, two overflow retention facilities, 20 storm flow regulating chambers, about 194 miles of trunk sewers, two water districts, and a solid waste division.

Westchester County DEF has been a leader in adopting environmental management systems (EMS). The Yonkers wastewater treatment plant (WWTP) was certified to ISO 14001 in the summer of 2006, and other DEF plants were certified in 2008. EPA Region 2 selected the Yonkers Joint Wastewater Treatment Plant to receive a 2008 Environmental Quality Award for its EMS.

Yonkers Service Area By the Numbers

- Sewered population: 802,000
- 7 WWTPs, operated by Dept. of Environmental Facilities
- Average combined flow: 131 MGD
- Yonkers Joint WWTP is largest.
- Power cost: $0.11/kWh

Yonkers Joint WWTP

The Yonkers Joint WWTP, the largest of DEF's facilities, treats 83 mgd in a typical activated sludge process and discharges into the Hudson River. It has three mesophilic anaerobic digesters that treat primary solids and scum and six mesophilic anaerobic digesters that treat secondary solids and scum.

Biogas has long been used in boilers to heat the digesters. In the late 1990s, DEF and the NY Power Authority (NYPA) installed a fuel cell run on biogas; NYPA removed it in 2010 because it no longer had parts available to keep it running. Much of the biogas is used to fuel engines that drive secondary treatment aeration blowers. The heat from these engines and from process boilers is used to heat the digesters and for space heating.

Yonkers Joint WWTP By the Numbers

- Sewerd population: 506,000
- 83 mgd average flow treated
- 65 plant staff
- 2 engines driving secondary treatment aeration blowers
- Installing 2 engine generators expected to meet 40% of WWTP electricity needs
- Trialed a fuel cell for ~10 years; removed it in 2010

Plans are to install an engine generator to use excess biogas to produce electricity. This project was estimated at $6.5 million, but, "once the gas cleaning equipment and additional requirements for a switchgear were added, the final project cost was higher," noted DEF Commissioner Thomas Lauro. As of October 2011, this major combined heat and power (CHP) project, which was expected to get Yonkers back into the electricity generation business, was ready to go out to bid, pending final word from the state regulatory agency on whether the new emissions from the engine would trigger issues with the facility's Title V air permit. The electricity generated, which will be net-metered, was expected to meet about 40 percent of the WWTP's electrical demand.

What barriers were encountered and how were they overcome?

Major barriers encountered included the following:

- **Funding.** This is the number one barrier they need to overcome. DEF leaders are promoting the addition of the engine generator for CHP. The cost would have to be justified with some reasonable payback.
- **Technical concerns.** DEF had significant concerns about siloxanes in the gas, and the extra cost of cleaning the biogas had to be weighed against the anticipated savings from reductions in purchased electricity.
- **Shortage of qualified workforce.** The most experienced employees at Yonkers Joint WWTP are retiring. "We lost 20 guys last year – knowledge out the door," noted Superintendent Charles Beckett.
- **Increasing costs of aging infrastructure.** This was a major problem that has been addressed over the past several years by DEF spending $100 million on updating the Yonkers Joint WWTP. But, noted Beckett, "The infrastructure under the streets is aging too; the county has been installing sewer liners on trunks, but the municipalities have not been keeping up on maintaining their feed-in sewer lines."
- Increasing costs of energy. The cost of electricity has gone up in the last few years.

The following strategies were used to overcome the barriers:

- **Funding.** DEF pulled together financing and cost savings to create a favorable payback scenario for the engine generator/CHP, so it was able to convince the board that DEF management worked with the NYPA to obtain low-cost financing. It anticipated reductions in the cost of purchased electricity, recognizing that these costs have been rising. These factors and others resulted in a favorable payback that was adequate to convince the board. The project was expected to save the department money and help reduce odors. At the same time, it helped that area legislators were pushing renewable energy projects. However, in comparison, during this same period, DEF found it could not justify investment in a microturbine CHP system at its Peekskill plant because of an unacceptable payback period.
- **Shortage of qualified workforce.** To address this issue, Beckett noted that "we are doing better in-house training." In addition, with the upcoming CHP project, "We have put in place a five-year maintenance contract that includes training the plant staff." The engine generator manufacturer will provide this maintenance and training but would not provide the five-year warranty the county demanded without also having the maintenance contract.
- **Sustainability and greenhouse gas reductions.** DEF considered its use of biogas as part of its responsible energy management program and greenhouse gas reduction strategy. It believed using biogas is the right thing to do and will likely make even more sense as the value of renewable energy and/or carbon credits increases in the future.

