PROJECT NO.

ENER19C17/4792

Food Waste Co-Digestion at Water Resource Recovery Facilities

Business Case Analysis

Food Waste Co-Digestion at Water Resource Recovery Facilities: Business Case Analysis

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2019

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WRF ISBN: 978-1-60573-436-1
WRF Project Number: ENER19C17/4792

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Acknowledgments

The research team would like to thank the many cycles of Environmental Law Institute interns who have contributed to the project throughout its duration, including interns Matthew Beyer, Candela Cerpa, Serena Choi, Jessica Foster, Kathryn Goodwin, Ian Hardman, Samantha Holtz, Alejandra del Maar, Kathleen McLean, Matthew Glen Miller, Kashaf Momin, Ian Moor, Simon Silverberg, Jessica Sugarman, Bryan Williams, and Christopher Wright; and Law Clerks Robert Abrams, Leigh Barton, Tim Briscoe, and Bridget Grotz. The team also would like to thank the Michael Curley, ELI Visiting Scholar, for his guidance on water sector financing, and Michael Salter, ELI Visiting Attorney, for his research on state policies.

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Abstract and Benefits

Abstract:

Co-digestion of food wastes with wastewater solids at water resource recovery facilities (WRRFs) can provide financial benefits to WRRFs, as well as a broad range of environmental and community benefits. With fewer than one in 10 WRRFs using anaerobic digestion (AD) to process wastewater solids, and about one in 10 of those co-digesting high strength organic wastes (HSW), there appears to be significant untapped potential for co-digestion. The goals of this report are 1) to provide insights about successful business strategies that WRRFs in the U.S. have employed to create value and manage the risks of adopting co-digestion of food waste – including fats oils and grease (FOG), food manufacturing residuals, and food scraps – with wastewater solids to enhance recovery of biogas, soil amendments, and nutrient products; and 2) to present a framework for WRRFs to analyze the opportunities co-digestion could provide in their own institutional, market, and policy contexts. The framework is intended to help WRRFs develop a long-term business strategy and implementation plan that leverages those opportunities in a way that advances their mission and long-term goals.

Benefits:

- Develops a framework for WRRFs to analyze the sustainability of co-digestion and develop a business case for a co-digestion program and for individual projects suited to their context.
- Presents six major case studies (Chapters 4-9) and 25 minor case studies (Appendix B) that provide examples of successful business strategies, as well as examples where co-digestion was not a good fit.
- Summarizes lessons learned about successful business strategies that WRRFs in the U.S. have employed to create value and manage the risks of adopting co-digestion of food waste.
- Identifies solutions to address financial impediments and manage financial risks.
- Summarizes lessons learned about the role of public policy in supporting WRRF successful business strategies.

Keywords: Business case, co-digestion, anaerobic digestion, risk management, value creation, food waste, FOG, HSW, food scraps, energy recovery, tip fee revenues, return-on-investment criteria, Utility of the Future.

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Acronyms and Abbreviations

AD	Anaerobic digestion
AD-PST	Anaerobic Digestion – Project Screening Tool
ADC	Alternative daily cover
ADM	Anaerobically digestible material
AGP	Aerobic grease pretreatment
ARRA	American Recovery and Reinvestment Act
BCA	Benefit-cost analysis
BioMAT Tariff	Bioenergy Market Adjusting Tariff
BOD	Biological oxygen demand
BRD	BioResources Development
BTU	British thermal unit
CAEAFTA	California Alternative Energy and Advanced Transportation Financing Authority
CAISO	California Independent System Operator
CBFT3	Columbus Biosolids Flow Through Thermophilic Treatment Technology
CCCSWA	Central Contra Costa Solid Waste Authority
CEC	Clean Energy Center / California Energy Commission
CES	Clean Energy Standard
cfm	Cubic feet per minute
C.F.R.	Code of Federal Regulations
CHP	Combined heat and power
CMSA	Central Marin Sanitation Agency
CNG, rCNG	Compressed natural gas, renewable compressed natural gas
CO2e	Carbon dioxide equivalent
COD	Chemical oxygen demand
CoEAT	Co-Digestion Economic Analysis Tool
CPP	Clean Power Plan
CSTR	Continuous stirred-tank reactor
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
CWW	Columbus Water Works
DAF	Dissolved Air Flotation
DBFOM	Design-build-finance-operate-maintain
DBFOOT	Design-build-finance-own-operate-transfer
DNR	Department of Natural Resources
DOE	United States Department of Energy
DSNY	Department of Sanitation of New York
DT	Dry tons
DTMA	Derry Township Municipal Authority
EBMUD	East Bay Municipal Utility District
EBS	Engineered BioSlurry® (Waste Management)
EERS	Energy Efficiency Resource Standards

EMP	Energy management program
EPA	Environmental Protection Agency
EPIC	Electric Program Investment Charge
EPP	Environmental Purchasing Policy
ESCO	Energy service company
ESD	Egg-shaped digester
ESPC	Energy savings performance contract
F2E	Food2Energy
FERC	Federal Energy Regulatory Commission
FIT	Feed-in tariff
FOG	Fats, oils, and grease
FPR	Food processing residuals
FSSD	Fairfield-Suisun Sewer District
GDDC	Greater Dubuque Development Corporation
GESA	Pennsylvania's Guaranteed Energy Savings Act
GGE	Gasoline gallon equivalents
GHG	Greenhouse gas
GIS	Geographic information systems
GLSD	Greater Lawrence Sanitation District
GO	General Obligation bonds
gpd	Gallons per day
GTW	Grease trap wastes
H_2S	Hydrogen sulfide
HEM	Hexane-Extractable Materials, formerly Oil & Grease
HP	Horsepower
HSW, HSOW	High-strength (organic) wastes
ICE	Internal combustion engine
ICI	Institutional, commercial, and industrial
IOU	Investor-owned utility
IRR	Internal rate of return
ITC	Investment Tax Credit
JWPCP	Joint Water Pollution Control Plant
JWWTP	Janesville Ohio Wastewater Treatment Plant
kW, kWh	Kilowatt, kilowatt-hour
L	Liter
LACSD	Sanitation Districts of Los Angeles Country
LCAMER	Life Cycle Assessment Manager for Energy Recovery
LCFS	Low Carbon Fuel Standards
LES	Liquid Environmental Solutions
LNG, rLNG	Liquefied natural gas, renewable liquefied natural gas
LWDS	Liquid waste disposal station
MCE	Marin Clean Energy

MCF	Thousand cubic feet
MG	Millions of gallons
mg	milligrams
mgd	Millions of gallons per day
MMBTU	Million British thermal units
MMSD	Madison Metropolitan Sewerage District
MRF	Materials recovery facility
MSS	Marin Sanitary Services
MSW	Municipal solid waste
MW, MWh	Megawatt, Megawatt-hour
MWRA	Massachusetts Water Resource Authority
NAAQS	National Ambient Air Quality Standards
NACWA	National Association of Clean Water Agencies
NO_X	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPV	Net present value
NRCS	National Resource Conservation Service
NYCDEP	New York City Department of Environmental Protection
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and maintenance
OFMSW	Organic fraction of municipal solid waste
OHSWA	Oneida-Herkimer Solid Waste Authority (OHSWA)
OMRC	Organic materials recovery center
OWASA	Orange Water and Sewerage Authority
OWL	Organic Waste Logistics
P	Phosphorous
PPP (P3)	Public-private partnership
PDA	Product development agreement
PG&E	Pacific Gas & Electric
PHMRF	Puente Hills Materials Recovery Facility
PI	Phosphorous index
PM	Particulate matter
POTW	Publicly owned wastewater treatment plant
PPA	Power purchase agreement
PSA	Pressure swing adsorption
PSC	Phosphorous source coefficient
psig	Pounds per square inch gauge
PTC	Production Tax Credit
PURPA	Public Utility Regulatory Policies Act
PV	Photovoltaic
QF	Qualified facility
RCRA	Resource Conservation and Recovery Act

REAP	Rural Energy for America Program
REC	Renewable Energy Credit
ReMAT Tariff	Renewable Market Adjusting Tariff (CA)
RFP	Request for proposal
RFS	Renewable Fuel Standard
RIN	Renewable Identification Number
RNG	Renewable natural gas
ROI	Return on investment
RPS	Renewable Portfolio Standard
RVSA	Rahway Valley Sewerage Authority
SAAS	Software as a service
SBWMA	South Bayside Waste Management Authority (CA)
SCADA	Supervisory control and data acquisition
scfd	Standard cubic feet per day
scfm	Standard cubic feet per minute
SGIP	Self-Generation Incentive Program
SoCalGas	Southern California Gas
SO_X	Sulfur oxides
SPWTP	Stevens Point Waste Treatment Plant
SRF	State Revolving Fund
SSO	Source-separated organic
SSOW	Source-separated organic waste
SWWTP	City of Sheboygan Wastewater Treatment Plant
TA	Total alkalinity
TBEL	Technology-based effluent limitation
TBL	Triple bottom line
TEC	The Energy Cooperative (OH)
TGC	Tempe Grease Cooperative (AZ)
TIFIA	Transportation Infrastructure Finance and Innovation Act
TKN	Total Kjeldahl nitrogen
tpd, tpy	Tons per day, tons per year
TS	Total solids
TSS	Total suspended solids
TVS	Total volatile solids
U.K.	United Kingdom
UOTF	Utility of the Future
U.S.	United States
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
VA	Volatile acids
VAR	Vector attraction reduction
VOC	Volatile organic compound

VS	Volatile solids
VSR	Volatile solids reduction
VSS	Volatile suspended solids
VVWRA	Victor Valley Wastewater Reclamation Authority (CA)
WARM	Waste Reduction Model
WE&RF	Water Environment & Reuse Foundation, now The Water Research Foundation
WEP	Water Environmental Program
WIFIA	Water Infrastructure Finance and Innovation Act
WM	Waste Management
WPCP	Water pollution control plant
WPS	Wisconsin Public Service
WQBELs	Water quality-based effluent limitations
WRA	Wastewater reclamation authority
WRF	The Water Research Foundation
WRF	Wastewater reclamation facility / Water resources facility
WRRC	Water and Resource Recovery Center (Dubuque IA)
WRRF	Water resource recovery facility
SPWTP	Stevens Point Waste Treatment Plant (WI)
WWTP	Wastewater treatment plant

Executive Summary

ES.1 Purpose

Co-digestion of food wastes with wastewater solids at water recovery facilities (WRRFs) can provide financial benefits to WRRFs, as well as a broad range of environmental and community benefits. Co-digestion is a core element of the wastewater sector's "Utility of the Future" (UOTF) initiative, which envisions WRRFs pioneering a new business approach in which they recover and reuse all residuals from treating wastewater in order to create valuable water, energy, and nutrient products.

With fewer than one in 10 WRRFs using AD to process wastewater solids, and about 1 in 10 of those co-digesting high strength wastes (HSOW), there appears to be significant untapped potential for co-digestion. The goals of this report are 1) to provide insights about successful business strategies that WRRFs in the US have employed to create value and manage the risks of adopting co-digestion of food waste – including fats oils and grease (FOG), food manufacturing residuals, and food scraps – with wastewater solids to enhance recovery of biogas, soil amendments and nutrient products; and 2) to present a framework for WRRFs to analyze the opportunities co-digestion could provide in their own organizational, market and policy contexts. Such a framework is intended to help WRRFs develop a long-term business strategy and implementation plan that leverages those opportunities in a way that advances their mission and long-term goals.

The topic of this report represents the last logical link in the series of topics covered in the program of research exploring the technology and economics of implementing co-digestion originally commissioned by the Water Environment & Reuse Foundation (WE&RF) and continued under the Water Research Foundation.

ES.2 Methods

The UOTF "innovation ecosystem" framework provides the analytical framework for the research. The pursuit of innovation is central to the UOTF vision of a clean water "innovation ecosystem", in which the wastewater utilities are at the core of a system including technology developers and suppliers, the finance community, energy utilities, public and private elements of the solid waste sector, and state and municipal governments. Through the combined efforts of all ecosystem members, they are enabled to take and manage risks as they increasingly manage valuable resources to the benefit of customers, the community, and the environment.

The research team conducted a review of existing literature on co-digestion, drawing heavily from previous WRF reports. They identified a pool of 116 WRRFs from which to select interview candidates for our major case studies. They narrowed down our pool of potential candidates using criteria based on financial performance, replicability, beneficial biosolids reuse, available data, and willingness to participate in the study. In total, the research team conducted 50 interviews between September 2017 and June 2019. Their final six case studies range in geographic distribution, size, feedstock procurement strategy and biogas end use.

ES.3 Lessons Learned

For each WRRF, the specifics of a successful business strategy for co-digestion will vary because it will depend upon the policy and market environment in the region, as well as utility long-term strategic goals, organizational culture, and resources. As a corollary, the costs and economic contributions will vary. As a result, the report does not offer economic rules of thumb for revenues or costs. It does offer the following lessons:

1. The right context is necessary to have a successful co-digestion program.
   Every list of essential elements for a successful co-digestion program includes the need for a co-digestion champion in the utility or municipal government. Our research identified five other elements as critical:
   - Enough site space for vehicles to deliver feedstocks and for other receiving station, AD, and energy equipment needs.
   - A business mindset to resource recovery.
   - Visionary utility board or municipal decision makers who will support projects beyond the core wastewater mission that make economic sense to rate payers.
   - Location with access to a sufficient supply of feedstock at a good price.
   - Location where energy markets and policies make it possible to generate energy cost-savings and/or energy revenues.
2. A successful business strategy employs a life-cycle perspective, taking into account revenues and costs from the time of initial investments through replacement investments.
3. A successful business case leverages available drivers in sync with WRRF mission.
4. A successful business strategy incorporates strategies to address financial risks.
5. A successful business strategy demonstrates the project will not compromise plant compliance with its environmental permits.
6. A successful business strategy typically will evolve over time, adding additional projects that build on past successes and reflect learning from challenges encountered.
7. A business case for investment capital that can be successful is to highlight the financial value co-digestion can contribute to larger investment projects required for regulatory compliance or for regularly scheduled maintenance and upgrades in the utility asset management plan.
8. A business case for investment capital that can be successful is to highlight the contributions the project will make to achieving environmental and community goals, along with its financial contributions.
9. A business case for investment capital for projects outside the core mission of the wastewater sector that can be successful is to employ a Public-Private-Partnership.

The report also identifies solutions to the set of financial risks a WRRF faces in implementing co-digestion, including insufficient, or highly uncertain, economic returns for the project (or program) and impediments to accessing financial capital.

CHAPTER 1

Overview of Report

1.1 Motivation and Goals of Report

The wastewater sector's "Utility of the Future" (UOTF) initiative envisions a transformation to a circular economy business model, shifting the sector mission from disposing of waste to managing critical resources. This transformation is reflected in the change in terminology from "wastewater treatment plants (WWTP)" to "water resource recovery facilities (WRRF)". In the UOTF initiative, WRRFs are pioneering a new business approach in order to recover and reuse all treatment residuals – water, energy, and nutrients. Resource recovery uses utility assets in innovative ways that will eventually yield financial benefits for the utility from reduced costs and increased revenues, while at the same time creating benefits for the environment and the community (NACWA, WERF, and WEF 2013).

This report focuses on WRRF decision making to adopt co-digestion of food waste, a core component of the circular economy for the wastewater sector. With co-digestion, the sector expands its anaerobic digestion (AD) feedstocks to include food waste and other high-strength organic wastes (HSOW). With a higher energy content than wastewater treatment solids, these co-digestion feedstocks enable WRRFs to substantially increase biogas production, providing a renewable energy source for heat, power, and fuel, and to extract nutrients for use as fertilizers and soil amendments. (See Figure 1-1.)

A culture of innovation is needed to accomplish this transformation, which is challenging in a sector that is averse to risks that could compromise its charge to protect public health. To this end, the UOTF envisions a clean water "innovation ecosystem" that supports the sector as it pioneers this new business approach. The sector developed the UOTF framework to promote innovation and economic resiliency in the face of increasingly stringent pollution regulations, limited funding, and community and state commitments to environmental sustainability.

Figure 1-1. Co-Digestion of Food Wastes and Resource Recovery at Water Resource Recovery Facilities.
Source: Michigan DEQ 2017.

Though WRRFs ranging in size and geography (and associated policy and market contexts) have adopted co-digestion, the rate of adoption is currently low. Fewer than one in 10 WRRFs have adopted AD and about one in 10 of those co-digest HSOW. Observers have identified a range of potential impediments to adoption.

This report has two main goals:

1) To provide insights about successful business strategies that WRRFs in the U.S. have employed to adopt co-digestion of food waste with wastewater treatment solids (hereinafter referred to as "solids") to enhance recovery of biogas, soil amendments, and nutrient products. These food wastes include fats oils and grease (FOG), food manufacturing residuals, and food scraps. Specifically, the most important insight is the necessity of creating value and managing risks, and the multiple strategies to do so. (While it is possible to co-digest other organic high-strength wastes, this report focuses on food wastes.)

2) To present a framework for WRRFs to analyze the opportunities co-digestion could provide in their own institutional, market and policy contexts. The framework is intended to help WRRFs develop a long-term business strategy and implementation plan that leverages those opportunities in a way that advances their mission and long-term goals.

The topic of this report represents the last logical link in the series of topics covered in the program of research exploring the technology and economics of implementing co-digestion commissioned by The Water Research Foundation (listed in Appendix G). Particularly important to the development of this report were WRF reports discussing the economic aspects of energy generation (Andrews et al. 2017, WERF 2015, Willis 2015), the operational and economic considerations of co-digestion (Van Horne et al. 2017, Appleton et al. 2017, Higgins et al. 2017, and Parry 2014), and the opportunities for Public-Private Partnership for WRRF energy projects (Hammond et al. 2017).

1.2 Potential Benefits of Co-Digestion

WRRFs can potentially accrue a range of benefits from co-digestion – including benefits to its finances, as well as to the environment and community (See Table 1-1). Water and wastewater utilities are typically the largest consumers of energy in municipalities, accounting for 30-40% of municipal energy bills (Copeland and Carter 2017). Increasing the production of energy with co-digestion of energy-intensive food waste can help each WRRFs reach their own energy-neutrality goals, create energy cost savings, and increase energy resiliency by reducing reliance on the power grid; further, in some cases, the sale of biogas energy products can generate a revenue stream. Additional "green payment" revenues can be generated by the sale of associated Renewable Energy Credits (RECs) or Renewable Identification Numbers (RINs) available through state or federal renewable energy policies. By accepting for co-digestion food waste that would otherwise go to incinerators or landfills, WRRFs can earn substantial tipping fee revenues, and also lower their operating costs for energy-intensive wastewater aeration and sewer maintenance. The financial benefits from co-digestion can contribute to keeping down increases in the rates utilities charge their customers.

At the same time, co-digestion can potentially provide a broad range of benefits to the public (See Table 1-1.). Increased substitution of renewable energy produced from WRRF biogas for fossil-fuel based energy reduces emissions of greenhouse gases (GHG) as well as emissions of conventional air pollutants. As major consumers of energy, WRRFs that expand renewable energy production can make a significant contribution toward community goals to increase renewable fuel use and reduce greenhouse gas (GHG) emissions.

Diverting food waste to AD that would otherwise go to wastewater processing, incinerators, or landfills can improve environmental quality while providing a service to waste generators seeking options to comply with new regulatory mandates. Sending FOG and food processing wastes directly to digesters can improve water quality by reducing the illegal disposal of these wastes in waterways and reducing sewer overflows from grease blockages in pipes. By providing an alternative outlet for food scraps, communities are able to divert waste organics from landfills or incinerators, providing another way to reduce releases of GHG and conventional air pollutants.

Table 1-1. Potential Benefits of Co-Digestion.

Financial	Environmental	Community
Energy cost savings **Increased energy security and resiliency** **Reduced wastewater operating and collection costs** **Creation of new revenues from tipping fees, renewable energy sales, and—in some cases—biosolid product sales** **Green payments for renewable energy (RECs, RINS), GHG mitigation, food scrap recycling**	Reduced GHG emissions from substituting renewable for fossil fuels, reduced flaring of excess biogas, and diverting food scraps from landfills Displacement of manufactured fertilizer with recycled nutrients Improved water, air and soil quality and healthier ecosystems	Affordable disposal location for industry, creating a business-friendly environment Improved sewer management (reduced pipe blockages and overflows) by digesting FOG Cost savings lower the need for rate increases Increased resiliency of the power sector

1.3 Tapping Unrealized Potential: The Way Forward

With fewer than one in 10 WRRFs using AD to process sludge, and about one in 10 of those also co-digesting HSOW, there appears to be significant untapped potential for co-digestion in the wastewater sector. The literature has identified various financial, operational, regulatory, stakeholder/political, and organizational impediments to adoption of co-digestion and related energy generation projects, which are outside core wastewater treatment services. To overcome the impediments, supporters of the UOTF framework recommend that WRRFs be innovative and resourceful.

To this end, UOTF envisions a clean water “innovation ecosystem”, with water utilities at the core of the system (Figure 1-2). Through the combined efforts of all ecosystem members, WRRFs are enabled to take and manage risks as they increasingly manage valuable resources to the benefit of customers, the community, and the environment.

The ecosystem is at its best when the different elements work together to promote innovation. Examples include:

- Project developers creating and adopting more effective and efficient technology.
- Utilities providing consulting engineers more latitude to be creative and solve problems.
- Regulators seeking solutions as opposed to prescriptions.
- The public sector providing financial support for the environmental benefits from market (or non-market) activities.
- The finance community assembling innovative packages of debt and equity from public and private sources.
- Both clean water and solid waste professional organizations supporting innovation through research and education.

Figure 1-2. Utility of the Future (UOTF) Innovation Ecosystem.

Source: *Water Resources Utilities of the Future.* NACWA, WERF, WEF, WateReuse. 2015.

Focusing specifically on co-digestion, experts convened by WRF in 2018 identified four key pillars of a co-digestion program, and key questions that apply to each (Lackey and Fillmore 2018):

- Fit with utility mission: What are co-digestion goals, and how do they fit with mission?
- Feedstock and generators: What quality, quantity and price will be available over time?
- Operations and WRRF staff: What will be required in terms of additional equipment, operational adjustments, and organizational focus to be successful?
- Products: What value will recycled products (energy, digestate, nutrients) and associated environmental impacts create?

Figure 1-3. Decision Framework for a Co-Digestion Program.
Source: Lackey and Fillmore 2018.

Building on these concepts, this report presents a framework that WRRFs can use to analyze the long-term sustainability of co-digestion given the current – and anticipated future – opportunities in their own institutional, market and policy context, and to develop a long-term business strategy leveraging the opportunities that fit with the WRRF mission and long-term goals.

1.4 Project Approach and Methods

1.4.1 Approach

The UOTF “innovation ecosystem framework” provides the analytical framework for the research. The literature indicates that a co-digestion champion and a commitment to the triple bottom line (TBL) goals of financial, environmental, and community sustainability, are important ingredients to making co-digestion work.

It also indicates that a long-term perspective is required. Building a robust program of co-digestion and resource recovery is a long-term process: the potential benefits and costs of co-digestion typically will not be fully realized until the program matures over time through a series of investments. Consequently, the challenge addressed is how to sketch out a long-term **Business Strategy** and **Implementation Plan** for a utility co-digestion program. The vision for the long-term potential can be used as a reference point for evaluating the **business case** for individual investment project proposals, as well as for assessing ongoing program performance. The governance board for each utility will define what performance criteria it will use to evaluate the business strategy developed for its utility – its minimum threshold for financial performance, and how much weight it will give to environmental and community factors in prioritizing investments.

Our primary focus is on the ways in which WRRFs develop strategies to create value, and to manage the **financial risks** that come with these opportunities for value creation. Financial risks may include issues of inadequate, and/or uncertain, financial benefit streams (e.g., due to lack of reliability in quantity, quality and price of feedstock supply or lack of reliability in quantity produced and sales price of WRRF end-products); and uncertainty about access to capital, and related challenges in getting approval of investment projects, financing, and ratepayer increases.

We are concerned with the other sets of impediments and risks to the extent that they affect the economics or access to capital. Other research has explored how to address **operational and regulatory risks** (Van Horne et al. 2017, Appleton et al. 2017). For the analysis, operational and regulatory risks are relevant because they may result in performance problems, which will reduce revenues (and increase costs), or require changes in operating processes or investments, which will impose costs. Similarly, the researchers identify **stakeholder risks** of different options, in order to identify potential equipment or operating changes (and associated costs) that may be needed to address them (or they could prevent accepting food wastes) – but they do not focus on strategies to work effectively with stakeholders. The report also highlights the potential for community and environmental benefits, and refer the reader to relevant literature to enable quantifying those impacts.

1.4.2 Methods

To understand past experience with WRRF co-digestion, the research team conducted structured interviews with more than 50 key organizations both in the wastewater sector and in other stakeholder groups of the innovation ecosystem who influence WRRF options and decision making. (In many cases, multiple interviews with a given individual or organizational team were conducted.) The other groups included municipal solid waste (MSW) utilities, private solid waste management organizations, technology developers, consulting engineers, regulators, energy utilities and energy project developers, the finance community, and solid waste and wastewater professional associations. Because it is important to learn not only from projects that worked, but also from ones that did not, the research covered WRRF co-digestion projects that were successful, as well as ones that were initiated but subsequently dropped, and ones formally evaluated that did not go forward.

The researcher’s goal was to elicit a representative sample of experiences across **WRRF characteristics** (including size and governance structure) and **policy and market contexts** (proxied by geographical region), as well as across **WRRF choices** among the several key options for feedstocks, energy generation, biosolids management, in-house vs Public-Private Partnership (PPP) contracting, and financing. The researchers were particularly focused on including a diversity of feedstocks, including food scraps, which currently is the least common type; a diversity of energy generation technologies, including vehicle fuel and pipeline injection, which are receiving major attention in recent years, as well as electricity generation; and some examples of PPP, with and without private project financing.

To identify the pool of co-digesting WRRFs from which to select interview candidates, the research team started with WRF's list of 116 co-digesting WRRFs, which included those co-digesting any high-strength organic waste (HSOW), not necessarily food waste. (The researchers started the process a year before EPA published its list of co-digesting WRRFs (Pennington 2018).)

The researchers also identified a set of criteria for selecting individual WRRFs:

- They have a strong financial performance, and have faced and solved some typical impediments.
- Their approach is potentially replicable in other places.
- They have at least a couple of years of experience, for which performance data are available.
- They have at least some information available in the literature (but are not an over-familiar example).
- Their management of biosolids included at least some beneficial uses.
- ***Practical***: The WRRF collects the data needed and supports being the subject of a case study, and has a contact person willing to work with the research team.

The research team sought advice from the Project Advisory Committee on WRRFs that might qualify, conducted a literature review of reports on co-digestion adoption, and researched individual WRRFs. The team evaluated 47 WRRFs for potential major case studies, of which 18 were contacted. The research team later dropped many of them when further research indicated they did not meet the selection criteria. A few declined to participate due to projects in progress or lack of interest.

This report features six major case studies, which were selected to achieve representation along the dimensions identified above. They range from 2.7 mgd to 280 mgd in size, are located in California (3), the Midwest (2), and the Northeast (1), and represent all feedstock type and energy product options.

To provide greater breadth and depth in coverage of WRRF characteristics, policy and market contexts, and WRRF choices among options for feedstocks and for end-products and uses, the major case studies are complemented the with thumbnail sketches of 25 additional facilities. In order to better understand the role of varying policy contexts in motivating adoption of co-digestion, additional WRRF interviews in the six states with the most co-digestion were conducted.

Table 1-2 provides a summary of key characteristics of the major and thumbnail case studies. (It does not include additional WRRFs that agreed to be interviewed on background.)

1.5 Outline of the Report

The first section of the report focuses on developing the decision-making framework for building a successful business strategy. Chapter 2 includes a literature review focusing on adoption rates over geography and time as well as the attributes and practices of co-digesting WRRFs, and on drivers and impediments and risks to adoption, including a section focusing specifically on the role of public policies. Chapter 3 provides a diagnostic framework for WRRFs to assess their mission and long-term goals and resources, and to analyze the market and policy context to inform the development of a business strategy for co-digestion over the long-term at their utilities. The research considers the implications and options individually for each of six key decision elements that are integral to developing a long-term co-digestion strategy. Four elements are production-related: AD co-digestion capacity and siting; organics feedstock supply; biogas supply and energy products, uses and technologies; and biosolids management. The final two relate to the structure of contractual relationships and the choice to establish a public-private partnership (PPP), and financing options. The final section concludes with a discussion of how to pull the pieces together to define strategy and make the business case for it, based on a TBL analysis tailored to the priorities of the utility's governance board. The team illustrates WRRF choices among the options with examples from the major and thumbnail case studies.

The second section of the report (Chapters 4-9) contains the six case studies of successful co-digestion enterprises, highlighting how WRRFs in different contexts put together their business strategies and implemented them in a series of investment projects over time. Appendix B contains thumbnail sketches for 25 additional WRRFs.

The third section of the report summarizes lessons learned. Chapter 10 focuses on lessons from a public policy perspective. First, highlighting the wide variation in policy portfolios among the six states with the most co-digesting WRRFs: they do not all look like California, with its aggressive policy portfolio. Second, the researchers explore the pattern of adoption across alternative types of digesters (including on-farm, stand-alone and WRRF) among the four New England states with statewide organics landfill bans, each of which has one or no WRRFs co-digesting food scraps. The team then highlights the intervening factors that influence what organics processing options have developed in response to the bans.

Chapter 11 focuses on lessons from a WRRF perspective, highlighting key factors for successful WRRF co-digestion business strategies and solutions to the impediments and risks of co-digestion, which were identified in the research (including prior literature). The report also highlight findings from WRRFs that dropped co-digestion or evaluated, but did not move forward with, co-digestion.

A number of appendices provide background information to the report. Appendix A provides more detail on the policy context for co-digestion at WRRFs, supplementing the discussion of policies in Chapter 2. Appendix B provides thumbnail sketches of the WRRFs studied in addition to the six major case studies. Appendix C provides profiles of innovative food waste feedstock suppliers, supplementing the discussion in Chapter 3.

Appendices D-G are intended to provide resources for WRRFs in their preliminary assessment of co-digestion, supplementing discussions in Chapter 3. Appendix D lists a variety of models and tools WRRFs may find useful for doing a preliminary screening of their business case. Appendix E provides a primer on investment decision-making criteria and metrics, focusing on the use of triple-bottom line analysis as a complement to traditional financial analysis. Appendix F provides a list of funding sources that WRRFs may find useful when doing a preliminary screening of their business case. Appendix G lists the studies in the program of research exploring the technology and economics of implementing co-digestion commissioned by The Water Research Foundation.

Table 1-2. Key Characteristics of WRRF Case Studies in the Report.

State	City	Facility Name	Utility	Average Dry Weather Flow (mgd)			Region	AD	Food waste feedstocks			Energy products					Biosolid mgmt					Notes
				0-<10	10-<50	50+		#, size of each (MG), type	FOG	FPR	scraps	CHP: onsite use	CHP: sell elec	sell nat gas: pipeline	sell nat gas: vehicle fuel	% energy neutral	landfill/ incin	Class B	Class A	liquid fertilizer	Processed product	Report Location
DIY AD/Energy																						
CA	Carson	Joint Water Pollution Control Plant	LACSD			280	CA	24, 3.7 MG, meso			1-yr con-tracts; WW/SW	29.7 MW	Sell to grid	future option (utility)	future option	100%+		X	X		X	Ch. 9
CA	Fairfield-Suisun	Fairfield Suisun Sewer District WWTP	Fairfield Suisun Sewer District		12		CA	2, 1.75 MG, meso, spherical		X		1.3 MW				100% w/ wind power			X		X	App B; PPP for biosolids
CA	Oakland	EBMUD WWTP	EBMUD			50	CA	11, 2 MG, thermo	DIY	DIY	LT Contract	11.1 MW	PPA with Port of Oakland			130-140%	X	X				App B
CA	San Rafael	CMSA	Central Marin Sanitation Agency	7			CA	2, 0.978 MG, meso	DIY		LT MOU	750 kW	starting Q1 2019			60%		X				Ch. 8
GA	South Columbus	South Columbus WRF	Columbus Water Works		40		SE	thermo	DIY			3.5 MW				40%			X			App B
IA	Des Moines	Des Moines WRF	Des Moines Wastewater Reclamation Authority			75	MidW	6, 2.7 MG, meso	DIY	DIY		4.6 MW		Indstry, utility pending		75% (2014)		X				App B
MA	Multiple in MA and NH	Greater Lawrence Sanitary District	Greater Lawrence Sanitary District		33		NE	4, meso			LT Contract	3.1 MW							X		X	App B, App C: WM thumbnail
NJ	Rahway	Rahway Valley Sewerage Authority WWTP	Rahway Valley Sewerage Authority		30		NE	3 digesters			LT Contract	6.2 MW							X			App B, App C: WM thumbnail
NY	Brooklyn	Newtown Creek WWTP	NYCDEP			240	NE	8, 1.5 MG, meso, egg			LT Contract			future			X	X				App B

Table 1-2. Key Characteristics of WRRF Case Studies in the Report (cont'd).

State	City	Facility Name	Utility	Average Dry Weather Flow (mgd)			Region	AD	Food waste feedstocks			Energy products					Biosolid mgmt					Notes
				0-<10	10-<50	50+		#, size of each (MG), type	FOG	FPR	scraps	CHP: onsite use	CHP: sell elec	sell nat gas: pipeline	sell nat gas: vehicle fuel	% energy neutral	landfill/ incin	Class B	Class A	liquid fertilizer	Processed product	Report Location
NY	Oneida County	Oneida County WPCP	Oneida County		48		NE	future 2 primary, 1 secondary			WW/SW	future										App B
OH	Newark	Newark Waste WWTP	City of Newark	8			MidW	2 primary, 1 secondary; 0.45 MG each	DIY	DIY				utility (75 scfm)				X				App B
OH	Wooster	Wooster WWTP	City of Wooster	3.5			MidW	3 digesters	DIY	DIY	past LT contract (quasar)	1.1 MW				48.75% (WWTP), 48.75% (water)		X	X			App B
OR	Durham	Durham Advanced WWTP	Clean Water Services		22		W	2, 1.3 MG	DIY			1.7 MW				60% with solar				X	X	App B
OR	Gresham	Gresham WWTP	City of Gresham		13		W	2, 1 MG	LT Con-tract	DIY		880 kW	10% donated to the grid			100% + with solar		X				App B
PA	Derry Township	Clearwater Road WWTP	Derry Township Municipal Authority	3.9			NE	1, 1.2 MG, meso	DIY	DIY	LT MOU (Divert); G2E	270 kW		ESCO in develop ment		21%		X	X (2018 dryer offline)		X	Ch. 7
PA	Hermi-tage	Hermitage WRRF	City of Hermitage Water Pollution Control	3.5			NE	3 meso, 1 thermo		DIY	DIY	600 kVA	net metering						X			App B
VT	Essex	Village of Essex Junction WRRF	Village of Essex Junction	3.3			NE	2, 0.35 MG, meso	DIY	DIY		150 kW				almost 100%			X		X	App B
WI	Appleton	Appleton WWTP	Wastewater Treatment City of Appleton		13.7		MidW	2 digesters		DIY		CHP not now in use									X	App B
WI	Fond du Lac	Fond du Lac Regional WWT Facilities	City of Fond du Lac Wastewater	8			MidW	2 meso, 2 thermo		DIY		450 kW				40-50%		X				App B
WI	Stevens Point	Stevens Point WWTP	City of Stevens Point	2.8			MidW	4, 0.735 MG and 1.5 MG, meso	Drop-ped in 2016	LT Con-tract	no	180 kW	Renew-able Energy Tariff			90%		X				Ch. 5

Table 1-2. Key Characteristics of WRRF Case Studies in the Report (cont'd).

State	City	Facility Name	Utility	Average Dry Weather Flow (mgd)			Region	AD	Food waste feedstocks			Energy products					Biosolid mgmt					Notes
				0-<10	10-<50	50+		#, size of each (MG), type	FOG	FPR	scraps	CHP: onsite use	CHP: sell elec	sell nat gas: pipeline	sell nat gas: vehicle fuel	% energy neutral	landfill/ incin	Class B	Class A	liquid fertilizer	Processed product	Report Location
PPP for AD/Energy (or mixed DIY and PPP)																						
CA	Victor Valley	Victor Valley Reg Water Reclam Facility	Victor Valley Wastewater Reclamation Authority		11.3 (2017)		CA	2, 1 MG, meso	DIY	DIY	DIY	1600 kW		PPP (DBFOM) in process		70%			X (case study)			Ch. 4
FL	Broward County	North Regional WWTP	Broward County Water & WW Services			95	SE		DIY			2 MW				19%		X				App B
IA	Dubuque	Dubuqe WRRC	City of Dubuque	7			MidW	4, 0.985 MG, 2 meso, 2 thermo	DIY	DIY		600 kW	no	PPP /utility (DBFOM)		40%			X			Ch. 6
OH	North Ridgeville	French Creek WWTP	Quasar & The City of North Ridgeville		11.25		MidW	0.9 MG, meso	LT Contract	LT Contract	LT Contract	1MW (quasar sells to WRRF)						X				App B
WI	West Bend	West Bend Sewer Utility	West Bend Sewer Utility	5			MidW	4, covered tanks	DIY	DIY		micro-turbines	Sell to We Energies									App B
No-Go or Stopped Co-digestion																						
NC	Carborro Chapel Hill	Mason Farm WWTP	Orange Water and Sewerage Authority	8			SE		NA	NA	NA								X			NO GO; App B
NY	Syracuse	Metro. Syracuse	Ondaga County Water Envir. Protection			65	NE	3, 1.8 MG primary; 1, 1.6 MG secondary	NA	NA	NA		350 kW				X					Stopped; App B
OH	Struthers	Struthers Water Pollution Control Facility	City of Struthers	4.5			MidW	?	NA	NA	NA	X										Stopped; App B
WI	Janes-ville	Janesville WWTP	City of Janesville		12.5		MidW	2.5 MG, meso	NA	NA	NA	460 kW	X		X	27% (2014)		X				Stopped; App B
WI	Madison	Nine Springs WWTP	Madison Metropolitan Sewerage District		41		MidW	7, 0.639 MG-1.014 MG, acid phase, meso, thermo	NA	NA	NA	950 kW				>30%		X	X		X	NO GO; App B
WI	Sheboy-gan	Sheboygan Regional WWTP	City of Sheboygan		10.9		MidW	3, 4.8 MG (total)	NA	NA	NA	700 kW				64% (2016)			X			Stopped; App B

CHAPTER 2

WRRF Co-Digestion: Current Status, Policy Context, Drivers and Impediments

Section 2.1 focuses on the key characteristics of co-digesting WRRFs, including their pattern of adoption over geography and time, and a literature review of attributes and practices of co-digesting WRRFs. Given the financial, environmental and community benefits of co-digestion outlined in Chapter 1, the question arises as to why the adoption of co-digestion is limited in the U.S. Section 2.2 focuses on the role of public policy in creating drivers and impediments. Section 2.3 summarizes findings in the literature on the broader set of drivers and impediments.