For more information, contact:

Charles Beckett , DEF superintendent, at ccbb@westchestergov.com.

About this project

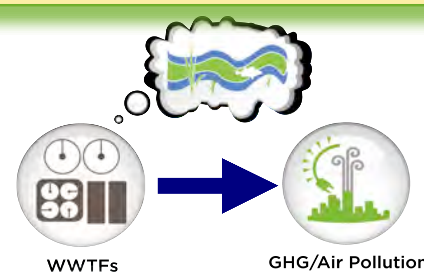
Wastewater treatment facilities are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage. The US Environmental Protection Agency reports that fewer than 20% of larger WWTFs with anaerobic digestion operations use biogas for heat and power. In 2011, the Water Environment Research Foundation (WERF) and New York State Energy Research and Development Authority (NYSERDA) conducted a study with Brown and Caldwell, Black & Veatch, Hemenway Inc., and the Northeast Biosolids and Residuals Association (NEBRA) to determine what barriers exist and how they can be overcome. This case study, produced in 2011, is part of that project.

APPENDIX B

BIOGAS FACTSHEET

Target: Wastewater Treatment Facilities
Query: What's stopping you from using biogas?

Resource Recovery
Generating Heat and Power from Biosolids



Wastewater treatment facilities (WWTFs) are built to reduce impacts on nature, but they can be energy-intensive to operate and they produce greenhouse gas emissions and residuals that are costly to manage.

The Water Environment Research Foundation (WERF) and New York State Energy Research Development Authority (NYSERDA) have joined forces to research – and address – why more wastewater treatment facilities are not maximizing recovery of energy in their wastewater. They are working with a team from Brown and Caldwell, Black & Veatch, Hemenway Inc., and North East Biosolids & Residuals Association (NEBRA). **Please consider joining this inquiry.** Here is what you need to know.

Known Barriers to Biogas – Sound Familiar?

- Lack of financial incentives
- Capital investment perceived too high
- Technology seen as not appropriate for size/scale/processes of facility
- Cannot sell back to grid
- Lack of expertise on staff or on call
- Too expensive to buy, own/operate
- Cannot get CHP air permit, or CHP will require a Title V permit
- Payback not great enough

What's the problem?

Utilities worldwide are capturing and using energy and resources in wastewater and residuals. But many who can or want to, are not.

This research evaluates tradeoffs and barriers preventing many utilities from generating valuable heat and power (directly or as electricity) from biogas (biomethane), or from using it as a fuel or for sale in the methane/natural gas market.

The US Environmental Protection Agency (US EPA) reports that fewer than 20 percent of the larger WWTFs with anaerobic digestion operations produce combined heat and power (CHP). Thus, there must be actual or perceived barriers to broader use of these heat-capture or energy recovery technologies. Many anaerobic digesters funded by the Construction Grants Program (especially small facilities) in the '70s and '80s were abandoned or converted to storage tanks or other uses.

What's the goal?

This research thoroughly explores the barriers and disincentives for biogas production for **all size plants**. It also focuses on biogas generation and CHP recovery by small plants – processing less than 4.5 million gallons per day (MGD).

The study examines the extent of each barrier or disincentive regionally within sectors by factors such as facility size, treatment or solids process configurations, and organic constituent content. It also will identify and examine non-technological obstacles, which may include management decisionmaking, market conditions, electric utility practices, energy regulations and grid constraints, environmental regulations (legacy and proposed under climate change), and operator training and education.

The strategy is aimed at overcoming a significant technical barrier – reducing the size threshold of wastewater facilities that can economically produce biogas and recover energy in some form.

How can I participate?