This chapter provides baseline information about the wastewater sector experience with co-digestion, which informs the framework for evaluating the business case for co-digestion at a specific WRRF presented in Chapter 3.

2.1 Key Characteristics of U.S. WRRFs Adopting Co-Digestion

Of the approximately 15,000 of WRRFs in the U.S., about 1,200 WRRFs (or one in 12.5) use anaerobic digestion to process their biosolids. However, because larger WRRFs are more likely to adopt anaerobic digestion (AD), AD covers almost half of wastewater treated. Of the ~1200 with AD, approximately 133 co-digest a wide range of organics, including food waste (food scraps, FOG, and food processing residuals) and other high strength industrial organic wastes (such as glycerin and biodiesel wastes) with biosolids from wastewater treatment (BioCycle 2017).

This report focuses on co-digestion of food waste substrates. A 2015 survey indicates that 78 WRRFs were co-digesting food waste at that time (Pennington 2018). (This number does not include WRRFs that started co-digestion of food waste, but had dropped it before 2015.)

2.1.1 Distribution of Adoption Over Geography and Time

The distribution of co-digesting WRRFs varies by state across the United States and is influenced by state, regional and local factors (Pennington 2018). (Figure 2-1.) As of 2015, the states with the highest number of co-digesting WRRFs are California (20), Wisconsin (9), New York (6), Iowa (5), Ohio (4) and Pennsylvania (4). Chapter 10 provides profiles of policies and co-digesting WRRFs for these six states as well as for the four New England states with organics landfill bans. (See Appendix A for a discussion of policies that can influence co-digestion adoption in a given state).

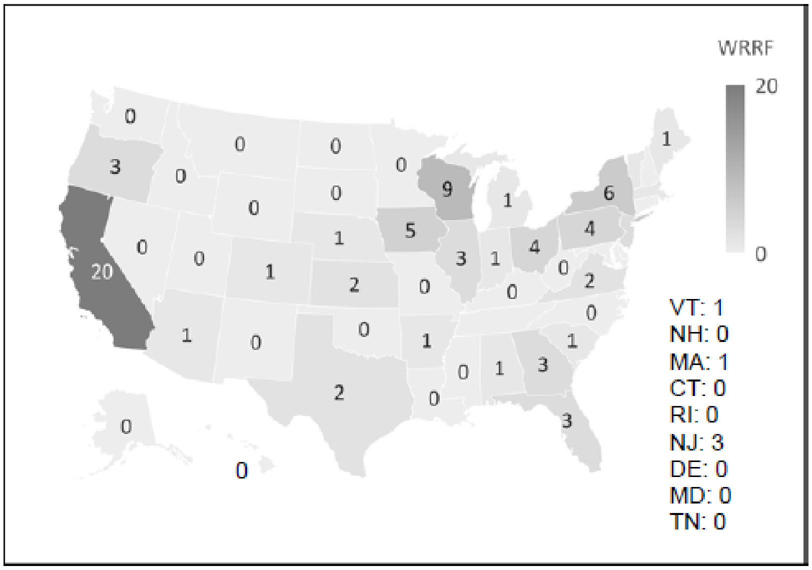

Figure 2-1. Number of Co-Digesting WRRFs, by State (2015).
Source: Pennington 2018.

2.1.1.1 Patterns of Change over Time in Adoption of Anaerobic Digestion and Co-Digestion

Co-digestion at WRRFs in the United States began as early as the 1960s (Tarallo et al. 2015). However, 44 out of the 78 (56%) co-digesting WRRFs in 2016 adopted the practice since 2009 (Pennington 2018). See Figure 2-2 for rates of co-digestion adoption over time. Factors such as changes in the presence of local food processing plants, federal infrastructure and renewable energy policies, and state or local food waste recycling policies can influence the adoption of co-digestion (Abhold et al. 2014). In addition, surveys of WRRFs with AD suggest that co-digestion adoption is growing. A 2015 survey of 169 WRRFs conducted by WERF identified 39 WRRFs with forthcoming co-digestion projects (Willis et al. 2015).

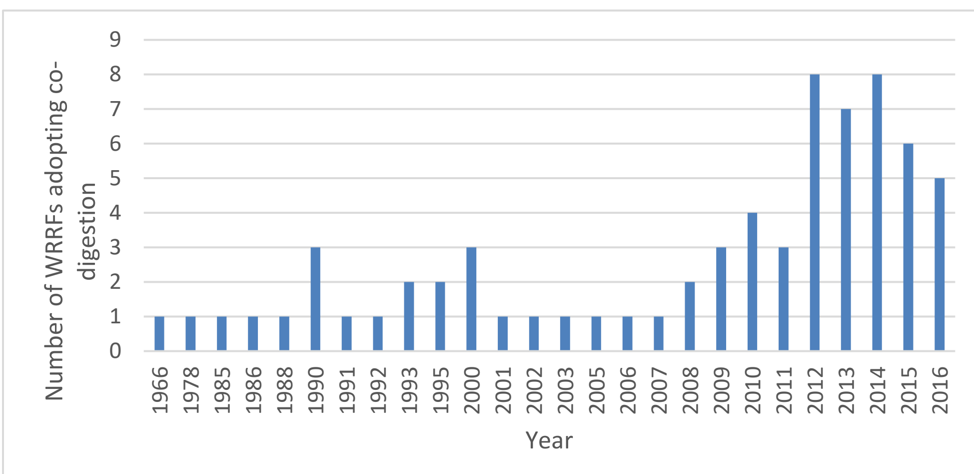

Figure 2-2. Number of Facilities Beginning Co-Digestion by Year (N=78).
Source: Pennington 2018.

2.1.2 Survey Results: Attributes and Practices of Co-Digesting WRRFs

For the literature review, the researchers rely on two surveys that provide useful information about co-digesting WRRFs. The first is a U.S. EPA survey conducted in 2015 on 78 co-digesting WRRFs with 72 respondents (Pennington 2018). The second is a WERF survey conducted in two phases in 2017. In the Phase 1, WERF surveyed 44 WRRFs, of which 28 were co-digesting. Phase 2 of the WERF study surveyed 13 co-digesting WRRFs (Van Horne et al. 2017).

Feedstocks: Co-digesting WRRFs mostly accept FOG and food industrial wastes. Of the 72 WRRFs that U.S. EPA surveyed, 62 (86%) WRRFs accepted FOG, 36 (50%) accepted food industrial wastes, 13 (18%) processed fruit/vegetative wastes, 16 (22%) processed food service wastes and eight (11%) processed retail food waste (U.S. EPA 2018). Co-digesting WRRFs process an average (median) of 3.66 millions of gallons (MG) of food waste per year (Van Horne 2017).

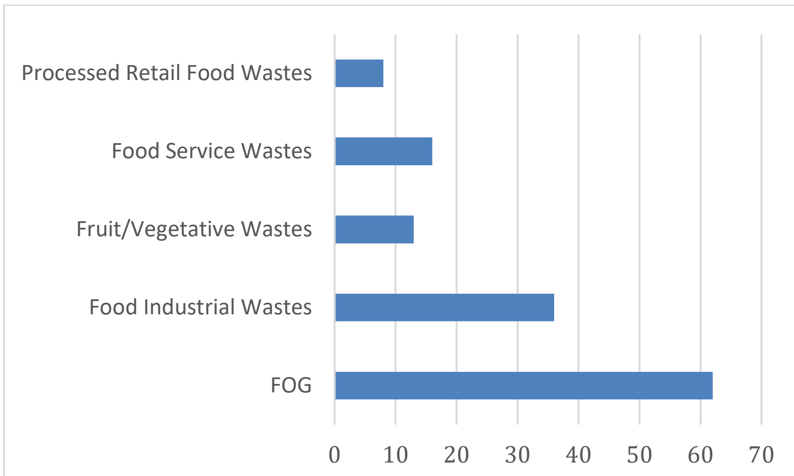

Figure 2-3. Number of WRRFs accepting feedstock type (2015).
Source: Pennington 2018.

Co-digesting WRRFs generally have a steady supply of HSOW. The selection of feedstock is based on local availability and the ease with which feedstock can be co-digested. Some WRRFs have contracts for feedstock supply, with durations ranging from one to five years (Van Horne 2017).

Prior to co-digestion adoption, many of the 13 WRRFs surveyed by WERF either already accepted outside HSOW elsewhere in the wastewater treatment process or had nuisance HSOW (e.g., FOG) that required improved management (Van Horne 2017). In many cases, the WRRFs conducted pilot studies testing different feedstocks types for their digestibility, which informed their decisions as to whether to accept an HSOW feedstock (Van Horne 2017). All 28 of the co-digesting WRRFs surveyed by WERF reported using some sort of pretreatment prior to adding HSOW to their AD system. The pretreatment stream typically includes pumping, rock traps, grinders, screening, and flow equalization as the most widely used methods.

Operations personnel time at the HSOW pretreatment facility averaged three hours per week per million gallons per year (MGY) of received HSOW. Expenditures related to equipment rehabilitation and replacement at the receiving and pretreatment facilities averaged $16,000/MGY of HSOW. Costs and personnel time associated with co-digestion at dewatering, sidestream treatment, and biogas handling facilities are negligible (Van Horne 2017).

Eight (64%) of the 13 surveyed WRRFs reported charging a tipping fee, with a median of $0.06 per gallon and a range of $0.03 - $0.15 per gallon. Among the others, one plans to collect tipping fees in the future (Van Horne 2017).

AD: Both the WERF and U.S. EPA surveys find that the majority of co-digesting WRRFs used mesophilic anaerobic digesters (87% and 91.67%, respectively). Of the 13 WRRFs surveyed by WERF, 38% reported enhanced volatile solids reduction (VSR) from the addition of HSOW. Additional operator time at a digestion facility due to co-digestion is approximately 2.5 hours per week/MGY of HSOW (Van Horne 2017).

Biogas Production: Of the 13 WRRFs surveyed in 2017, 12 (89%) observed enhanced digester gas production from the incorporation of HSOW. Reported increases in biogas range from 15% to 300%, varying with quality and quantity of waste received.

Energy Technology and Uses: Co-digesting WRRFs report diverse biogas end uses. U.S. EPA reports 50% (36) of co-digesting WRRFs beneficially use biogas. Of those 36 WRRFs, 71% produce heat and electricity using CHP technologies, where 13% sell electricity to the grid. Also, 61% and 32%, respectively, used fuel boilers and furnaces to heat digesters, and to heat other spaces. One WRRF reported selling compressed natural gas as vehicle fuel to customers, and two WRRFs reported injected renewable natural gas into pipelines. The traditional strategy for use of biogas has been to heat a boiler to warm the digester and other elements of the WRRF and to flare the excess. Recently, a drive for increasing the beneficial use of the biogas and the proliferation of renewable energy support policies has led WRRFs to consider investment in CHP technologies, and renewable natural gas production.

Biosolids Management: Land application and landfilling are the most common methods of biosolid disposal used by co-digesting WRRFs. Co-digesting WRRFs may also send their biosolids to composting facilities. Of co-digesting WRRFs surveyed by U.S. EPA, 69 (96%) produce Class A or Class B biosolids. Of those, 80% produce Class B biosolids while 20% produce Class A biosolids (Pennington 2018).

Contracting and Financing: Grant funding is an important source of financing for co-digesting WRRFs. WRRFs reported received grants ranging from $65,000 to $3.5 million to implement co-digestion projects (Van Horne et al. 2017).

2.1.3 Competition and Growth Potential

2.1.3.1 Growing Competition for Food Waste Feedstocks

As co-digestion adoption increases, competition among WRRFs and other food waste processing facilities may increase. Organics landfill bans or recycling mandates are resulting in growing popularity for several organics management strategies. As a result, both composting and other types of anaerobic digestion facilities have increased in number. (See Table 10-1 for the numbers of composting facilities and farm, standalone and WRRF AD facilities accepting food wastes, for the six states with the greatest number of WRRFs co-digesting and the four New England states with landfill bans for organic wastes.)

In 2015, at least 154 anaerobic digesters processed 12.7 million tons of food waste. WRRF digesters comprised approximately 50% of the digesters accepting food waste yet only processed 22% of the food waste accepted at digesters nationwide. Standalone digesters processed 77% of the solid tons of that waste, while farm digesters processed <1% of food waste.

Composting Facilities
Approximately 4,700 composting facilities in the U.S. receive organics at on-farm and standalone sites. Approximately 800 (19%) of these compost sites accept food waste feedstocks from external sources. In addition, some on-farm (8%) and institutional (6%) composting sites also compost food scraps generated onsite. Composting is suitable for food scraps but is not generally suitable for liquid FOG or food processing residuals, unless the composting facility is equipped with tankage or storage facilities that enable it to accept liquids.[1]

Anaerobic Digesters: Farm, Standalone, and WRRF
Digestion of food wastes can occur in on-farm digesters, in merchant (standalone) food digesters, and in digesters at WRRFs. Anaerobic digesters can accept preprocessed food scraps as well as liquid FOG and food processing residuals. Of the 1,567 anaerobic digesters in the U.S., 1,269 are located at WRRFs (American Biogas Council 2018). In addition, there are 58 confirmed standalone systems that digest primarily or only food waste and 248 digesters on farms (Pennington 2018). Among the on-farm digesters, U.S. EPA confirms that 18 conduct co-digestion for a total of 76 non-WRRF facilities that digest or co-digest food waste (Pennington 2018). See Figure 2-4 for a map illustrating the distribution of all three types of digesters, in comparison with the distribution of excess food waste.

2.1.4.2 Estimates of Additional WRRF Potential for AD, Co-digestion, Beneficial Use of Biogas
In concept, the U.S. biogas industry has significant potential for growth in the wastewater sector beyond the ~133 WRRFs currently co-digesting any form of HSOW. Approximately 70% of the ~1,200 WRRFs with AD use biogas for beneficial use (including heating systems), but most are not co-digesting. The infrastructure barriers are potentially lower for these WRRFs relative to those not already using biogas beneficially (Shen et al. 2015). The presence of energy infrastructure, such as CHP, with excess capacity can be a ready source of economic gains with the production of more biogas by adopting co-digestion. By adopting AD, the ~1,067 WRRFs with AD that are not co-digesting have surmounted a large infrastructure barrier to co-digestion, whether or not they are making beneficial use of biogas.

[1] For example, Royal Oak Farm in Evington, VA accepts 20,000 gal/day of FPR liquids; McGill's facilities in Waverly, VA and New Hill, NC have glass-lined tanks for receiving liquid solids; and Crowell Dairy Farm in Asheville, NC takes in grease trap wastes.

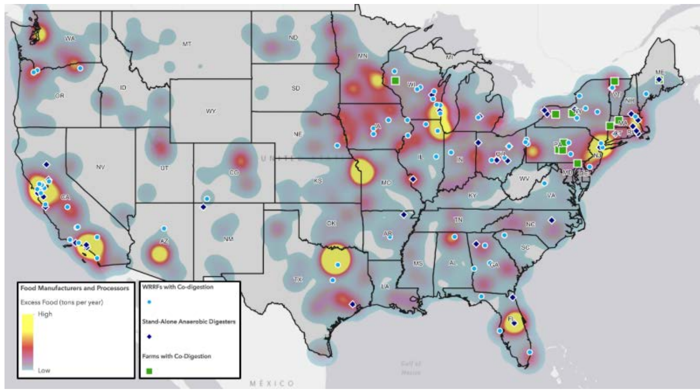

Figure 2-4. Stand-Alone Digesters, WRRF Digesters and Farm Digesters Accepting Food Waste and the Availability of Excess Food Waste (from the MSW System) from Food Manufacturers and Processors.[2]
Source: U.S. EPA Excess Food Opportunities GIS Database, https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map.

2.2 Policy Context

Given the potential financial benefits to WRRFs, as well as the environmental and community benefits of co-digestion with public policy support (in some locations) identified in Chapter 1, the question arises as to why the adoption of co-digestion is limited in the U.S. This section focuses on the role of public policy in creating drivers and impediments. Section 2.3 summarizes the literature on the broader set of drivers and impediments.

The researchers briefly highlight two major classes of policies that influence co-digestion: regulations permitting wastewater treatment facilities, which may represent impediments to adoption; and policies that create, expand, or impede access to potential co-digestion product or feedstock markets, which can potentially serve as drivers (or impediments) to adoption. Appendix A provides more details about the policies highlighted briefly in this section.

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[2] Following is a list of facilities for which geo-coding was not available in the EPA file to include them in Figure 2-4:

- **Co-digesting farms**: Link Energy in Riceville, IA; AgriReNew (Sievers Family Farms) in Stockton, IA; Noblehurst Green Energy in Pavilion, NY; Mill Creek Dairy in West Unity, OH; Monument Farms Three-Gen in Weybridge, VT, Clean Fuel Dane, LLC in Dane, WI, Allen Farms Digester in Oshkosh, WI.
- **Co-digesting WRRFs**: Joint Water Pollution Control Plant, Carson, CA; City of Hayward Water Pollution Control Facility, Hayward, CA; Santa Rosa Regional Water Reuse Plant, Santa Rosa, CA; DLS Middle Basin, Overland Park, KS; Joint Meeting of Essex and Union Counties, Elizabeth, NJ; Opequon Water Reclamation Facility, Winchester, VA; City of Kiel, Kiel, WI.
- **Standalone Anaerobic Digesters**: Miller Coors Brewery, Irwindale, CA; CR&R Material Recovery Facility, Perris, CA; J.R. Simplot Potato Processing Plant, Caldwell, ID; Waste No Energy, LLC, Monticello IN; American Crystal Sugar, East Grand Forks, MN; Hometown BioEnergy, Le Sueur, MN; American Crystal Sugar, Moorhead, MN; American Crystal Sugar, Hillsboro, ND; Lassonde Pappas, Seabrook, NJ; CH4 Generate Cayyuga LLC., Auburn, NY; Emerald BioEnergy, Cardington, OH; Dovetail Energy, Fairborn, OH; Stahlbush Island Farms, Corvallis, OR; D.G. Yuengling and Son, Inc., Pottsville, PA; Kline's Services, Salunga, PA; J.R. Simplot Potato Processing Plant, Moses Lake, WA; Bush Brothers & Company, Augusta, WA; Montchevre – Betin, Belmont, WI; Greenwhey Energy, Turtle Lake, WI.

2.2.1 Policies Regulating WRRF Environmental Performance

The first class of policies pertain to permitting anaerobic digestion and energy technologies at WRRFs. Of particular relevance is how the introduction of co-digestion with food waste may affect what requirements are included in facility permits to establish compliance. The National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act represents the primary, water quality-based regulatory program for WRRFs. The liquid and solid byproducts of anaerobic digesters are covered by the plant's NPDES permit. Federal and state water quality standards impose limits on the pathogen and nutrient content of the effluent that is discharged from the plant and on biosolids (in liquid or dry form) that are applied to farm land.

Anaerobic digesters and the related processes of energy production and biosolids management also may be subject to federal and state permitting requirements for emissions to the air and for solid waste disposal/management. Permits required by state and federal statutes are generally managed at the state level; as a result, regulations will vary by state. Multiple sets of permitting requirements, which may be complicated, expensive, and uncertain, can further complicate the adoption of co-digestion.

In some states, acceptance of food waste as a feedstock may result in the designation of the digester as a waste processing facility, which trigger solid waste regulations promulgated under the Resource Conservation and Recovery Act Subtitle D (for non-hazardous solid wastes). State-level solid waste permitting for food waste digesters is a new process in many states; as a result, permitting can take an extended time period.

Local permitting and zoning challenges may also exist when installing new digesters and energy production equipment; however, these issues are beyond the scope of this appendix.

Emissions from combustion-related equipment used for onsite energy production are regulated by both federal and state air quality regulations. Federal emission standards from the Clean Air Act are a minimum threshold; state standards may be more stringent.

2.2.2 Policies that Expand or Impede Access to Co-Digestion-Related Markets

This second class of policies pertain to creating or expanding market demand for the energy and nutrient/soil amendment end-products of anaerobic digestion (co-digestion), or market supply of the food waste feedstocks for co-digestion.

For energy markets, whether and how states implement various "market-access" policies has a substantial effect on the ability of distributed power sources (such as WRRFs) to achieve positive economic returns from energy production in-house, particularly in this period of low natural gas prices. Returns from heat and power generation may be in the form of cost savings from reducing purchases from the electric power utility (which may be limited by tariff structures with fixed fees and demand charges) or revenues from selling electricity to the power grid (through access and pricing mechanisms such as net metering, feed-in tariffs, and grid interconnection agreements). Returns from renewable gas sales may be in the form of revenues from either selling it directly as vehicle fuel (or cost savings from fueling municipal fleets), or distributing it through natural gas pipelines (which will be controlled by interconnection standards and utility rate structures).

Another set of energy policies that can be critical to achieving positive economic returns is financial incentive programs for environmental sustainability activities – notably renewable energy (in electricity or fuel form), energy efficiency, or greenhouse gas mitigation. In particular, with state renewable portfolio standards for electricity generation (RPS), covered renewable energy sources can earn Renewable Energy Credits; further RPS can provide incentives for utilities to offer favorable tariffs and long-term contracts for renewable energy. Further federal and state renewable fuel policies provide incentives for establishing RNG fuel projects. Since U.S. EPA qualified biogas from AD as a new pathway for cellulosic biofuel in 2014 under the federal Renewable Fuel Standard (and the associated D3

Renewable Identification Numbers (RINs) credits have increased substantially in value), the federal renewable fuel standard has become a potentially significant revenue stream for biogas energy projects. However, access to D3 RINs is complicated by the fact that once food scraps are added, the resulting biogas no longer qualifies for cellulosic pathway. Thus co-digesting digesters only are eligible for the lower-valued advanced biofuel pathway (D5 RINs). The American Biogas Council and others are in negotiations with the EPA to identify methods for a simplified methodology to identify a D3/D5 split for co-digesting WRRFs in order to increase revenue potential (Pleima 2019).

State low carbon fuel standards may also provide a source of green payments, even for out-of-state projects if they can be injected into an interstate pipeline. Various federal and state agencies also provide grants or low-interest loans for renewable energy projects.

For nutrient and soil amendment markets, various policies create both public, and in some cases, private demand for digestates or enhanced soil amendment products, including compost, made from digestate.

Finally, various regulatory and incentive-based policies promote – either directly or indirectly – a reliable supply of food waste feedstocks for organic processing, such as AD. As such, they represent drivers for co-digestion. Organics landfill bans or recycling mandates are designed to create a reliable supply of food scrap feedstocks for organic processing, as well as to promote the reduction and reuse of wasted food. State and local governments, and quasi-governmental agencies, may also provide grants or low interest loans for the development of composting or anaerobic digestion infrastructure to recycle food waste. Further, local or state policies increasing the stringency of requirements for managing fats, oils, and grease (FOG) or industrial food processing wastes may provide a stimulus to co-digesting those feedstocks.

2.3 Summary of Literature: Drivers, Impediments and Risks to Adoption of AD and Co-Digestion

This section consolidates and integrates the various lists in the literature pertaining to drivers, impediments, and risks for adoption of AD and for adoption of co-digestion. Chapter 11 returns to these issues, and Table 11-2 sets out the solutions to these impediments and risks observed in the research.

2.3.1 Drivers

Co-digestion is motivated by different factors, which will vary with the context of each utility. A 2017 WERF report (Van Horne et al. 2017) and Abhold et al. (2014) conducted surveys of co-digesting WRRFs (with sample sizes of 28 and 25 respectively) that provide snapshots of currently co-digesting WRRFs. The economic benefit of reducing energy costs through increased biogas production was cited as the strongest driver for co-digestion (Abhold et al. 2014). Improving community relations is cited as another driver: WRRFs accept food wastes to provide a service to nearby industry seeking disposal options and/or help meet local or state landfill diversion targets (Van Horne et al. 2017). Regulatory drivers such as organic waste bans can create feedstock markets for co-digestion, while renewable energy policies can create markets for energy generated from biogas. Lastly, the removal of certain feedstocks from the sewage system and treatment train can create operational benefits. For example, hauling FOG to digesters reduces clogging in sewer pipes thus reducing the potential for sewer overflows.

Table 2-1 provides a detailed list of economic, operational, regulatory, political and organizational cultural drivers for co-digestion.

Table 2-1. Co-Digestion Drivers.

Source: Abhold et al. 2014; Hammond et al. 2017; Willis et al. 2015; Coker 2017; Carr et al. 2015.

Drivers for Co-Digestion
Financial
• Co-digestion revenue streams can improve the payback periods of core-mission capital projects. • High energy costs can motivate increased biogas production for onsite energy generation. • Generating renewable energy from increased biogas can generate energy cost-savings and/or revenue from energy sales. • Generating renewable energy from increased biogas can generate revenue streams from state and federal renewable energy policies (including RINs and RECs). • Accepting HSOW feedstocks can increase feedstock tipping fee revenues. • Removing FOG or other HSOW from headworks can reduce wastewater treatment energy costs. • Removing FOG from sewers can reduce sewage collection costs and potential fines for water quality non-compliance. • Grant funding for project investments from various federal and state sustainability incentive programs can reduce project costs borne by utility. • Tax incentives can reduce the effective costs when projects are financed privately. • Disposal regulations and high landfill tipping fees can motivate generators and waste haulers to find alternative options for organic waste.
Operational
• Adding feedstocks can take advantage of excess capacity in digesters. • Expanding biogas production can take advantage of excess capacity in energy generation. • Removal of FOG from sewer lines reduces sewer line clogging and overflows. • Removal of HSOW from energy-intensive aeration process in primary treatment improves energy efficiency.
Regulatory
• Federal and state energy regulations and policies that incentivize co-digestion, including the Federal Renewable Fuel Standard and State Renewable Portfolio Standards. • State or local landfill diversion mandates can create a supply of feedstocks. • Stringent pretreatment mandates for industrial waste or stringent land application restrictions for industrial wastes can create sources of food waste feedstock. • FOG management ordinances can create sources of FOG feedstock. • Capital projects to comply with new regulatory requirements (e.g., nutrient effluent requirements) provide an opportunity for add-on investments to expand digester and energy-generation capacity.
Public and Political Stakeholders (Board, feedstock sources, ratepayers, neighbors)
• Helping plants achieve plant energy neutrality and energy efficiency goals • Establishing a leadership role in achieving community sustainability goals, such as recycling food waste, producing renewable energy to replace fossil fuel energy, creating a smaller carbon footprint • Accepting HSOW and other feedstocks can provide a service to local industry, which can translate into economic development benefits, such as the retention of local industry and jobs • Food industry corporate responsibility requires an environmentally friendly method of food waste disposal
Organizational Culture
• A staff champion for resource recovery can motivate co-digestion • Co-digestion can keep rates low for rate payers by adding new revenue streams • Utility commitment to resource recovery can motivate co-digestion • Utility commitment to energy use reduction can motivate co-digestion

2.3.2 Impediments and Risks

Facilities pursuing co-digestion note several risks that can deter adoption. Risks include uncertainty in feedstock consistency, both in terms of quality and quantity, Table 2-2 summarizes these impediments and risks.

The impediments to adoption of co-digestion most frequently cited in the literature are economic feasibility and financing (Abhold et al. 2014). Adding co-digestion to WRRF operations can require significant capital investment, though the investments can be bundled with others focused on increasing energy efficiency and moving toward energy neutrality.

Also ensuring predictable revenues is critical to the economic success of co-digestion, and to demonstrating economic viability for financing. Unpredictable supplies of quality feedstock and the associated tipping fee revenues can pose a financial risk, as can market unpredictability for biogas energy products, and underdeveloped markets for soil amendment and nutrient products. Thus anticipated revenue flows may not be sufficient to generate a positive rate of return.

Limited funding available for WRRF capital investments often means that other projects related to the core functions of the WRRF crowd out funding for co-digestion and energy production investments. The financial risks associated with co-digestion, including unpredictable revenue streams (variable tipping fees and feedstock supplies, and unstable incentives for renewable energy generation), can also deter its adoption.

WRRFs also face a variety of operational risks. Due to the relatively recent adoption of co-digestion, research on the extent of operational impacts and strategies to mitigate them has been limited to date. To date, there is a lack of consensus on best practices for facility design and operations when incorporating co-digestion. The lack of predictability of feedstock quantities and quality can also impose risks of digester upsets, which can interfere with the core facility mission of processing wastewater. Energy production equipment is prone to shutdown, making it difficult to realize consistent financial benefits from biogas use. In addition, added feedstocks may lead to potential increases in the quantity and quality of biosolid production that may be cause for concern in increasingly stringent regulatory environments for biosolid land application. (The WRF program of research on co-digestion is designed to address this gap, and inform the development of a WEF Manual of Practice. See Appendix G for a list of WRF research projects on co-digestion.)

The addition of food wastes to digesters may trigger new regulatory requirements or may influence compliance with existing regulations. Food waste may increase the nutrient content in wastewater effluent, which can affect NPDES permit compliance. The addition of food waste to digesters may also trigger requirements for a solid waste permit in some states.

Political impediments to co-digestion can include a lack of public will and political support. WRRFs successfully co-digesting often cite an individual or group of individuals that act as the project promoters. Without these “project champions” WRRFs may not be inclined to pursue projects outside of their core functions. Issues such as increased odor and trucking due to co-digestion may also decrease public support for co-digestion.

Finally, organizational culture can impose impediments. As protectors of the environment and public health, wastewater utilities are risk-averse to accepting new technologies or practices that will have unknown implications for their ability to achieve that mission. This organizational culture has been a factor in the slow rate of adoption of AD and co-digestion of food waste (source). Also the co-digestion of food waste requires collaboration between the solid waste and wastewater sectors, which can be difficult due to sectoral cultural differences.

Table 2-2. Co-Digestion Impediments and Risks.

Source: Abhold et al. 2014; Hammond et al. 2017; Willis et al. 2015; Coker 2017; Carr et al. 2015.

Co-Digestion Impediments and Risks
Financial
Project-level • Insufficient, or highly uncertain, economic returns - inadequate payback periods or return on investment. • Scarce financial capital for implementing infrastructure improvements needed for co-digestion, which may include investments to expand AD capacity, to generate energy from additional biogas and to manage increase biosolids, as well as receiving station investments. **Feedstock** • Variable and uncertain quantity, quality and price (tip fees) of feedstock supplies. • Landfill tip fees for food scraps may be lower than costs to supply food scrap slurry, reducing the incentive to dispose of food waste at WRRFs. **Energy** • Cost savings maybe low and/or uncertain due to: low energy prices, or high fixed and demand charges. • Access to the grid for selling electricity may be constrained, reducing revenues. • Access to pipelines for injecting biomethane may be constrained and/or costly, reducing revenues. **Biosolids** • Increases in the quantity or changes in quality of biosolids will increase management costs.
Operational
Feedstock/AD • Digester upsets may occur due to variable feedstock quantity and quality. • Increased foaming and struvite build-up will require more O&M. **Energy** • Energy generation equipment is often difficult to maintain and prone to shutdowns. **Biosolids** • Current management options may not have capacity for additional biosolids. • Increased HSOW may result in decreased dewaterability of biosolids.
Regulatory
• Air permits may be required, and compliance challenging in non-attainment areas, when biogas is used for drying, boilers, co-generation (or incineration). • Accepting materials from the municipal solid waste stream may trigger solid waste regulations. • Accepting food waste may increase nutrient loading in effluents and biosolids.
Public and Political Stakeholders (Board, feedstock sources, ratepayers, neighbors)
• Stakeholders may be concerned about utility performance, future rates, neighborhood nuisances. • Political leadership promoting renewable energy and food waste recycling may be lacking.
Organizational Culture
• Risk-averse wastewater sector culture, and lack of research/knowledge base on co-digestion impacts. • Utilities may lack information on financial aspects of co-digestion, or be uncertain how to capture and communicate non-monetary benefits. • Wastewater and solid waste cultural differences may hinder collaboration in supplying feedstocks.

As noted in Chapter 1, the researchers' primary focus is on financial risks. They are concerned with the other sets of impediments and risks to the extent that they affect the economics or access to capital. Chapter 11 highlights the findings about solutions WRRFs have developed to address financial impediments and risks to adoption of co-digestion, and summarizes them in Table 11-1.

CHAPTER 3

Framework for Decision Making to Adopt Co-Digestion

Co-digestion of food waste with wastewater solids, and the enhanced recovery of energy and nutrients it enables, is outside the "core" services of the wastewater sector. Traditionally utilities have applied strict Return on Investment (ROI) criteria on such investments and put them at the back of the queue for scarce capital resources.

The UOTF perspective brings a new approach to evaluating initiatives that will enhance resource recovery, which will eventually reduce costs and increase revenues to support the utility (NACWA, WERF, and WEF 2013). This new approach has four key elements:

- Taking a broader, TBL perspective on what is valued, and applying more flexible financial criteria.
- Taking a life-cycle perspective on investments to understand the full benefits and costs over the lifetime of the investments.
- Developing a blended approach to funding, with WRRFs seeking state and federal grants to provide compensation for the environmental benefits accruing to people outside the service area (who are not part of the rate base).
- Drawing on innovative partnerships with private solution providers to share program risks and rewards.

In this context, the first challenge a utility faces is to determine if co-digestion is a fit with its mission and long-term strategic goals. If it is, the next challenge is to sketch out a long-term **Business Strategy** and **Implementation Plan** for a mature utility co-digestion program, as well as to develop detailed investment project proposals, as they are needed to carry out the plan over time. Developing the business case requires 1) identifying the fit with utility mission and organizational culture and resources and 2) presenting performance projections –applying the performance indicators utility decision makers will use to evaluate co-digestion projects. The vision for the long-term performance potential can be used as a reference point for evaluating the business case for individual investment project proposals, as well as for assessing ongoing program performance.

It is important to recognize that co-digestion does not fit in all contexts and time periods: in some contexts, the business case will indicate the best option, under the current understanding of life-cycle potential, is to not move forward at the current time.

This chapter provides a diagnostic framework for developing the required analysis. The first section of this chapter provides a framework for assessing whether co-digestion is a fit with the utility. The second section provides a framework for evaluating the impacts of co-digestion on WRRF operations and the options for business opportunities that arise as a result, for each of six key decision elements that are integral to developing a long-term co-digestion strategy.

Four elements are production related: AD co-digestion capacity needs, technology, and siting; organics feedstock supply; biogas supply and energy products, uses and technologies; and biosolids management. The basic considerations include:

- How much infrastructure capacity (for AD, energy, biosolids management) does the plant have available to accept new food waste feedstocks for co-digestion and generate beneficial uses from them? What additional equipment would be needed to make best use of new feedstocks and the energy and biosolids residuals?
- What values can the plant generate by accepting new food waste co-digestion feedstocks, and what are the associated risks?

- What values (financial, environmental, community) can the plant generate by recovering energy from additional biogas, and what are associated risks?
- What values and/or costs (financial, environmental, community) will accrue to the plant from additional biosolids, and what are the associated risks? (Are there management options available to manage additional biosolids?)
- Does the plant have space onsite for the additional equipment needed to implement co-digestion and make best use of residuals, for example to receive new feedstocks, to generate energy, manage biosolids, and for the additional truck traffic to deliver hauled-in wastes?
- What will be the regulatory implications of co-digestion: will the changes in operations affect current permits (NPDES, air, other)? And will additional permits be required to accept the additional types of waste?

The final two elements relate to the structure of contractual relationships and the choice to establish a public-private partnership (PPP), and financing options.

- Are there barriers to moving forward with a co-digestion project that a PPP can address, such as lack of expertise, operating risks, financial risks, or difficulty in public financing approvals?
- What options are available for financing the project?

The third section highlights the basic steps to create the business strategy from decisions on the individual elements and to develop the business case for co-digestion that can inform the utility governance board and other stakeholders.

3.1 Fit with Long-Term Strategic Goals and Organizational Culture and Resources

Fit with Long-Term Strategic Goals, Organizational Culture and Resources: Strategic Questions
Over-arching strategic question: Could co-digestion create value for the ratepayers, the environment and the community, and help achieve utility mission and long-term goals?
Is co-digestion consistent with the mission of the WRRF? Its long-term strategic goals?
What criteria will utility decision makers use to evaluate projects to implement co-digestion and recover resources (biogas, energy, nutrients/soil amendments)?
What are the drivers for co-digestion at the WRRF? Which stakeholders will benefit? Which stakeholders may have concerns?
Does the utility have an organizational culture that supports innovation?
Does the utility have the resources to manage the co-digestion program (using internal resources and/or managing contracted resources) and to develop stakeholder support for the program - or a strategy to attain them?
If additional or upgraded facilities will be needed to implement co-digestion, such as hauled-in waste receiving, AD, energy generation and biosolids management facilities, does the utility site have sufficient, suitable space onsite? Or, if developing new sites not on current WRRF property, is there suitable zoning classification and political/public acceptance? (Equipment requirements will be explored in Sections 3.2, 3.3, 3.4, 3.5.)

The first step of the process in developing a business case is to establish whether the business opportunities that co-digestion provides are consistent with the mission and long-term strategic goals of the utility. Co-digestion potentially provides long-term opportunities for sustainability, cost-savings, revenue stream development and enhanced reliability, as well as service to waste generators and the community. However, they are outside the core wastewater treatment mission and may not meet strict ROI criteria for each individual project.

The literature is clear that having an internal champion is critical to the success of innovative resource-recovery activities at WRRFs, such as generating energy to achieve energy neutrality or implementing co-digestion. The work of the champion includes translating the strategic vision, promoting a resource-recovery mindset to key external stakeholders and staff, and articulating the Triple-Bottom-Line (TBL) benefits of projects. Support from political champions and key utility decision makers is essential because they will determine what decision criteria are applied to investments to support co-digestion. For example, will they apply strict financial criteria, or will they use a TBL approach, which considers a broader set of factors and more flexible financial thresholds? See Appendix E for a discussion of the use of decision-making criteria for both approaches.

Support from internal staff is also essential, because co-digestion expands the scope of their responsibilities beyond wastewater treatment. Finally, it is important to communicate with the broader community about the goals and benefits, as well as solicit information from the neighbors of the facility and of the site of biosolids land applications about what risks are of greatest concern to them.

3.2 Anaerobic Digestion Capacity, Space, and Siting Assessments

<table>
<tr><th colspan="3">AD Capacity and Siting Strategy Questions</th></tr>
<tr><td colspan="3">Over-arching strategic question: What strategy for AD capacity utilization can ensure wastewater services for the utility’s core customers, and optimize the opportunities to create value with the residual capacity?</td></tr>
<tr><td rowspan="2">Does the plant have sufficient AD capacity to accept additional feedstocks for co-digestion?</td><td>Yes</td><td>Are co-digestion considerations part of utility planning for AD upgrades to improve the efficacy and cost-effectiveness of the digester?</td></tr>
<tr><td>No (includes plants with no AD)</td><td>Are co-digestion considerations part of the utility planning to invest in (additional) AD capacity?</td></tr>
<tr><td colspan="3">• Truck access:
• Are there adequate routes and access for tractor-trailer access to deliver hauled-in wastes?
• Are there nearby commercial truck weigh stations if on-site weigh scales are not used?</td></tr>
</table>

If there is no AD in place, typically the decision to adopt AD will be driven by a broader set of factors than the decision to implement co-digestion, including regulatory compliance or improved cost-effectiveness and/or sustainability of wastewater solids management. Nonetheless, the approval of an AD construction project may be reinforced by the energy costs savings and tip fee revenues that result from co-digestion.