Project researchers are requesting help and support from any US WWTF that has digestion but is not using biogas, has digestion and is using biogas, or does not have digestion but is interested in digesting and producing/using biogas. Here's what you can do to participate:

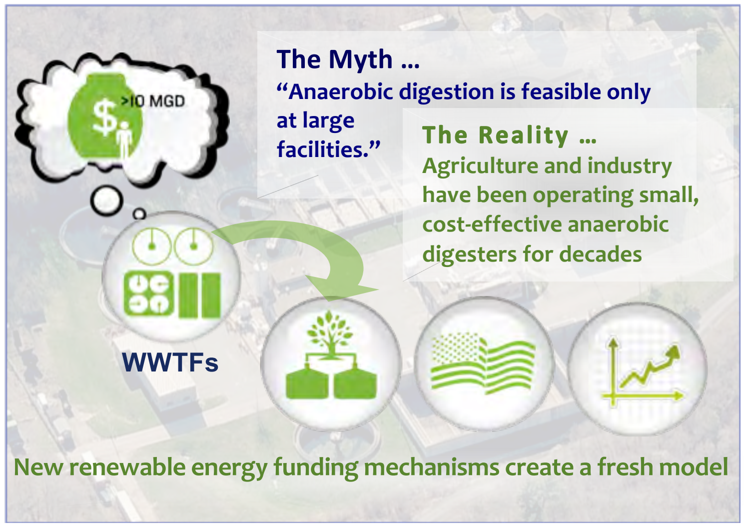
☎ **Contact** Karen Durden, PE, Brown and Caldwell, 770-673-3671, KDurden@brwncald.com.

Plan to join a focus group with researchers at one of the following meetings (times to be confirmed):

- WEF Nutrient Recovery and Management 2011 in Miami, Sun 1/9/2011 from 1-5pm
- New York Water Environment Association Annual Conference in New York City, Wed 2/9/2011 from 1-5pm
- WEF Residuals and Biosolids 2011 in Sacramento, Wed 5/25/2011 from 1-5pm
- WEF Water and Energy 2011 in Chicago, Wed 8/3/2011 from 1-5pm

Take an online survey. Interested utilities contacting Karen Durden above will be informed when an online survey for relevant utility employees is posted.

WERF • NYSERDA • Brown and Caldwell • Black & Veatch • Hemenway Inc. • NEBRA



What are the benefits?

WERF subscribers and utility participants will benefit from this research by having access to the final comprehensive report with general recommendations. Perhaps more important, the reported information on barriers and disincentives will be shared with federal agencies (including US EPA and US Department of Energy) and state agencies that have the ability to remove barriers to the use of biogas for energy recovery and to increase implementation of these practices.

In addition, when significant technological barriers are identified, the project will address research needs and future technology gaps, ultimately advancing the wastewater sector towards energy self-sufficiency.

This project complements existing WERF tools and resources, such as Life Cycle Assessment Manager for Energy Recovery (LCAMER), and is part of WERF's Operation Optimization Challenge. The project involves collaboration from multiple stakeholders.

Background*

According to EPA, more than 16,500 publicly owned wastewater treatment works (POTWs) in the United States treat more than 40 billion gallons of wastewater each day, generating more than eight million dry tons of biosolids annually.

Anaerobic digestion (AD) of wastewater solids has been a dominant solids stabilization practice in the United States and around the world for decades. Traditional mesophilic AD, with operating temperatures of 30º–38º C, is well understood and, with proper attention to operational parameters, provides consistent and reliable reduction in the volume of solids while producing digester gas.

Historically, AD systems were installed as a way to stabilize solids and reduce their volume. But many facilities have tapped the energy potential in digester gas, and that is becoming a leading reason for new AD installations.

Over the past few years, there has been an explosion of interest in new anaerobic digestion and energy systems. An informative 2007 US EPA Combined Heat and Power Partnership (CHPP) primer on CHP opportunities at wastewater treatment facilities provides some perspective. CHPP estimates that if all 544 WWTFs in the United States that operate anaerobic digesters and have influent flow rates greater than 5 MGD were to install CHP, approximately 340 MW of clean electricity could be generated, offsetting 2.3 million metric tons of carbon dioxide emissions annually. These reductions are equivalent to planting about 640,000 acres of forest, or the emissions of some 430,000 cars.

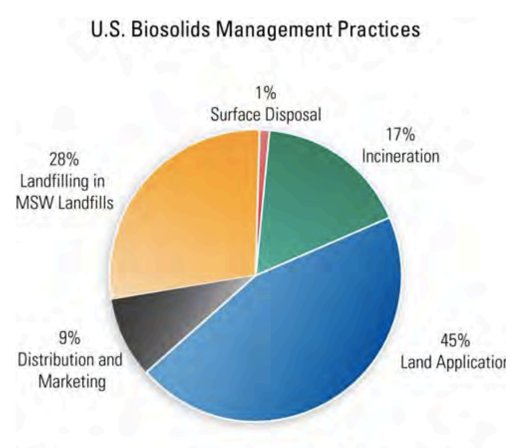
If additional anaerobic digestion systems are installed and energy is recovered, the potential for energy generation and its associated benefits are even greater.

* Sources: US EPA (http://www.epa.gov/chp/); National Association of Clean Water Agencies (NACWA) *Renewable Energy Resources: Banking on Biosolids (2010-05-14).*

Energy available from biosolids and other energy sources:

1 pound of dry biosolids	8,000 Btu
1 kiloWatt hour of electricity	3,412 Btu
1 cubic foot of natural gas	1,028 Btu
1 cubic foot of biogas	600-700 Btu
1 cord of wood	20 million Btu

Unprocessed biosolids typically contain about 8,000 British thermal units per pound (Btu/lb) on a dry weight basis (2.3 kWh/lb), similar to the energy content of low-grade coal. For comparison, the average daily residential energy use in the U.S. is 31 kWh per home, which would require the energy equivalent of 13.4 lbs of biosolids. *Source: NACWA*



APPENDIX C

BIOGAS POSTCARD MAILER

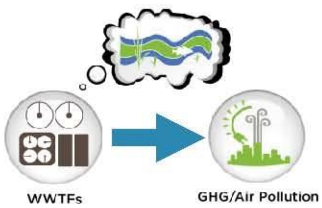
Renewable Resources

Generating Heat and Power from Biosolids

The Water Environment Research Foundation (WERF) and New York State Energy Research Development Authority (NYSERDA) have joined forces to research – and address – why more wastewater treatment facilities are not maximizing recovery of energy in their wastewater. They are working with a team from Brown and Caldwell, Black & Veatch, and Hemenway Inc. Please consider joining this inquiry. Here is what you need to know.

What's the problem?

Utilities worldwide are capturing and using energy and resources in wastewater and residuals. But many who can or want to, are not.



This research evaluates tradeoffs and barriers preventing many utilities from generating valuable heat and power (directly or as electricity) from biogas (biomethane), or from using it as a fuel for selling in the methane/natural gas market.

For more information, visit www.werf.org

WERF NYSERDA • Brown and Caldwell • Black & Veatch • Hemenway Inc. • NEBRA

How can I participate?

Project researchers are requesting help and support from any US WWTF that has digestion but is not using biogas, has digestion and is using biogas, or does not have digestion but is interested in digesting and producing/using biogas. Here's what you can do to participate:

- Contact Karen Durden, PE, Brown and Caldwell, 770-673-3671, KDurden@brwncald.com.
- Plan to join a focus group with researchers at one of the following meetings (times to be confirmed):
  - WEF Nutrient Recovery and Management 2011 in Miami, Sun 1/9/2011 from 1-5pm
  - New York Water Environment Association Annual Conference in New York City, Wed 2/9/2011 from 1-5pm
  - WEF Residuals and Biosolids 2011 in Sacramento, Wed 5/25/2011 from 1-5pm
  - WEF Water and Energy 2011 in Chicago, Wed 8/3/2011 from 1-5pm
- Take an online survey. Interested utilities contacting Karen Durden above will be informed when an online survey for relevant utility employees is posted.

APPENDIX D

DECISION THEORY AND ANALYSIS; INNOVATION DIFFUSION THEORY

Decision Theory and Analysis

Decision theory is a school of thought that distinguishes how decisions should be made (rational or normative decision making) and how decisions are actually made (descriptive decision making). Decision analysis, which is closely related, includes the philosophy, theory, methodology, and professional practice necessary for decision making.