In contrast, co-digestion will be the motivator for constructing or upgrading receiving stations to accept new feedstocks, so that the costs will be attributable to the co-digestion project.

Investments in new AD and receiving capacity for co-digestion will frequently be a part of larger investment projects to upgrade and maintain the plant in order to provide its core services. These investments should be integrated into the plant capital budget and asset management plans for future maintenance and upgrade projects.

3.2.1 Evaluating Anaerobic Digestion Capacity and Siting Requirements

The first step is to evaluate current capacity availability and to project future capacity needs, taking into account the availability of high-strength organic waste (HSOW) feedstocks, as well as projections for population changes and possible future nutrient removal requirements that would affect solids production (such as chemical, rather than biological, phosphorus removal). Wastewater resource recovery facilities (WRRFs) without current AD capacity to manage solids evaluate current and potential future solids production, taking into account the same factors, in order to size the potential future AD system for those mass and volumetric loadings.

Producing biogas for renewable energy consumption using co-digestion requires a dedicated area for the main processing equipment (reactors, biogas cleaning, energy production) as well as ancillary facilities such as a truck receiving area, weigh scales, storage tanks, and pretreatment equipment. If the WRRF has an existing AD system, then the evaluation of siting alternatives focuses on the ancillary receiving and pretreatment facilities, which could be on land adjacent to or nearby the WRRF's AD reactors. In some cases, co-digestion ancillary facilities are located at more distant sites (Coker 2017).

3.2.2 Investment Decision Making to Adopt or Upgrade AD

A number of WRRFs have adopted co-digestion as part of an investment project to construct new or additional AD capacity in order to enhance their ability to supply core wastewater services.

- Derry Township Municipal Authority (DTMA) adopted AD in order to reduce costs and improve the sustainability of its biosolids management practices. The WRRF had, since its inception, accepted waste sludge from the Hershey Company industrial pretreatment plant and mixed it with the WRRF sludges (primary and waste-activated). Once the digester was installed in 2001, the Hershey sludge (in combination with the plant sludges) was fed directly to the digester. Subsequently it has expanded its co-digestion program to include high-strength organic wastes (HSOW) and food scrap slurries. (See Chapter 7.)
- Victor Valley Wastewater Reclamation Authority (VVWRA) chose to expand its AD capacity by upgrading and bringing back online previously mothballed digesters, in order to provide AD capacity when its other digesters are taken offline for maintenance. When all digesters are online, these newly renovated digesters will allow VVWRA to substantially expand its co-digestion program. VVWRA plans to inject the additional biogas into a nearby pipeline, thus creating more revenue for the WRRF. (See Chapter 4.)
- South Columbus Water Resources Facility chose to invest in a unique thermophilic digester system to create high quality biosolids as a result of pressure from increasingly strict biosolid regulations. FOG additions to the digester helped to generate enough biogas to heat the thermophilic digesters. As a result, the system is the first thermophilic digester system in the United States heated entirely by digester gas.

Alternatively, in some cases, investments in organic waste receiving stations to support co-digestion are part of larger utility projects to upgrade AD facilities to improve their efficiency, including the cost-effectiveness of biogas recovery.

- At Central Marin Sanitation Agency (CMSA), a $2 million project to install an organic waste receiving station, with 300,000-gallon tank, mixing pump, rock trap grinder, paddle finisher, and odor control system, was bundled within a $7.65 million investment package that included digester upgrades such as new flexible membranes, pump mixing systems, and hydrogen sulfide scrubbers.

3.2.3 Public and Political Considerations

Even if the WRRF has available land and AD technology in place, it may face the NIMBY syndrome due to potential issues related to increased truck traffic and odors from deliveries of expanded hauled- in HSOW.

3.3 Organics Feedstocks

Organics Feedstock Strategy Questions
Overarching Strategic Question: What feedstock strategy can meet utility goals for biogas production and revenue generation, and address constraints on biosolids management, without causing operational issues?
What are the options for feedstocks: (how) can the utility acquire supplies of them, with predictable quantity, quality and price?
What on-site investments (e.g., receiving station and pretreatment capacity) and operating changes (e.g., acceptance criteria, mixing/loading procedures) could: • Mitigate operating risk? • Mitigate regulatory compliance risks? • Optimize biogas recovery? • Optimize biosolids production?
What strategy can the utility use to set tip fees, in order to achieve feedstock quantity, quality and revenue goals?
What strategies can the utility use to manage the operational, regulatory and financial risks?

The addition of organic feedstocks contributes to the two key streams of economic benefits: tipping fees and energy cost-savings or revenue from the additional biogas produced. Tipping fees generally represent two-thirds to three-fourths of co-digestion revenues, with energy providing the remainder, according to a rule of thumb among engineering consultants and financiers. Therefore, continuing access to a reliable supply of quality feedstock at a robust and stable (or at least predictable) price is critical to the economics of co-digestion. (The economic contribution of energy is anticipated to be higher where WRRFs are able to access D3 RINs and California Low Carbon Fuel Standard [LCFS] payments for vehicle fuel uses.)

Potential operational challenges with adding organics feedstocks include risks of operational upsets, issues with regulatory compliance, and increasing biosolids, and therefore biosolid management costs.

To operationalize the addition of organics feedstocks, a WRRF must evaluate requirements for a receiving station, including pretreatment equipment and routing pipes to the digester; marketing and customer relations; feedstock acceptance criteria and screening protocols; and operational adjustments to the digester loading. The impact of co-digestion feedstocks on biogas and biosolids production will depend upon the characteristics of the waste and of the digester context. (The potential to create economic streams of revenues, cost-savings, or costs from biogas or biosolids is discussed in Sections 3.4 and 3.5, respectively.)

3.3.1 Food Waste Feedstock Options and Supply Sources

The most frequently used substrates for co-digestion with wastewater solids are food and beverage processing residuals (FPR); fats, oils and greases (FOG); and food scraps. The first three are often currently managed through the wastewater system, and therefore are known to WRRFs. In contrast, food scraps are managed through the solid waste system, which has a different organizational structure, culture, and economics from the wastewater sector. Typically, the solid waste sector in a community includes a highly competitive mix of public and private service providers in contrast to the wastewater sector, which is a highly regulated, public sector monopoly.

The substrates have different properties, and they are collected and supplied to WRRFs through different channels. WRRFs generally contract with grease haulers for FOG or directly with generators for food processing residuals; generally, neither do pretreatment before delivery. In contrast, food scraps need to be slurried before they can be added. Innovations in sourcing arrangements are emerging, where the solid waste sector (or companies from related sectors) provide aggregating and pre-treatment services to create food scrap slurries. (See Appendix C for profiles of selected providers of food waste feedstocks.)

Chemical characteristics of feedstocks vary widely. In order to understand digester impacts of food wastes, several chemical parameters of each feedstock should be measured prior to their addition to the digester. These parameters include chemical oxygen demand (COD), total solids (TS), volatile solids (VS), organic and hydraulic flows, nitrogen and phosphorus profiles, metals, and sulfur (WERF 2018). Table 3-1 highlights the digester impacts of a few of these chemical characteristics.

Table 3-1. Operational Impacts of Feedstocks Added to the Digester Based on Chemical Characteristics.
Source: Erdal et al 2011, Higgins et al 2017.

Characteristic	Value	Potential Impact
pH	Low	Reduction in biogas production; risk of toxicity to methanogens
	High	Potential reduction in volatile solids and biodegradation times (López Torres 2008); potential higher biogas production and quality
COD	Low	Consume reactor volume with no increase in biogas production
	High	Potential for increased biogas production; risk of increased scum formation
TSS	High	Increased solids production
VSS	High	Potential for increased biogas production
Ammonia	High	Risk of toxicity to methanogens

3.3.1.1 HSOW including Food and Beverage Processing Residuals (FPR)

High-strength organic wastes include industrial processing wastewaters. In this category are residuals from food and beverage processing plants such as baked/processed foods, fruits and vegetable processing, meat processing, breweries and wineries, or virtually any processing plant that makes human or domestic pet foods. FPR also can include solid wastes like processing line start-up and shut-down solids or out-of-date/recalled products and liquids such as Dissolved Air Flotation (DAF) sludges produced in the plant's industrial pretreatment process.

The potential for generating methane relative to wastewater residuals varies with the industrial source (Figure 3.3-1), as do the sources' other bio-chemical properties. They may have high or low pH, high COD and/or high Biochemical Oxygen Demand (BOD), high Total Suspended Solids (TSS), high Volatile Suspended Solids (VSS), or high concentrations of biodegradable chemical constituents like ammonia. See Table 3-1 for the operational impacts of the different characteristics on the co-digestion process.

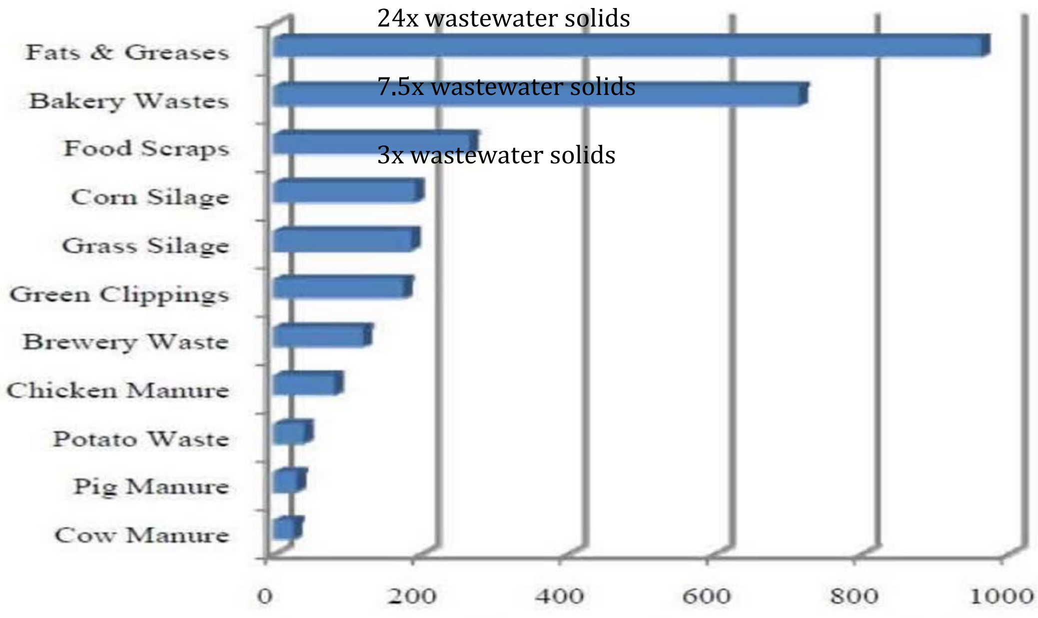

Figure 3-1. Biogas Production (m^3) per Ton of Substrate.
Source: American Biogas Council.

Supply Sources

Most food processing plants operate on 24/7/365 schedules, and most have little on-site storage capacity. Standard practice is for dedicated haulers under contract to the generator to leave a collection vehicle or container on-site and come by one or more times per day to collect and route it to disposal, land application, AD, or composting. Unlike FOG haulers, HSOW/FPR haulers usually only serve one generator at a time.

WRRFs implementing co-digestion may start sourcing feedstocks by reaching out to HSOW generators that have industrial permits to pretreat and discharge liquid wastes directly to the WRRFs via sewer. Because these discharges often can be energy-intensive to treat, diverting HSOW to anaerobic digesters has the added benefit of reducing energy use and energy costs for the co-digesting WRRFs.

3.3.1.2 FOG

Of the various food waste substrates, FOG has the greatest potential for generating methane (24 times that of wastewater solids) (Figure 3-1). FOG wastes are highly variable in their chemical characteristics. In general, FOG has a low pH, high COD, variable but low TSS, high VSS/TSS ratio, and high nitrogen content (Erdal 2011). Several studies have observed that FOG additions to the digester improve dewaterability (Higgins et al. 2017).

FOG is collected from the cleaned grease traps of food service establishments. Most WRRFs are familiar with sources of these materials in their service areas due to the problems these materials cause in the sewage collection system. To mitigate these problems, many municipalities have issued regulations requiring periodic cleaning of these traps and disposal of their contents in ways other than through the sewer.

WRRFs report challenges with FOG feedstocks, due to high variability in TS across loads, high corrosivity, and high levels of contamination; also, because grease traps are cleaned out periodically, deliveries may be episodic.

Supply Sources

Hauling companies, typically already in the septic tank pumping industry, use tanker trucks to pick up these substrates from multiple facilities, dewater them, and aggregate them for disposal at a landfill or for recycling at a WRRF. Local haulers, the most common source, typically do not pretreat to remove contaminants and will not accept long-term contracts. In contrast, national companies, such as Liquid Environmental Solutions, may do some pretreatment and may accept long-term contracts.

3.3.1.3 Food Scraps

The food scrap supply chain has two components: the industrial/commercial/institutional (ICI) side and the residential side. Both have similar characteristics, in that food must be prepared in kitchens where preparation wastes are generated (this is known as pre-consumer food scraps) and that food, once served (either in homes, restaurants, cafeterias, or at catered events) cannot be repurposed as edible foods and is discarded. This second waste stream is called post-consumer food scraps. Both streams are suitable co-digestion substrates.

Supply Sources

The challenge with food scraps is that to pump the substrate using current WRRF pump technology, the food scraps need to be converted from a solid form to a slurry. Further, outside of states or cities with landfill organics bans or recycling mandates, most communities do not yet have source-separated organics collections, either for commercial or residential sources, though this is changing.

To date, food scraps represent a feedstock option with substantial untapped potential. However, a wide variety of innovative supply arrangements are arising to address this, with their traction greatest in areas with landfill bans/mandates (Table 3-2).

Table 3-2. Evolving Innovations in Sourcing for Food Scrap Slurries: Examples.

Traditional Solid Waste Firms	New Entrants into the Solid Waste Market	Public Solid Waste Agency in Partnership with a WRRF	WRRF Pretreatment Onsite
Waste Management **(See App C)**	Grind2Energy (See App C)	EBMUD (See App B)	Hermitage, PA (See App B)
Recology (EBMUD, See App. B)	Divert (See App C)	LACSD (See Ch. 9)	EBMUD (See App B)
Marin Sanitary Services (CMSA, See Ch. 8)	OWL (See App C; currently only in the U.K)	Oneida- Herkimer, NY (See App B)	Muscatine, IA (In development)
Burrtec (LACSD. See Ch. 9)			

One solution involves private companies that serve a supply coordination and pretreatment role. From the solid waste sector, the national firm, Waste Management (WM), has entered the market with its Engineered BioSlurry product (EBS®) produced by its patented CORe® process. WM is currently supplying a handful of WRRFs with its EBS®. On a more local scale, individual private regional solid waste companies may serve this function in other locations. Examples include the partnerships between Recology and the East Bay Municipal Utility District (EBMUD), Marin Sanitary Services and Central Marin Sanitation Agency (CMSA), and Burrtec and the Sanitation Districts of Los Angeles Country (LACSD).

New entrants, originating in product lines related to the solid waste sector, include Divert (previously Feed) and Emerson. Divert provides food waste reduction consulting as well as feedstock and is also operating in multiple markets, though on a much smaller scale than WM. Emerson's Grind2Energy product also has launched in many regions throughout the country. All three of these approaches produce a "bioslurry" of depackaged, decontaminated and macerated food scraps (the products have the consistency of cooked oatmeal) that is hauled to the WRRF customer.

The primary form of public sector initiatives involves leadership by municipal solid waste agencies to work in partnership with the wastewater utility in developing the capacity for food scrap pretreatment and supply to the WRRF, which is occurring in California and NY. The final delivery option is for a WRRF to do depackaging and slurrying onsite. Hermitage, PA and EBMUD are two WRRF examples to date, and Muscatine, IA is in the process of constructing a similar facility.

Both LACSD (Chapter 9) and EBMUD (Appendix B) are currently, or have at one point, employed virtually the full portfolio of delivery options. (See Appendix C for profiles of various food scrap slurry providers.)

Pretreatment Practices for Food Scraps
Preparing food scraps to make these materials more suitable for pumping into the WRRF may include removal of contaminants, depackaging, particle-size reduction, and/or the addition of water. Food scrap contamination can include a wide variety of non-degradable items such as twist-ties, rubber bands, film plastic bags, composite packaging, shrink wrap, and metal and plastic serving ware. There are a growing number of technologies coming into the U.S. market to remove contaminants.

Depackaging systems can also reduce contamination by removing low-density polyethylene film bags and packaging. Most depackaging systems on the market today are various configurations of horizontal or vertical screw augers, designed to tear open the packaging. Particle size reduction is often accomplished with grinding or shredding equipment and/or by extrusion equipment. The processing goal is to produce a material suitable for introduction into the AD reactor, which is often a slurry of less than 10% total solids (TS).

The most effective method of reducing contaminants, however, is source control at the point of collection. This can be implemented through proactive outreach programs working with suppliers (also known as "the carrot") or significant contamination surcharges (i.e., "the stick").

3.3.2 Operationalizing Co-Digestion

As noted above, currently there is a lack of consensus on best practices for operationalizing co-digestion. As part of an initiative to create a research base for decision making, WRF has supported research to evaluate the efficacy of alternative practices in mitigating operational risks (Van Horne et al 2017, Appleton et al 2017). Reducing operational risks, by implication, will reduce the financial risks that come with operational issues and/or failures. For a further discussion of the state of the literature on co-digestion best practices, see Lackey and Fillmore 2018.

Market Development
To understand market potential – both in terms of quantity and pricing – it is essential to conduct an initial market assessment. In addition, a number of WRRFs (including CMSA, Durham, VVWRA, and Hermitage) cite use of a feedstock outreach coordinator for continuing marketing and customer relations to ensure a continuing supply of feedstocks.

Acceptance Criteria Guidance
Prior to accepting a new feedstock, WRRFs can inform their decisions by testing the feedstock to ascertain the potential for producing biogas, affecting digester operations, or affecting the quality of biosolids. Characteristics often tested include pH, VS, TS, and COD. Feedstocks can be tested for total Kjeldahl nitrogen (TKN), phosphorus, metals, and sulfur, all of which might influence the quality of biosolids. TKN testing is particularly important to assess the potential for ammonia toxicity to digester

bacteria (Appleton et al 2017). The desired frequency of sampling for each hauler and feedstock will depend on the consistency in quality and the initial characteristics of the HSOW. WRRFs also can inform their decisions by checking each load visually for consistency, contamination, odors, or other unforeseen problems (Lackey and Fillmore 2018).

Digester Loading Procedure Guidance

Careful loading of HSOW to the digester is crucial for optimal biogas production and for avoiding digester upsets. For example, feedstocks loaded to the digester can be homogenized and heated to maintain a consistent liquid feed from the HSOW receiving station to the digester. Feedstock consistency can also be maintained by blending and mixing HSOW with wastewater solids prior to digestion. Some research suggests an upper volatile solids loading limit of 0.15 lbs VS per cubic foot per day to minimize foaming (Appleton et al 2017). Rapid changes in COD loading to the digester can be problematic. Monitoring volatile acid-to-alkalinity ratios, alkalinity, pH, volatile solids loading rate and gas quality can ensure a stable digester.

Onsite Pretreatment Guidance

Criteria for selecting among pretreatment options include considerations not only for impacts on digester operations, but also for the quality of biosolids, including size, contamination, nutrient content. In addition to NDPES permit requirements, state or local regulations may specify minimum quality standards for land-applied biosolids.

It may be possible to introduce hauled-in high-strength wastewaters (e.g., dissolved air flotation solids from a food processor) into the WRRF AD system without any handling other than to meter it into the reactor at a controlled hydraulic and organic loading rate. FOG should be heated and blended with wastewater solids prior to introduction to the digester. Some form of contamination control is also needed to manage FOG feedstocks, which are often highly contaminated; such controls include rock traps, which can manage large heavy material, and grinders, which can manage softer or stringy material that could cause different operational issues in downstream equipment at the WRRF (Van Horne et al. 2017). For food scrap slurries, WRRFs may want to supplement pretreatment by slurry providers with additional pretreatment onsite. For example, to minimize any risks to digester operations, CMSA added a paddle finisher to remove small contaminants such as twist ties and other debris from the slurry hauled to the plant by solid waste firm Marin Sanitary Services (MSS).

3.3.3 Operational Impacts

3.3.3.1 Digester Upsets

One concern is the potential for operational upsets. The best practices identified above are designed to avoid digester upsets, such as foaming or rapid volume expansion. Another strategy to avoid upsets is to gradually introduce new substrates, being careful to minimize variations in volatile solids loading, and monitor the results, allowing for incremental adjustments.

3.3.3.2 Impact on Regulatory Compliance

The addition of food wastes to the WRRF may increase nutrient loading in the WRRF's treatment train. For WRRFs with strict nitrogen and phosphorus limits, additions of nutrients to the effluent stream may affect compliance with NPDES permits. WRRFs should also be cognizant of the nutrient impact on biosolids. In areas with strict nutrient limits for land application, an increase in N or P concentration in biosolids may reduce the allowable application rate of biosolids per unit of land.

In addition, the recycling of food scraps at a WRRF may trigger a requirement for a solid waste permit and coordination with the state solid waste agency. States differ on how they regulate co-digestion at WRRFs (see Appendix A and Chapter 10). For example, Oregon Department of Environmental Quality requires co-digesting WRRFs to have a hauled waste plan. Other states require WRRFs to update their NPDES permit when initiating co-digestion (Lackey et al 2018).

Biogas
As noted above, one important benefit is the increase in biogas produced. Though the literature provides estimates of biogenic potential, the results will vary in individual contexts. The changing chemical composition of digester feedstocks as a result of co-digestion also may have an impact on air emissions, which could impact air permit compliance.

Biosolids
Another concern is the potential to increase biosolids and biosolid management costs. Researchers evaluating these substrates for impact on WRRF AD systems have determined that co-digestion generally had only slight impacts on digester rheology (how the viscosities of reactor contents change due to forces imparted by mixing) and related issues of volume expansion due to foaming and gas holdup. They also found that cake quality in terms of odorant production was generally better when HSOW were added to digesters, and concluded that the net wet solids production leaving the plant is often lower with HSOW addition when the HSOW loading was less than about 20% additional volatile solids (VS) loading (Higgins et al 2017). This was observed for post-consumer food waste and FOG, but not for pre-consumer food waste.

3.3.4 Economic Considerations

3.3.4.1 Income Streams

Feedstock Contracting and Setting Tip Fees: For project and financing approval processes, defined revenue streams from multiple-year supply contracts at specified prices are a big plus. They mitigate the financial and operational risks of uncertain feedstock supplies and revenues. For high-strength wastewaters and discarded organic solid wastes from industrial sources, it is usually possible to negotiate a sole-source multi-year contract for an agreed tip fee. For FOG, it can be difficult to get haulers to commit to multi-year contracts. For companies that have invested in capital equipment to process food scraps, multi-year arrangements are typical.

WRRFs can set tip fees based on market rates or, if WRRF costs are lower, can charge a fee that is sufficient to cover WRRF costs. (For example, Victor Valley has followed the latter strategy, on the grounds that, as a public utility, they are not to make a profit. See Chapter 4.) Feedstocks that are of higher quality (with lower contamination levels, and in a form well-suited to digestion) and that are more certain are more valuable to WRRFs, which means WRRFs will tend to accept lower tip fees for them than for lower quality, uncertain feedstocks.

To be willing to supply feedstock to WRRFs (or other AD or composing facilities) and pay their tip fees, private waste haulers will need to cover their costs of collecting, preprocessing and transporting the feedstock; their revenues may come from a combination of fees from waste generators and green subsidy payments. In contrast, food manufacturing or institutional food supply companies with sustainability goals may be willing to pay more than the cost of the landfill alternative for an outlet that is recycling the food waste.

For contexts in which haulers will not commit to contract terms, utilities compete by treating their haulers as customers who choose to engage with them, by setting declining fee schedules that reward full trucks, and by undercutting the alternatives.

Subsidies: Programs incentivizing the diversion of food scraps from landfills may provide subsidies to WRRFs for accepting food scrap slurries.

3.3.4.2 Costs and Cost-Savings

Investment Costs
The primary capital investment is for a receiving station, potentially including onsite pretreatment equipment that can range in complexity from bar screens to paddle finishers. In addition, WRRFs may need to add piping and pumping to offload feedstocks from truck to receiving tank and from the

receiving tank to the digesters. Lastly, heating and mixing equipment may be required to ensure feedstock is homogenous and stays in liquid form (Appleton et al, 2017).

The scale of investment varies tremendously across WRRFs, depending upon the facilities currently available, the quality of incoming feedstock supply, and the stage of commitment to co-digestion.

- **FOG**: Having experienced operating issues and grease flecks in biosolids, DTMA's Clearwater Road WRRF installed an aerobic grease pretreatment facility to improve the quality of FOG hauled to the plant 10 years after beginning to accept FOG. This pretreatment facility and the associated receiving station cost $1.2 million and allowed the WRRF to substantially expand its FOG acceptance, thus increasing tip fee revenue.
- **FPR**: Stevens Point split the cost of a $1.3 million, 40,000-gallon HSOW receiving tank and pipeline with a nearby brewery that planned to send their wastes to the plant using the pipeline. Grant funding from Wisconsin Focus on Energy provided a $114,000 grant to pay for the infrastructure. Installing the receiving tank allowed Stevens Point to avoid future costs in expanding their WRRF to accommodate the growing quantity of wastes from the expanding brewery. It also allowed the WRRF to accept wastes from other food processors thus increasing tip fees to the plant.
- **FPR:** VVWRA spent only $10,000 to upgrade an existing tank to receive HSOW. Other WRRFs have spent substantially more for receiving station investments.
- **Food Scraps**: CMSA spent $2 million on an organic waste receiving station which includes a 300,000-gallon tank, mixing pumps, rock trap grinder, paddle finisher, and odor control system. The station receives slurried food scraps from MSS.

Operational Cost-Savings

WRRFs cite savings on wastewater treatment aeration costs by diverting FOG or industrial wastewaters from the headworks to digesters (North Regional WWTP, Stevens Point) and on avoided sewer clogs by accepting FOG to the digesters.

3.3.5 Risk Management

Feasibility studies and trial periods are key to identifying and addressing operational issues. The results from demonstration projects have also proved to be a useful entry point for board members to approve a new strategy; successful results from trial periods are useful for convincing board members to approve capital investments for co-digestion projects (VVWRA, Stevens Point, DTMA, Gresham, and JWPCP).

3.3.6 Stakeholder Considerations

Many WRRFs indicate that they value the fact that co-digestion can provide a service to FOG, industrial wastewater and food scrap generators that are facing regulatory pressure. Fond du Lac, Stevens Point, and Dubuque also cite reducing costs for nearby industries, by providing an option that is closer, and has lower hauling costs, than the alternatives.

With food scraps managed through the solid waste system, solid waste agencies have been the initiators of wastewater-solid waste partnerships to create AD co-digestion options for their organics waste stakeholders to comply with new landfill ban/recycling mandates in NY State (at the Oneida Water Pollution Control Plant) and in California (at LACSD). In the latter case, it is the solid waste department of the joint wastewater-solid waste utility, which is also where the energy efficiency and recovery unit is located, that initiated the co-digestion project, in partnership with the WRRF.

However, differences in organizational structure, culture and economics (including capacity to raise rates) between WRRFs and municipal solid waste agencies raise potential impediments to collaboration.

3.4 Energy Products, Uses, and Technologies

Energy Strategy Questions:
Overarching strategic question: What energy strategy can meet utility goals for energy neutrality and for cost savings or revenue generation, without causing operational issues?
How much additional biogas could result from feedstock strategy options?
Does the plant currently have capacity in energy generation equipment to beneficially use the additional biogas?
What options are available for generation and onsite or external end-use of renewable energy from the biogas? For each option: • What additional onsite investments are required? Does the plant have the necessary space? How much will they cost? • What operational and regulatory challenges does it pose? • What is the potential for energy cost-savings and/or revenue generation? • Are there challenges with gaining market access for external sales? What energy tariff and green payment options exist?
What strategies are available to manage operational and financial risks?

For the most part, the current energy strategies of co-digesting WRRFs revolve around generating electricity. A driver for co-digestion in the 2000s was the high and rising energy prices in many areas, which have declined since then. Further the value of financial support programs for renewable power in the form of renewable energy credits (RECs) is declining in many states, while financial support for renewable vehicle fuel has expanded (including several state LCFS as well as the federal renewable fuel standard [RFS]). Consequently, WRRFs are directing increasing attention to RNG options for vehicle fuel uses. However, locational factors are critical to the economics of both. For pipeline injection to be economical, the WRRF needs to have access to distribution pipeline relatively close by. Direct sales (or internal use) for vehicle fuel requires being in a market area with demand for renewable CNG fuel.

Given the variety of options for onsite use and potentially for external sales, it is important to evaluate the options carefully to craft an energy strategy that makes the most operational and economic sense for the plant. Though a plant may have excess capacity in its current technology(ies), and the additional biogas can be directed there, the availability and economics of other options may have improved since the last time the WRRF made decisions about energy recovery. Further, the additional biogas production may make some options more cost-effective due to economies of scale.

3.4.1 Options, Technologies, and Pretreatment Requirements

3.4.1.1 Electrical Generation (Combined Heat and Power)

Many AD plants combust biogas in a combined heat-and-power (CHP) system to produce electricity and capture waste heat from the generator and/or exhaust gases. CHP systems can be based on internal combustion engines (commonly used), turbines/microturbines, or fuel cells. Table 3-3 summarizes the key features of CHP technologies (U.S. EPA 2017).

Table 3-3. Summary of CHP Technologies.

<table>
<tr><th>CHP System</th><th>Advantages</th><th>Disadvantages</th><th>Available</th></tr>
<tr><td>Gas turbine</td><td>• High reliability.
• Low emissions.
• High-grade heat available.
• No cooling required.</td><td>• Require high pressure gas or in-house gas compressor.
• Poor efficiency at low loading.
• Output falls as ambient temperature rises.</td><td>500 kW to 40 MW</td></tr>
<tr><td>Microturbine</td><td>• Small number of moving parts.
• Compact size and lightweight.
• Low emissions.
• No cooling required.</td><td>• High costs per kW
• Relatively low mechanical efficiency.
• Limited to lower temperature cogeneration applications.</td><td>30 kW to 350 kW</td></tr>
<tr><td>Spark ignition reciprocating engine</td><td rowspan="2">• High power efficiency with part-load operational flexibility.
• Fast start-up.
• Relatively low investment cost.
• Can be used in island mode and have good load following capability.
• Can be overhauled on-site.
• Operates on low-pressure gas.</td><td rowspan="2">• High maintenance costs.
• Limited to lower temperature cogeneration applications.
• Relatively high air emissions.
• Must be cooled even if recovered heat is not used.
• High levels of low-frequency noise.</td><td>< 5 MW</td></tr>
<tr><td>Diesel/compression Reciprocating Engine</td><td>High speed (1,200 RPM):
≤ 4 MW
Low speed (60-275 RPM):
≤ 65 MW</td></tr>
<tr><td>Steam turbine</td><td>• High overall efficiency.
• Any type of fuel may be used.
• Ability to meet more than one site heat grade requirement.
• Long working life and high reliability.
• Power-to-heat ratio can be varied.</td><td>• Slow start-up.
• Low power-to-heat ratio.</td><td>50 kw to 250 MW</td></tr>
<tr><td>Fuel cells</td><td>• Low emissions and low noise.
• High efficiency over load range.
• Modular design.</td><td>• High costs.
• Low durability and power requirements.
• Fuels require processing.</td><td>200 kW to 250 kW</td></tr>
</table>

A rule of thumb for electrical production with biogas in CHPs is that about 100 cubic feet per minute of biogas can drive a 300-Kilowatt engine, which is enough power for about 300 homes (Greene 2015).

In addition to electricity, a WRRF can capture waste heat produced by the electrical generation system. Uses for this energy include heating the digester, space heating at the WRRF, or possible sale to a nearby industry that can benefit from the resource, such as a greenhouse.

Biogas Pretreatment Requirements
Biogas can be used directly to produce hot water, cold water, or mechanical power for on-site use. Prior to using biogas for producing electricity, the gas needs to be upgraded by removing contaminants, particularly water vapor and hydrogen sulfide, and by raising the heating value of the gas. Moisture is removed with a gas dryer or chiller. Hydrogen sulfide can be removed biologically, chemically, or by activated carbon treatment.

3.4.1.2 Renewable Natural Gas Generation

Biogas Pretreatment: Pipeline Injection

Utility specifications for pipeline injection may include minimum heating value (MMBTU), and the maximum concentrations for carbon dioxide, oxygen, total sulfur, water, and siloxane. Other measurements such as hydrocarbon dew point, temperature, particulates, biological matter, and heavy metals may also be required.[3]

To achieve utility pipeline specifications, biogas needs to be upgraded, including removing contaminants, pressurizing, and increasing methane content for pipeline injection. Technologies for upgrading include Pressure Swing Adsorption (PSA), chemical solvent scrubbing, membrane separation, and cryogenic distillation. PSA is the most commonly used method for biogas upgrading, and is installed at a number of WRRFs with pipeline injection, including Newark WWTP (OH), San Antonio WWTP (TX), and Point Loma WWTP (CA).

Biogas Pretreatment: Vehicle Fuel
To produce vehicle-grade rCNG and rLNG, raw biogas must be upgraded to biomethane. Moisture, siloxanes, hydrogen sulfide (and possibly other contaminants) are cleaned from the biogas and then the methane content is increased, producing biomethane (typically to >88% methane). To be used as a vehicle fuel, biomethane also needs to be compressed. Compressed biomethane (or compressed RNG) is equivalent to compressed natural gas (CNG), an alternate vehicle fuel, which contains about 24,000 BTU/gallon compared to approximately 120,000 BTU/gallon for gasoline and 140,000 BTU/gallon for diesel fuel.

3.4.2 Operational and Economic Considerations: Market Access, Revenues, Incentive Policies

3.4.2.1 Electricity

Self-generated electricity can be used on-site either through an “isolated” system (disconnected from the grid) or can be operated with a connection to the grid (“in parallel”). Most WRRF on-site uses are operated in parallel mode. The extent of energy cost-savings will depend upon the level of energy prices and also on the structure of the tariff and the potential for net metering. Fixed fees and demand charges can substantially reduce accrued cost-savings.

It may also be possible to establish and interconnection agreement with the utility to sell the electricity back into the utility grid, through a long-term contract, known as a Power Purchase Agreement (PPA). Opportunities for interconnect agreements and tariff structures will vary across the states, due to variation in energy market economics, utility policy, and public policies. (See Appendix A and Chapter 10.) Utilities may offer attractive tariff opportunities in long-term PPA in order to comply with Renewable Portfolio Standards, mandating a certain share of power generation from renewable sources by specific dates.

[3] The American Biogas Council provides recommendations for upper and lower limits for these qualifications: https://americanbiogascouncil.org/resources/rng-purity-recommendation/.

Also some states and the federal government have established programs to offer grants (or subsidized loans) for feasibility studies or construction of renewable energy projects. Also, when financed through a private party, federal Investment tax credit programs for renewable energy investments can provide substantial economic benefits.

- For example, many Wisconsin utilities voluntarily set up feed in tariffs with 10-15 year contracts at favorable prices. State funding from Wisconsin Focus on Energy, a technical assistance and funding entity that works to improves Wisconsin's energy efficiency, helped to purchase microturbines allowing WRRFs to invest onsite energy production equipment. However, the low caps on participation for the voluntary tariffs have been met, therefore reducing the financial incentive for investing in renewable energy generation.
- In New York State, the state's energy research agency, NYSERDA, has dedicated ample funding and research to developing anaerobic digestion, energy efficiency and CHP adoption at New York WRRFs. However, the New York state electricity market is unregulated and some WRRFs have negotiated low electricity rates that disincentive onsite renewable energy production. Even in cases with high prices, electricity rate structures with high fixed fees reduce can make it difficult for WRRFs to realize cost-savings by producing energy onsite.

3.4.2.2 Renewable Natural Gas (RNG) for Pipelines

Pipeline Access and Costs

A number of elements must be satisfied for a pipeline injection project to be viable (Coker 2018). First, there must be nearby access to a suitable pipeline. Pipeline extension costs can significantly increase pipeline injection project costs, though hauling by truck to the pipeline is another option that can be considered.

Suitability of the pipeline includes the following considerations:

- Is there sufficient demand for the gas downstream from the point of injection?

Seasonable variations in demand can complicate injection.

- Is the pipeline operating at a pressure at least as great as the pressurized gas being injected?
- Is the pipeline operating near the pressure maximum of the pipeline?

If so, upgrades to the pipeline at various stress points may be necessary to avoid pipeline failure.

- Are there safety-related operational constraints in the system?

Gas pipelines are constantly inspected for safety-related issues and operating volumes and/or pressures can be reduced for long periods while pipe upgrades are designed and built, which can complicate injection plans.

Second, the plant needs to negotiate an interconnect agreement with the natural gas utility, with an agreement on gas quality standards that must be met, conditions for the interconnection, and on pricing and supply commitments, which may include minimum and maximum levels of supply. Third, the plant needs to install the necessary equipment to upgrade the gas to meet the utility standards. Costs for renewable natural gas pipeline injection include costs of biogas cleaning, biogas upgrading, construction of a pipeline extension, construction of an interconnection station, interconnection fees, monitoring of RNG quality at interconnection, and any pre- or post-analysis of the project. The most expensive pieces of the pipeline injection process are the biogas cleaning and biogas upgrading infrastructure, which can add more than 50% of project costs. Costs vary with the size of the system, the method used, and the manufacturer. Substantial economies of scale are present in capital costs, and also in operating costs up to the scale of 900,000 scfd throughput (Hauser 2017).

Interconnection costs include the cost of pipeline extension, the interconnection infrastructure (point of receipt), and taxes. Proximity of the pipeline is a major factor for the first element. For interconnection infrastructure, natural gas utilities in California charge biogas generators for pre-studies of injection feasibility, an interconnection fee, the interconnection facility, monitoring equipment, metering controls, and periodic testing of biomethane.

The first WRRF pipeline injection project in California at the Point Loma WWTP cost a total of $45 million, substantially due to the length of pipeline and number of right-of-way agreements that had to be negotiated; interconnection costs were $1.99 million (UC Davis 2014). In contrast, where WRRFs have suitable pipelines running through their property and do not face restrictive conditions such as in the California, the costs can be modest. The interconnection costs of three projects developed through 2013 outside of California were $82,546, $70,816, and $272,170 ($2013) (Escudero 2013).

Revenues and Green Payments

Another potential revenue source for biomethane made from biogas is RINs from EPA's Renewable Fuel Standards (RFS) program. RINs and their properties vary by the type of fuel used. D3 is a more restrictive use than D5, and thus is more valuable than D5. Vehicle fuel produced from treating wastewater solids at a WRRF qualifies for D3 RINs. Once food waste is introduced to the digester, then the WRRF may not qualify for D3 RINS, but rather for D5 RINs. EPA has set up a procedure whereby biogas producers can provide justification for apportioning the percentage of biogas that may be classified as D3 separately from the D5 gas and claim proportional credits for each. Because of the complexity and data-intensiveness of the EPA process, American Biogas Council has proposed an alternative simplified approach. The strategy of WRRFs with multiple digesters and both combined heat and power and vehicle fuel uses is to allocate the biogas from wastewater solids-only digesters for the vehicle uses (EBMUD and LACSD).