Understanding decision theory and analysis can be helpful in advancing use of biogas, because they provide insights into how to integrate uncertainties and risks into decisions. In looking at barriers to biogas use, there are random or poorly understood influences operating behind decisions to explain why one WWTF proceeds with biogas projects when a similar one does not.

The greatest challenge comes from integrating uncertainties and risks into decision making. For example, a common factor about which decision makers have limited information is the future price of electricity, with which biogas-produced electricity competes in economic modeling. Several participants in the project noted that economic models developed by consulting engineers often use multiple conservative estimates for future values of electricity and other factors, resulting in economic forecasts that are unrealistically conservative.

Decision theory addresses these uncertain futures. It provides insights into how some decisions are made under "certainty," under "risk," "uncertainty," or "ignorance." A decision matrix can be applied to a decision in a similar way it can be to assessing risk. Probabilities of factors are estimated and then multiplied to estimate an outcome.

Application of decision theory, decision mapping, decision trees, influence diagrams, and other tools would better define the scope and critical factors of decisions around biogas use. For example, should the value of removing FOG from a WWTF's influent by offering a low-cost disposal option that feeds it directly into a digester (as is done at Des Moines and Gwinnett County) be considered in the analysis and decision? How can that value – larger community benefits and the role that the WWTF can play in community sustainability – be integrated into the economic analysis? There is an expected cost savings from fewer sewer back-ups and overflows. But because of the complexity of integrating this larger scope into the economic models and decision-making process, this benefit is often left out of the analysis.

Another approach to decision making is "real options valuation," which emphasizes keeping open possibilities (options) as decisions are made and steps forward are taken. Thus, when considering how to treat wastewater solids, a real-options approach would recognize that building an anaerobic digester to stabilize solids opens up the options of biogas use and taking in outside wastes. Biogas use does not have to occur, but the option is there for the future. In contrast, other potential wastewater solids treatments, such as lime stabilization, do not open additional future options, but actually narrow them. The real-options approach asks this question in the decision-making process: "Will the next step open up more options and increase the value of options, or not?" This approach can also enable digesters to be built as an initial phase with the potential for adding biogas use at a later time.

Innovation Diffusion Theory

Although use of biogas from WWTFs is not new, it is reasonable to argue that the focus on biogas use over the past several years, driven by new demands for renewable energy and greenhouse gas reductions, is similar to an innovation. This is further supported by the fact that technologies have advanced considerably since anaerobic digestion and uses of biogas were initiated decades ago. There is a strong, rising tide of interest in biogas use, making this phenomenon an innovation that is diffusing into the marketplace.

Innovation diffusion theory was first introduced by Everett Rogers in his 1962 book, *Diffusion of Innovations*, and is critical in product development and marketing. The theory defines the following categories of individual humans and their responses to something new, taken for ease of reference, from Wikipedia (http://en.wikipedia.org/wiki/Innovation_diffusion).

- ***Innovators*** *– the first individuals to adopt an innovation; they take risks and have the financial resources to absorb failure, if that happens.*
- ***Early adopters*** *– the next to adopt a new thing; they tend to be opinion leaders, in front socially.*
- ***Early majority*** *– Slower in the adoption of an innovation; they tend to be followers*
- ***Late majority*** *– These people tend to adopt an innovation only after a majority of others have done so; they are skeptical about innovations.*
- ***Laggards*** *– The last to adopt an innovation; they don't like change; they are not opinion leaders.*

The descriptions of innovators and early adopters that appear in innovation diffusion theory literature are good descriptions of the leading individuals and agencies that have developed successful biogas use projects over the past decade, such as Essex Junction, Vermont and Sheboygan, Wisconsin.

Innovation diffusion theory also describes the following stages through which an individual passes as he or she encounters an innovation (from Wikipedia, link above):

1. **Knowledge –** *or lack thereof.*
2. **Persuasion –** *The individual is interested in the innovation and actively seeks information/detail about the innovation.*
3. **Decision –** *The individual takes the concept of the innovation and weighs the advantages/disadvantages of using the innovation and decides whether to adopt or reject the innovation.*

4. ***Implementation*** *– The individual employs the innovation to a varying degree depending on the situation; during this stage the individual determines the usefulness of the innovation and may search for further information about it.*

5. ***Confirmation*** *– The individual finalizes his/her decision to continue using the innovation and may use the innovation to its fullest potential.*

The first of these stages, knowledge (or lack thereof), is the same as one of the underlying barriers identified in the surveys and focus groups.

Innovation diffusion theory also talks about the "rate of adoption" – how quickly it gets into widespread use – and "critical mass" – the point at which the diffusion process will continue on its own, without push from promoters. Rogers outlines several strategies to foster critical mass, including demonstrating that a highly respected individual within a social network is using the innovation, thus creating an instinctive wider-spread desire for a specific innovation. A pro-active approach is to inject an innovation into a group of individuals who would readily use it. Another is to highlight positive reactions and benefits for early adopters of an innovation.

Perhaps the most powerful concept in innovation diffusion theory is that it is at least as important to focus on the qualities of the innovation as it is on trying to move the population toward adoption of the innovation. The following factors are considered critical in this decision-making process (from Wikipedia, link above):

- ***Relative advantage*** *– How improved an innovation is over its previous generation.*
- ***Compatibility*** *– The level of compatibility with an individual's life so it can be assimilated into that individual's life.*
- ***Complexity or simplicity*** *– If the innovation is too difficult to use an individual will not likely adopt it.*
- ***Trialability*** *– How easily an innovation may be experimented with as it is being adopted; if a user has a hard time using and trying an innovation this individual will be less likely to adopt it.*
- ***Observability*** *– The extent to which an innovation is visible to others; an innovation that is more visible will drive communication among the individual's peers and personal networks and will in turn create more positive or negative reactions.*

Examples of how the concepts of innovation diffusion theory can be applied to biogas use at WWTFs are in Section 8.3.

A topic for further study would be to assess where adoption of modern biogas use currently lies on the continuum of "innovator" to "laggard." The choice of appropriate strategies for leveraging further dissemination of biogas use depends on whether current adoption is at the early-adopter, the early-majority, or the late-majority stage.

References

1. U.S. EPA (United States Environmental Protection Agency) Combined Heat and Power Partnership (October 2011). *Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field*. U.S. Environmental Protection Agency, Washington, D.C.

2. Electric Power Research Institute (March 2002), *Water and Sustainability (Volume 4): U.S. Electrical Consumption for Water Supply and Treatment – The Next Half Century*.

3. Wiser, J.; Schettler, J.; Willis, J. (2011). *Evaluation of Combined Heat and Power Technologies for Wastewater Treatment Facilities* (EPA 832-R-10-006). U.S. Environmental Protection Agency, Washington, D.C.