It also is possible to receive credits from the several state LCFS in California and Oregon, even if the project is located out of state. For example, the Ameresco/San Antonio Water System is receiving CA LCFS credits for a pathway to supply renewable vehicle fuel to California from Texas based on pipeline-quality biomethane. The biomethane is produced from the mesophilic anaerobic digestion of wastewater solids at a publicly owned wastewater treatment plant (POTW) using grid-based electricity, and then delivered to CNG dispensing stations in California via pipeline.

Examples of RNG Pipeline Projects: Operating and In Development

- **Dubuque WRRC, BioResource Development, Iowa.** To use increasing supplies of biogas from co-digestion, the Dubuque WRRC rejected the option to expand electricity production. They found that the low tariff based on avoided costs offered by the utility would not provide a reasonable payback for expansion. Instead, the WRRC partnered with BioResource Development to implement a RNG pipeline injection project with a unique financing structure that will provide an estimated $50,000 to $100,000 in revenue per year. Currently the WRRC receives D5 RINs and hopes to apply for a D3/D5 RIN split.
- **Newark WWTP, Guild Associates and TEC, Ohio**. The Newark WWTP in Newark, Ohio has injected biogas to a nearby gas utility, The Energy Cooperative (TEC), since 2011. Guild Associates' Molecular Gate technology cleans biogas generated by digesters at the WRRF to standards set by TEC. Newark generally produces 100 to 300 decatherms of natural gas per month through a 75 scfm PSA system installed by Guild Associates and receives $0-$5,000 in revenue per month.
- **Des Moines WRF, Des Moines, Iowa.** The Wastewater Reclamation Facility (WRF) in Des Moines, Iowa is currently constructing a pipeline injection project that is projected to go online in late 2019. Federal incentives for renewable fuels makes pipeline injection particularly attractive for the WRF. Moreover, the production of renewable natural gas supports the sustainability initiatives of both the Wastewater Reclamation Authority (WRA) and the City of Des Moines. WRA estimates the project

will cost $14 million and will have a payback period of four to five years. The WRF is currently considering both short and long-term contracts for RIN sales.

3.4.2.3 Renewable Natural Gas (RNG) for Direct Vehicle Fuel Use

Direct fuel uses are eligible for RFS credits. However, they will only be eligible for state LCFS credits if they are distributing the fuel within a state with a program.

The challenge with direct use of RNG for vehicle fuel is finding the market demand. Conversion of utility or broader municipal vehicle fleets can be a source of demand, or other fleets from sustainability-oriented organizations. The low prices for natural gas are improving the ROI for converting diesel truck fleets (such as garbage trucks, buses, etc.) to CNG to under five years (Voell 2013). This high ROI makes the use of rCNG as an adjunct or replacement for CNG very attractive, provided there is a CNG refueling station nearby. However, demand may be slow to grow even in large urban areas. For example, LACSD has put on hold its plan to expand its capacity at its CNG fueling station until it gets additional fleet customers and needs the capacity.

3.4.3 Risk Management

WRRFs are developing a variety of approaches to manage operational and financial risks associated with energy generation. CHP cogeneration engines and microturbines can require extensive maintenance, which results in equipment downtime. DTMA highlights that, despite the cost, redundancy in equipment can be more cost-effective and environmentally beneficial in the big picture because it helps avoid periods of flaring biogas due to lack of energy capacity.

Another strategy is to develop a diversity of energy capacities and uses such that the allocation of biogas among them can be managed to optimize revenues and/or to manage operational risks of downtime on one set of equipment.

- The Janesville WWTP strategically allocates its biogas between electricity production, which is then sold to Alliant Energy, and a CNG production facility onsite for local vehicle fuel sales, depending on electricity demand. (Janesville WWTP is not currently co-digesting.)
- LACSD and VVWRA are both developing flexible energy systems so that biogas production can be allocated to electricity or RNG based on the most lucrative end use at any given time.
- As part of its new energy PPP, the Dubuque WRRC will choose how much biogas to allocate to the RNG system operated by its partner BioResource Development (BRD), and at no cost to Dubuque BRD will replace all biogas above a certain threshold that is allocated to RNG with natural gas.

3.4.4 Stakeholder Partnerships and Public Support

Public and private power companies are not necessarily good partners when it comes to co-digestion projects. On the one hand, power companies have an obligation to meet renewable power targets in the form of RPS. On the other hand, their vested interest lies in increasing power demand, whereas the WRRF's vested interest is in reducing its power consumption, which is one of its highest operational costs. It is therefore extremely important for the WRRF to either have the expertise to negotiate with its power suppliers on an equal footing, or to retain the services of someone within the community to assist it.

Reducing energy costs is a key driver for WRRFs and ratepayers. The sustainability contributions are also important: they send a compelling message to the public that their utility is generating their own electricity from a renewable source that was previously considered a waste product and, in the process, is reducing the community's GHG emissions.

3.5 Biosolids Management

Biosolids Strategy Questions:
Overarching strategic question: What biosolids strategy can meet utility goals?
What potential changes in quantity and quality of biosolids production could result from feedstock strategy options?
Does the plant have capacity in its current biosolids management approaches to handle any anticipated increase in quantity? If not, what alternatives are available?
What capital investments or operating adjustments may be needed to handle operating or regulatory challenges from any changes in quality (increased grease or nutrients)?
Can the increase in biogas or the operating challenges in biosolids management attributable to co-digestion motivate the adoption of new strategies to recover resources and create valuable products from biosolids?
What strategies can the utility use to manage operational and financial risks?

Mesophilic digesters are the most common AD technology at WRRFs, and typically the Class B biosolids that they produce represent a net cost element, which means that increasing the quantity of biosolids increases plant costs. In addition, co-digestion may increase the nutrient content or grease content, which poses operating challenges and may increase operating costs.

If biosolids are projected to increase with the planned scale of co-digestion, a lack of capacity in current management options could result in a WRRF deciding not to accept additional co-digestion feedstocks. For example, DTMA Clearwater WTF has stopped taking Divert food scrap slurry since it lost its thermal dryer for biosolids due to flooding damage in 2018. Alternatively, combined with a context of tightening biosolids regulations, projected increase in biosolids could motivate investments in technology to upgrade biosolids or to remove nutrients for sale as products.

3.5.1 Biosolid Management Options, Products and Economics

The primary beneficial use of biosolids is to supply soil amendments for land application, which requires farmers – with sufficient farm lands for agronomic applications – who are willing to accept biosolids during the growing season, as well as available storage capacity in the months when land application is not allowed. Class A biosolids face fewer restrictions on land application than Class B biosolids. Thermophilic AD will produce Class A solids directly, but only a small share of AD technology at WRRFs is thermophilic. Alternatively, post-processing of Class B biosolids through various technologies, including drying and composting, can produce a Class A product. Alternatively, biosolids are sent to be landfilled or incinerated.

WRRFs potentially can generate revenues by selling Class A biosolids as fertilizer products, though revenues for biosolid products will vary widely depending upon the specifics of the local market.[4] WRRFs

[4] The American Biogas Council's new Digestate Certification program was developed to help this trend grow. Biosolids from WRRF co-digestion reactors will still need to meet the requirements of 40 CFR Part 503 for environmental and public health protection, but the ABC Certification program helps producers assure customers of a high-quality product.

incur costs for hauling and land application for Class B biosolids, and for hauling and tip fees for landfill or incineration.

In the face of growing regulatory restrictions on nutrients, a new trend is for WRRFs to invest in technologies to recover nutrients from biosolids and sidestreams, to be sold in either liquid or solid form. These technologies can reduce the operating costs associated with meeting regulatory restrictions on P for land application and minimize nuisance struvite formation and reduce operations and maintenance (O&M) costs to manage it, as well as provide the WRRF with an additional revenue stream (Khunjar 2012).

3.5.2 Operating Impacts and New Technologies

This section discusses strategies to address operating challenges that co-digestion may cause for dewatering biosolids, as well as technologies to upgrade biosolids products and generate revenues.

3.5.2.1 Dewatering

Most WRRFs that contemplate the feasibility of co-digestion likely have mechanical solids dewatering systems in place. Adding substrates to digesters that have high levels of TSS (e.g., DAF solids) will increase solids quantities removed from the reactor to maintain a set digester residence time. WRRFs should evaluate the ability of their dewatering systems to handle higher loadings. Addition of the organic fraction of municipal solid wastes (OFMSW) to a digester reactor increases the viscosity of the solids (Björn et al. 2017), which has been shown to degrade centrifuge dewatering performance (Klinksieg 2017).

WRRFs that do not use dewatering technologies for solids may wish to examine adding that technology as part of a co-digestion feasibility study. Dewatered solids can be hauled longer distances with greater cost efficiencies. Suitable dewatering technologies for co-digested solids include centrifugation, screw and volute presses, plate-and-frame filter presses and belt filter presses. Natural dewatering systems, such as drying beds, may also be potentially suitable, depending on the site and soil/groundwater characteristics. The suitability of a particular technology will be influenced by the oil and grease content of the solids, which may be elevated based on the co-digestion substrate. For example, higher concentrations of oil and grease can degrade the performance of membrane-based filtration dewatering systems.

3.5.2.2 Production of Class A Biosolids

A number of technologies exist to upgrade Class B biosolids to produce a Class A or Class A EQ product including a thermal dryer and composting. For DTMA and Stevens Point, the additional biogas produced by co-digestion supported investments in thermal dryers to produce Class A biosolids. For DTMA, this was the best use of the biogas at the time because caps on electricity prices made a CHP investment not cost-effective. DTMA markets its Class A EQ product as Clearwater SteadiGro, which sells for $10 per ton. (See Chapter 7.)

3.5.2.3 Nutrient Recovery

Nutrient recovery to create marketable fertilizers is now a mainstream technology. Technologies include chemical precipitation, electrodialysis, gas permeable membrane absorption, gas stripping and solvent extraction. Both biosolids and sidestreams from biosolids processing are potential feedstocks to nutrient recovery technologies, although technologies for recovery of nutrients directly from biosolids are not yet at the stage of commercial development. Much of this developmental work is being done in Europe, where land application is subject to greater restrictions than in the U.S.

Effluent from dewatering solids is normally returned to the liquid side of the WRRF, often to the headworks, or to a clarifier in the secondary treatment train. As some of the nutrients (nitrogen, phosphorus, potassium, and others) are soluble, they partition to the effluent from the dewatered solids. This nutrient-enriched effluent can cause problems in the effluent recycle loop at the WRRF, in the tertiary nutrient removal processes of advanced WRRFs. At the same time, it presents an opportunity to manufacture a valuable product for sale.

One of the main complications of nutrient-enriched effluent is struvite (magnesium ammonium phosphate hexahydrate), a crystalline precipitate. It can create clogging and fouling in WRRFs' dewatered effluent recycle piping and pumps, and in AD systems due to the re-release of captured phosphate from solids under the anaerobic conditions present in the AD reactor. Co-digestion feedstock analyses can alert the WRRF to potentially problematic levels of struvite-forming ions.

Struvite can be deliberately precipitated in either a fluidized-bed reactor or in a continuous stirred-tank reactor (CSTR) and there are several commercial technology providers in the market. The recovered struvite is marketed as a slow release fertilizer. Struvite recovery is most feasible when the dewatering effluent sidestream contains less than 15% of the influent total nitrogen load and less than 20% of the influent phosphorus load (Khunjar 2012).

Nitrogen can also be recovered from biosolids and sidestreams using gas stripping and ion exchange. This may be needed for tertiary WRRFs that have nitrogen and phosphorus discharge limitations. These technologies tend to have high capital costs and are best suited for nitrogen concentrations above 1,000 mg/L (Khunjar 2012).

As part of a shift in biosolids strategy to address both recent regulatory changes for tertiary treatment of nutrients as well as current market challenges for land application, the Stevens Point WTP has invested in a thermal dryer to produce Class A biosolids, and is considering investments in nutrient harvesting technologies to remove sidestream phosphorus. The plant has a 7-year compliance period to comply with the new plant limit on P in its revised water permit, implementing new Wisconsin effluent regulations covering phosphorus (Chapter 5).

3.5.3 Stakeholder Support

Support for land application can be a challenge, even in states with extensive farming. If co-digestion will increase biosolids and the current management practice is land application, as is typically the case, the WRRF and other community leaders need to decide whether there is a "tipping point" to going beyond the current extent of land application.

3.6 Contracting and Public-Private Partnerships[5]

Contracting Strategy Questions
Overarching strategic question: Can contracts be designed to address the barriers to moving forward with a co-digestion project, such as lack of expertise, operating risks, financial risks, or difficulty in public financing approvals?
What aspects of risk are of greatest concern, for example: • Uncertain construction costs and time to completion • Uncertain feedstock sources and tip fee revenue streams • Uncertainty about operating challenges with equipment (including periods of downtime) and effects on other operations • Financial risks with equipment operations: uncertainty about O&M costs of managing the equipment, energy cost-savings or revenues
Are there any regulatory constraints on the use of public-private partnerships in the state? In the utility charter?
Which elements of the project would you consider for a performance-based PPP: designing and building? Operating? Financing?
What are the needed investments to co-digest, and produce energy?

[5] This section draws extensively from Hammond et al 2017.

After addressing the questions regarding the individual production elements, the next choice element is for type of contracting model to carry out construction and operations. In the traditional model, a utility contracts out the design of the project, and then puts out a request for proposals to build the project, with the award going to the lowest bidder according to procurement rules. Under traditional Design-Build contracts, the private partner assumes the risk for equipment and construction quality and performance. However, the WRRF bears the risks of additional costs due to design errors or construction cost over-runs, as well as all of the subsequent operational risks and the financial risks associated with changing regulatory or market conditions.

As WRRFs move into energy business lines outside of their core wastewater competency, it is valuable to consider alternative models for public-private partnerships (PPPs) structured around performance-based contracts that generate guaranteed streams of cost-savings or revenue. The potential benefits include: transfer of risks – including regulatory, financial and performance risks – to the private partner, access to specialized expertise outside of the core wastewater mission, efficiency gains, performance accountability, and access to alternative financing, including tax incentives unavailable to the public sector.

PPPs can reduce development risks, provide more cost-effective and timelier infrastructure delivery, offer the potential for better ongoing maintenance, and leverage limited public sector resources, all while maintaining the appropriate level of public control over the project (Hammond et al. 2017).

PPPs may facilitate construction and operations at multiple points in the co-digestion process, singly or in combination, including AD, energy generation, feedstock supply, and biosolids management.

3.6.1 Contracting Options

A range of models for public-private partnerships are available for AD, energy generation and energy efficiency, and biosolids management projects. Because the quality and quantity of feedstocks affect biogas production, some PPPs focused on energy also include feedstock supply and revenue commitments. And because feedstock choices in turn affect quantity and quality of biosolids generated, some of the PPPs include biosolids management as well.

Below is a selection of models that energy projects in particular have applied. However, there are many alternatives for organizing and structuring the partnerships, and a utility can design one in a way that best suits them (Hammond et al. 2017).

3.6.1.1 Energy Savings Performance Contract (ESPC)

In an ESPC, Energy Savings Companies (ESCOs) act as project developers for a comprehensive range of energy conservation measures and assume the technical and performance risks associated with a project. An ESPC differs from other PPPs in that an ESPC guarantees that infrastructure upgrades will deliver a specified amount of energy production and operational savings over a period of time. The ESCO's compensation is directly tied to actual energy cost-savings. The ESCO provides post-installation monitoring, evaluation, and operational and/or service support through contract performance period.

Example of an ESPC: DTMA and ESG

For DTMA, ESG will serve as an ESCO to construct various new or upgraded facilities, covering the WRRF's AD, HSOW receiving infrastructure, and biogas conditioning for injecting RNG into an interstate pipeline. ESG will assist DTMA in developing new sources of HSOW feedstocks in order provide sufficient biogas for the new biogas to RNG system and will guarantee revenues through RNG sales and HSOW tipping fees. DTMA anticipates financing the project through municipal bonds. (See Chapter 7.)

Example of an ESPC: North Regional WWTP and Opterra Energy

The North Regional WWTP in Broward County entered into an ESPC with Opterra Energy, which installed a 2-MW CHP engine and a FOG receiving station to create a "Green Energy Facility" using biogas from its digester. The diversion of FOG from the headworks to the digesters reduced the energy costs of aeration by $1.5 million per year, and increased biogas production, which contributed to increased electricity generation and reduced electricity costs. Projected environmental benefits include the reduction of the treatment plant's carbon footprint by over 50%. (See Appendix B.)

3.6.1.2 Power Purchase Agreement (PPA)

In a PPA, the buyer (WRRF) is the onsite host of the power generation equipment, which the seller (typically, a private partner) owns and operates. The PPA defines the price of the power generated and other terms. Availability of a guaranteed revenue stream permits the seller to attract private financing, while the buyer can take advantage of predictable power prices generated from clean electricity over the contract period. The private developer also is able to take advantage of tax incentive policies.

Example of a PPA: French Creek WWTP and Biosolids

The French Creek WWTP in Northridge, Ohio has a PPA with Quasar for processing its solids. Facing an $800,000 upgrade for their solids processing infrastructure due to new state regulations, the French Creek WWTP opted instead to shift to anaerobic digestion to manage their solids. Rather than constructing their own facilities, they lease land to Quasar, an AD and organics recovery management company, on which it was authorized to design, build, own and operate a digester. In addition to making lease payments to French Creek WWTP, Quasar also sells electricity back to the WRRF at a fixed discounted price. Quasar financed and constructed an anaerobic digester that accepts the solids from French Creek and organic wastes collected from around Ohio. (See Appendix B.)

Example of a PPA: VVWRF and Anaergia

Victor Valley has a PPA in place with anaerobic digester company Anaergia. (See Chapter 4.)

3.6.1.3 Design-Build-Finance-Own-Operate-Transfer (DBFOOT)

In a DBFOOT agreement the private partner finances, designs, builds, owns, and operates a project for a specified contract period, after which ownership of the infrastructure assets are optionally transferred from the private partner to the WRRF.

Example of a DBFOOT: Wooster WWTP and Quasar

Due to limited available funding, the Wooster WWTP in Ohio implemented a DBFOOT with Quasar for digester improvements, a cogeneration system, and biosolid and feedstock management. The WWTP was expected to pay Quasar a tip fee for managing biosolids and purchase electricity from Quasar's biogas energy generation system over the course of 20 years with an option to transfer assets at the end of the term. However, due to issues with public relations, Wooster purchased the Quasar -owned assets in 2017 and now manages the cogeneration system, feedstock procurement, and biosolid disposal on their own. (See Appendix B.)

3.6.1.4 Design-Build-Finance-Operate-Maintain (DBFOM)

In a DBOMF agreement, the private partner is responsible for project design, construction, O&M, and financing. O&M responsibilities incentivize employing high quality construction, methods, and materials to reduce future maintenance expenses, while financing for the life of the PPP project maximizes the incentive to be cost- and schedule efficient so that cash flows begin as quickly as possible for servicing debt and providing adequate returns to equity investors. Asset ownership remains with the public sector.

Example of a DBFOM: Fairfield Suisun Sewage District and Lystek

In the context of California's ever-tightening biosolids regulations, the Fairfield Suisun Sewage District (FSSD) in Fairfield, California entered into a PPP with Canadian company Lystek, which included a lease agreement allowing Lystek to Design-Build-Finance-Own-Operate-Maintain an organic materials recovery center (OMRC) on its property. From biosolids supplied by FSSD and other WRRFs in the area, the OMRC produces a Class A EQ biosolid product for sale. Revenues from product sales will be shared between Lystek and FSSD. (See Appendix B.)

3.6.1.5 Lease

The private sector partner leases infrastructure assets or facility premises from a public entity in order to operate the facilities, and is compensated with the revenue stream that the assets generate, rather than on a fee-for-service basis. Asset ownership remains with the public sector. The risk of future net revenue generation is borne by the private sector, incentivizing cost control and performance outcomes.

Example of a Lease: Dubuque WRRC and BioResource Development
The City of Dubuque has a lease arrangement with BioResource Development (BRD), which allows BRD to build and operate an RNG facility on the Dubuque WRRC site. The WRRC receives an annual leasing fee plus a fixed share of the revenues generated from RNG production produced in a facility without exposing the WRRC to operating cost risk. As the WRRC allocates an increasing share of its biogas to the RNG facility, BRD will replace the biogas used onsite at no cost. (See Chapter 6.)

3.6.2 Considerations in Evaluating Whether to Create a PPP

3.6.2.1 Potential Advantages of PPP

According to Hammond et al. 2017, creating a PPP can provide a variety of potential advantages.

Access to Private-Sector Expertise: Private companies operating numerous facilities of different sizes and in various geographical settings can bring industry-wide best practices for utility operations, enhanced asset management, and advanced technologies, all while working alongside local employees who are knowledgeable about the specific facility or system. Further, where utilities do not have core capacity or the appetite for risk to operate new technologies, the private partner can accept that risk and build a utility's capacity to deliver on long-term energy objectives.

Increased Efficiencies: Private companies operating on a regional or national basis can take advantage of economies of scale to further contribute to cost efficiencies and quality of service. PPPs can also benefit from more efficient procurement and faster delivery of projects.

Transfer of Risk to Party Best Able to Manage It: The chief mechanism for realizing cost-savings in a PPP derives from the transfer of regulatory, financial, managerial, and performance project risks from the public to the private sector. Under conventional procurement, taxpayers bear most of the risks (e.g., design flaws, construction cost overruns, higher maintenance costs, and missed demand projections) including those risks that the public sector is not well positioned to influence. The net benefit from PPP procurement is maximized when: 1) a given controllable risk is allocated, and the related decision-making authority is delegated, to the party that can best influence it; and 2) any risk that no party can control is allocated to the party that is best able to manage or diversify it. In general, as the number of related risks that can be appropriately transferred to the private partner increases, the incentives for cost-saving are strengthened.

Alternative Financing: Wastewater infrastructure is very capital-intensive, and years of deferred maintenance have resulted in significant immediate upgrading needs. Whether governments are unwilling or unable to increase public debt to meet investment needs, the private sector can supply capital and alternatively finance infrastructure projects through PPP arrangements without impacting municipal balance sheets. This type of alternative financing can come from capital sources such as leveraging guaranteed cost-savings, private activity bonds, commercial debt financing, and equity investment, which can include private developers, infrastructure funds, pension funds, and institutional investors who seek investment in public infrastructure projects in exchange for steady long-term, lower-risk returns.

Accountability: The outcome-based contractual nature of PPP projects inherently establishes a high level of accountability. The private sector partner is bound to performance specifications, allowing the public entity to monitor and enforce as intended.

3.6.2.2 Potential Disadvantages of PPP

The potential downside, however, is that the procurement and financing costs may be higher as part of a PPP arrangement (Hammond et al. 2017). Therefore, a key component in understanding the economic implications of using a PPP is evaluating whether by entering into a PPP agreement, the utility is likely to obtain a better value for investment compared to conventional approaches to procure the same project. To do so requires a full life-cycle analysis that includes the savings achieved over the life of the entire project under the PPP arrangement through reduced costs (e.g., efficiency gains and economies of scale) associated with design, construction, operations, maintenance, and risk allocation.

3.7 Financing and Funding Options

Financing Strategy Questions
Overarching strategic question: What financing strategy can utility goals for implementing investments that will create value while minimizing financial risks to ratepayers?
How much external funding is needed (net of grant monies available, and internal funds)?
What public sector loan options are available? • Clean Water State Revolving Fund (CWSRF): Does the project qualify for the below-market SRF loan program in the state (based on type of activity, financial requirements, etc.)? • Are other state or federal loan programs available to finance the project? • Municipal loans: What is the credit situation of the utility authority (or the municipality): what is their current debt burden, and credit rating?
What private options are available through PPP? • Do important advantages accrue with private financing through PPP that make the tradeoff of incurring a higher interest rate worthwhile?
Evaluating the options: • What interest rate and loan terms are available? • What auxiliary conditions must be met?
What streams of revenues (or cost-savings) can the utility generate to pay back the loan?

The final element is choosing the financing of the project. This stage of decision making requires three steps: conducting a preliminary needs assessment based on project cash-flows, evaluating public (and potentially private) financing options, and making a preliminary determination from project cash-flows of how the loans will be paid back.

3.7.1 Needs Assessment for External Financing

To determine how much of the project costs will need to be financed, one consideration is whether the project is eligible for grants that can cover part of the costs, for example from programs promoting greenhouse gas reductions, renewable energy generations, and food scrap diversion. A number of options have been highlighted in sections above. Another consideration is whether the utility has the capacity to allocate internal capital account funds – either through regular budget allocations to the fund or through a windfall – to finance in part or in full the costs remaining after external grants.

3.7.2 Identifying and Evaluating the Options

The primary sources of external finance for wastewater sector projects, including AD, receiving station facilities, energy, and biosolids projects, are below-market Clean Water State Revolving Funds and municipal bonds. In addition, a number of federal or state public programs beyond CWSRF provide grants for feasibility studies as well as grants or loans for capital projects. Infrequently, co-digestion projects receive private funding through PPP arrangements.

3.7.2.1 Clean Water State Revolving Fund

The option with the lowest interest rate is typically each state's implementation of the Clean Water State Revolving Fund (CWSRF) program. Set up as a federal-state partnership, CWSRF provides communities a permanent, independent source of below-market financing for a wide range of publicly owned drinking water, wastewater, and storm water infrastructure projects, particularly those needed to achieve or maintain compliance with federal and state regulations relating to water supply and wastewater treatment. Some municipalities may be eligible for further subsidy (principal forgiveness) to reduce their loan size.

Federal and state funding to State Revolving Funds and other state sources, which supplement the direct issue of municipal bonds, have not kept pace with the investments needed over the next 20 years in U.S. drinking water and wastewater treatment infrastructure for repairs, upgrades and replacement. As a result, non-core WRRF infrastructure projects may have difficulty competing for bond funds against core WRRF projects to supply wastewater treatment and achieve compliance with changing regulatory requirements (Vedachalam, et al. 2017).

The majority of clean water funds are distributed in the form of direct loans. As of 2014, the maximum term for CWSRF loans is 30 years. Interest rates for these loans vary across the states; however, all states provide loans at below-market interest rates. In poorer areas, states can further subsidize loans. The average interest rate of CWSRFs in 2015 was 1.7%, compared to a market rate of 3.15%.

3.7.2.2 Other Federal and State Loan and Grant Programs

Many states have designed capital funding programs to provide loans and grants for water and energy related projects that are structured to run separately from the SRF program. Several federal programs in addition to CWSRF provide loans and grants for water and wastewater infrastructure projects: EPA, U.S. Department of Agriculture (USDA) and U.S. Department of Housing and Urban Development (HUD) are the main sources. Information on sources of funding can be accessed through the U.S. Environmental Protection Agency's Water Infrastructure and Resiliency Finance Center. (See Appendix F.)

3.7.2.3 Municipal Bonds

When below-market federal or state sources of finance are not available, the primary alternative is municipal bonds. The majority of municipal public bonds are tax exempt, which results in a lower interest rate relative to taxable bonds. However, only the small share of wastewater systems that have high credit ratings are able to issue bonds at competitive interest rates, and consequently represent a large proportion of these bonds.

3.7.2.4 Private Finance

As pointed out in Section 3.5, Public-Private Partnerships (PPP) can provide private financing alternatives. This high interest rate option may be attractive when the utility has maxed out its borrowing capacity on prior projects. Further private financing potentially can expedite the project, by circumventing the extensive public approval processes for utility public financing. However, it appears that many utilities are not inclined to pursue PPPs, and in particular not inclined to pursue financing through a PPP. In some cases, the utility charter may disallow PPP financing.

In addition, PPPs can provide access to private debt and equity through with Design-Build-Finance-Operate-Maintain (DBFOM) energy contracts. The pros and cons of private financing need to be evaluated carefully. When capital funds for non-core projects are scarce, access to private funding can be valuable. Further private developers may have access to federal tax incentives not available to public agencies using tax-exempt debt. Further, the WRRF can avoid increasing the rates it charges its customers despite negative cash flow early in the project, so long as the project has a positive ROI over time.

However, it is important to recognize that the private interest rate and ROI hurdle rate for private investments will be higher than the public financing options available to public utilities.

Equity investment can come from infrastructure funds, which pool diverse sources of investors to finance infrastructure projects, or pension funds that directly invest in infrastructure. Various private capital firms that are providing funding for large projects in the biogas project space recognize WRRF biogas projects associated with food waste diversion and co-digestion as an area of interest; however, their priority appears to be financing standalone food waste digesters. When partnering with utilities, private companies such as construction companies will often invest their own capital in projects.

3.7.3 Determining Capacity for Payback

Ultimately, the funding for the payback of debt must be covered by utility revenue. For projects with a positive rate of return, the cost-savings or revenues generated by the investment will fund payback, plus can support other projects or a reduction in rates. In fact, maintaining low rates for customers can be a driving motivator for large capital projects that improve a utility's economic efficiency.

For projects that are required for regulatory compliance, additional funding options include residential and commercial customers or broader tax revenue sources. However, some states, such as New York, have a tax cap which limits the increases in property taxes that could potentially be triggered by large capital projects.

3.7.4 Solutions to Financing Challenges: Examples

3.7.4.1 Derry Township Municipal Authority (DTMA), Pennsylvania

In the past, DTMA has financed energy and hauled waste receiving station projects through General Obligation (GO) bonds issued by the Authority and guaranteed by the township at a favorable interest rate due to the township's low debt and strong credit rating. DTMA has been able to mitigate rate increases with the revenues it earns from hauled-in waste (particularly septage and FOG). In a new project being developed under a performance-based contract with ESG, DTMA is anticipating the municipality will again issue bonds taking advantage of its strong credit rating. ESG will guarantee revenue streams from RNG sales and from increased HSOW tipping fees, which will fund DTMA's pay back of the loan. (See Chapter 7.)

3.7.4.2 Essex Junction WWTP, Vermont

Because the State and Federal loan sources Essex Junction had used to finance prior projects were no longer available or available only at much-reduced levels, in 2011 Essex Junction successfully sought area voter approved of $15.3 million in funding to upgrade existing infrastructure throughout the WRRF. In addition, the utility received grants from Vermont Energy Investment Corporation and Efficiency Vermont toward the cost of their higher powered CHP system. (See Appendix B.)

3.7.4.3 The Rahway WRRF, New Jersey

Funding a Public-Private Partnership project through a State Revolving Fund loan can be difficult as these loans usually require a public request for proposals to procure a private partner. SRF staff often want to be involved in the project and want all permits in place before a procurement process for a private partner takes place (Rick Sapir, interview with authors, September 21, 2018). (See Appendix B.)

The Rahway WRRF accomplished a noteworthy example of outside-the-box financing using SRF funds to finance a PPP project with Waste Management, where the contract with Waste Management had already been inked when the SRF funds were sought.

3.7.4.4 Stevens Point WWTP, Wisconsin (Chapter 5)

Stevens Point financed several projects to launch a co-digestion partnership with a local brewery without seeking external funds. They did this by relying on a combination of grants from the Wisconsin Focus on Energy Program, support from the brewery for constructing the pipeline to convey the brewery residuals to the WWTP, and internal multi-year operating funds from the Sewer Utility Fund. (See Chapter 5.)

Its future organic waste receiving station will be financed through the Wisconsin implementation of the CWSRF, its Clean Water Fund Program.

3.7.4.5 Victor Valley Wastewater Recovery Authority, California

With its capacity for further bond financing stretched thin due to $200 million investments in prior major upgrades, Victor Valley has placed recent major co-digestion-related projects on its operating budget by arranging for the private partner in its PPP to be responsible for financing, as well as construction and operations. (See Chapter 4.)

3.8 Making the Business Case: Putting It All Together

The first two parts of this chapter provided a diagnostic framework for WRRFs to assess the fit of co-digestion with utility goals and resources, and to evaluate options for the six key decision elements that are integral to developing a long-term strategy and implementation plan.

- The next challenge is to put together the pieces from the diagnostic assessment of opportunities. Though the chapter considered each of the six decisions serially, the diagnostics clearly highlighted that a decision for one will have impacts on the opportunities, challenges, and financial potential of the others. Putting together the design of the full project must include a holistic evaluation of these tradeoffs and synergies, taking a long-term perspective.
- The steps for putting the pieces together to create a **business strategy** include:
    - Make choices for each element, taking into account impacts on others.
    - Determine what form of contracting is desired, and what scope of WRRF activities are to be covered and how the contract will be structured to share financial rewards and risks.
    - Conduct a full analysis of project cash-flows and financial risks, incorporating the financial aspects of each element, including projected life-cycle revenues, costs (including for future asset maintenance and upgrade requirements), grants, and green payments.
    - Identify environmental and community impacts.
    - Integrate required investments into the utility capital budgeting plan to determine the timing of investments.
    - With timing and financial risk considerations factored into the financial analysis, determine loan requirements.
    - Determine how program costs (including loan repayments) will be funded over time, including self-generated resources and rate increases.

Appendix E provides guidance on the use of alternative metrics to evaluate financial performance and on conducting financial risk analysis. However, only **Net Present Value (NPV)** calculated over the lifetime of the investment provides information about the **total net gains** (revenues minus costs) from the project. Not taking into account the financial implications over the full lifetime of the project may result in rejecting projects that require a long time horizon to fulfill their potential. Also. other criteria may yield different rankings of projects. Appendix E also provides a discussion of triple-bottom line analysis, including a version of the analysis that applies weights to different performance indicators. Most utilities that consider environmental and community impacts use a more informal approach, without weights.

The final steps are to lay out the **business case** for the long-term strategy and/or specific project proposals and take the case to utility decision makers and other stakeholders. The business case will include sections 1) identifying the fit with utility mission and resources and 2) presenting performance projections on all indicators relevant to stakeholders – including financial impacts for ratepayers, as well as environmental and community impacts. The vision for the long-term potential can be used as a reference point for evaluating the business case for individual investment project proposals, as well as for assessing ongoing program performance.

CHAPTER 4

Victor Valley Regional Water Reclamation Facility, Victor Valley Regional Water Reclamation Authority (VVWRA)

4.1 Context and Summary

About the Utility

- Service area: Town of Apple Valley, City of Hesperia, City of Victorville and San Bernardino County service areas 42 and 64, California
- Operating since: 1981
- Wastewater customers served: 384,000
- Employees: 33
- Governance: Joint Power Authority with four member entities (Town of Apple Valley, City of Hesperia, City of Victorville and San Bernardino County service areas, California)

About the Valley Regional Water Reclamation Authority

- Location: Victorville, CA
- Size: 18 mgd (permitted); average daily dry-weather flow in 2017 is 11.3 mgd
- Anaerobic digesters: two 1-mg digesters (mesophilic); plus three decommissioned 330,000-gal digesters, which are currently being recommissioned
- Food waste feedstocks: anaerobically digestible material ("ADM", food processing byproducts and food scrap slurries) and FOG
- Food waste as share of total AD feedstocks: ~10% of volume, and 20% of TSS
- Feedstock preprocessing: haulers bundle and preprocess to remove contaminants, create slurry
- Electricity provider and costs: Southern California Edison, 2014: $0.124/kWh; 2015: $0.182/kWh; 2016: $0.228/kWh (includes demand charges and standby fees, which have increased on a per kWh basis, as purchases have declined dramatically during this period)
- Co-Digestion increased biogas production from 115 MCF per year to over 250 MCF per year (+120%) in 2016
- Biogas use: onsite heat and power generation (two 800-KWh generators) for internal use; projects in development include an advanced microgrid and flow cell battery storage system to enable electricity sales through net metering, and biogas conditioning to enable injection of renewable natural gas into Southwest Gas pipeline
- % energy neutral prior to new Internal Combustion (IC) Engines and co-digestion (2014): 0%; after (2016): 73% (VVWRA 2017)
- Biosolids management: land application of Class A biosolids (Note: co-digestion did not increase biosolids)

Drivers and Goals

- Drivers: electric power instability due to voltage irregularities, financial support for renewable energy (subsidies, tariffs and grants)
- Goals (first round of co-digestion): energy efficiency (lower energy use), improved treatment process control parameters, and energy neutrality
- Goals (second round of co-digestion): supply electricity to the grid to benefit offsite VVWRA facilities through the Renewable Energy Self Generation Bill Credit Transfer program, and supply renewable natural gas to existing onsite natural gas distribution pipeline

Summary

In 2006, the Victor Valley Wastewater Reclamation Authority (VVWRA) was facing $800,000 in fines and 120 water quality violations due to delayed maintenance and inefficient operations at its wastewater resource recovery facility (WRRF). In addition, each month VVWRA was spending $40,000 on natural gas and approximately $67,000 on electricity, and facing rising energy prices and energy costs. Though the WRRF had digester capacity onsite, reducing energy costs through the beneficial use of biogas was not possible due to the lack of biogas treatment equipment.

Facing these challenges when he joined VVWRA as general manager in 2006, Logan Olds has championed the transformation of the WRRF into an energy-neutral and environmentally sustainable plant that meets environmental permit requirements. The vision was 1) to increase energy efficiency (and thereby reduce energy use) – while improving treatment performance to enhance water quality and achieve regulatory compliance; and 2) to increase the beneficial use of biogas to achieve energy neutrality (WERF 2015). For example, VVWRA added a biogas conditioning system in 2012 to enable use of self-generated biogas for cogeneration.

In the ensuing years, VVWRA substantially reduced average daily energy use. (It dropped from 1.2 MW in 2006 to 0.9 MW as of 2013.) However, the facility was still 15-25% short of the biogas needed to reach energy neutrality (Logan Olds, Interview with authors, July 3, 2018). To address the gap, VVWRA launched its Waste to Energy Program, with co-digestion of organic wastes central to achieving VVWRA's goal of energy neutrality. As outlined in Project 1 below, in 2011 VVWRA began experimenting with food waste feedstocks, and in 2012 issued a request for proposal (RFP) for a public-private partnership (PPP) to design, build and finance energy production facilities to make effective use of the expanding biogas resources, with minimal upfront investment from VVWRA.

VVWRA is currently developing a new PPP arrangement to include the next phase of its Waste to Energy program, which involves investments to enable transferring electricity to the grid through net metering and injecting renewable natural gas into a utility pipeline on its property (Project 2).

4.2 Project 1: Waste-to-Energy Project Phase 1

4.2.1 Managing Feedstock Risks

4.2.2.1 Trial Implementation

In 2011, VVWRA became the first WRRF to partner with Waste Management (WM) to bring food scraps to its digester. WM tested its Engineered BioSlurry (EBS®) at the plant's digesters, but VVWRA chose not to move forward with WM after the pilot ended. In 2012, Logan Olds commissioned a fats, oil and grease (FOG) feedstock marketing study for $25,000 to estimate the potential production of biogas from excess FOG in the area. The study found that there was sufficient FOG waste in the surrounding area to boost biogas. Over time, other liquid wastes would come to dominate FOG in the plant's feedstock mix.