4. Rogers, E.M. (1962). Diffusion of Innovations. Free Press, New York.

WERF Subscribers

WASTEWATER UTILITY

Alabama
Montgomery Water Works & Sanitary Sewer Board
Alaska
Anchorage Water & Wastewater Utility
Arizona
Avondale, City of
Glendale, City of,
Mesa, City of
Peoria, City of
Phoenix Water Services Dept.
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 Sanitation District
Dublin San Ramon Services District
East Bay Dischargers Authority
East Bay Municipal Utility District
Fairfield-Suisun Sewer District
Fresno Department of Public Utilities
Inland Empire Utilities Agency
Irvine Ranch Water District
Las Gallinas Valley Sanitary District
Las Virgenes Municipal Water District
Livermore, City of
Los Angeles, City of
Montecito Sanitary District
Napa Sanitation District
Novato Sanitary District
Orange County Sanitation District
Palo Alto, City of
Riverside, City of
Sacramento Regional County
Sanitation District
San Diego, City of
San Francisco Public Utilities,
City & County of
San Jose, City of
Sanitation Districts of Los Angeles County
Santa Barbara, City of
Santa Cruz, City of
Santa Rosa, City of
South Bayside System Authority
South Coast Water District
South Orange County Wastewater Authority
Stege Sanitary District
Sunnyvale, City of
Union Sanitary District
West Valley Sanitation District
Colorado
Aurora, City of
Boulder, City of
Greeley, City of
Littleton/Englewood Wastewater Treatment Plant
Metro Wastewater Reclamation District, Denver
Platte Canyon Water & Sanitation District
Connecticut
Greater New Haven WPCA
District of Columbia
DC Water
Florida
Broward County
Fort Lauderdale, City of
Jacksonville Electric Authority (JEA)
Loxahatchee River District
Miami-Dade County
Orange County Utilities Department
Pinellas County Utilities
Reedy Creek Improvement District
St. Petersburg, City of
Tallahassee, City of
Toho Water Authority
West Palm Beach, City of
Georgia
Atlanta Department of Watershed Management
Augusta, City of
Clayton County Water Authority
Cobb County Water System
Columbus Water Works
Fulton County Department of Water Resources
Gwinnett County Department of Public Utilities
Savannah, City of
Hawaii
Honolulu, City & County of
Idaho
Boise, City of
Illinois
Greater Peoria
Sanitary District
Metropolitan Water
Reclamation District of Greater Chicago
Wheaton Sanitary District
Indiana
Jeffersonville, City of
Iowa
Ames, City of
Cedar Rapids Water Pollution
Control Facilities
Des Moines, City of
Iowa City
Kansas
Johnson County Wastewater
Unified Government of Wyandotte County/ Kansas City, City of
Kentucky
Louisville & Jefferson County
Metropolitan Sewer District
Sanitation District No. 1
Louisiana
Sewerage & Water Board of New Orleans
Maine
Bangor, City of
Portland Water District
Maryland
Anne Arundel County Bureau of Utility Operations
Howard County Bureau of Utilities
Washington Suburban Sanitary Commission
Massachusetts
Boston Water & Sewer
Commission
Massachusetts Water Resources
Authority (MWRA)
Upper Blackstone Water Pollution Abatement District
Michigan
Ann Arbor, City of
Detroit, City of
Holland Board of
Public Works
Saginaw, City of
Wayne County Department of Environment
Wyoming, City of
Minnesota
Rochester, City of
Western Lake Superior Sanitary District
Missouri
Independence, City of
Kansas City Missouri Water
Services Department
Little Blue Valley Sewer District
Metropolitan St. Louis Sewer District
Nebraska
Lincoln Wastewater &
Solid Waste System
Nevada
Henderson, City of
New Jersey
Bergen County Utilities Authority
Ocean County Utilities Authority
New York
New York City Department of Environmental Protection
North Carolina
Charlotte/Mecklenburg Utilities
Durham, City of
Metropolitan Sewerage District of Buncombe County
Orange Water & Sewer Authority
Ohio
Akron, City of
Avon Lake Municipal Utilities
Butler County Water & Sewer
Columbus, City of
Metropolitan Sewer District of Greater Cincinnati
Montgomery County Water Services
Northeast Ohio Regional Sewer District
Summit, County of
Oklahoma
Oklahoma City Water &
Wastewater Utility Department
Tulsa, City of
Oregon
Albany, City of
Clean Water Services
Eugene, City of
Gresham, City of
Lake Oswego, City of
Oak Lodge Sanitary District
Portland, City of Water Environment Services
Pennsylvania
Philadelphia, City of
University Area Joint Authority
South Carolina
Beaufort-Jasper Water &
Sewer Authority
Charleston Water System
Mount Pleasant Waterworks & Sewer Commission
Spartanburg Water
Tennessee
Cleveland Utilities
Knoxville Utilities Board
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
Fairfax, County of
Fauquier County Water and Sanitation Authority
Hampton Roads Sanitation District
Hanover, County of
Henrico, County of
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
Seattle Public Utilities
Sunnyside, Port of
Yakima, City 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
Wausau Water Works

Water Services Association of Australia
ACTEW Corporation
Allconnex Water
Barwon Water
Ben Lomond Water
Central Highlands Water
City West Water
Coliban Water Corporation
Cradle Mountain Water
Gippsland Water
Gladstone Area Water Board
Gosford City Council
Goulburn Valley Water
Hunter Water Corporation
Linkwater
Melbourne Water
Onstream
Power & Water Corporation
Queensland Urban Utilities
Seqwater
South Australia Water Corporation
South East Water Limited
Southern Water
Sunshine Coast Water
Sydney Catchment Authority
Sydney Water
Townsville Water
Unity Water
Wannon Regional Water Corporation
Watercare Services Limited
Water Corporation of Western Australia
Water Secure
Western Water
Yarra Valley Water

Canada
Edmonton Waste Management Centre of Excellence
Lethbridge, City of
Regina, City of, Saskatchewan
Toronto, City of, Ontario
Winnipeg, City of, Manitoba

STORMWATER UTILITY

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

Colorado
Aurora, City of
Boulder, City of

Florida
Orlando, City of

Georgia
Griffin, City of

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

Kansas
Overland Park, City of

Kentucky
Louisville & Jefferson County Metropolitan Sewer District

Pennsylvania
Philadelphia, City of

Tennessee
Chattanooga Stormwater Management

Washington
Bellevue Utilities Department
Seattle Public Utilities

STATE

Connecticut Department of Environmental Protection
Fresno Metropolitan Flood Control District, CA
Harris County Flood Control District, TX
Kansas Department of Health & Environment
New England Interstate Water Pollution Control Commission (NEIWPCC)
Ohio River Valley Sanitation Commission
Urban Drainage & Flood Control District, CO

CORPORATE

Advanced Data Mining International
AECOM
Alan Plummer Associates, Inc.
American Cleaning Institute
Aqua-Aerobic Systems Inc.
Aquateam–Norwegian Water Technology Centre A/S
Atkins
Benton and Associates, Inc.
Black & Veatch
Brown & Caldwell
Burgess & Niple, Ltd.
Burns & McDonnell
CABE Associates Inc.
Carollo Engineers
CDM Smith Inc.
CH2M HILL
CONTECH Stormwater Solutions
CRA Infrastructure & Engineering
CSIRO (Commonwealth Scientific and Industrial Research Organisation)
D&B/Guarino Engineers, LLC
Damon S. Williams Associates, LLC
Effluential Synergies LLC
EMA Inc.
Environ International
EMA Inc.
Environ International Corporation
Environmental Operating Solutions, Inc.
Freese & Nichols, Inc.
ftn Associates Inc.
Gannett Fleming Inc.
Garden & Associates, Ltd.
Geosyntec Consultants
GHD Inc.
Global Water Associates
Greeley and Hansen LLC
Hazen & Sawyer, P.C.
HDR Engineering, Inc.
HNTB Corporation
Holmes and McGrath Inc.
Hydromantis Environmental Software Solutions, Inc.
Infilco Degremont Inc.
Jacobs Engineering Group Inc.
KCI Technologies Inc.
Kelly & Weaver, P.C.
Kennedy/Jenks Consultants
Larry Walker Associates
LimnoTech Inc.
Malcolm Pirnie, The Water Division of ARCADIS
MaxWest Environmental Systems, Inc.
McKim & Creed
MWH
NTL Alaska, Inc.
Odor & Corrosion Technology Consultants Inc.
O_2 Environmental
Parametrix Inc.
Praxair, Inc.
Pure Technologies, Ltd.
RMC Water & Environment
Ross & Associates Ltd.
Sanipor, Ltd.
Siemens Water Technologies
Southeast Environmental Engineering, LLC
Stone Environmental Inc.
Stratus Consulting Inc.
Synagro Technologies Inc.
Tata & Howard, Inc.
Tetra Tech Inc.
The Cadmus Group
The Low Impact Development Center Inc.
Trojan Technologies Inc.
Trussell Technologies, Inc.
URS Corporation
Westin Engineering Inc.
Wright Water Engineers
Zoeller Pump Company

INDUSTRY

American Electric Power
American Water
Anglian Water Services, Ltd.
Chevron Energy Technology
Dow Chemical Company
DuPont Company
Eastman Chemical Company
Eli Lilly & Company
InsinkErator
Johnson & Johnson
Merck & Company Inc.
Procter & Gamble Company
Suez Environnment
United Utilities North West (UUNW)
United Water Services LLC
Veolia Water North America

List as of 5/25/12

WERF Board of Directors

WERF Research Council

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.

WERF

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. OWSO11C10

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.co
IWAP ISBN: 978-1-78040-101-0/1-78040-101-9

June 2012