Logan Olds pitched to the VVWRA Board a plan for an experimental trial period for co-digestion, with a subsequent phase-in to full implementation if successful. The project would require limited investment and impose low risk to digester operations, while providing an opportunity for waste haulers to learn how to meet the plant's needs. By allowing staff to address operational issues with accepting new wastes, the experimental period was also intended to provide an opportunity to gain staff buy-in.

Within weeks of the VVWRA board approval, the WRRF spent $10,000 to convert the primary clarifier FOG equalization tank into a liquid receiving station for FOG and other anaerobically digestible material (ADM), including food processing residuals and food scrap slurries, where the plant dewaters and mixes the FOG and ADM feedstocks.

During the experimental phase, VVWRA accepted ADM and FOG from feedstock providers without charging a tipping fee. Because the service was provided at no cost to haulers, VVWRA felt no responsibility to accept food waste, thus allowing staff to reject individual loads, and to terminate the experimental phase at any point, if needed. The trial period helped to build the WRRF's reputation with nearby industry and allowed both VVWRA and feedstock haulers to experiment with feedstocks. VVWRA used this phase to set contamination and chemical standards for feedstock accepted at the WRRF, while feedstock suppliers adjusted their waste mixes to create feedstock mixes that are chemically beneficial for VVWRA's digesters. During the 14-month trial period, VVWRA stopped operations only once to address an operational upset.

After the experimental phase, the WRRF established a fee of $0.04 per gallon of FOG or ADM (compared to $0.936 per gallon for septage). This low price[6] was designed to cover the costs of operations and maintenance associated with the food waste feedstock, and provide an attractive option for haulers. Given that the utility is not allowed to make a profit, it does not set its tip fees to maximize potential earnings (Logan Olds, interview with authors, July 3, 2018).

Full Implementation: Feedstock Providers

In 2017, wastewater solids represented 80% of digester feedstock by volume, with "anaerobically digestible materials" 18%, and FOG 2%. The "anaerobically digestible material" category includes industrial food processing liquid waste, as well as slurries created by combining food scrap slurries supplied by solid waste firms with food processing liquid waste, which VVWRA finds works well in their digesters.

Recognizing that they have a relatively small plant, VVWRA strives to maintain a flexible feedstock program, with an emphasis on customer service to their haulers in order to maintain a robust feedstock supply, balanced by checks in the system to ensure co-digestion feedstocks do not disrupt operations. They rely on suppliers to aggregate and preprocess the food wastes as needed – removing physical contamination where needed and mixing them into a liquid or slurry that is chemically balanced for VVWRA's digesters before delivery to the WRRF. If haulers do not maintain low contamination standards, the WRRF will not accept their waste.

To reduce the burdens on haulers, VVWRA only requires new suppliers to provide biological oxygen demand (BOD), chemical oxygen demand (COD), and solids content for each feedstock. Generally, if suppliers introduce a new substance with unfavorable chemical characteristics, VVWRA will work with haulers to develop a blend of feedstock that has chemical characteristics more suited to their digester. For example, if a hauler brings a watery waste, it can be mixed with other wastes to achieve a more desirable consistency. A plant employee who is invested in plant operations oversees the unloading of FOG or ADM to provide quality control (Logan Olds, email with authors, October 9, 2018).

Due to hauler preferences, VVWRA does not have contracts with haulers. Among its haulers, the national FOG hauler, Liquid Environmental Systems, offered to provide a long-term contract if VVWRA would award it an exclusive franchise; however, VVWRA declined because it would be politically untenable to exclude local haulers to support an outside company. Should haulers suddenly stop bringing their waste to VVWRA, WRRF staff have an agreement with one hauler that they will make up for any quantity of waste lost from other haulers.

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[6] Publicly posted tipping fees in California have a median of $45 per ton disposed, though about 80% of loads at landfills in California could be charged discounted fees resulting in much lower effective fees. As a result, the effective median landfill tipping fee for most waste in California could be as low as $20 per ton (CalRecycle 2015).

4.2.2 Power Purchase Agreement/Lease for Energy Upgrade

With bond financing stretched thin due to the $200 million investments in major upgrades to the treatment plant and interceptor system, VVWRA sought a PPP to both develop and finance the investments in energy production capacity needed to make effective use of the increasing supply of biogas. Their request for proposals further specified that the developer provide self-financing. Anaergia, a renewable energy and resource recovery company, submitted the only proposal that met the terms of the RFP.

The project was designed to yield energy savings. The PPP agreement was structured as a power-purchase-agreement/lease arrangement, where Anaergia develops and owns the infrastructure built on land leased from VVWRA, and sells energy back to VVWRA at a guaranteed price schedule. VVWRA operates and maintains the equipment. The cost to the plant – including the charge for electricity supplied by Anaergia, as well as the cost for the in-house operations and maintenance it supplies – is approximately $0.124/kWh and decreases as more power is produced, compared to $0.182 kWh (2015) from Southern California Edison (SCE), VVWRA's electricity provider (VVWRA 2017).

In 2014, Anaergia provided two 800-kW cogeneration engines to produce heat and power. In addition, Anaergia piloted at VVWRA their new Omnivore recuperative digestion technology in the U.S. for the first time. The digester technology features a recuperative thickening process that allows total solids (TS) loading up to 6%, two times the average digester TS loading, which increases the capacity of the digester relative to others of the same volume. Anaergia also negotiated the interconnect agreement with SCE in 2103-2104, for which upfront costs were about $300,000.

To finance the project, Anaergia's private funds were supplemented with a $4 million grant from California's Self Generation Incentive Program (for power generation) and a $2 million Innovative Technology Grant from the California Energy Commission (for the digester upgrading) (WERF 2015).

4.2.3 Project Impacts and Risk Management

4.2.3.1 Operational Impacts

Operational Upsets

VVWRA has not experienced operational upsets with the advent of full implementation of co-digestion.

Regulatory Compliance

With co-digestion, the plant has not faced any new issues in complying with water or air quality standards. Due to its location in the Mojave Desert Air Quality Management District, which has stringent non-attainment air quality requirements for nitrogen oxides (NO_x), VVWRA set rigorous air quality performance standards for the IC engines in order to meet the standards. Engine performance has exceeded those standards. The utility won the highest award from its air quality management district for the project.

Biogas

With the added ADM/FOG feedstock, biogas production increased from 115 MCF per year in 2014 to over 250 MCF per year in 2016, surpassing the 180 MCF needed for energy neutrality. Substantial flaring continues to occur, which has motivated projects discussed below to expand energy production.

Biosolids

Co-digestion has not led to an increase in biosolid production.

4.2.3.2 Financial Impacts

With the investment in new energy production capacity financed privately through a PPP, the project appears on the VVWRA's operating budget not its capital budget.

Co-Digestion Revenue and Operating Costs
In 2017, the plant earned tipping fees of $249,963 from accepting food wastes and $661,579 from septage (authors' calculations based on VVWRA 2018a, VVWRA 2018b). This represented a net gain of $330,000 annually after operating costs associated with co-digestion (Logan Olds, interview with authors, July 3, 2018). These gains go into repair fund accounts that support maintenance to address the wear and tear from co-digestion. VVWRA will use this additional revenue to complete a $500,000 equipment coating project (Logan Olds, interview with authors, July 3, 2018).

Energy Revenue and Costs
As a result of the introduction of biogas cleaning equipment, purchases of natural gas declined from 261,491 therms in FY2011-2012 to an average of 25,000 therms in FY2012-2013 through FY 2015-2016, for annual savings of $421,639 in natural gas purchases. The introduction of the cogeneration engines has resulted in average additional electricity production of 541,470 kWh a month, providing estimated annual electrical savings (relative to 2015) of $274,541 in 2016 (VVWRA 2017, 4). It also has provided heat for the digesters.

Biosolid Revenue and Operating Costs
No impact, because biosolids production has not changed.

Sewer O&M Costs
Any reduced sewer system costs are accruing to the four local member governments, which manage most of the sewer pipes in the service area. Two of these municipalities were having issues enforcing grease ordinances because haulers did not have an easily accessible disposal site. With VVWRA as an alternative method of FOG disposal, the VVWRA's member municipalities started enforcing the ordinances. As a result, they have observed reduced clogging in their sewer pipes, which suggests their costs for operations and maintenance of wastewater infrastructure have declined, but the dollar impacts have not been quantified.

4.3 Project 2: Waste-to-Energy Project Phase 2

VVWRA is looking beyond its initial goal of energy neutrality, toward business opportunities that will add value to the utility. The authority is currently building an advanced microgrid and flow cell battery storage system. Further, it is currently negotiating another PPP with Anaergia to develop the infrastructure to supply renewable natural gas to a Southwest Gas distribution pipeline located on VVWRA property. To take advantage of the additional energy production capacity, the utility is expanding digester capacity by bringing three smaller decommissioned anaerobic digesters back online. When all five digesters are operating, the plant will be able to produce 900,000 scfd of biogas.

4.3.1 Selling to the Electricity Grid

The WRRF is close to full energy neutrality, but has not quite reached it yet. For one, the VVWRA is still required to purchase 80 kW at all times from the grid due to the interconnection agreement in the Authority's Southern California Edison contract (Andrews and Olds 2015; WERF 2015). Moreover, the WRRF's cogeneration engines are unable to handle large instantaneous power demands. The engines require two to three seconds to respond when there is an increased power demand, such as when a large blower is turned on at the WRRF. In those two to three seconds, the WRRF needs approximately 200 to 300 kW of additional power. Therefore, to maintain compliance with the interconnection agreement and address variable loads VVWRA uses approximately 300kWh of electricity from the grid.

Pending investments in an advanced microgrid and flow cell battery storage system, paired with net energy metering, will allow VVWRA to provide 100% of its onsite power and gas needs. The microgrid system will address the power delay, by storing the 200kW needed for engine operational reliability. Biogas Engineering is assisting VVWRA with the interconnection and net energy metering agreements with SCE. Installation is projected to occur in spring 2019.

The total value of the microgrid and flow cell batteries is approximately $2.7 million (Logan Olds, interview with authors, July 19, 2018). A grant from the California Energy Commission's Electric Program Investment Charge (EPIC) Program is covering the costs of purchasing the equipment. VVWRA is providing an in-kind match, in the form of labor to build, monitor and maintain the equipment. VVWRA has estimated that energy cost savings will increase from around $700,000 per year under the prior configuration, to over $1 million per year (VVWRA 2017, 4).

4.3.2 Pipeline Injection of Biogas

VVWRA is also seeking to expand its digester capacity to produce additional biogas, and inject the biogas into a Southwest Gas natural gas pipeline that passes through VVWRA property. VVWRA is negotiating a Design-Build-Finance-Operate-Maintain (DBFOM) PPP agreement with Anaergia. VVWRA will supply the biogas and will receive a revenue stream; Anaergia will be solely responsible for gas clean up and preparation of renewable natural gas for pipeline injection. Anaergia will be seeking payments from the federal Renewable Fuel Standard and the CA Low Carbon Fuel standard, which will multiply the returns relative to the current market sales price for natural gas of around $3/MMBTU.

VVWRA is seeking to build sufficient flexibility into its energy production system so that it could allocate its renewable natural gas to the highest-valued use. Because the income streams from vehicle fuel production currently are much higher than the income streams from renewable electricity, one option would be to scale the pipeline injection project so that all of the biogas the plant produces could be allocated to pipeline sales.

The current renovation of VVWRA's three 330,000-gallon digesters that have been offline is both a regulatory requirement and a business investment. The additional digesters will be available to supply lost capacity when the two currently operating 1-mgd digesters go offline soon for their periodic cleaning and maintenance. Once the required maintenance is finished, all five digesters will have the capacity to accept additional food wastes. The renovation of the three digesters is anticipated to cost $1.3 million dollars, with an estimated 3-year payback period based on tip fees plus energy revenues from the two projects.

4.4 Lessons Learned

4.4.1 Create Value and Manage Risks

For Logan Olds, General Manager of VVWRA, achieving water quality is not simply a regulatory requirement, but also provides a business opportunity. In pursuing new projects, Olds aims to add value to VVWRA operations. According to Olds, developing a business case analysis with a strong return on investment that maintains or improves water quality is crucial to project acceptance. Moreover, identifying the political, operational and financial risks and developing strategies to mitigate those risks helps smooth project approval.

Given that co-digestion investments are not core to the WRRF's environmental protection mission, Olds' strategy has been to convince the public why these investments make sense, and then bring that public support to the political decision-making process. To build external support, VVWRA conducted two years of outreach to stakeholders in all four member entities under the VVWRA's joint power authority to explain the benefits of resource recovery and the utility's long-term vision of energy neutrality.

A public resolution from the Authority Board in 2013 articulating VVWRA's commitment to sustainability helped the WRRF attract both grant money and feedstock clients. Haulers in the Victor Valley area were able to market VVWRA's sustainability to their clients, thus increasing their profit margin.

With the Authority's Board, Olds' approach is to work through Board committees involving senior management at each of the Member Entities organizations before taking proposals to the full board. Olds gained political buy-in for co-digestion from the utility board by creating a plan that allowed for experimentation before full implementation, which allowed VVWRA to mitigate any potential risks before full program operations.

To build internal staff support, Olds has focused on empowering his staff by involving them in operational decision making, encouraging their creativity and ensuring they are involved in equipment selection.

To address operational risks, VVWRA sets quality standards for feedstock providers in order to facilitate optimal digester performance without specifying extensive testing requirements, and works closely with haulers to develop feedstocks that work well with the digesters. While they are open to new substances, VVWRA is strict about contamination.

To address financial risks, VVWRA's strategy has been to develop public-private partnerships (PPP), where the private partner is financing the project as well as designing and building it, so that the Waste-to-Energy project primarily appears on its operating budget, not its capital budget. (The exception is the advanced microgrid and flow cell battery storage system.) With private funding and the assistance of grants, $12 million in infrastructure has been installed with zero impact to ratepayers.

Finally, according to Olds, the most important element for a Utility of the Future approach to wastewater management is having motivated staff who view change as an opportunity and not a challenge.

4.4.2 Replicability

This approach to managing risks appears replicable elsewhere. The value creation strategies benefit from the relatively high energy prices and the generous subsidies for renewable energy and food waste diversion activities available in California.

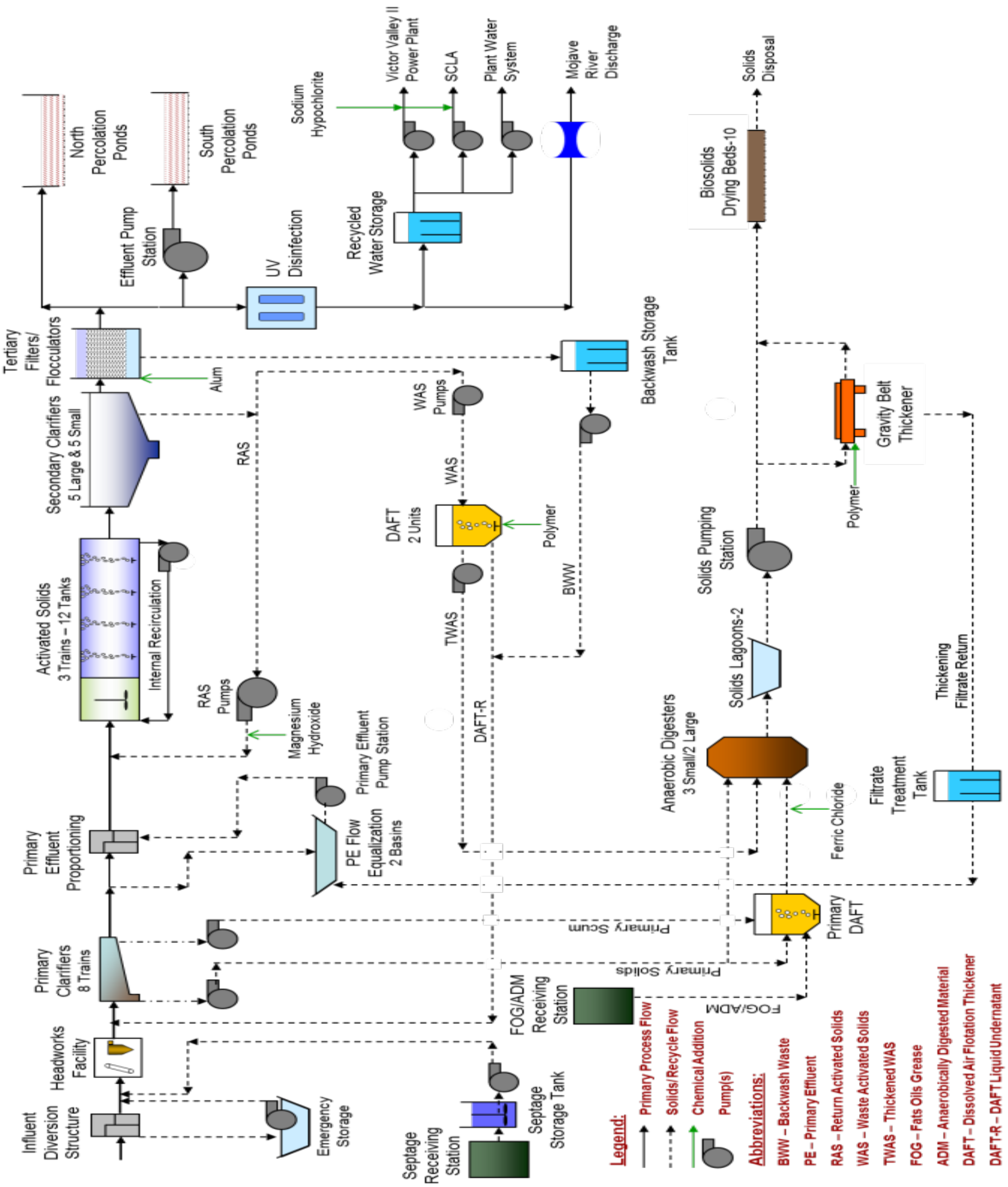

Figure 4-1. VVWRA Process Schematic 2018.
Source: VVWRA 2018.

Figure 4-2. VVWRA 2G Generators.
Source: http://vvwra-prod.civica.granicusops.com/edu_resources/wep.htm (Last Accessed 9/6/18).

Figure 4-3. A VVWRA flow cell battery.
Source: VVWRA staff photo.

CHAPTER 5

Stevens Point Waste Treatment Plant, Public Utilities Dept., City of Stevens Point, Wisconsin

5.1 Context and Summary

About the Utility

- Service Area: City of Stevens Point and Village of Park Ridge
- Operating since: 1940
- Wastewater customers served: 27,500 residents + 10,000 college students
- Employees: 5-6
- Governance: City of Stevens Point Board of Water and Sewerage Commissioners

About the Stevens Point Waste Treatment Plant

- Location: Stevens Point, WI
- Size: 2.8 mgd average flow; 4.5 mgd permitted flow
- Anaerobic digesters (AD): three 735,000 gallon mesophilic digesters, plus a 1.5-million-gallon digester (converted in 2018 from a wastewater solid storage tank)
- Food waste feedstocks: Brewery wastes, food processing residuals
- Food waste as share of total AD feedstocks: 34.1% by volume (39.7% by TVS)
- Feedstock preprocessing: onsite 1-inch bar screen, rock trap, large grit sump at bottom of mixing tank, chopper pump and metered into digester.
- Electricity provider and costs: Wisconsin Public Service (WPS) sells to Stevens Point Waste Treatment Plant (SPWTP): $0.13/kWh peak; $0.04/kWh off-peak; WPS purchases back at: $.10/ kWh peak; $.05/ kWh off-peak under the WPS renewable energy tariff (Lefebvre and Lemke, interview with authors, March 18, 2019).
- Biogas end use: 180 kW combined heat and power (CHP) generation; boilers to heat digesters and WRRF buildings
- % energy neutral with addition of new internal combustion (IC) engines after co-digestion: 90%
- Biosolids management: Land application

Drivers and Goals

- Drivers: Avoid need for major investments to treat dramatically expanding brewery wastes; Wisconsin Focus on Energy (energy efficiency and renewable energy program); increasing restriction on land applications for industrial processing wastes, biosolids
- Goals: achieve energy neutrality through energy efficiency and generation; keep operating costs (and rates) low; provide reliable outlet for brewery and other food processing wastes

Summary

The City of Stevens Point, Wisconsin is transforming its wastewater treatment facility to a wastewater resource recovery facility to carry out the utility's mission to treat wastewater effectively and efficiently. The utility began its journey toward energy efficiency in the early 2000s, as an early participant in Wisconsin Focus on Energy, the state's energy efficiency and renewable energy program (Willis 2015).

Over time, plant staff realized that if the plant reduced energy use sufficiently, it could become energy self-sustaining with the addition of food waste feedstocks, and investments in an upgraded AD system and a new 180kW combined heat and power (CHP) system (WERF LIFT 2015). Indeed, the utility was one of the first in the nation to produce sufficient electric power and heat to be nearly self-sustaining (Willis 2015).

The utility, led by Jeffrey Cramer, the former Wastewater Superintendent, Joel Lemke, Public Utilities Director, and Chris Lefebvre, Wastewater Superintendent, has put great effort into building a co-digestion program for high strength wastes and maximizing biogas utilization over the past decade. One important external driver was the rapidly expanding production wastes from the Stevens Point Brewery, which threatened to tax the treatment capacity of the plant. Further, because the wastes are highly energy-intensive to aerate, treatment through the headworks was an impediment to achieving the plant's energy efficiency goals. To address this challenge, Stevens Point created a public-private partnership with the Stevens Point Brewery to pipe brewery processing residuals to the WRRF, which both enables increased production of renewable energy and reduces onsite energy costs.

The plant also has developed sources for hauled food waste feedstocks for co-digestion. FOG was initially accepted; however, now they have more demand for their digester capacity than they can fulfill. As a result, the plant only accepts hauled food processing residuals, which are more consistent in quality and quantity than the FOG deliveries were. All of the liquid organic wastes enter the plant at the high strength waste receiving station built in 2014 as part of the brewery partnership.

The plant is currently engaged in a new project to expand resource recovery, with investments to add AD capacity and a new biosolids drying facility with a thermal oil paddle dryer. A primary goal of the project is to support a shift in their biosolids strategy to address both recent regulatory changes for tertiary treatment of nutrients as well as current market challenges for land application. The new drying facility will enable the plant to shift from producing Class B biosolids to producing Class A biosolids that can be sold as agricultural fertilizer. The plant team also is considering investments in nutrient harvesting technologies to remove sidestream phosphorus in order to comply with Wisconsin's new effluent regulations covering phosphorus (P) as well as the new plant limit on P in its revised water permit, which has a 7-year compliance period (WERF 2015).

Joel Lemke and Chris Lefebvre cite a small, tight-knit staff as crucial to building staff buy-in to the plant's energy efficiency and resource recovery projects. In addition, a long-standing trusting relationship with their board helps to overcome political obstacles that may impede new projects at the SPWTP.

5.2 Project 1: Co-Digestion Creates Efficiency Gains

The goal of this award-winning project was to achieve net-zero energy use while keeping customer rates low, by avoiding high investment costs to expand treatment capacity and increase efficiency. This first wave of Stevens Point co-digestion investments had three components: the public-private partnership with Stevens Point Brewery, the investment in energy generation equipment to create value from the additional biogas, and the acceptance of other high-strength wastes from outside its service area.

5.2.1 "Brewing a Better Future Together": Public-Private Partnership with Stevens Point Brewery

5.2.1.1 Feedstock Strategy

The Stevens Point Brewery has manufactured Point Beer since 1857, and the liquid wastes from beer production have entered the headworks of SPWTP - as part of the wastewater utility's pretreatment program - since the construction of the WRRF. The brewery underwent a dramatic expansion during the decade of the 2000s (and beyond), the continuation of which threatened to tax the treatment capacity of the plant and the potential for the town to accept new "wet" industries that would require treatment of their wastes (Lefebvre and Lemke, interview with authors, March 18, 2019). Further, the high Biological Oxygen Demand (BOD) in brewery wastes resulted in operational upsets, as well as high energy costs for aeration in the WRRF's treatment train.

In 2012, SPWTP and the brewery implemented a pilot project to reduce energy costs by hauling brewery wastes to the plant and feeding them directly into the digesters. The purpose of the pilot was to evaluate whether sufficient biogas could be produced to warrant the addition of a cogeneration system, and whether brewery wastes would cause any major operational issues. When the pilot demonstrated that the brewery wastes provided a significant amount of biogas with minor effects on operations, SPWTP received Board approval to continue accepting high-strength waste (HSW) feedstocks and to invest in a cogeneration and biogas conditioning system (WERF 2015).

As a result, in 2014 SPWTP established a public-private partnership with the Stevens Point Brewery to send the brewery wastes to the plant digester by dedicated pipeline. The two parties agreed to share equally in the costs of a new HSOW receiving station and pipeline. The WRRF paid the costs upfront, and the parties currently have a contract specifying that the Stevens Point Brewery will pay its share over 10 years, in equal annual assessments. The pipeline is a four-inch, 3,000-foot long force main from the brewery to the plant. The HSOW receiving station includes a 40,000-gallon receiving tank, with a Vaughan mixing system and chopping system, and a bar screen and rock trap, which is used to preprocess the hauled HSOW the plant receives (Lefebvre and Lemke, interview with authors, March 18, 2019).

Brewery wastes are separated and stabilized at the brewery before being sent through the pipeline to SPWTP. Because they are pumped twice before getting to the receiving tank, they are not contaminated with solids and the WRRF does not pretreat them (Lefebvre and Lemke, interview with authors, March 18, 2019).

The brewery wastes have a pH of 4.2, but are exempt from the Industrial Pretreatment Program pH limit (> 5) on wastewater solid discharges because they are transmitted on a dedicated pipeline. In the contract, the WRRF specified they would take whatever quantity of wastes the brewery generated, so long as they were within specific ranges for BOD (minimum BOD of 25,000 mg/L) and Total Solids content. These conditions were designed to prevent the brewery from sending excessive amounts of water down the pipeline.

The utility set the brewery tipping fee at the standard fee for feedstocks with high biogas production value ($6.06 per 1000 gallons).

5.2.2 Energy Strategy to Upgrade AD and Energy Generation

The goal of the plant's energy strategy was to generate heat and electricity for the plant with the additional biogas from co-digestion, and move substantially toward energy self-sufficiency. With the board's approval following the successful brewery pilot, in 2012 SPWTP added a biogas-driven, 180-kW cogen engine and biogas conditioning equipment. At the same time, they added a low-energy digester mixing system (to replace one that had stopped working) and a low-energy pumping system. These AD upgrades enabled the plant to further increase energy efficiency.

Chris Lefebvre explained that they chose an internal combustion engine (ICE) rather than microturbines because the latter require higher pressure and therefore additional infrastructure to operate.

5.2.3 Incorporating Other HSW Feedstocks

Due to tightening restrictions on land application, haulers of other food wastes started contacting SPWTP in their search for alternative waste disposal sites. The WRRF began accepting truck deliveries of fats, oils, and greases (FOG) in 2010, and deliveries of high quality food processing residuals (FPR) from nearby plants followed shortly thereafter (Donahue & Associates 2016). The plant is well-situated on

Interstate 39 in an area with various food processing plants. Currently, the demand for FPR disposal is so great in the Stevens Point area that the WRRF digester is operating at capacity and regularly turns away calls from nearby industries. They coordinate with the only other WRRF co-digesting in the area, Wisconsin Rapids WRRF, which is 20 miles away.

Today, approximately one-third of offsite organic wastes the plant receives are from the Stevens Point Brewery and two-thirds are from nearby food processing industries.

The plant accepted FOG between 2010 and 2016. However, WRRF staff decided to stop accepting FOG when sufficient quantities of less contaminated, more consistent feedstocks became available to fill the digester. Deliveries of FOG were often inconsistent in terms of quality and generally occurred only once a month when the grease traps were emptied. Chris Lefebvre and Joel Lemke noted that when they did accept FOG, total solids ranged from 0.5% to over 15% and the FOG was frequently contaminated with an assortment of debris, including spoons, steel wool, aprons, t-shirts, and even cell phones.

Though SPWTP has no contracts with feedstock suppliers other than the brewery, the plant now receives regular deliveries of FPR from a set of haulers who have been delivering to them over an extended time period. When haulers' schedules or the content of their loads will diverge from the usual, they notify the plant. The FPR supplies are normally liquids (4-7% total solids) and can include substances such as marinade from chicken nuggets, batter from chicken fries or dissolved air flotation wastewater solids from food production facilities (Lefebvre, interview with authors, July 20, 2018). Haulers pump the manufacturers' waste into their tanker trucks, and then unload the tanks at the SPWTP receiving station. At the WRRF, the trucked-in waste goes through a one-inch bar screen. The wastes are mixed together and treated using a rock trap grinder, large grit sump, and a chopper pump before being metered into the digesters (Lefebvre and Lemke, interview with authors, March 18, 2019).

The plant has specified quality parameters that the feedstocks must meet. Before they are accepted, the wastes must be tested by a third-party lab for the several constituents that would influence biosolid quality including metals, N, P, BOD, and COD. The WRRF prefers high Chemical Oxygen Demand (COD) and low Total Suspended Solids (TSS) feedstocks to improve biogas production. Because they have been anticipating the new tighter phosphorus discharge limits, they have turned away feedstocks with low COD and high P contents, such as dairy waste (Lefebvre and Lemke, interview with authors, March 18, 2019).

5.2.4 Project Impacts and Risk Management

5.2.4.1 Operational Impacts

Operational Impacts on Digester Operations

During the initial stages of FOG acceptance, SPWTP staff found that overfeeding and inconsistent feeding caused digester upsets. By watching what feed-in rates caused upsets, the staff was able to determine that if biogas production goes above a certain level, too much feedstock is being added. Using historic ratios of volatile acids to total alkalinity (VA:TA) and monitoring the corresponding gas production, the WRRF staff is able to pace digester feed-in and avoid digester upsets (Donahue & Associates 2016).

Some odors were experienced, notably from overfeeding the digesters and from the malodorous nature of FOG. This problem was addressed by dropping FOG as a feedstock, and by mixing the feedstocks before feeding them to the digester.

Operational Impacts on Biogas Production and Energy Use

With co-digestion, SPWTP now produces 100,000 scfd, which represents a doubling of biogas production. The biogas powers the 180 kW CHP engine, which generates enough electricity to supply 90% of the WRRF's electricity needs. In addition, the plant now is regularly able to push excess power to the grid. The plant has an agreement with Wisconsin Public Service to purchase electricity back from the utility under a Renewable Energy Tariff ($.10/kWh peak, $.05/kWh off-peak. The greater share of sales is off-peak (3-6am) and in the warmer months of the year. The utility retains the renewable energy credits (RECs) associated with the purchases. On average, 5% of the WRRF's annual electricity production is sold to Wisconsin Public Service, a local investor-owned utility (IOU).

In addition, about 85% of the waste heat from the CHP (engine coolant and exhaust gases) is captured and used to heat the digester and plant buildings, supplying 90% of the heat the facilities need.

Approximately one-third of the biogas is flared because the WRRF currently does not have the capacity to use it.

The cogeneration system requires a substantial amount of maintenance, and is periodically down.

Operational Impacts on Biosolids

Biosolids volume increased by roughly 12% with the addition of co-digestion. The quality of the biosolids has not changed.

The plant currently land-applies its biosolids (5% TS) on nearby farms, but is running into obstacles including the availability of land (which then can mean additional storage must be found), and public opposition to Class B biosolid land applications. Wisconsin prohibits the land application of biosolids during winter months, and consequently requires WRRFs to have 180 days of onsite biosolids storage (USEPA 2014). SPWTP has two biosolid tanks, which are covered to keep out precipitation and also have mixing capacity. With a capacity of 1.6 million gallons each, they represent 180 days of storage under normal weather conditions. However, in the winter of 2018/2019, the plant needed to seek additional storage because weather challenges have limited their access to farmers' fields to apply the biosolids (City of Stevens 2018).

These obstacles are part of the motivation for the new biosolids strategy the plant will be implementing with its new project (see description below).

Regulatory Impacts

No adjustments were required to the plant's NPDES, air or solids permits.

5.2.4.2 Financial Impacts

Investment

One way to gain approval from the City of Stevens Point Board of Water and Sewerage Commissioners for projects is to demonstrate that the project is needed to meet a regulatory requirement, and will do so cost-effectively. Other projects must meet an ROI hurdle rate and have a reasonable payback period. Chris Lefebvre and Joel Lemke present each project to the board with projected purchase and installation costs, and operating revenues and costs over a life cycle of 20 years. Including operational costs in project analyses allows the plant to invest in equipment with a higher capital cost but lower long-term operating costs.

In the case of the receiving station and pipeline, the investment was evaluated relative to the avoided costs of anticipated future wastewater treatment investments (new aeration basins, which are expensive given the underground rock formations, and new selector tanks) as the brewery wastes continued to grow with the rapidly expanding brewery. The net cost of the receiving station and pipeline was $1.293 million, after taking into account a Wisconsin Focus on Energy grant of $114,000. The utility and the brewery split the cost of the receiving station, and the utility paid for its share from its operating budget. The board approved the expenditures because the avoided costs of wastewater investments to treat the growing brewery wastes would be multiple times the costs associated with the co-digestion infrastructure.

The cost of the cogen engine and biogas treatment system was $1.273 million. After a Focus on Energy program grant of $225,000, the net cost to the plant of the biogas investments was $1.048 million. The utility financed the net project cost of $1.048 million with a combination of internal operating funds and Build America Bonds – taxable municipal bonds that provided tax credits or federal subsidies for local governments at a very favorable rate. (The Build America Bond Program expired in 2010.) The projected payback of the cogeneration and biogas conditioning project was estimated to be 12 years. Due to unanticipated gas conditioning expenses, however, the current payback period estimate is 13-14 years.

Net Operating Revenues and Costs

By removing brewery wastes from the headworks, the WRRF saves $150,000 per year in wastewater treatment costs. The pipeline also saves the brewery $150,000 in annual wastewater surcharges (Lefebvre and Lemke, interview with authors, March 18, 2019).

The additional costs for operating the receiving station were minimal, primarily for increased billing and paperwork. The plant receives $110,000 in tipping fees for food waste feedstocks on average each year.

Up until October 2018, Lemke and Lefebvre determined tipping fees based on the desirability of the waste. Brewery, distillery, and FPR wastes with high gas production value were charged $6.06 per 1000 gallons. Wastes with less desirable impacts on the digester, such as dairy wastes, were charged more: $39.88 per 1000 gallons. Beginning in November 2018, SPWTP charges a uniform price of $39.88 per 1000 gallons – regardless of feedstock quality – for generators located outside of its service area, and a uniform price of $6.06 per 1000 gallons for generators located within its service area. Since all of the food processing wastes are from outside of the SPWTP service area, this will represent an increase in price for most of those haulers. The increase is motivated by the increasing costs associated with the new biosolids project described below (Lefebvre, interview with authors, July 19, 2018).

No additional O&M costs were incurred for running the anaerobic digesters.

Extensive maintenance is required periodically for the IC engine, which results in episodic downtime as well. On average, operating costs for the energy system increased $30,000 per year, primarily due to engine O&M costs. The WRRF saves $90,000 per year in electricity costs and $9000 in heating costs. SPWTP also sells electricity produced from the cogeneration system to their electricity provider, Wisconsin Public Service, at a cost of $0.10/kWh on peak and $0.05/kWh off peak. In 5 years, the WRRF generated $29,284 in electricity sales revenue (Lefebvre and Lemke, interview with authors, March 18, 2019). With the additional biosolids and the difficulties with land application due to weather and decreasing farmer acceptance, biosolids O&M and hauling costs increased by 66% or approximately $60,000 per year on average since 2016.

5.3 Project 2: Expanding Co-Digestion and AD and Energy Investments

5.3.1 Project Strategy

The utility's new project includes investments to expand AD capacity and biogas storage and to construct a new biosolids drying facility that will house a new thermal oil paddle dryer.

With this new project, Lemke and Lefebvre aim to shift their biosolids strategy to address both recent regulatory changes for tertiary treatment of nutrients, as well as current market challenges for land application. The new drying facility will enable the plant to shift from producing Class B biosolids, which the WRRF currently pays hauling costs to land apply, to producing Class A biosolids that can be sold as agricultural fertilizer. These AD and biogas storage investments will enable the utility to increase feedstocks (and tipping fees) and to produce additional biogas to support the dryer (Lefebvre and Lemke, interview with authors, March 18, 2019).

In the face of increasing popularity of producing renewable natural gas (RNG) from biogas, SPWTP has explicitly chosen to pursue energy self-sufficiency, as opposed to increasing revenue by producing RNG for pipeline injection or direct sales as vehicle fuel. According to Lefebvre, the equipment for upgrading biogas into liquefied natural gas for pipeline injection is quite expensive due to the high quality required by utilities for pipeline injection. As a result, the economics of producing compressed natural gas for vehicle fuel are not favorable unless 1) grant funding essentially buys the processing equipment and 2) the WRRF has no capital costs other than the conversion of their vehicle fleet to natural gas (Lefebvre, interview with authors, July 19, 2018).

In addition, the Lemke and Lefebvre are considering investments in nutrient harvesting technologies to remove sidestream phosphorus, to comply with the new Wisconsin effluent regulations covering phosphorus (P) and the new plant limits on P in its revised water permit, which have a seven-year compliance period (Lefebvre and Lemke, interview with authors, March 18, 2019).

5.3.2 Potential Project Impacts and Current Status

SPWTP plans to spend about $16 million to upgrade a sludge storage tank to a digester and to construct the biosolids drying facility. Because a primary goal of the project is to address recent regulatory changes for tertiary treatment of nutrients, the utility Board did not require the project to pass a formal ROI or payback period test. The Wisconsin Clean Water Fund Program will provide the financing in a 20-year bond at an interest rate of 1.892%, along with a principal forgiveness grant of $700,000. The plant is looking for additional grant funding – for example, from the Wisconsin Focus on Energy program – to offset more of the costs (Lefebvre and Lemke, interview with authors, March 18, 2019).

As of August 2018, the AD expansion was completed, in which a wastewater solid storage tank was converted to a 1.5-million-gallon digester. Construction of the Class A biosolids project has started and is expected to be operational in late 2019.

5.4 Lessons Learned

5.4.1 Create Value and Manage Risks

Led today by two sustainability champions, Joel Lemke, Public Utilities Director, and Chris Lefebvre, Wastewater Supervisor (and previously by Jeffrey Cramer, former Wastewater Superintendent) the utility has been focusing throughout the last two decades on creating value and increasing efficiency by recovering resources in service of the utility's mission to treat wastewater effectively and efficiently.

As early participants in Wisconsin Focus on Energy, the state's energy efficiency and renewable energy program, they realized that – with sufficient energy use reduction – co-digestion would allow them to become energy self-sustaining both by increasing energy efficiency and enabling onsite production of renewable energy. The resulting energy cost savings benefit their customers by keeping their customer rates down.

The small utility was able to address political/stakeholder, operational and financial risks by making incremental changes, and by then evaluating and fine-tuning strategy based on performance. Chris Lefebvre cites the availability of a willing brewery partner and existing AD capacity, as well as a small, dedicated staff and a close working relationship with their Board, as factors essential to the success of their co-digestion project.

Operations and maintenance personnel initially resisted the change in operations to achieve increased energy efficiencies because the plant had historically met its discharge requirements without any issues, and energy efficiency is not required for funding or for permit conditions (Willis 2015). By starting out with a pilot project with the local brewery to test the co-digestion strategy, managers were able to foster staff buy-in by including staff members in the decision making process for each operational change. With the results of the pilot project, the SPWTP also was able to demonstrate the efficacy of the plan to the utility Board.

The presence of a committed provider of feedstock of consistent quality and quantity reduced the risk of feedstock loss in what can be a highly volatile feedstock market.

Finally, SPWTP's approach of incremental improvements, relying to a great extent on internal operational funds, supplemented by a few state grants, is a conservative way to finance co-digestion.

This project has been recognized by Water and Waste Digest (2015), WEF/WERF Utility of the Future Today (2016), and American Council of Engineering Companies of Wisconsin (Donahue & Associates 2015).

5.4.2 Replicability

Stevens Point demonstrates that small WRRFs with project champions, a strong relationship with their Board, state support for renewable energy markets, and an ample and reliable supply of feedstock can successfully implement co-digestion. The long-term feedstock commitment of the Stevens Point Brewery – a special element in this case – was an important driver for co-digestion. Further, the plant is in a good location for a robust supply of other feedstocks, which allows it to be selective in what it accepts. Project champions Chris Lefebvre and Joel Lemke cite a "Do the Right Thing" attitude among utility leaders and staff as the motivation for many of the sustainability related projects they have implemented.

CHAPTER 6

Dubuque Water and Resource Recovery Center, Dubuque, IA

6.1 Context and Summary

About the Utility

- Service area: City of Dubuque
- Wastewater customers served: 58,000 city residents; with industries included, Dubuque serves a population equivalent of 120,000
- Governance: City Government with a City Council and City Manager

About the Dubuque Water and Resource Recovery Center

- Location: Dubuque, IA
- Size: average daily flow of 7 mgd
- Employees: 15
- Operating since: 1969 (replaced prior plant)
- Anaerobic digesters: 2 mesophilic, and 2 thermophilic, 985,000 gallons each (total volume, 3.94 MG)
- Food waste feedstocks: food processing residuals (Hormel, Rousselot), fats, oils and grease (FOG); other high-strength organic wastes (HSOW) include biodiesel processing waste
- Food waste as share of total AD feedstocks: 22% by volume; 44% by TSS
- Feedstock preprocessing: some feedstock suppliers conduct centrifugation, screening and DAF use; WRRC does not preprocess feedstocks
- Electricity provider and costs: Alliant Energy Interruptible Service Program
- Biogas use: microturbines for CHP (2014), and pipeline injection to a Black Hills Energy natural gas distribution line (2018)
- % energy neutral prior to new microturbines and co-digestion: 0%; As of Q2 2019, WRRC is 40% energy neutral due to reduced turbine output and increased plant demands (W. O'Brien, comments to author, June 27, 2019).
- Biosolids management: 15.5 tons of Class A biosolids are produced per day, and are land applied as soil amendment, with Nutri-Ject Systems contracted to distribute them

Drivers and Goals

- Drivers: large scale investment to upgrade the outdated and inefficient facility provided an opportunity to incorporate resource recovery
- Goals: public health, environment, energy efficiency, energy neutrality, resource recovery, service to waste generators, revenue stream

Summary

The City of Dubuque, with a population of 58,000 situated on bluffs of the Mississippi River where Iowa, Wisconsin, and Illinois meet, is committed to economic and sustainable development. The city initially articulated its commitment to sustainability in 2006, in its Sustainable Dubuque vision statement.

Through partnerships among city government, private industry, and the Greater Dubuque Development Corporation, Dubuque subsequently has implemented multiple initiatives to achieve its sustainability goals.

In its early years, a major component of the Sustainable Dubuque initiative was upgrading and re-envisioning its wastewater treatment plant. During 2002-2007, Dubuque experienced numerous alleged violations of its NPDES permit due to sanitary sewer overflows, resulting in violation of effluent limits for TSS, total residual chlorine, and CBOD, as well as failures to comply with its pretreatment program permit requirements. In 2011, following several years of negotiation, the City of Dubuque reached a settlement with the State of Iowa and the U.S. Department of Justice for the alleged violations. The planned major upgrade of the city's Water Pollution Control Plant was acknowledged by and incorporated into the consent decree as a remedial measure to ensure compliance with the Clean Water Act and its NPDES permit.

Leveraging a major overhaul of an outdated and inefficient facility, the city used the Sustainable Dubuque Principles as a framework to design the transformation of the 10-mgd plant from a Water Pollution Control Plant into a Water and Resource Recovery Center (WRRC). AD was selected as the biosolids management method based on this sustainability framework. Building on the AD investments, which were sized to accommodate future growth, the city also made investments in microturbines to produce combined heat and power, and installed piping with connections to the AD to incorporate HSOW from local biodiesel and food processing plants.

After the $67 million upgrade was in place, the WRRC was producing more biogas than it could use in-house. In 2018, a public-private partnership between the City of Dubuque and BioResource Development built a renewable natural gas production facility at the WRRC that transforms biogas into renewable natural gas (RNG) that is injected into a nearby natural gas distribution pipeline of Black Hills Energy.

The City of Dubuque demonstrates that, with a commitment to sustainability, a community can transform an outdated and inefficient pollution control plant into a revenue-generating Water and Resource Recovery Center.

6.2 Project 1: Aqua est Vita: Transformation from a Pollution Control Plant to a Resource Recovery Facility

6.2.1 Sustainable Dubuque Initiative and a Consent Decree

6.2.1.1 A City-Wide Ethic for Sustainability

In 2006, the City of Dubuque promulgated "Sustainable Dubuque," a community-led sustainability initiative spearheaded by Mayor Roy D. Buol in consultation with residents about their priorities for the city. The goal of Sustainable Dubuque aimed to push Dubuque to the forefront of urban sustainability. Its 12 principles fall into three categories (City of Dubuque 2013):

- Economic prosperity: community design, smart energy use, resource management, regional economy.
- Environmental and ecological integrity: clean water, healthy air, native plants and animals, reasonable mobility.
- Social and cultural vibrancy: community knowledge, green buildings, healthy local foods, community health and safety.

Through partnerships among city government, private industry and the Greater Dubuque Development Corporation, Dubuque has implemented multiple sustainability programs to achieve its goals. One that is particularly relevant to the wastewater utility transformation is Smarter Sustainable Dubuque, initiated in 2009. Working with IBM's Watson Research Center and other partners, the City of Dubuque has deployed "smart" technology to track the delivery of services like water, energy, transit, health and wellness, and waste management. With the technology, consumers acquire greater knowledge and control over their usage, and city policymakers receive new insights on how to conserve Dubuque's resources, become more sustainable, and improve opportunities in an increasingly competitive world economy (Greater Dubuque Development Corporation).

Another relevant element is Dubuque's commitment to climate action. In 2013, Dubuque partnered with the non-profit Green Dubuque to develop a climate action plan to implement its commitment to a 50% reduction in greenhouse gases relative to 2003 by 2030.

6.2.1.2 Consent Decree for Remedies for Clean Water Act Violations

In 2011, the U.S. Department of Justice and the Iowa Department of Natural Resources (DNR) lodged a consent decree requiring the city to take all necessary measures to achieve compliance with federal and state water pollution control laws and the city's NPDES permit. Between 2002 and 2007, the city of Dubuque accrued approximately 687 alleged violations of effluent limits for total residual chlorine, carbonaceous BOD, and total suspended solids from its Water Pollution Control Plant (WPCP), primarily in wet weather conditions. In addition, the city's WPCP was cited for failure to issue pretreatment permits to industrial users and for 39 sanitary sewer overflows (United States District Court for the Northern District of Iowa Eastern Division 2011).

To provide remedies for these alleged violations, the decree required the city to implement a number of system and process upgrades, including an upgrade of the WPCP in accordance with a construction plan designed by Strand Associates and approved by the Iowa DNR. Other remedies included three-million dollars in construction upgrades for the sewer collection system (which was completed prior to the consent decree), remedial action for biosolids disposal to avoid accumulation of solids in the WPCP's effluent, and a $205,000 fine (United States District Court for the Northern District of Iowa Eastern Division 2011).

6.2.2 Aqua est Vita (Water is Life): Transformation into a WRRC

Prior to implementation of the consent decree, the Dubuque WPCP was a 10-mgd secondary treatment plant with no anaerobic digestion. The plant sent over 10.5 tons of wastewater solids per day to a fluidized bed incinerator, which cost the plant $300,000 annually in fuel alone. Ash from the incinerator was sent to a landfill. Water effluent leaving the plant was treated using chlorine disinfectant, resulting in chlorine discharges to the Mississippi that periodically exceeded permit limits.

The city used the Sustainable Dubuque principles as a framework to design the transformation from a Water Pollution Control Plant into a Water and Resource Recovery Center (WRRC) (U.S. Department of Energy 2016). Jonathan Brown, the plant manager at the time, explained the significance of the name change: *Aqua est vita. Water is life, in Latin. Resources are those other things we need for life. Recovery is bringing those resources back to use. Center, the place where it happens*.

The plant redesign and upgrade included 1) improved wastewater treatment technologies that enable reuse of effluent for heating and cooling, and 2) adoption of anaerobic digestion to manage wastewater solids, which also enabled the acceptance of high-strength waste from local industry and the recovery of energy and nutrients contained in biosolids. The design process considered opportunities to achieve greater sustainability by repurposing structures, reusing biosolids, promoting energy efficiency, generating renewable energy, and reusing water. Several pieces of the upgrade – including cogeneration, septage receiving, energy recovery, high-efficiency buildings, low energy lighting, and low maintenance landscaping – went above and beyond the elements in the 2011 consent decree.

To engage local stakeholders, the city held a series of public meetings covering the content of the project. An additional meeting was held with the largest users. The Dubuque City Council made the final decision to approve the design project, taking into account both financial return on investment and sustainability factors.

6.2.2.1 AD, Wastewater Solid/Hauled Waste Receiving Station, and Biosolids Management

In keeping with the principle of repurposing obsolete structures, the WPCP renovated the biosolids incineration building to include biosolids dewatering and conveyance, as well as a waste-activated wastewater solid storage tank. The AD process included equipment from Ovivo. In-house staff constructed the receiving station.

The plant added four digesters, two mesophilic and two thermophilic, with a volume of 985,000 gallons each, for a total capacity of 3.94 million gallons.

To make it possible for the plant to accept hauled feedstocks directly into the digesters, it also added a hauled waste receiving station. The receiving station consists of piping with camlock fittings that discharge to the WRRC's blended wastewater solid storage tanks, where wastewater solids and HSOW are continuously mixed. The total capacity of the two blended wastewater solid tanks is 110,000 gallons. The feed-in rate to the AD is controlled by adjusting the speed of the rotary lobe digester feed pump. The receiving station does not have any equipment to screen out contaminants from HSOW or FOG.

Noting that he did not want to enter the biosolids hauling business, Jonathan Brown contracted Nutri-Jects Systems to haul and land apply biosolids on approved farm land. Brown notes that contracting with a company that can communicate the benefits of biosolids and address any concerns of farmers helps to simplify the biosolids disposal process (Day 2015).

6.2.2.2 Biogas Production and Energy Generation

To generate power, Unison Solutions provided the combined heat and power system, including three 200-kW Capstone microturbines. The CHP system generated 75% of the plant electricity needs, around 530 kW of the 650 kW electricity demand on a typical day. The modular CHP system has room to expand – it can accommodate two more turbines (Day 2015).

6.2.2.3 Other Elements to Increase Sustainability

In addition, the plant added a UV light disinfection (OZONIA) system to replace the chlorine disinfection system, a new supervisory control and data acquisition (SCADA) system, a new primary clarifier, new grit removal equipment, and odor control covers for the four primary clarifiers. To reduce water use, the WRRC added sustainable landscaping such as rain gardens, native plants and low-mow grass. In order to reuse water, treated effluent from the plant is pumped through a heat exchanger to the administrative buildings and laboratory to provide building heat. This is the first WRRF in Iowa to meet Energy Star requirements (U.S. DOE 2016).

Most upgrades were completed by October of 2013, with the final set of upgrades completed by 2014.

6.2.3 Implementing Co-Digestion

As noted above, the plant redesign incorporated elements to accommodate hauled-in waste. One of Dubuque's motivations for co-digestion was to increase biogas production, and create energy cost-savings. However, another important motivation was to provide a service to local companies generating liquid wastes, while protecting the regional environment from their waste products. Local leaders promoting economic development believe Dubuque is a more attractive location for business expansion and for new businesses as a result of the availability of this service (City of Dubuque 2015b).

Dubuque began accepting hauled-in wastes for co-digestion in 2014. Food manufacturing and bio-diesel companies were the initial suppliers of co-digestion feedstock, including Hormel, Rousselot and Western Dubuque Biodiesel (City of Dubuque 2015b). With the new facility, companies were able to shorten the distance they haul their waste products by as much as 90 miles (City of Dubuque 2015b). Hormel realized a 60% reduction in disposal costs due to the ability to dispose of wastes at the WRRC. The WRRC also accepts FOG.

William O'Brien, plant manager since Jonathan Brown retired in 2016, notes that feedstock quantities have been consistent since implementation. With its current level of co-digestion, the WRRC still has 20%-25% unused AD capacity. The utility is planning to construct a permanent receiving station in a few years, at which time they will consider expanding co-digestion to use the excess capacity. (See more details below.)

Tipping fees, which are negotiated with each industry based on feedstock gas production, digestibility, and the market, range between $0.03 and $0.06 per gallon (William O'Brien, interview with authors, December 12, 2018). FOG tip fees are $0.06 per gallon.

6.2.4 Project Impacts and Risk Management

6.2.4.1 Operational Impacts

AD Operational Upsets

The WRRC has addressed some operational challenges, particularly when starting co-digestion. At times the plant has found it difficult to achieve a consistent feed-in rate. Once the WRRC overloaded their digester, causing an upset; as a result, haulers had to take their wastes out of town for a month. And WRRC staff have observed foaming and rapid rise in their digesters on occasion, which they attribute to the high amount of volatile solids fed to the digesters, and not specifically to one source of waste. The variability in feedstock content can also pose a challenge. FOG contamination is particularly challenging because the plant does not currently have the capacity to screen it (William O'Brien, interview with authors, December 12, 2018).

To address these challenges, the WRRC is planning to spend an estimated $1.6 million to upgrade to a permanent receiving station and storage system in FY2022 and FY2023. WRRC staff estimates these upgrades, which will include equipment for screening, pumping, storage, and mixing, will reduce operating costs by $30,000. When the upgrades are complete, the utility plans to explore options to expand co-digestion, including the possible inclusion of food scrap slurries.

WRRC staff also observe struvite buildup from additional ammonia and phosphorus (P). The WRRC piloted the AirPrex phosphorus removal system to test P removal. The investment is scheduled in the capital budget for FY24 and FY25: it did not fit in budget prior to that time due to debt service expense. Currently, the city manages struvite with additional monthly equipment cleanings. The WRRC is part of the city's nutrient reduction strategy, which helps to limit nutrients to the Mississippi River.

Biogas Production

Prior to the 2013 major upgrades, the plant did not produce biogas. With the addition of anaerobic digestion, the WRRC produced on average 225,000 scf of biogas per day from plant wastewater solids. Co-digestion increased output by 75,000 to 175,000 scf per day, for a total of 300,000 to 400,000 scf per day.

Energy Efficiency, Production, and Purchases

Innovations in design, construction and management of the facility have cut heating and cooling uses by 25-30% compared to the prior plant configuration, and have cut electricity demand by 40-50%, from 1000 kW to 500-650 kW as of 2016 (U.S. DOE 2016).

Soon after installation, the microturbines were operating much of the time, and producing 75% of onsite electricity demand. As a result of the increased efficiency and onsite generation, the plant's electricity purchases dropped from 1000 kW to 200 kW as of 2018 (City of Dubuque 2019).

However, equipment downtime has increased over time and – even though the WRRC has a protection plan for microturbine parts – they have to wait five to six months for replacements at times. Onsite production averaged 3,356,826 kWh per year in 2016, 3,024,405 kWh in 2017, and 2,051,784 kWh in 2018. At current production rates they are on track to produce a little over 3,000,000 kWh for 2019.

Biosolids

In 2011, prior to the upgrades, the plant incinerated its wastewater solids and sent the ash to landfills. Now, with anaerobic digestion of the wastewater solids, about 100 wet tons of Class A biosolids are produced each week, and applied to nearby agricultural lands (U.S. DOE 2016).

With the adoption of co-digestion, the increase in biosolids has been minimal. The plant's HSOW feed stocks are highly digestible, and do not contribute greatly to biosolids production.

Environmental Impacts and Regulatory Compliance

The 2013 upgrades have removed 10 tons of BOD per day from the effluent discharged to the Mississippi River and removed one ton of chlorine gas introduced to the atmosphere per week (Dubuque Water & Resource Recovery Center 2015).

By reducing electricity use by 400 kW per year, the plant has reduced GHG emissions by 4,715 metric tons of CO2e (U.S. DOE 2016). The WRRC is in general compliance with their NPDES with irregular exceedances attributed to wet weather.

6.2.3.2 Financial Impacts

Investment Costs

The total investment cost of the project was $67 million. It was funded by a $65 million, 26-year Iowa State Revolving Fund (SRF) loan with 0% interest on the design phase and 2.0% interest on the construction phase. The plant financed two of the three microturbines with a 20-year 2013 SRF loan for $3 million with an interest rate of 2.0%; the third one was funded by a local company as part of a federal Consent Decree for noncompliance with EPA regulations (O'Brien, personal communication with authors, 6/19/19).

The WRRC pays approximately $3.7 million per year to pay back the 2010 SRF loan and approximately $186,000 per year to pay back the 2013 loan, with final payment years of 2039 and 2033.

To cover a portion of the increase in debt service, Dubuque has increased its customer fees. Residential user rates have increased from $31.91/800 cubic feet (cf) water in FY2014 to $40.32/800 cf in FY2018, representing a 26.4% increase since the project's completion in 2014. For comparison with other communities, the average household rate per month in 11 Iowan cities with populations over 50,000 ($37.31) was only 8.5% below that in Dubuque ($40.43) in FY2019, despite the fact that Dubuque has one of the newest wastewater treatment plants in the state.

Operating Revenues and Costs

As a result of the major plant upgrades, the plant receives a consistent source of new revenue from HSOW tipping fees and has realized savings in electricity purchases and biosolids management costs.

Operating efficiencies have reduced the need for one staff person, reducing staff costs by $80,000 per year (City of Dubuque 2015b). Sewer O&M costs also have decreased with the diversion of FOG to the digesters. On the other hand, equipment maintenance costs have tripled from approximately $60,000 per year to $180,000 per year.

Anaerobic Digestion: In the startup year for co-digestion, the WRRC received $87,000 in tipping fees in FY2014, the lowest year due to co-digestion startup. The highest tipping fee revenue to date occurred in FY2017, when the WRRC received $274,326. Tipping fees from HSOW generators were $189,644 in FY2018 (City of Dubuque 2017).

Energy Production: As of 2015, the plant has realized $237,000 in annual electricity cost savings due to the combined impact of the plant's efficiency upgrades and onsite electricity production, which reduced annual electricity costs from $579,205 in FY2011 to $384,033 in FY2019 (City of Dubuque 2020).

Biosolids Management: The WRRC saves on average about $200,000 per year using AD and contracted biosolids hauling. Currently the WRRC pays a fixed fee of $174,000 to Nutri-Ject for biosolids hauling in addition to a variable fee of $19.50 per dry ton of biosolids. The WRRC also observed increased polymer costs because a more expensive polymer is required for treating anaerobic digestate compared to primary and secondary wastewater solids sent to incineration.

On the other hand, the plant is saving $300,000 in fuel costs previously incurred to run the fluidized bed incinerator. Maintenance costs for the incinerator ranged from ~$12,000 to $50,000 per year. Maintenance for the anaerobic digesters tracks similarly: the WRRC included $40,000 in FY2019 and $60,000 in its FY2020 equipment maintenance budget to clean one digester per year.

6.3 Project 2: Conditioning Biogas for Pipeline Injection

William O'Brien and others were troubled that the WRRC was producing more biogas than it could use at the plant, and consequently was flaring the excess. David Lyons, the Sustainable Innovations Coordinator for the Greater Dubuque Development Corporation (GDDC), began searching for a partner that could create value by recovering the excess methane. GDDC, Dubuque's local economic development group, supports economic growth throughout the city and acts as a liaison between Dubuque's businesses and city government. GDDC's effort to develop an approach for recovering the excess methane aligned with the city's 2013 plan to reduce GHG emissions to 50% below 2003 levels by 2030.

GDDC and the city identified key goals for the project, including (City of Dubuque 2015a):

- Create additional positive environmental outcomes.
- Generate revenue or cost reductions.
- Create opportunity for additional economic development and growth in the Greater Dubuque region.
- Not require additional direct investment or risk from the city.

6.3.1 Pipeline Injection was Chosen as Preferred Strategy

The city concluded that the best strategy was conditioning its biogas to meet the requirements for pipeline injection into a nearby Black Hills Energy distribution pipeline. The city could have added another microturbine to produce electricity; however, their agreement with Alliant Energy currently does not allow them to export electricity to the grid and prohibits the WRRC from producing any more electricity than the total demand minus 150kw. If the WRRC were to sign a new interconnect agreement and a power purchase agreement to sell to the grid, Alliant would pay a tariff based on avoided cost, which represents a steep discount from the price Dubuque pays Alliant for its electricity and would not provide a sufficient rate of return. In contrast, the pipeline injection option offered an acceptable ROI.

The city contracted with BioResource Development (BRD), an Omaha, NE-based biogas upgrade company, to implement the strategy. GAIN Clean Fuel, a division of U.S. Venture Inc., manages the downstream activities related to RNG production for BRD. This is the second project in which BRD and GAIN Clean Fuel have worked together. Dubuque's Mayor Roy D. Buol said, "This project results in new revenue to the city, the reuse of waste, and progress in cleaner air. It's a 'win-win-win.'" (Digital Journal 2018).

In February 2018, BRD completed the installation of a Pressure Swing Adsorption (PSA) system manufactured by ANR. The system is sized to process the 350 scfm produced by the WRRC's digesters.

Dubuque is an ideal partner for BRD. The WRRC already had biogas conditioning equipment located onsite, which produced biogas with 70% methane at 100 psi for use in the microturbines. The BRD PSA upgrades this biogas to 97% methane for pipeline injection. In addition, the WRRC already had an onsite pipeline that was previously used for distributing natural gas to the incinerator. No pipeline extension was needed but a second service was added near to the original service.

6.3.2 Financial Structure Allocates Operational Risks to BRD

BRD and Dubuque have a public-private partnership, in which BRD assumes the financial risks associated with operating its system. The city owns the biogas conditioning facility, while BRD owns the PSA system. BRD funded the capital improvements needed for the installation of the PSA system and pays the city $10,000 annually to have the right to operate the facility; it also covers all of the operating costs to run the PSA system. BRD pays the city 5% of the gross revenues generated from the sales of Renewable Identification Numbers (RINs) and the renewable natural gas.

The City of Dubuque and BRD work under a unique financing agreement that will slowly transition from allocating the WRRC's biogas to both CHP and pipeline injection, to allocating all of the WRRC's biogas to pipeline injection. As more of the WRRC's biogas is directed away from the microturbines to the PSA system, BRD further will pay the city to replace each unit of biogas diverted to PSA with a unit of natural gas to run the turbines (Dubuque Water & Resource Recovery Center 2015). BRD has not yet completed the upgrade to the turbines to allow them to use natural gas, so they are not yet providing the expected volume of replacement natural gas.

Since February 2018, the WRRC produces approximately 300,000 cubic ft per day. It projects BRD will pay the WRRC $214,354 in FY2019, increasing to $221,609 in FY 2020. In 2019, this line item represents 5% of the gross revenue for BioResource Development from RNG sales and RINS ($63,843), lease of the site ($10,000), staff time reimbursement ($56,000), reimbursement of gas ($12,000) and electric cost ($79,766) (City of Dubuque 2019).

BRD has currently registered the project for D5 RINs. They are developing an application for a D3/D5 RIN split.

6.4 Lessons Learned

The City of Dubuque demonstrates that, with a commitment to sustainability, a community can transform an outdated pollution control plant into a revenue-generating and sustainability-enhancing Water and Resource Recovery Center that generates revenue and enhances sustainability.

6.4.1 Create Value and Manage Risks

6.4.1.1 Creating Value

The WRRC experiences challenges with co-digestion. At the same time, co-digestion contributes to achieving the economic, environmental, and social goals outlined in the Sustainable Dubuque principles. The city receives substantial revenues from tip fees and from RNG sales, and accrues energy and O&M cost-savings from diverting FOG and other HSOW from the sewer collection system and wastewater treatment process. With its production and use of renewable energy, the city has reduced GHG emissions. And the new environmentally friendly disposal option provides a service for local companies generating liquid organic wastes. Local leaders believe that Dubuque is more attractive for business expansion as a result of this service.

6.4.1.2 Managing Risks

Stakeholder Support

In the mind of Jonathan Brown, the plant manager during the planning and initiation of the major renovation, buy-in for the project from the rate-paying public was critical to long-term economic success. To engage stakeholders when the project was being developed, the city held several public meetings, including one specifically for the city's biggest wastewater customers. The community did provide support for improving sustainability. For example, some residents complained of the wasted opportunity when observing biogas flaring, advising the city to seek a better use for the energy source (William O'Brien and Jonathan Brown, interview with the authors, June 12, 2019).

The WRRC developed backup outlets for its liquid waste feedstocks, to manage the risk of not being able to provide a disposal site for liquid waste generators due to operational issues. It also is proactive in addressing any concerns farmers have with land application.

Operational and Regulatory Risks

Operational risks from digester upsets currently are managed primarily by control of feed-in rates and laboratory analysis. Now that co-digestion has proven successful, the city plans to invest in permanent HSOW receiving and preprocessing infrastructure to enable better control of the FOG and HSOW feedstocks entering the digesters. This investment is anticipated to reduce digester issues and lower O&M costs, as well as to make it possible for the plant to expand co-digestion, boosting biogas and increasing tipping fee revenue.

Co-digestion increases nutrients in the wastewater treatment process, which can lead to operational challenges with struvite formation that are currently managed through regular maintenance. It also can lead to increasing ammonia levels in liquids from the digester, which is currently addressed by capturing the centrate and pacing its flow back to the wastewater treatment train. With the prospect of future restrictions on nutrients in effluent, the plant is monitoring nutrient levels and evaluating future equipment investments to mitigate nutrient levels.

6.4.2 Replicability

O'Brien indicates the key elements to Dubuque's success with co-digestion, as part of its broader upgrade to become a resource recovery center, include the city government's commitment to the Sustainable Dubuque principles, broad community support for the resource recovery goals, and public/ private partnerships to implement the new vision. He believes their co-digestion success is replicable at other WRRFs where there is excess capacity in their digesters; WRRC staff have an experimental attitude, dedication to "doing the right thing", and a willingness to build partnerships; and there is strong support for investments in resource recovery from the utility decision makers and from the rate-paying public.

CHAPTER 7

Clearwater Road Wastewater Treatment Facility, Derry Township Municipal Authority (DTMA), Pennsylvania

7.1 Context and Summary

About the Utility

- Service area: Township of Derry, portions of Hummelstown Borough and Townships of South Hanover, Lower Swatara, Londonderry, and Conewago
- Operating since: 1977
- Wastewater customers served: 20,000 in six municipalities
- Wastewater treatment plants: Clearwater Road WRRF, and Southwest WRRF (unstaffed satellite facility, 0.6 mgd capacity)
- Employees: 36
- Governance: seven-member Derry Township Municipal Authority Board

About the Clearwater Road WRRF

- Location: Hershey, PA
- Size: 5.0 mgd permitted flow, 3.9 mgd average flow
- Anaerobic digesters: one 1.2-mgd primary egg-shaped mesophilic digester, one secondary digester
- Food waste feedstocks: FOG (enters through headworks), Hershey wastewater solids, Divert food scrap slurry (2017-2018, suspended acceptance as a result of the 2018 flood that damaged the ancillary components of the biosolids thermal dryer process), Grind2Energy slurry, food processing residuals; food waste as share of total AD feedstocks: 35% volatile solids (VS) load (Rehkop 2018b)
- Feedstock preprocessing: DTMA pretreats FOG onsite; Divert and Grind2Energy preprocess food waste offsite
- PPL is the electricity provider, current cost is $0.0632/kWh (2019) for generation and transmission; with distribution charges, the average total cost is $0.07/kWh (2019)
- Biogas Use: 270kW cogeneration engine, biosolids thermal dryer, boilers. Biogas production: prior to food scrap addition: 4.5 MCF per month, post food waste addition: 8 MCF per month
- Energy (electricity) neutrality: 21% (2014-2018 average)
- Biosolids management: Class B dewatered cake for land application; and from 2009 until July 2018 (when the thermal dryer went offline due to flooding), DTMA produced Clearwater SteadiGro Class A EQ product, which has a PA Department of Agriculture Registration as a fertilizer and was sold for $10 per ton

Drivers and Goals

- Drivers: biosolids management challenges, increasing electricity prices
- Goals: increase onsite energy generation, keep customer rates low, provide a nearby outlet for community sources of FOG and reduce improper management

Summary

The Derry Township Municipal Authority (DTMA) has articulated a threefold mission: 1) to provide cost-effective public service to protect and enhance the water environment and quality of life for their local and regional community, 2) to become self-sustainable by utilizing beneficial renewable energy on-site and decrease dependency in the volatile electric and petroleum marketplace, and 3) to generate increasing amounts of annual cost savings to DTMA and our rate payers" (Rehkop 2018b). DTMA embodies a "Utility of the Future" outlook, with its dual focus on sustainable practices and on generating revenues by creating business ventures to recover valuable resources. Over time, the utility has incrementally expanded the scale and scope of food waste feedstocks at its primary wastewater treatment plant on Clearwater Road. Primary goals for co-digestion are to provide a disposal option for the generators and to create value from the production of energy and biosolid products enabled by the increasing biogas production.

The Clearwater plant has collected tip fee revenues for hauled waste starting in the 1990s with deliveries of septage and FOG. Following its investment in an egg-shaped digester (ESD) in 2000 to improve wastewater solid management, it started producing biogas. To mitigate operational problems resulting from the acceptance of FOG, the plant implemented a FOG pretreatment system in 2005; as a result, the WRRF was able to greatly expand its acceptance of FOG, becoming the region's primary FOG disposal option. Because of electricity market conditions at the time, it was not cost-effective to invest in combined head and power (CHP), so the additional biogas was directed to a steam-based dryer for biosolids purchased in 2007, enabling production and sales of a Class A EQ fertilizer product, Clearwater SteadiGro.

Following investments that increased the efficiency of biogas use for managing biosolids, changes in the PA electricity market and increasing amounts of biogas flaring, in 2010 it became cost-effective for DTMA to invest in a small (270 kW) CHP engine. The engine yielded energy cost savings, though the pace of projected cost savings has not been realized due to substantial downtime as a result of facility flooding and frequent maintenance issues.

With a goal of moving toward energy neutrality, the Clearwater plant began experimenting with accepting other food wastes in 2017 to understand its digester capacity and ability to generate additional biogas. Divert, an organic waste management company, supplied the greatest share in the form of a food scrap slurry.

Currently the Clearwater plant is embarking on a very ambitious expansion of its anaerobic digestion (AD) capacity, its co-digestion program, and its energy generation capacity, with the immediate goal of achieving onsite energy neutrality and a long-term goal of selling biomethane via tube trucks or pipeline injection. Under the legal authority of Pennsylvania's Guaranteed Energy Savings Act (GESA), DTMA has entered into a Project Development Agreement (PDA) with an energy savings contractor (ESCO) for a performance-based component of the expansion, including a guaranteed revenue stream from tipping fees. In addition, DTMA is proceeding with a traditional design-bid-build project to upgrade and expand the existing gas conditioning system, waste gas flare and safety equipment, and a combined heat and power (CHP) cogeneration facility. The project will also include the replacement of the existing secondary digester cover to a flexible membrane cover for improved gas storage.

7.2 A Series of Investments in Energy and Materials Recovery

7.2.1 Investment in Anaerobic Digestion to Treat Biosolids

As part of a long-term series of investments to upgrade wastewater solid management, in 2001 DTMA installed a 1.2-mg egg-shaped anaerobic digester to further process the solids. The AD stabilized the solids and reduced their volume by 55%, yielding Class B biosolids. This improved the environmental impact and reduced the cost of biosolids management.

To manage wastewater solid in the early years (1977-1994), the WRRF used a vacuum filter and incinerator to dispose of biosolids during winter months, and used agricultural application of cake during the summer. In 1994, the incinerator was in need of expensive upgrades to ensure compliance with new air regulations, and DTMA shut down the incinerator instead. Through 2001, DTMA relied mostly on landfill disposal (62-70% of biosolids sent to landfill) with the remaining share disposed of via lime stabilization and subsurface liquid injection, which increased wastewater solid management costs substantially (Rehkop 2018b).

7.2.2 Adding FOG Feedstocks and Addressing Contamination

7.2.2.1 First Round of Food Waste Feedstocks

In 1991, the Clearwater plant started accepting trucked-in septage through the facility headworks, but at the time refused grease trap wastes due to concerns about operational issues. In 1995, DTMA began noticing a high percentage of FOG, originating from restaurants mostly located in Derry Township, was mixed with septage trucked to the plant. At that time, DTMA requested that the haulers dilute the FOG waste to help reduce any operational issues at the Clearwater plant.

When the AD was constructed in 2000, the WRRF also constructed a two-lane FOG and septage receiving station to facilitate the acceptance of FOG and septage. The new receiving station used the new plant headworks to perform the screening and grit removal of the FOG and septage. FOG and Septage receiving has been a source of revenue that saves ratepayers money, and it also makes a contribution to biogas production.

7.2.2.2 Preprocessing Strategy: FOG Pretreatment and Receiving Station

Accepting FOG initially caused operational issues, including clogging in the primary wastewater solid line and primary clarifiers, which required removing 30-40 cubic yards of grease from primary clarifiers every three months. Also, biosolids produced from the AD constructed in 2000 were visibly contaminated with grease specks (Schutz 2017).

Given the abundant supply of FOG in the area, DTMA determined that investment in FOG pretreatment could mitigate the operational issues, and thereby make it possible for them to accept more FOG which could yield more revenue as well as substantially increase biogas production (Chin 2009). In 2005, DTMA invested in an aerobic grease pretreatment process (AGP) and located it near the septage receiving station. Trucked-in full-strength FOG is aerated and mixed in a 40,000-gallon process tank for 48-72 hours. Bacteria enzymes and magnesium hydroxide are also added to the FOG for pH control and to accelerate the breakdown of long chain volatile fatty acids. The pretreated FOG mixed liquor is discharged from the AGP into the headworks with plant influent, which passes through screening and grit removal processes. After settling out in the primary wastewater solids, the pretreated FOG makes a positive contribution to biogas production in the anaerobic digester due to high volatile solids and good alkalinity.

Having addressed the operational challenges of FOG, DTMA’s FOG acceptance program has become the region’s primary FOG disposal option. Due to its location near a tourist hub (Hershey PA hosts the Hershey chocolate plant, the Hershey Park amusement park and many other Hershey-related destinations), an ample supply of local FOG is available. Moreover, DTMA is located along a transportation route for FOG haulers and is therefore a convenient option for disposal (Bill Rehkop, interview with authors, July 25, 2018). Though they do not have contracts with the haulers, they receive a predictable supply of FOG from a consistent set of haulers.

7.2.3 Energy Investments

7.2.3.1 Thermal Dryer and Centrifuge for Biosolids

With the additional biogas produced from FOG acceptance, DTMA commissioned a study to evaluate various energy options in 2004. Because electricity prices were still capped at the time in Pennsylvania, investing in a CHP engine did not make economic sense. Driven by the desire to produce a marketable Class A biosolid product, in 2005 DTMA alternatively invested in a steam-based dryer for biosolids fueled by biogas. The dryer enabled production of a valuable Class A EQ fertilizer product, marketed as Clearwater Steadigro. In 2008, the installation of a centrifuge that dewatered the biosolids improved the energy efficiency of biosolids production and reduced biogas use by increasing cake solids.

Currently, the dryer remains out of service due to a flood in July 2018 that damaged the dryer's ancillary systems. DTMA is evaluating options to replace the existing dryer with alternate dryer technologies in order to meet the projected design solids loading and to produce a marketable Class A biosolids product.

7.2.3.2 CHP Investment

As a result of the increased energy efficiency, the Clearwater plant was flaring waste biogas. DTMA was motivated to find a way to create value from this excess biogas. Combined with a 20-30% increase in electricity rates when electric power deregulation occurred, as well as an increased opportunity for Renewable Energy Credits (RECs), the economics of investing in a CHP system to use the excess biogas became more economically feasible than when previously considered.

DTMA chose a Liebherr 270-kW cogeneration engine for their CHP. Because biogas was primarily allocated to biosolids drying, the cogeneration engine size selected was relatively small. The engine was installed in 2010, and the associated heat recovery process for heating three buildings and the digester during cold weather went online in 2010.

7.2.4 Adding Food Waste Co-Digestion Feedstocks

When a 2015 study of the economic feasibility of purchasing a second CHP engine concluded that the plant produced insufficient biogas to support the investment, DTMA conducted a study to assess the feasibility of accepting bulk food scraps as a strategy to expand biogas production to enable future energy investments. The study concluded that while receiving and treating such waste was feasible and potentially beneficial, the logistics of generator storage, pick-up and transport as well as the difficulty and expense of debris separation proved to be significant if not insurmountable hurdles (DTMA 2017a).

Alternatively, DTMA began accepting hauled waste from various commercial food manufacturers, as well as a food scrap slurry through the Grind2Energy program in January 2017 (Bill Rehkop, interview with authors, June 14, 2019).

Then in early 2017, DTMA received a cold-call from Divert, an organic waste management company, offering to supply a preprocessed food scrap slurry, which would circumvent the logistical hurdles of pre-processing at the plant. In addition to advising firms on how to reduce or donate edible food that is wasted, Divert has moved into supplying an easily digestible food scrap slurry to digesters. The firm collects expired food wastes from nearby grocery stores, removes contamination, and grinds and mixes the organic fraction into slurry suitable for AD in a newly constructed facility in Mechanicsburg, PA. DTMA and Divert initiated a pilot program to test 18,000 gallons/week of the slurry in the WRRF's egg-shaped digester in May 2017.

DTMA did not need to make any infrastructure changes to accept Divert's slurry, which was successfully added to the egg-shaped digester with minimal operational issues (Bill Rehkop, interview with authors, July 25, 2018). To mitigate the potential for operational upsets, DTMA slowly ramped up additions of the slurry to the digester over the course of the first month. During this time, DTMA monitored volatile suspended solids (VSS) loading and destruction, biogas production, volatile acid to alkalinity ratio, and biosolids dewaterability. Following a successful pilot, DTMA and Divert established a long-term, non-binding Memorandum of Understanding, outlining the terms of the partnership (DTMA 2017b), which including an agreement to accept up to two loads a day.

As of May 2018, Divert was delivering five to 10 truckloads (30,000 gallons) per week to the WRRF. In addition, through the Grind2Energy Program, Redner's Food Market supplied 5,000 to 10,000 gallons per month, and Archer Daniel Midlands supplied 10,000 to 15,000 gallons per month of corn syrup processing waste. DTMA also accepted wastes from pet food manufacturers. Food waste loading to the digester was 12% of total load to the digester and 35% of volatile solids (Rehkop 2018b). Following the damage to the thermal dryer's ancillary systems as a result of a flood in July 2018, DTMA suspended its acceptance of Divert feedstocks.

7.2.5 Impacts and Risk Management

7.2.5.1 Operational Impacts

AD Operations

When co-digestion started, DTMA staff were careful to slowly acclimate the digester to the higher volatile solid loading associated with the new feedstocks. To mitigate the potential risk of overfoaming, DTMA added an additional foam suppressor nozzle to their digester for managing potential digester foaming.

Grease Buildup and Biosolids Contamination

FOG feedstocks (which enter through the headworks) caused grease buildup throughout the WRRF and grease specks in biosolids. With the addition of FOG pretreatment, the plant eliminated the grease build up within a few weeks, and the grease "specks" in biosolids cake in a few months. However, the addition of the aerobic system required DTMA to solve new issues including scum formation, odor, and foaming issues at the aerobic pretreatment site. To address these problems, WRRF staff added a rock trap and macerator to preprocess the truck discharges at the AGP, upgraded the system's mixing nozzles, and switched pH control from manual addition of lime to automatic addition of magnesium hydroxide (Rehkop 2018a).

After three years of various improvements, the DTMA director declared the new system a success (Chin 2009). Once DTMA eliminated major operational issues following the adoption of the new FOG pretreatment system, it changed its philosophy regarding accepting FOG waste. The WRRF staff began accepting concentrated FOG waste and dedicated grease trap loads in order to improve biogas production at the WRRF's egg-shaped digester.

Biogas Production

The WRRF had, since its inception, accepted waste wastewater solids from the Hershey Company industrial pretreatment plant and mixed it with the WWPT wastewater solids (primary and WAS). Once the digester was installed in 2001, the Hershey wastewater solid (in combination with the plant wastewater solids) was fed directly to the digester. The addition of FOG through the headworks also contributed to biogas production; however, WRRF staff found it difficult to quantify the increase in biogas attributable to FOG feedstocks because of all the variables involved in the digestion of wastewater solids (Schutz 2017).

With the addition of HSOW, biogas production at Clearwater Road WRRF increased around 40% during the period May 2017-April 2018 (including the three-month ramp-up period), relative to Jan 2017-April 2017 (Rehkop 2018b, 18). At that time, the WRRF was producing 8 MCF per month, an increase from approximately 4.5 MCF per month. DTMA attributes 32% of the WRRF's biogas production to Divert's food waste and 6% to the other added food wastes (Rehkop 2018b).

Combined Heat and Power Generation

For the CHP engine, unanticipated Acts of God, such as 2011 flood, as well as extensive maintenance needs combined with a lack of system redundancy, have resulted in extensive downtime and greater flaring of plant biogas. Maintenance issues are exacerbated because any parts required for upkeep of the Leibherr engine, which is produced in Germany, must be shipped across the Atlantic. The WRRF must take the CHP engine offline while waiting for necessary parts for regular maintenance and repairs (Bill Rehkop, interview with authors, July 25, 2018). The engine also experienced an issue with the air-fuel ratio mixing control.

The extent to which the plant is able to cover its heat and power needs with internal production varies over the year with the time the engine is online. In 2017, it was online most of the time, and the plant was able to offset 25% off its electricity and 100% of heating needs (Rehkop 2018b). The five-year average (2014-2018) for energy neutrality was 21%.

Biosolids Production
FOG was part of the baseline feedstock load (to the headworks) when the AD was installed. As noted above, adoption of FOG pretreatment substantially improved the quality of biosolids.

Food scraps have a higher volatile solid destruction rate than wastewater solids; as a result, though new food waste feedstocks increased VS loading by 50% in 2017, biosolids production only increased 15% (Rehkop 2018b). Biosolid nitrogen content and micronutrient content remained stable with the addition of food waste, while P content was "more consistently high" (Rehkop 2018a). Biosolid dewaterability and heavy metal content also remained stable. DTMA also has observed debris from food waste appearing in biosolids and has thereby required an additional filtration step at the off-site preprocessing facility to reduce the debris (Rehkop 2018a).

Thermal Dryer: In the first two years following startup of the dryer, 41% of total biosolids that the plant produced were Class A. The peak yield occurred in 2009, when it produced 1,479 dry tons (DT) of Class A biosolids, which represented 98% of its biosolids. The equipment was down for much of 2011 and 2012, due to the impact of Tropical Storm Lee. The 2018 flood also damaged the dryer's ancillary systems, and the dryer remains offline for now. DTMA plans to implement a new biosolids treatment process to produce Class A biosolids in the next five years.

With the dryer, 29% of DT of biosolids produced by the plant between April 2008 and June 2018 were Class A (Rehkop 2018b) and were marketed as Clearwater SteadiGro. This product was sold in bulk to farmers for $10 per ton, and also resulted in savings by eliminating the hauling and land application costs that DTMA incurs for Class B biosolids.

Regulatory Compliance
DTMA has experienced no issues with regulatory compliance with its NPDES permit for effluent or biosolids.

7.2.5.2 Financial impacts
DTMA investments have been designed to support the core water quality mission of the utility for its effluent and biosolids, and also three areas that bring in revenues and enable them to keep rate increases down: biosolids management/nutrient products, feed stock revenues and energy production. This research focuses on the financials of the investments for feedstock receiving and energy generation.

AD: The digester cost $3.1 million. With the investment, the plant lowered biosolids management costs, and also produced a more environmentally friendly end product relative to prior landfilling and subsurface injection of lime stabilized wastewater solids.

FOG/Septage Receiving Station and FOG Preprocessing System: The receiving station and preprocessing investments to support the expanded food waste program cost $1.2 million.

FOG and septage revenues increased with the installation of the anaerobic digester and FOG and septage receiving station in 2001 and again with the installation of the FOG pretreatment program in 2005. Facilities Director Bill Rehkop views both septage and FOG acceptance as a valuable business decision. With tip fee revenues from FOG and septage contributing to offset the debt service and plant operating costs over the years, the investment has paid itself off many times.

Expansion of Co-Digestion to Include Food Wastes (2014): The WRRF did not need to invest in additional equipment for the new food waste feedstocks.

Operating costs: Because food scraps are added directly to the digesters, the plant experiences minimal additional costs for operations and maintenance (O&M) costs with food scraps, compared to FOG and septage, which are added through the plant headworks. With the 23% increase in biosolids, the plant experienced increased biosolids costs.

Energy savings: With the additional biogas from feedstock, DTMA produced 1,505,182 kWh of energy resulting in $120,000 in electricity cost savings and savings of 17,492 gallons in fuel oil purchases worth $27,975 in 2017.

Tip fee revenues: In 2017, DTMA and Divert agreed to lower the tip fee for food scraps to $28.60 per 1,000 gallons, compared to a tip fee of $110.60 per 1,000 gallons of FOG and $37.80 per 1,000 gallons of septage (Bill Rehkop, interview with authors, July 25, 2018). Surcharges are added for comingled wastes in order to encourage haulers to separate wastes (for example, FOG should be in a separate truck from septage). In addition, DTMA's billing is based on the actual capacity of hauling trucks to encourage full truckloads.

In 2018, the WRRF collected a total of $1.114 million in tip fees from FOG, septage, and food waste. FOG wastes represented 13% of accepted volume and 33% of tip fee revenues. Other food wastes (including Divert, Redner's G2E slurry and other feedstock providers) represented 12% of tip fee revenues and 16% of accepted volume.

CHP Investments

Investment and Operating Cost: The total capital cost for the cogeneration system was $2.2 million. DTMA received a $500,000 grant from the Pennsylvania Green Energy program (financed by the ARRA and Department of Energy), and financed the remaining $1.7 million cost through municipal bonds issued by the Authority and guaranteed by the township. Between 2010 and 2018, DTMA has spent $207,722 in CHP O&M and $100,384 in biogas treatment equipment O&M.

Energy Savings: The engine was projected to produce 1,500,000 kWh/year in electricity, or 20% of the WRRF's energy consumption. DTMA estimated that they would save $150,000 in electricity costs using an estimated price of $0.10 per kWh. In addition, DMTA projected that they would save 20,000 gallons of number 2 fuel oil due to heat provided by the CHP, resulting in $47,000 in savings using an estimated price of $2.635 per gallon. Based on the $1.7 million cost to the WRRF, the payback period was estimated to be eight years (Bill Rehkop, interview with authors, July 25, 2018).

As a result of the operating issues, in 2018 – eight years after the installation of the engine – only about 50% of the cost of the engine ($688,135) has been recouped and the projected payback period is now estimated to be 20 years. It should be noted that the original engine was destroyed in the 2011 flood and the replacement unit was not installed and fully operational for more than six months.

From CHP installation in 2010 through 2018, DTMA has saved $199,742 in fuel costs and $724,564 in electricity costs. In 2017 specifically, the WRRF saved $120,000 in electricity costs (at $0.0791/kwh) and $27,975 in no. 2 fuel oil savings due to heat recovery (using a fuel cost of $1.59 per gallon). Between installation in 2010 and 2018, the DTMA has received $71,935 in RECs (Rehkop 2018b).

In hindsight, DTMA notes that redundancy may be just as important in the energy production system as it is in the rest of the plant. If WRRFs can demonstrate that engine redundancy can result in significant cost savings to decision makers, utility boards may be more amenable to the necessary increased upfront investment to achieve it (Bill Rehkop, interview with authors, July 25, 2018).

7.3 Major Expansion for "Sustainability into the Future"

DTMA is embarking on a very ambitious expansion of its AD capacity, its co-digestion program, and its energy generation capacity, for the purpose of increasing revenues (and biogas production) by expanding high-strength organic waste (HSOW) feedstocks, achieving onsite energy neutrality, and potentially selling biogas via tube trucks or pipeline injection.

DTMA is carrying out a significant portion of the expansion, with an estimated investment cost in the range of $25-$30 million, through a performance-based contract with an energy service company (ESCO). DTMA is using this financial structure to expand an ongoing business opportunity that will boost revenue to the WRRF. Unlike a typical energy savings performance contract, DTMA will rely on tip fees from HSOW and RNG revenues (long-term approach) as the revenue sources with which to pay back their debt service. Rehkop explained that, because this large project goes above and beyond wastewater treatment, they are using a performance-based structure to ensure that the project will pay for itself and be self-sustaining, and not become a burden on their ratepayers. Another advantage of the alternative delivery contracting is that it will shave off an estimated 12 months from the total time until construction completion relative to an estimated four to five years required with traditional design-bid-build contracting.

In addition, DTMA is proceeding with a traditional design-bid-build project to upgrade and expand the existing gas conditioning system, waste gas flare and safety equipment, and a combined heat and power (CHP) cogeneration facility. The project will also include the replacement of the existing secondary digester cover to a flexible membrane cover for improved gas storage. This project, with an estimated investment cost of $14 million, is currently in the design stage.

7.3.1 Performance-based Contract: Structure of Responsibilities and Risks

Under the legal authority of Pennsylvania's Guaranteed Energy Savings Act (GESA), DTMA prepared a Request for Proposals for an ESCO and based their ESCO selection on experience with food waste generator contracts or partnerships and prior experience in implementing similar co-digestion projects.

DTMA has entered into a first contract with their ESCO for project development, which includes concept, alternatives analysis, design, organics marketing, and project guarantees and price. If DTMA makes a "go" decision on the resulting Project Development Agreement, then they will sign a second contract for construction completion and startup. There will also be an option for a follow-on contract to provide additional support service.

As of September 2019, the project development is still in a preliminary phase, but the current scope of the project, and the concepts for allocating the responsibilities and risks include the following:

- Upgrades to the current egg-shaped digester.
- A new egg-shaped digester.
- Upgrades to and expansion of the HSOW receiving station.
- A new HSOW storage tank and digester feed pumping system.
- Upgrades to dewatering system to accommodate increased biosolids.

The ESCO will be responsible for the initial startup of the facilities and development of an expanded program of HSOW feedstock marketing. They will assist the DTMA staff to ensure smooth startup of installed upgrades. The ESCO will provide assistance in the sourcing of HSOW, focusing on liquid sources (not food scraps). DTMA anticipates that, in fewer than two years, DTMA will assume sole operational responsibilities for both from the ESCO.

DTMA will own all the facilities and equipment, and will be responsible for arranging financing. Based on current plans, the ESCO estimates the investment cost will be between $25 and $30 million. Since Derry

Township (the municipality) has a very strong credit rating and a low current level of debt, the option of private financing through the ESCO for the project did not offer any financial benefit. The current financing plan is for DTMA to issue municipal bonds.

However, the structure of the contract is designed to mitigate the financial risks of the utility taking on such a large debt. First, the GESA structure ensures a fixed negotiated construction price with a payback period maximum of 20 years, and with a guarantee that DTMA bears no risk of additional costs due to design errors or other incidents during construction (Bill Rehkop, interview with authors, June 7, 2019).

Second, the ESCO will provide guarantees related to the annual revenue from HSOW tipping fees for the 20-year period established in GESA legislation: they will continue after DTMA takes over operations. Initial concept is that the ESCO will guarantee between $1 million - $1.5 million annually in revenues from tipping fees. The ESCO's economic model estimates annual revenues from tipping fees to be around $900,000 per year.

As of September 2019, this project is still in a preliminary phase and economic analyses to confirm project feasibility are in draft form, but they indicate that the project has a positive cash flow. With tip fees and other revenues, the estimated payback is 20 years or less (Bill Rehkop Interview, June 7, 2019).

The project includes a significant upside potential for tipping fee revenue that make the project payback more favorable or allow DTMA to invest in other capital projects.

7.3.2 Biogas Impacts and Energy Strategies

Part of the project contribution to the DTMA bottom line is through additional energy savings and energy revenues. DTMA and the ESCO estimate that, with the construction of DTMA's new egg-shaped digester, and the enhanced HSOW feedstock program it makes possible, DTMA could increase biogas production by four times. This amount would be sufficient to produce enough electricity to increase coverage of onsite needs from 21% to 100%, plus the potential to supply 400 scfm toward tube trucks or pipeline injection.

7.3.2.1 Onsite Electricity Generation

The electricity portion of the energy expansion is being done through a traditional design-bid-build project, independent of the performance based contract. DTMA will maintain a contract with their electricity supplier, which will include a minimum purchase requirement. Until the specifics of the new equipment and associated energy needs for the performance-based contract are finalized, the final specifications for the engines have not been determined. The plan is to purchase a service contract that provides for major and minor maintenance at specified time periods; the contract cost will be based on kWh produced, which provides incentives for keeping the equipment running.

7.3.2.2 RNG Sales through Pipeline Injection

The residual biogas, after covering onsite needs for digester heating and the CHP engine, has the potential to be allocated to production of RNG to be injected into a natural gas pipeline for vehicle use. The ESCO will evaluate the potential for implementing an RNG system, and assume the investment cost and revenue risks, providing a fixed price guarantee for the gas cleaning and compression system, as well as a guarantee for revenues for sales of RNG and RINs. The economic and regulatory analysis indicates that the most beneficial approach is to provide tube trucks that will transport the RNG to the nearest suitable interstate pipeline. The ESCO also will provide all the necessary regulatory and documentation to achieve EPA RFS compliance.

The ESCO and DTMA anticipate selling the RNG to a buyer with the greatest economic benefit. UGI Utilities, DTMA's natural gas supplier, has already been approached by eight organizations looking to send biogas to the pipeline including landfill gas producers and farm digesters, though DTMA is the first WRRF.

The purchase price would provide DTMA with a stable stream of revenue for the sale of RNG to provide for capital recovery, operating/maintenance costs along with additional revenue to offset other DTMA expenditures or investments.

7.4 Lessons Learned

7.4.1 Create Value and Manage Risks

DTMA's mission statement reflects its commitment to public service that protects and enhances the water environment and community quality of life and that is cost-effective and self-sustainable. To this end, it has sought out business opportunities to create value from excess capacity in its facilities by accepting HSOW feedstocks and recovering renewables to generate cost savings.

Over time, DTMA has become the region's primary FOG disposal option, due to a prime location in a tourist-heavy part of PA and convenient location on a transportation route for FOG haulers. Subsequently, it expanded its co-digestion program to include food processing residuals and, when Divert provided the opportunity, food scrap feedstocks. It currently is engaged in an ambitious new expansion of co-digestion and energy production to achieve onsite energy neutrality and the potential to create energy revenues from selling RNG for pipeline injection.

DTMA sees financial risk management as an essential element of the new project, which it considers to be a business opportunity beyond its core activity of wastewater treatment. To mitigate the risks, DTMA is developing a performance-based contract with a private partner that will provide investment cost and revenue guarantees to ensure that the project will pay for itself and be self-sustaining, and not become a burden on their ratepayers.

To manage operational risks from co-digestion, DTMA has taken the strategy of slow ramp-ups of new feedstocks, and careful monitoring to detect any issues. To manage operational risks in energy production, DTMA has learned the value of redundancy in energy systems despite the high upfront costs.

7.4.2 Replicability

The DTMA example demonstrates that, with a leader and staff motivated to create new business opportunities and a location with ample feedstock sources, a small plant can successfully co-digest and create multiple business and partnership opportunities for co-digestion in a state without strong policy incentives for renewable energy production, greenhouse gas reduction, or food scrap diversion.

Based on the ESCO's experience in several locations, DTMA has the key requisites for a successful co-digestion project: the WRRF must have a business mindset, it must have access to a sufficient scale of HSOW feedstock for which it can charge a good market price, it must have enough site space for vehicles to deliver feedstocks and for other equipment needs, and it must have a visionary Board that will approve projects that are beyond the core wastewater competency but that make economic sense for the Authority's ratepayers.

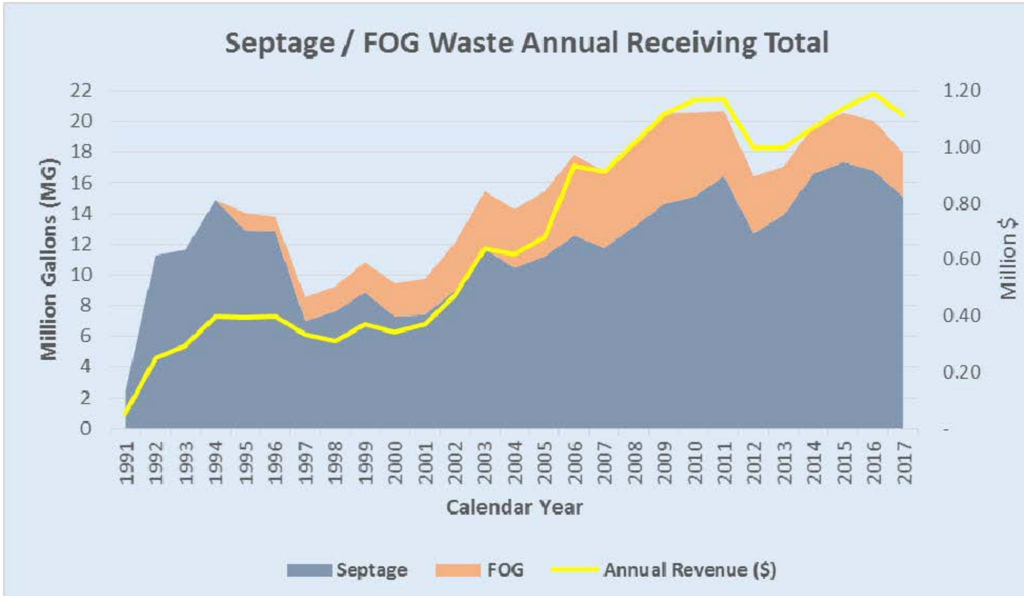

Figure 7-1. FOG and Septage Annual Gallons accepted and Annual Revenue.
Source: Rehkop 2018b.

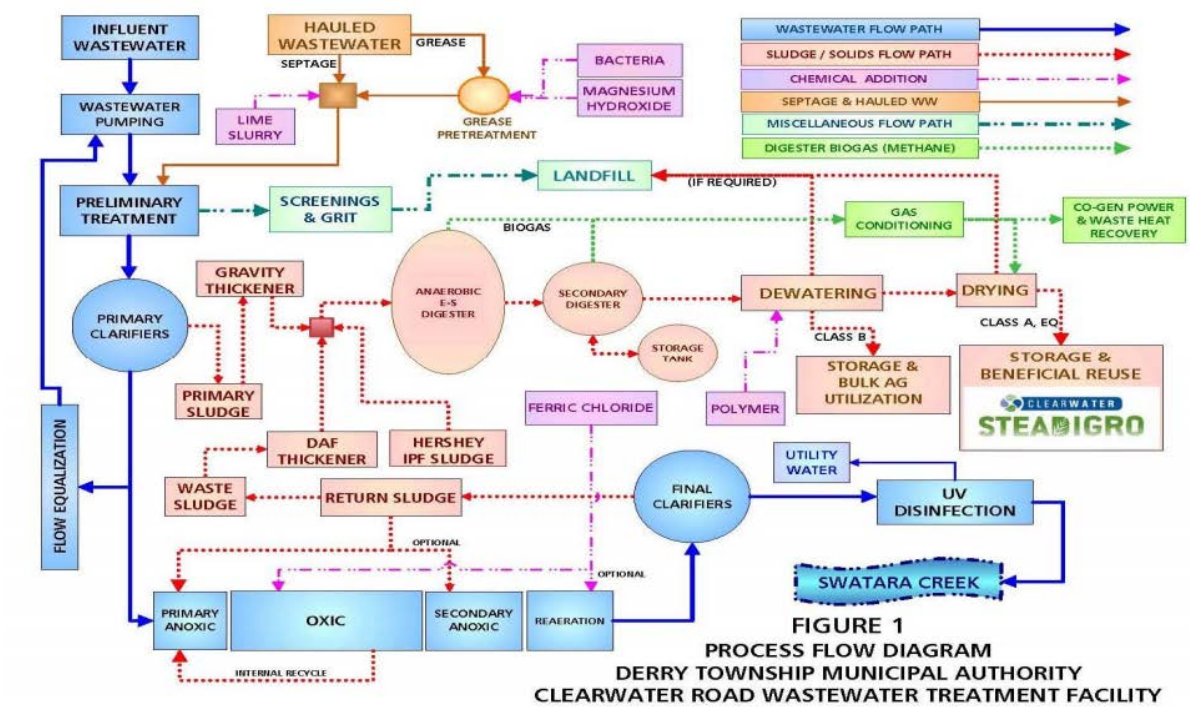

Figure 7-2. DTMA Process Flow Diagram.
Source: Rehkop 2018a.

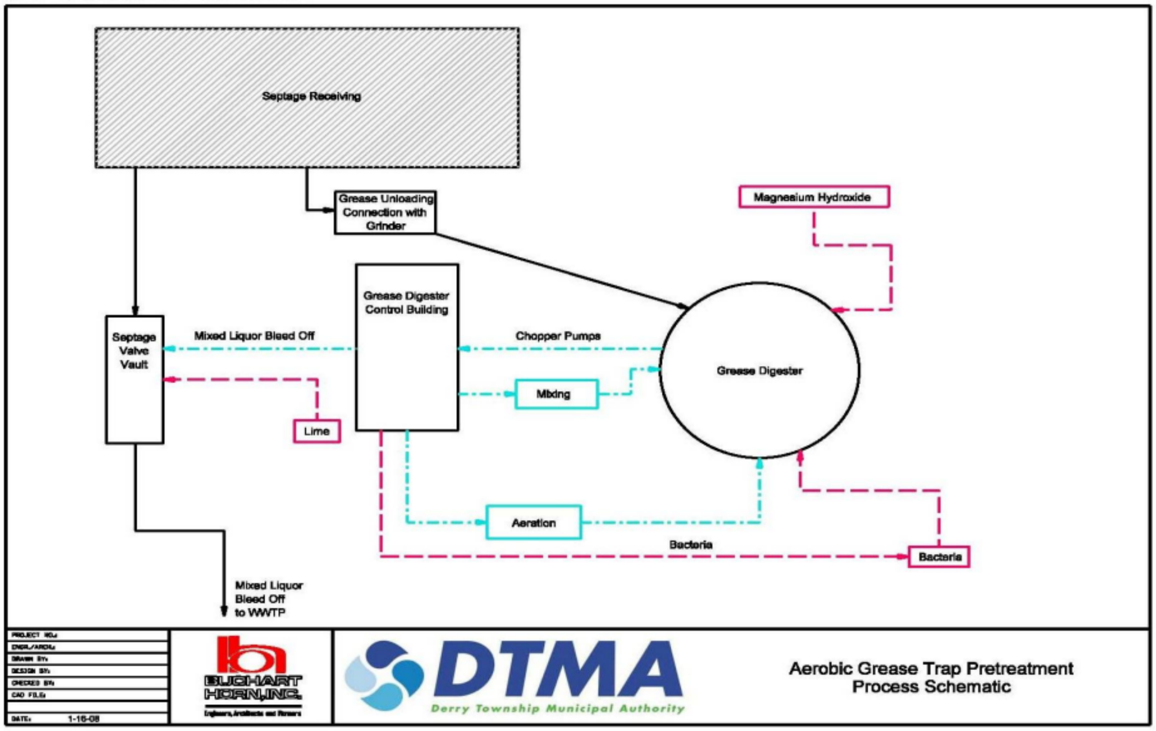

Figure 7-3. DTMA Aerobic Grease Trap Pretreatment Process Schematic.
Source: Schutz 2010.

CHAPTER 8

Central Marin Sanitation Agency Treatment Plant, Central Marin Sanitation Agency, California

8.1 Context and Summary

About the Agency

- Service area: several municipalities and unincorporated areas, and San Quentin State Prison, in the San Rafael and Ross Valley areas of central Marin County
- Operating since: 1979 (CMSA 2018a)
- Wastewater customers served: 104,500 (CMSA 2018a)
- Employees: 44 (CMSA 2018a)
- Governance: Joint Powers Authority with four member agencies, with a six-member Board of Commissioners representing the four member agencies

About the Central Marin Sanitation Agency Treatment Plant

- Location: San Rafael, California
- WRRF operating since 1985
- Size: 7.5 mgd average dry weather plant flow (permitted dry weather flow: 10 mgd)
- Anaerobic digesters: two 130,700-cubic feet mesophilic digesters
- Food waste feedstocks: FOG and slurried food scraps
- Food waste as share of total AD feedstocks: 20% by volume (Jason Dow, supplied data tables to authors, December 20, 2018)
- Feedstock preprocessing: food scraps: Marin Sanitary Services, sole supplier of food scraps, does extensive preprocessing, WRRF does additional preprocessing with a rock grinder and paddle finisher; FOG: CMSA does preprocessing
- Electricity provider and costs: MCE Deep Green
- Biogas end use: 750-kW engine generates heat and power for internal use; in future project, will sell excess electricity to Marin Clean Energy for $.105/kWh and build an additional cogen facility
- Biosolids management: (projected for 2019) Class B applied to farmland in Sonoma County (only in dry season, June-October), 55%; Alternative Daily Cover at landfills, 25%; and Class A quality bio-fertilizer (produced at the Lystek facility at Fairfield CA), 20% (Jason Dow, supplied data tables to authors, December 20, 2018).

Drivers and Goals

- Drivers: PG&E grant for feasibility study (motivated by California Greenhouse Gas Solutions Law, AB 32 (2006); Marin County's Zero Waste Goal by 2025 plus new state requirements on food scrap recycling; new state reduction goals on short-lived climate pollutants and a mandated 50% organic waste diversion from landfill.
- Goals: food scrap diversion from landfills, natural gas and energy savings and energy self-sufficiency, using underutilized digester and energy generation equipment, providing a service to local solid waste hauler.

Summary

The Central Marin Sanitary Agency (CMSA) manages the wastewater treatment for several municipalities and unincorporated areas, as well as San Quentin State Prison, in the San Rafael and Ross Valley areas of Central Marin County. It operates a wastewater treatment plant with average daily dry weather flow of 7.5 mgd and a peak wet-weather capacity flow of 125 mgd (daily flows have a wide range). CMSA's road to co-digestion began in 2008 when the City Manager of San Rafael convened a meeting with Jason Dow, the CMSA general manager, and Patty Garbarino, president of the nearby private solid waste hauling company Marin Sanitary Services (MSS), and Pacific Gas & Electric representatives to pursue a GHG emissions reduction grant from Pacific Gas and Electric (PG&E) for a feasibility study to reduce GHG emissions. San Rafael obtained the grant. With a green corporate culture and seven franchise agreements covering a service area closely aligned with CMSA's service area, MSS seemed like a good partner for sustainability-oriented CMSA. Further, the opportunity seemed fortuitous for both parties. Garbarino was looking for food waste diversion opportunities to reach Marin County's goal of zero food waste by 2025. And Dow was looking for opportunities to put to beneficial use its extra digester and cogeneration engine capacity.

Dow and Garbarino developed the concept of a Food2Energy (F2E) program that would deliver food scraps collected by MSS to a CMSA organic waste receiving facility for processing and then anaerobic digestion. In order to get the support of the community-elected bodies that approve projects and associated rate increases, and ultimately their Boards, they dedicated a lot of time explaining the program to stakeholders in their service areas.

With a positive conclusion from the methane capture feasibility study, the two organizations – the public wastewater utility and the private solid waste company – launched a close and successful F2E partnership. CMSA invested in a new receiving station for food waste and FOG, as part of a $7.65 million project to upgrade the digesters and related equipment. CMSA financed the project with extra funds in its capital investment accounts, due to leftover monies from a prior bond issue for a wet water flow management project (and substantial investment returns on the leftover monies). The communities supported rate increases spread out over five years to pay back the bonds.

CMSA modeled its onsite treatment system on concepts from nearby co-digestion pioneer, EBMUD. However, the partners were determined to avoid EBMUD's problems with feedstock contamination. As a result, MSS limited F2E feedstocks to pre-consumer commercial food waste, and built many features into its outreach, collection and preprocessing to produce a clean feedstock. CMSA conducts additional preprocessing onsite.

For a variety of reasons – including limited enforcement to date of the California organics recycling mandate – the quantity of food scraps has not grown to the expected scale. As a result, FOG represents about two-thirds of CMSA's co-digestion feedstocks.

After conditioning the biogas, CMSA uses it to run its cogeneration engine to produce electricity. The biogas displaces purchases that CMSA would otherwise make of non-renewable natural gas. Valued in terms of natural gas displacement, the energy savings are relatively low due to low natural gas prices.

With the current co-digestion program, CMSA has achieved near energy self-sufficiency. Because it still has excess digester capacity, it is planning to expand co-digestion and energy production. It recently negotiated a new contract to sell biogas to Marin Clean Energy, Marin County's clean-energy community-choice aggregation program, and set up an interconnection agreement with its local utility to enable the transmission. The next step of the project is to build a second cogeneration engine to produce heat and power.

8.2 Project 1: Food2Energy Co-Digestion Partnership with MSS

8.2.1 Managing Feedstock Risks

The 2008 Methane Capture Feasibility Study, supported by a PG&E grant, concluded that an MSS and CMSA Food2Energy partnership could create a cost effective co-digestion program to increase biogas production and facilitate its beneficial use. In 2009, CMSA and MSS developed a Food2Energy (F2E) Work Plan, which included a project outreach and education strategy, and a predesign for the F2E facilities at MSS and CMSA (Kennedy/Jenks Consultants 2011). Jason Dow of CMSA and Patty Garbarino of MSS held extensive meetings with stakeholders in their service areas to explain the program. As a result, they gained the support of the community-elected bodies that approve projects and associated rate increases, and ultimately their respective Boards.

At CMSA, a digester rehabilitation and upgrade project was expanded to include an organic waste receiving station. By enabling co-digestion of FOG and food scraps, the receiving station would allow the utility to leverage underutilized digester and cogen capacity. A further critical factor was the availability of extra funds in the capital investment accounts, due to leftover funds from a prior bond issue for a wet water flow management project (and associated investment returns).

In May 2013, MSS and CMSA entered into a formal agreement to begin the F2E partnership to support co-digestion at CMSA. As part of the agreement, MSS delivers food scrap slurry solely to CMSA.

8.2.1.1 Strategies to Reduce Contamination

The partners identified approaches at each step of the feedstock supply chain to minimize contamination. One key element was to restrict the F2E feedstocks to commercial back-of-the-house food scraps only: they excluded post-consumer commercial and residential sources of food scraps to avoid their higher contamination levels.

MSS Strategies

MSS focuses on generators' establishments as the first line in quality control. It offers two organics recycling options. The standard one accepts comingled organics, including plant materials, food-soiled paper, and food scraps, and sends them to composting. Food2Energy imposes more restrictions: it targets large food waste generators (restaurants, delis, grocery stores), and restricts collections to back-of-the house commercial food scraps. For commercial customers who choose to participate in F2E, MSS supplies an F2E bin, which is separate from a comingled organics bin.

A dedicated MSS outreach coordinator works closely with generators, starting with an assessment as to which organics option is right for each generator. She organizes the official enrollment in the F2E program, provides staff training and monitoring, and provides re-training over time as needed. Another element promoting the quality of generators' participation is a dedicated rear-loader garbage truck. Though the rear-loaders are more expensive, MSS chose this model so that the driver can inspect loads as he empties the bins into the truck hopper; the driver notes any contaminants, and communicates this back to the outreach coordinator who follows up with the responsible generator. MSS has dropped a few participants due to repeated quality problems, but its focus is on retraining any customers with repeated contamination episodes, so that all provide clean supplies. As a result of this first line in quality control, the MSS material delivered to the transfer station is very clean.

The second line in quality control is the processing onsite at the MSS transfer station. Staff first pick out contaminants on the tipping floor, and then send the material on a conveyor belt past a manual picking station line with two sorters who remove plastics, metals, etc. and past a magnet that removes any remaining ferrous metal. In the final stage, the scraps go into a grinder that produces pieces no bigger than 1" square. The processed scraps then are put into an airtight 20 cu. yd. container and hauled to CMSA, about a mile away.

CMSA Strategies

The third line of quality control is at CMSA, where the food scraps are mixed with FOG to create a slurry, and then further processed with a rock trap/grinder, followed by a drum screen paddle finisher. The resulting slurry (with up to 10% solids) is pumped into the digester.

The paddle finisher is able to remove small contaminants like twist-ties and food stickers; nearly all reject material is organic and fibrous and is composted. When the paddle finisher was first installed, CMSA planned to run biosolids through it, which would have contaminated the fibrous rejects, making them unsuitable for composting. CMSA decided not to use this practice so MSS can take fibrous material to the composting facility they use for their standard organics collection, WM Earth Care.

8.2.1.2 Strategies to Generate a Consistent Quantity of Supply

CMSA and MSS are also concerned with generating a consistent supply of quality feedstock. One key element is the level of services provided by the F2E coordinator, who actively recruits participants and provides guidance for enrollees. Another element is pricing. CMSA charges MSS a tip fee that is lower than the tip fee MSS pays for landfilling waste, a saving that MSS passes on to its customers. F2E collection is also partially subsidized by garbage collection fees. (Traditional recycling is fully subsidized by garbage collection fees.)

As a result, the fees MSS charges for F2E commercial collections, which vary by container size and service frequency, average less than 50% of the garbage rates. Over 90% of enrolled customers are able to realize cost-savings by removing their food waste from their landfill containers. Small customers who already have the minimum level of landfill service do not see cost savings but support the program because they recognize the positive environmental impacts outweigh the program cost (Scheibly, email correspondence with authors, July 16, 2019).

The MSS Outreach Coordinator works closely with the customers the first few weeks on program implementation to determine the best container size and frequency of pickup; during this time, the fee for the program is waived. When the program started, MSS offered F2E pickup service three days per week, but quickly ramped up to offer up to 6 days per week of service. However, five years into the program MSS supplies 8 tpd of food scraps, about half the feasibility study estimate that 15 tpd was available. Part of the difference is because the feasibility study estimate included both pre- and post-consumer food, whereas MSS subsequently decided to exclude post-consumer waste to avoid its higher contamination levels (Jason Dow, interview with authors, August 27, 2018). MSS also cites the currently limited enforcement of the current organics diversion mandate as another reason. As of June 2019, approximately half of our commercial customers meet the 4CYs per week of MSW threshold and ~25% are compliant with AB 1826. Contrary to expectations, MSS finds that the non-compliant organizations include some of the largest sources.

As a result, CMSA also accepts FOG, which now represents about 85% of food waste feedstocks based on volume, and about 65% based on tipping fee revenues (Jason Dow, supplied data tables to authors, December 20, 2018). While FOG greatly increases biogas production, MSS acknowledges a concern that the FOG supply is not guaranteed because haulers have a number of options in the area, and are unwilling to make contractual commitments in order to be able to respond quickly if their economic opportunities change.

8.2.2 Project Impacts and Risk Management

8.2.2.1 Operational Impacts

Operational Upsets

CMSA has not experienced operational upsets with its co-digestion.

Biosolids

Production of biosolids may have increased, but any effect is hard to quantify due to the many factors causing variability. CMSA sends its Class B biosolids to a diversified set of uses, in accordance with restrictions set by California regulations, and anticipates maintaining a comparable allocation across the uses if the quantity increases. In the face of tightening California restrictions on biosolids uses, CMSA recently has begun sending a portion of its biosolids to the Lystek facility in Fairfield, CA, where it is turned into agricultural fertilizer. The remainder is applied to nearby farmlands in the dry season, or sent to landfills as alternative daily cover in the wet season. For 2019, the projected allocations are 20%, 55%, and 25%, respectively.

Biogas and Electricity Generation

The co-digestion project increased annual biogas production to 180% of prior production levels. Biogas production is around 280,000 cu ft/day as of summer 2018 (Jason Dow, supplied data tables to authors, December 20, 2018). Biogas is sent through the Biorem SulfaTreat scrubber to remove H_2S, siloxane, and moisture before going to a 750 kW internal combustion engine generator to produce electricity and heat (Johnston 2015). The co-generation equipment has experienced some downtime. The worst was in FY2013, when it was offline for 202 days because the manufacturer recommended a major offsite overhaul for preventative maintenance. Since then performance has improved – with no days offline in 2016 and 2018, and 45 days, 27 days, and 42 days offline in FY2014, FY2015 and FY2017, respectively (Jason Dow, supplied data tables to authors, December 20, 2018). When the cogen engine is down, the natural gas goes directly to heat CMSA's two hot water boilers and additional electricity is purchased from PG&E to meet the facility's needs. Otherwise, waste heat from the cogen system heats the digesters.

Before co-digestion, biogas powered the facility up to eight hours per day when the cogen system was operating; now biogas powers the facility 23 hours per day on average when the co-generation system is running.

Regulatory Impact

CMSA did not experience any issues with compliance with its water permits (Kuo 2015). CMSA conducted an analysis on the environmental impacts of running a biogas-fueled combined heat and power (CHP) engine and found no significant impact that would compromise compliance with California air emissions standards**.**

8.2.2.2 Financial Impacts

MSS

MSS spent $530,000 on upgrades to their facilities, and purchased a rear-loader truck (at a cost of around $250,000. Yearly operational costs (excluding loan repayment costs) are $422,000. Currently, three FTEs work in the program: one driver, one outreach coordinator, and one FTE sorter/processor (Kim Scheibly, email communication, July 16, 2019).

On a per ton basis, commercial food waste is more expensive to collect relative to commercial garbage by about 30% and relative to mixed organics (for composting) by about 10%; commercial recycling has the highest per ton collection costs, primarily due to the lower density of the material collected. When disposal/processing costs and recycling material sales revenues are factored in, food waste collection remains more expensive per ton than the other waste streams and commercial recycling is the least expensive.

The capital costs of the F2E program were covered by a 0.22% increase in base fees for all customers. About 75% of the operating costs are covered by subscription fees for the Food2Energy program, which vary with container size and service frequency. The remaining costs were subsidized by garbage rates. (As noted above, no fee is charged for traditional recycling in the MSS service areas: program costs are entirely subsidized by the garbage rates.)

CMSA

Investment Costs: CMSA incurred $2 million in costs for the organic waste receiving station (Jason Dow, interview with authors, August 27, 2018) which includes a 300,000-gallon tank, mixing pumps, rock trap grinder, paddle finisher and odor control system (CMSA 2014). This investment was bundled within a $7.65 million investment package of digester upgrades, including new flexible membranes, pump mixing systems and hydrogen sulfide scrubbers. CMSA covered the investment costs for the whole package from its capital investment accounts, including funds left over from a prior bond issue for a storm water management project, and the investment returns from those funds.

Operating Revenues and Costs: CMSA charges MSS a fee of $22.50 per ton for food waste (as of 2018), which is lower than the fee that MSS pays for landfill disposal. CMSA calculates this is equivalent to $.0938/gallon, based on its lab measurements indicating that one gallon of food slurry weighs 8.34 lbs. (The fee is adjusted each year using the San Francisco Bay Consumer Price Index.) The CMSA ordinance fee schedule for FOG (effective as of July 2016) charges a sliding scale tipping fee, which declines from $.06/gallon for the first 1500 gallons to no charge above 15,000 gallons of FOG (CMSA 2016).

In 2017-2018, the WRRF earned an average of around $150,000 in tip fees, and accrued around $120,000 in savings of avoided natural gas purchases as a result of co-digestion relative to average purchases in 2011 and 2012, before co-digestion started (Jason Dow, interview with authors, May 31, 2019).

The plant has experienced increased equipment maintenance, but has not needed to hire additional staff to implement the program. The plant does weekly preventive maintenance for pomace bins, the equipment area and the rock trap grinder; monthly maintenance for the pumps and paddle finisher; and quarterly cleaning of the receiving station tank. It has also experienced unplanned maintenance of the feed pump hoses, averaging 6 hose replacements per year for a total of $12,000 in repairs.

As of 2017, increased operating revenue and avoided natural gas expenses usually exceed increased operating costs.

8.3 Project 2: Expanding Co-Digestion and Energy Production for Sales to the Grid

By 2019, CMSA had achieved near energy self-sufficiency with its current scale of co-digestion. Noting that they still had excess digester capacity to take advantage of, the WRRF staff began to look into new ways to create value from biogas that could be produced with additional co-digestion. However, because its air permit does not allow it to flare biogas except in emergency circumstances, CMSA's first priority was to establish its ability to export to the grid. The agreement and required improvements by CMSA were completed in early 2019.

A related priority was to establish a long-term contract with a favorable feed-in tariff for the sales to the grid. In negotiating tariff options, CMSA confronted various challenges. Because its engine had been installed in 2005, CMSA was not eligible for the highest-value option, the 12.7c/kWh Bioenergy Market Adjusting Tariff ("BioMAT Tariff"), set up under CA Senate Bill 1122, which added an additional 250 MW of capacity for investor owned utilities (IOUs) to offer feed-in tariff Power Purchase Agreements (PPAs).

The remaining options were the 8.923c/kWh Renewable Market Adjusting Tariff ("ReMAT Tariff") offered by PG&E, and a 10.5c/kWh tariff offered by Marin Clean Energy (MCE), its local Community

Choice Aggregation program. (California AB 117 created the non-profit Community Choice Aggregation programs, allowing groups of communities to purchase power on behalf of their residents and businesses, with automatic enrollment and an opt out option.) Completely supported by revenues rather than taxpayer subsidies, MCE has structured the feed-in tariff program to allow renewable energy generators to enter into 20-year contracts with a fixed price per kWh generated. MCE's allocation was 15 MW of projects. Eligible projects are sized at 1 MW or smaller. CMSA qualified under the base load-energy price schedule, which is lower than the peak-energy supply schedule, and higher than the intermittent one.

The PG&E ReMAT tariff came with requirements for specified quantities of energy supply, with penalties for under-delivery and non-payment for over-delivery (as did the BioMAT tariff). In contrast, the only constraint on the MCE tariff was a self-specified maximum for annual sales.

As a result, CMSA inked a PPA to sell electricity to MCE at $.105/kWh, and recently began selling MCE biogas through a PG&E interconnection. CMSA interconnection improvements cost around $100,000 for design and installation, and were completed in March 2019.

CMSA is looking to maximize its power output by procuring new sources of organic waste in order to take advantage of the MCE tariff agreement. Before embarking on a feedstock marketing program, its first priority is to understand how much additional capacity the digester has to accept VSS without triggering digester upsets. In spring 2019, they are installing two 300-gallon pilot digesters to conduct digester testing over the next nine months.

For preventative maintenance, CMSA has completed an overhaul of its existing engine. In addition, it is currently designing a new more efficient cogen facility to increase the potential for power production. In the near term, the new engine would be the primary engine and the existing engine would be the backup. A Clean Water State Revolving Fund loan with 75% loan forgiveness is funding the planning and pre-design of the cogeneration system. Design and construction will require a $7 million investment, which CMSA anticipates will be covered by the issuance of tax-exempt revenue bonds in FY 2020.

8.4 Lessons Learned

8.4.1 Create Value and Manage Risks

8.4.1.1 Creating Value

Central Marin Sanitation Agency has embraced an expanded vision as "an industry leader … providing innovative, efficient, and sustainable wastewater services, capturing and utilizing renewable resources, and delivering renewable power" (CMSA 2018A). Co-Digestion is an important element of its efforts to recover renewable resources and deliver renewable power. To support food scrap generators facing new organics recycling mandates, CMSA partners with MSS, a local sustainability-oriented solid waste firm supplying preprocessed food scraps.

To date, CMSA has been able to achieve close to energy self-sufficiency with co-digestion. As CMSA focuses on expanding its capacity for co-digestion and energy production, it will be able to increase operating revenues by selling excess electricity production.

8.4.1.2 Managing Risks

Stakeholder Risks: CMSA and MSS worked in partnership from the beginning to develop and promote the program, recognizing that the project would involve a big commitment of time and money. Together they conducted extensive outreach to stakeholders in their service areas in order to get the support of the community-elected bodies that approve projects and associated rate increases. With their support, both Boards approved the project. Staff from both organizations were involved with the project as it developed. Neither facility experienced any concerns from neighbors.

Operational Risks: The F2E partnership was very focused on avoiding issues that EBMUD has faced with contaminated food waste feedstocks. The partnership instituted multiple levels of quality control, starting with limiting feedstocks to pre-consumer commercial food scraps, followed by preprocessing at MSS, the option for testing by CMSA prior to acceptance, and further preprocessing at CMSA. Because the supply of food scraps from MSS service areas has not achieved anticipated levels to date, FOG is currently the dominant food waste. CMSA is able to do FOG preprocessing onsite, because it designed the receiving station it built in 2012 to enable co-digestion to accommodate both FOG and food scrap slurries. To reduce supply risks with FOG feedstock, for which haulers are unwilling to sign long-term contracts, CMSA instituted a tiered fee structure that reduces tipping fees for higher volumes delivered.

CMSA has tailored its operations and maintenance routines to manage co-digestion. Redundancy in equipment, such as spare hoses, helps to keep the program running smoothly in the case of equipment failure.

Financial Risks: CMSA was able to finance the initial investment from internal funds previously raised in a bond issue, and pay it back through rate increases approved to fund the repayment. MSS has mitigated its financial risks by relying on fees paid by its subscribers.

As it moves into sales of electricity to the grid, CMSA is mitigating energy price risk with a long-term feed-in tariff contract.

8.4.2 Replicability

Key conditions that enabled CMSA's success with co-digestion include California's environmental policy landscape, and the presence of a nearby solid waste partner committed to sustainability to develop the food scrap recycling component (F2E) of CMSA's co-digestion program. Also important has been the availability of funds. The initial stage of the project used capital account funds that were left over from a prior bond issue, substantially augmented by high interest returns on the leftover monies; the boards of the communities in its service area had previously agreed to raise rates to cover repaying the bonds. CMSA will finance the new cogen engine by issuing revenue bonds.

MSS considers its model to be replicable. Critical to its success are its focus on providing service to F2E generators, keeping costs down, and coordinating closely with CMSA. Efficient routing is the key to keeping costs down: the MSS Route Manager works with the MSS Outreach Coordinator to provide a level of customer service that benefits the generators and results in efficient routing. Kim Scheibly, MSS Director of Compliance & Customer Relations, also highlights the contribution of the weekly communication between CMSA and MSS.

Underlying factors important to its success include the California recycling mandate, which creates the customer base (though it could be strengthened with enforcement) and MSS's exclusive franchises for commercial service, which result in more efficient collection routes relative to open hauling. Another valuable factor is the highly coincident service areas, which means that any program financial benefits from lower wastewater fees affect their shared customers.

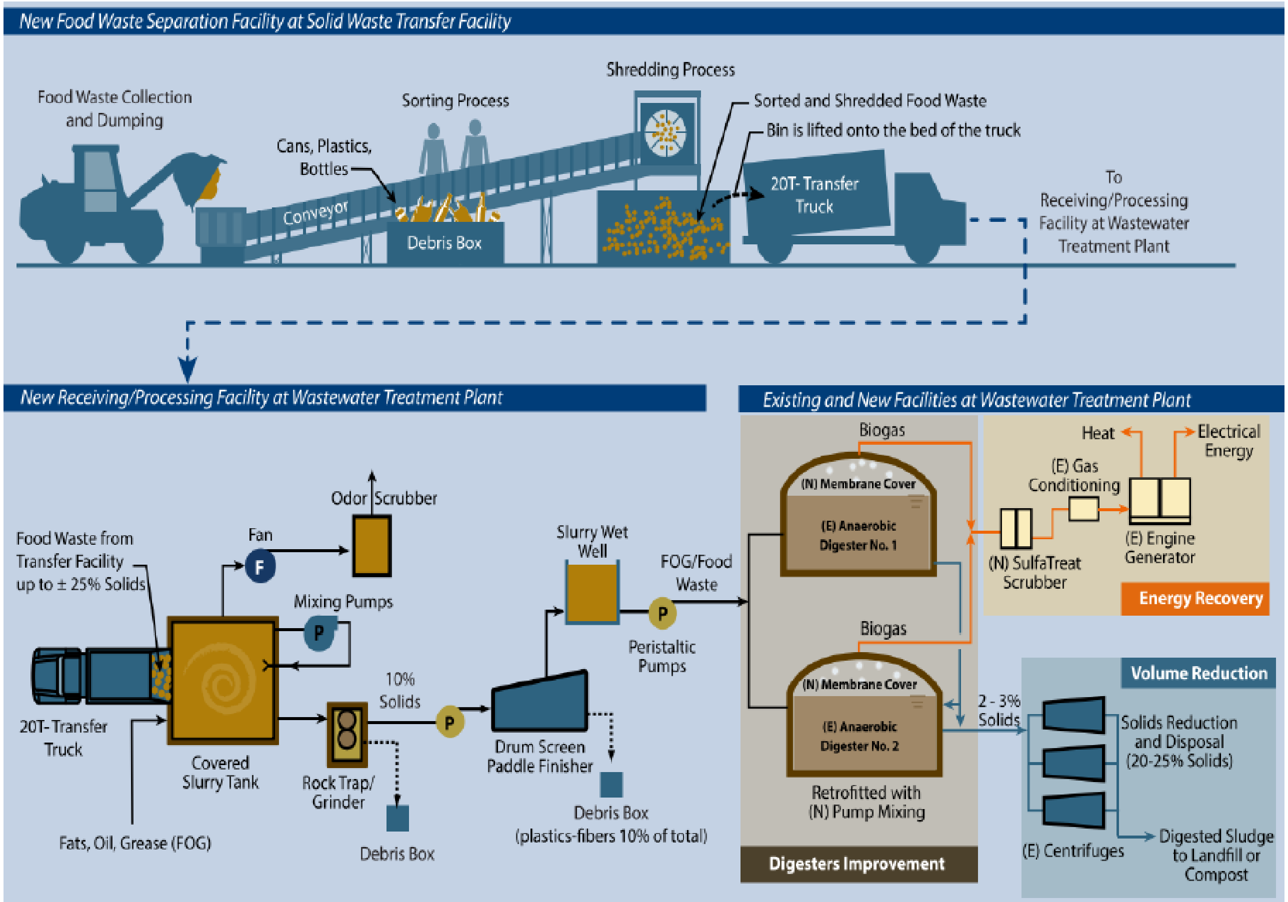

Figure 8-1. CMSA Food Scrap Treatment Train.

Source: Presentation. Central Marin Sanitation Agency. NACWA Energy Working Group. January 26, 2017.

CHAPTER 9

Joint Water Pollution Control Plant (JWPCP), Sanitation Districts of Los Angeles County (LACSD)

9.1 Context and Summary

About the Utility

- Service area: covers 820 square miles, and 78 cities and unincorporated areas (covering about half the population of Los Angeles County)
- Wastewater facilities include: 10 wastewater treatment plants, one pollution control plant that discharges to the ocean
- Solid waste facilities include: Two operating sanitary landfills, four closed landfills, three materials recovery facility/transfer stations
- Operating since: 1928
- Employees: 1656 (LACSD 2018)
- Governance: governing board with members from the 24 independent special districts in LACSD, working cooperatively under a Joint Administration Agreement (Mark McDannel, interview with authors, March 19, 2018)

About the Joint Water Pollution Control Plant

- Location: Carson, CA
- Size: 400 mgd (permitted); average daily flow is 280 mgd
- Wastewater customers served: ~3.5 million (LACSD n.d.a)
- Employees: 285 (LACSD 2018)
- Anaerobic digesters: 24 3.7-mg mesophilic digesters
- Food waste feedstock sources: slurried food scraps from Waste Management (WM), Puente Hills MRF (LACSD), Burrtec, and Grind2Energy; contracts with other suppliers of food scraps are in negotiations
- Food waste as share of total feedstocks in co-digesting digesters: demonstration project and design for full implementation: 9% by liquid volume, 30% by solid weight (Schmidt 2017) (For WM co-digestion demonstration project, one digester accepted food waste; in full implementation, the WRRF's plan is for five to accept food waste)
- Feedstock preprocessing: food scrap slurry providers preprocess food scraps in their facilities; at JWPCP, systems remove grit and plastic films
- Electricity costs: purchases electricity through the Districts' Direct Access program at $114/MWh (Tarallo et al. 2015); sells electricity on the spot market to the California ISO grid via an interconnection agreement with Southern California Edison
- Biogas end use: current: onsite electricity and heat generation (three 9.9-MW turbines) for internal use, and electricity sales to the grid; future: adding CNG production for onsite vehicle fuel station (phase I) and for pipeline injection or additional electricity production (phase II)
- Energy neutrality: prior to food waste co-digestion: 95-100%; following full implementation of co-digestion program: ~130% (David Czerniak, interview with authors, November 8, 2018)
- Biosolids management: 85% of biosolids to land application and composting (including Class A sites in California, four to five Class A EQ composting sites in California, two of which are LACSD-owned) and one Class B land application site in Arizona); 15% to landfill for disposal (Mark McDannel, interview with authors, March 22, 2019)

Drivers and Goals

- Drivers: California Global Warming Solutions Act AB 32; California Mandatory Commercial Organics Recycling Law AB 1826; California Mandatory Commercial Recycling Law AB 341; CA Low Carbon Fuel Standard; U.S. Renewable Fuel Standard; South Coast Air Quality Management District 1191 Vehicle Fleet Rules; future implementation: SB 1383 Organic Waste Reduction.
- Goals: Provide food scrap diversion option for local haulers, convert waste into renewable energy and soil amendments.

Summary

Los Angeles County Sanitation Districts (LACSD), a regional agency that operates under a Joint Administration Agreement with 24 special districts in the county, oversees wastewater treatment as well as solid waste disposal and recycling. (In the solid waste arena, the agency is responsible for solid waste disposal and recycling facilities; the local governments and the LA County Department of Public Works are responsible for solid waste collections.) The utility's mission statement highlights converting waste into resources as part of it mission "to protect public health and the environment through innovative and cost-effective wastewater and solid waste management." It has been creating electricity from biogas since the 1940s and reclaiming water for re-use since the 1960s. LACSD's flagship wastewater resource recovery facility (WRRF), the Joint Water Pollution Control Plant (JWPCP), is one of the largest in the United States, processing an average of 280 mgd. With the formation of its Energy Recovery Operations and Engineering Section of the Solid Waste Management Department in the late 1990s, LACSD achieved a new level of commitment to energy efficiency and energy resource recovery (Tarallo et al. 2015). From its initial focus on promoting energy efficiency and energy recovery from landfill gas to generate electricity, the section has expanded its scope to include energy recovery from co-digestion.

The extensive set of California state policies supporting greenhouse gas mitigation, renewable energy development and food waste diversion has spurred investments to enable co-digestion at JWPCP and to expand energy production from the resulting biogas. Motivated to provide an affordable option for food scrap diversion for haulers in the county, as well as to increase renewable energy production, LACSD's Energy Recovery team has led the utility's effort over the last decade to explore the technical and economic potential of co-digestion at the plant. A sequence of studies culminated in a four-year demonstration project (2014-2018) with Waste Management's Engineered BioSlurry (EBS®) feedstock, produced from its patented CORe process. The agency also has been evaluating a range of options for creating value from the biogas (LACSD 2012).

Following the success of the demonstration project, LACSD recently initiated a very large scale co-digestion program (with capacity up to 550 tpd of food scrap feedstocks), and Phase I of an energy strategy for the additional biogas. To meet the full co-digestion target of up to 550 tpd of food waste, LACSD is developing a diversified set of sources for food scrap slurries from private sector suppliers, as well as from its own food scrap preprocessing facility installed at its Puente Hills Materials Recovery Facility in 2018. The WRRF currently produces more than enough electricity to meet plant needs most of the time. In Phase I, the utility will produce RNG for direct sales at the local fueling station on JWPCP property. LACSD is still evaluating options for Phase II of the energy project; some options include pipeline injection of biomethane and others include production of additional energy to sell to the grid.

In February 2019, the utility paused the largest ticket item in its full-implementation co-digestion project, the food waste receiving station, while it re-evaluates options to reduce costs and waits for market demand to develop. They anticipate a slow increase in food scrap feedstocks leading up to 2024, when full enforcement of generator recycling requirements is scheduled. JWPCP continues to receive about 117 tpd of diverted food scraps (which represents about 160 tpd of slurry) through the headworks, and is continuing with Phase I of its energy project.

9.2 Project 1: Experimentation with Organic Feedstocks

California's ambitious solid waste diversion goals set out in AB 341 prompted LACSD to conduct a feasibility study of co-digestion in 2011. The study found that co-digestion was technically feasible, allowed under the current regulations, and could help LA county, as well as local cities and private haulers meet pending diversion requirements, but further information was needed to project the economics of the project (Schmidt 2017).

9.2.1 Feedstock Strategy

9.2.1.1 Bench-Scale Study with Waste Management

At the same time that LACSD was looking into co-digestion, WM was developing its food scraps management technology. In 2012, JWPCP conducted a bench scale study of co-digestion using WM's EBS® as a feedstock. No negative impacts on digester operations were observed. In the bench scale study, LACSD was able to characterize the slurry and quantify the biogas production potential from the added food waste. Further, they developed their specifications for food scrap feedstocks and determined a target feed rate for co-digestion (Schmidt 2017).

9.2.1.2 Demonstration Project with Waste Management

Building from the bench scale studies, JWPCP began a four-year demonstration project with Waste Management (WM) to assess whether co-digestion at a large scale could provide a viable and economically feasible option for landfill diversion for commercial establishments in local communities (Mark McDannel, interview with authors, March 19, 2018). The goal was to provide an affordable disposal option for organic waste, so that small- to medium-size hauling companies could remain competitive in the organic waste disposal market (Mark McDannel, interview with authors, March 19, 2018).

At their Organic Recycling Facility in the City of Orange, approximately 30 miles from the Carson plant, WM preprocesses commercial food scrap collections, expired produce and prepackaged food products, and off-spec and expired soda products, and blends them to form a liquid slurry. Starting in 2014, WM began delivering 20,000 gallons of EBS® per day to the JWPCP. During the demonstration project, the plant fed slurry to only one of its 24 digesters, with four digesters serving as controls. Over time, WM increased the amount of slurry hauled to the plant up to 100,000 gallons (84 tons) per day, which is capable of producing an additional 800 KW of electricity (Mark McDannel, interview with authors, March 22, 2019). (Note: 62 tons of food waste yields 84 tons of food waste slurry.)

In January 2018, WM and LACSD ended the demonstration project and signed an interim agreement with WM through December 2019 to increase food waste deliveries, in anticipation of signing a long-term agreement that would start after the LACSD installs a new receiving station. In the interim period, all food waste slurries are entering the headworks of the plant (Mark McDannel, interview with authors, March 22, 2019).

9.2.1.3 Other Private Hauler Food Scrap Deliveries

JWPCP has also been testing slurries from other private suppliers at its digesters. Burrtec, a regional solid waste firm, currently delivers around 30 tpd and Insinkerator's Grind2Energy currently delivers fewer than 5 tpd to JWPCP.

As with the WM slurries, these slurries are entering the plant through the headworks until a new food scrap receiving station is built.

9.2.2 Project Impacts and Risk Management

9.2.2.1 Operational Impacts

Receiving Station and Digester Impacts

The co-digestion demonstration project had no significant negative impacts on digester performance. The plant staff members have observed increased debris, which will have to be removed during digester cleaning. To control odors, the plant pumps the food waste from WM tanker trucks into closed, sealed storage tanks and has installed activated carbon canisters (Schmidt 2017).

The demonstration project also highlighted the need to streamline the offloading process and the need to plan for increased traffic with the expansion of the co-digestion program (Schmidt 2017).

Regulatory Impacts

The co-digestion demonstration project had no impact on regulatory compliance with air and water permits. Because the facility is in a non-attainment area for ozone, PM_{10}, and $PM_{2.5}$, the facility routinely conducts source monitoring to ensure compliance.

Biogas Impacts

With the addition of 84 tons of EBS®to one digester, biogas production increased by 100,000 scf per day. The biogas was used to displace natural gas purchases to power LACSD's combined cycle turbine power generation facility, and yielded an additional 800kW in electric production (Mark McDannel, interview with authors, March 19, 2018).

Biosolids Impacts

No impact has been detected in plant-wide biosolids production. (However, the impact of co-digestion in one digester out of 24 would be hard to detect given natural variations.)

9.2.2.2 Financial Impacts

Costs

Participation in the demonstration was self-funded by WM and JWPCP. JWPCP spent $2 million on installing a food scrap slurry receiving station, operating the system, conducting laboratory analysis, and conducting research and other engineering analysis. (For reference, JWPCP's FY2017 operating expenses were around $250 million) (Ken Rademacher, interview with authors, December 28, 2017). WM covered costs associated with procurement of the temporary receiving station and distribution piping, as well as for receiving station O&M, which mainly involved replacing the pumps periodically.

JWPCP costs for receiving station O&M and for managing the additional biosolids during the demonstration project were estimated to be around $17 per ton of food scraps delivered at 14% TS. In addition, $250,000 was spent on disposal costs for the undigested food waste inerts.

Revenues

JWPCP charged WM $10 per ton of food slurry in tipping fees, which partially covered the additional operating costs of the demonstration project associated with accepting food waste. When the receiving station is operational, the agency plans to set tip fees so they fully cover O&M costs associated with the receiving station and the increase in biosolids costs.

The plant, with a maximum design capacity of approximately 35 MW of electricity, typically generates about 20 MW of power for onsite uses, including electricity and heat for the digesters (Ken Rademacher, interview with authors, December 28, 2017). The plant goal is to continuously export at least 200 kW in order to minimize the risk of utility grid disruptions that could knock the plant offline and impair operations. Because power plant biogas output varies with digester gas availability, at times natural gas is purchased for co-firing with digester gas in order to maintain the target level of export. The WRRF sells to the CAL ISO grid via an interconnection agreement with Southern California Edison. It sells to third parties on the unscheduled market due to unpredictable fluctuations in biogas production.

As a result of the demonstration, electricity sales increased by 800 kW, yielding an additional $260,000 per year in revenues.

9.3 Project 2: Full Implementation of a Food Waste Co-Digestion and Energy Program

Given the success of the Waste Management demonstration project and increased feedstock availability due to the 2014 commercial organics recycling mandate (AB 1826), LACSD has begun implementing a full-scale co-digestion project. The two key elements are a very large scale co-digestion program (with capacity up to 550 tpd of food scrap feedstocks), and two phases of energy investments to create value from the additional biogas (Ken Rademacher, interview with authors, December 28, 2017). In Phase I, the utility will allocate the first tranche of additional biogas to producing renewable vehicle fuel. For Phase II, the utility is still evaluating options, which could involve pipeline injection of renewable natural gas or increased generation of electricity to sell to the grid.

Several elements have been put on pause pending further evaluation, in part due to the long lag until enforcement of SB 1383 kicks in, which is anticipated to increase feedstock supplies substantially.

The plans for expanding co-digestion at JWPCP involve a number of capital investments (LACSD No. 2 2018):

- Demolishing an out-of-service digester to make room for the new food waste receiving facility.
- Construction of biogas pipelines within JWPCP to convey additional digester gas to the flares and to the on-site power generation facility.
- Expansion of the biogas conditioning system for production of RNG for vehicle fuel at the CNG Fueling Station at JWPCP.
- Constructing a new food waste receiving facility, including food waste receiving and storage tanks and associated pipelines and connections to existing digesters, and modification of the entrance with a new guard station, new gate and driveway improvements *(on hold while waiting for the market to develop and as lower cost options are evaluated).*
- Construction of new backup flares for destruction of additional biogas generated by food waste *(on hold).*
- Possible expansion of the capacity at the CNG Fueling Station, with two additional islands and new driveways. *(This element will be added when [if] the plant gets additional fleet customers and needs the capacity.).*

The other critical investment made for the project is a new $1.9 million facility at the Puente Hills Materials Recovery Facility where LACSD can create food scrap slurries in-house. The facility opened for food scrap deliveries in April 2018.

9.3.1 Feedstock Strategy

9.3.1.1 Managing Risks

The long-term plan is to expand co-digestion by increasing food waste feedstocks from 62 tpd to up to 550 tpd, and to expand co-digestion from the demonstration project's one digester to five digesters. In order to process the associated increase in feedstocks, the plan is to build a new food waste receiving facility to receive 310 tpd of food scraps, and to increase loadings at the plant's liquid waste disposal station (LWDS) by an additional 240 wet tpd of waste from food and beverage manufacturing and fats, oils and grease from restaurants and commercial establishments. No physical improvements are required to accommodate the expanded deliveries of liquid wastes.

As noted above, the construction of a new food waste receiving facility is currently on hold pending development of a simpler and more cost-effective receiving station design, and pending the anticipated increase in supply over the next five years as SB 1383 recycling targets and enforcement kick in. In the interim, the LWDS is receiving all food waste deliveries, because WM removed the temporary food waste receiving station it brought in for the demonstration project.

Sourcing Food Scrap Feedstocks

The strategy is for a diversified set of private solid waste firms, as well as in-house production at the Puente Hills Materials Recovery Facility (MRF), to supply the WRRF with food waste slurry feedstocks derived from pre- and post-consumer commercial food waste.

As mentioned previously, JWPCP plans to continue accepting deliveries from Waste Management, Burrtec and Grind2Energy. It is currently holding discussions with them, and other solid waste hauling companies, to gauge long-term interest in the program and determine appropriate tip fees (Mark McDannel, interview with authors, March 19, 2018). During this interim period before a food waste receiving station is installed, LACSD is writing two-year contracts with feedstock suppliers, with no quantity minimums. They test every load for pH and conductivity, and they will collect samples from random loads to send to the laboratory to test for other parameters, including Total Suspended Solids (TSS) and Total Volatile Solids (TVS).

Ultimately, LACSD is looking to negotiate five- to 10-year contracts, with put-or-pay provisions, specifications for quality parameters and testing requirements, and a tipping fee that is tiered based on quantity supplied and quality. The tip fees will be set in order to cover the costs of feedstock operations and maintenance costs, testing, biosolids management costs, and capital recovery.

In addition, LACSD has developed in-house capacity at Puente Hills MRF (PHMRF) to create food scrap slurries. The stated motivation for this investment, in addition to diversifying supply sources, is to ensure that small haulers have an option that charges a reasonable tipping fee to process their SSO collections. Large solid waste companies have developed, or are contemplating plans to develop, their own preprocessing capability (Mark McDannel, interview with authors, March 19, 2018). The MRF charges haulers a tipping fee of $70/ton to deliver food scraps, substantially in excess of landfill fees in the area of around $35-40/ton (Mark McDannel, interview with authors, March 19, 2018). To provide incentives to generators and haulers to recycle their food scraps, the LA County Department of Public Works, a separate agency that is responsible for collections in the unincorporated areas of the County, provides rebates of $60/ton to haulers of food waste diverted from commercial business in its service area. For haulers to be eligible to receive the rebate incentive, the food scraps must be delivered to the PHMRF and meet acceptable contamination requirements (C. Skye, email correspondence with M. McDannel, March 12, 2019).

Having opened the slurrying facility in April 2018, the PHMRF has received a steady supply of about 30 tpd of source-separated food scraps collected by independent haulers, after a short ramp-up period. At full implementation, the facility aims to have supply to fill its capacity of 165 tpd diverted food scraps.

Preprocessing at the Puente Hills MRF

For preprocessing the source-separated food scraps, the MRF purchased a Doda Bioseparator Facility. (See Figures 9-1 and 9-2.) The first stage is to remove contaminants on the MRF floor. Next, the food waste is loaded into the Doda feed-in hopper and forced through a 15-mm screen. Inerts are rejected to a nearby waste hopper for disposal. Reclaimed water dilutes the food waste slurry into a pumpable solution, approximately the consistency of cooked oatmeal. The slurry then passes through the Doda secondary separator using an 8-mm screen, where the material is further cleaned and "polished" of inerts. The food waste slurry is pumped into one of three storage tanks and then loaded into 5,000-gallon tanker trucks for delivery to the JWPCP.

The WRRF has not experienced contamination issues with the slurry (C. Skye, email correspondence with M. McDannel, March 12, 2019).

Current and Future Plans for Receiving at JWPCP

Designs for a new food waste receiving station, which are currently being revised, are anticipated to include grit and plastic film removal systems, as well as an odor control system to remove odors vacated from the head space of the food waste slurry storage tanks. When a new receiving station is in place and the plant moves into full-scale implementation, JWPCP plans to extend the hours it accepts deliveries from six days a week/12 hours per day to seven days a week/24 hours a day. Maintenance for the new food waste receiving facility will include quarterly maintenance of pumping, grit removal and odor control equipment.

9.3.1.2 Financial Impacts

Investment Costs

LACSD has incurred $1.9 million in investment costs for the Food Scrap Processing Facility at PHMRF. The utility does not have a cost estimate for the receiving station because the designs are still being developed (but it is anticipated the cost will be less than for the prior design, $9.45 million).

Operating Revenue and Costs

The Puente Hill MRF is charging tip fees of $70/ton, for an estimated $630,000 per year in tip fees at the current rate of delivery of food scraps (30 tpd). This fee covers processing equipment O&M and capital recovery.

The WRRF is currently charging an interim tip fee rate of $17 (Insinkerator's Grind2Energy) - $20 per ton (other haulers) to bring the slurries to the plant. The tip fee is intended to cover the operating costs of the receiving station. The fee for Grind2Energy is lower largely because it was an early, long-term contract. Prices have been rising since that contract was signed (Mark McDannel, interview with authors, March 19, 2018 and April 12, 2019). At the current rate of deliveries, estimated annual tip fees are about $685,000.

9.3.2 Energy Strategy

Full implementation of co-digestion is projected to increase biogas by 1,440 cubic feet per minute (cfm), from their baseline (no co-digestion) level of 5000 cfm. Approximately 400 cfm will be allocated to Phase I energy project, producing RNG vehicle fuel for sale. LACSD is still evaluating options for a future Phase II using the additional 1040 cfm. Options include variations on a pipeline injection project, using the SoCalGas pipeline under the adjacent roadway, and variations on purchasing additional CHP infrastructure to produce more electricity for sale (Dave Czerniak, interview with authors, October 30, 2018). The choice will be made after the food waste receiving station is installed and WRRF staff understand how much food waste is available for their operations. Another factor they will be monitoring over time is the extent to which the value of RINs and LCFS subsidies decline, as more renewable vehicle fuel enters the market.

The renewable biomethane produced in Phase I will be used to fuel LACSD's fleet vehicles and to help LACSD's compliance with South Coast Air Quality Management District 1191 Fleet rules (LACSD n.d.b). These rules require public agencies to lower emissions associated with vehicle fleets and convert to alternative fuel use. In addition, the fueling station is open to the public 24/7, and is used by taxis, local buses, and individuals.

With the current level of 117 tpd of food waste feedstocks incorporated through the headworks, the plant is producing approximately an additional 234 scfm (or 1400 GGE/day). Utility modeling estimates that 40% of the gas-producing potential is lost by using the LWDS.

Installation of the biogas conditioning and conveyance equipment for Phase I will cost $5.6 million and will be partially funded by a $2.5 million grant from the California Energy Commission.

CNG sales from the new biogas production are projected to generate $2 million in revenue based on current market conditions (Dave Czerniak, interview with authors, October 30, 2018).

9.3.3 Combined Project Financial Analysis

Energy improvements at LACSD are typically initiated by the Energy Recovery Team, not the individual facilities implementing them. The decision criteria for approval include that the project does not reduce the quality of wastewater treatment and the payback period is five to 10 years, with shorter periods expected for projects with more uncertain estimates of net revenues. According to LACSD staff, as long as LACSD projects do not lose money and can ensure adherence to regulatory requirements, the District's board is generally open to new projects (Mark McDannel, interview with authors, March 19, 2018).

The total cost for the elements that are currently moving forward is estimated to be $11.65m: this includes the slurry station at PH MRF ($1.9m), the demolition of the out-of-service digester to make room for the receiving station ($4.1m), and the addition of biogas conditioning and biogas pipeline equipment ($5.6m). Partial offsets include a $2.5 million grant from CEC toward the biogas conditioning equipment, and a $1.1 million tax exclusion credit from the *California* Alternative Energy and Advanced Transportation Financing Authority (CAEAFTA). Consequently the net cost to LACSD of these project elements is anticipated to be $9.1 million (Dave Czerniak, interview with authors, October 30, 2018).

The economics for vehicle fuel are highly sensitive to variations in the price of RINs and LCFS credits, which multiply many times the current sales price of $3/MMBTU for natural gas. LACSD is assuming a revenue range of $20-40/MMBTU for the renewable vehicle fuel. A critical factor is that the project would qualify for the more remunerative D3 RINs by allocating biogas from non-codigesting digesters to the vehicle fuel uses (Dave Czerniak, interview with authors, October 30, 2018).

The investment will be financed internally through Solid Waste Department funds.

9.4 Lessons Learned

9.4.1 Create Value and Manage Risks

9.4.1.1 Creating Value

The large food waste co-digestion project that LACSD has initiated at JWPCP reflects the utility's long-standing focus on sustainability – recovering resources from waste to achieve environmental, community and financial benefits. The incorporation of food scraps in co-digestion is facilitated by the utility's joint responsibility for solid waste and wastewater management.

Given its very large scale, the co-digestion program has surfaced a number of private solid waste firms that represent entrants in the market to supply a new product – food scrap slurries – suited to co-digestion feedstock through long-term contracts. It also has highlighted another new trend: public sector entrants into food scrap preprocessing.

9.4.1.2 Managing Risks

Stakeholder Risks: The project is designed to serve the utility's solid waste stakeholders, while using wastewater infrastructure and keeping wastewater treatment rates unchanged. Enabling the solid waste haulers to meet their new regulatory requirements for food scrap diversion has been an important motivation for including food scraps. No rate increase for either wastewater or non-food solid waste will occur due to this project.

LACSD also consults closely with neighbors of its facilities, through citizens' advisory councils.

Operational Risks: The JWPCP plant staff initially were concerned about operational risks that could compromise their primary mission of ensuring water quality. To investigate the potential risks, the utility conducted a preliminary study, a pilot, and then a demonstration project with preprocessed food scrap slurry as digester feedstock to evaluate operational risks and benefits of co-digestion and to identify best practices/challenges and solutions. The conclusion was that the operational risks are all manageable. Based on the lessons learned during the trial periods, the plant staff has adopted an approach of making co-digestion work.

The specialized staff of the utility's Energy Efficiency and Energy Recovery section, located in the Solid Waste Department, brought its long energy experience, including recovering biogas from landfills, to the planning to address operational risks associated with the energy component of the project.

Financial Risks: The extended timeframe for testing out the concepts and the internal financing are both strategies to mitigate financial risk.

9.4.2 Replicability

The LACSD strategies to create value benefit from California's relatively high energy prices and the strong regulatory structure and generous subsidies for renewable energy and food waste diversion activities. The state policies promoting recycling of food scraps have supported the inclusion of food scraps as digester feedstocks, which occurs infrequently in states without aggressive policies.

JWPCP is one of the largest WRRFs in the country. The large scale of the plant makes possible the very large scale of the co-digestion and energy production operations, which allows JWPCP to realize a variety of positive factors: economies of scale; redundancy, which is important for efficiency; specialized staff focusing on energy efficiency and renewable energy; and the capacity both to finance investments and to manage new energy and food scrap preprocessing facilities in-house.

LACSD is also one of the relatively few utilities that combine solid waste and wastewater under one general manager and board of directors. Mark McDannel, Division Engineer with the Energy Recovery Section, believes that having the two combined in one organization provides a substantial advantage, because co-digestion of food scraps requires collaboration between the wastewater and solid waste sectors. The JWPCP wastewater treatment plant carries out the co-digestion. The LACSD Solid Waste and Recycling Department has brought to the initiative a focus on providing a service to solid waste haulers in the area, and on maintaining low solid waste collection fees for LA county residents in independent districts while implementing the high-cost organics diversion mandate. In addition, the Solid Waste Department leverages its solid waste experience to develop the food scrap feedstock strategy and conduct the negotiations with feedstock haulers; it also designs the energy projects, leveraging the expertise its Energy Recovery Section developed with earlier projects recovering biogas from solid waste landfills.

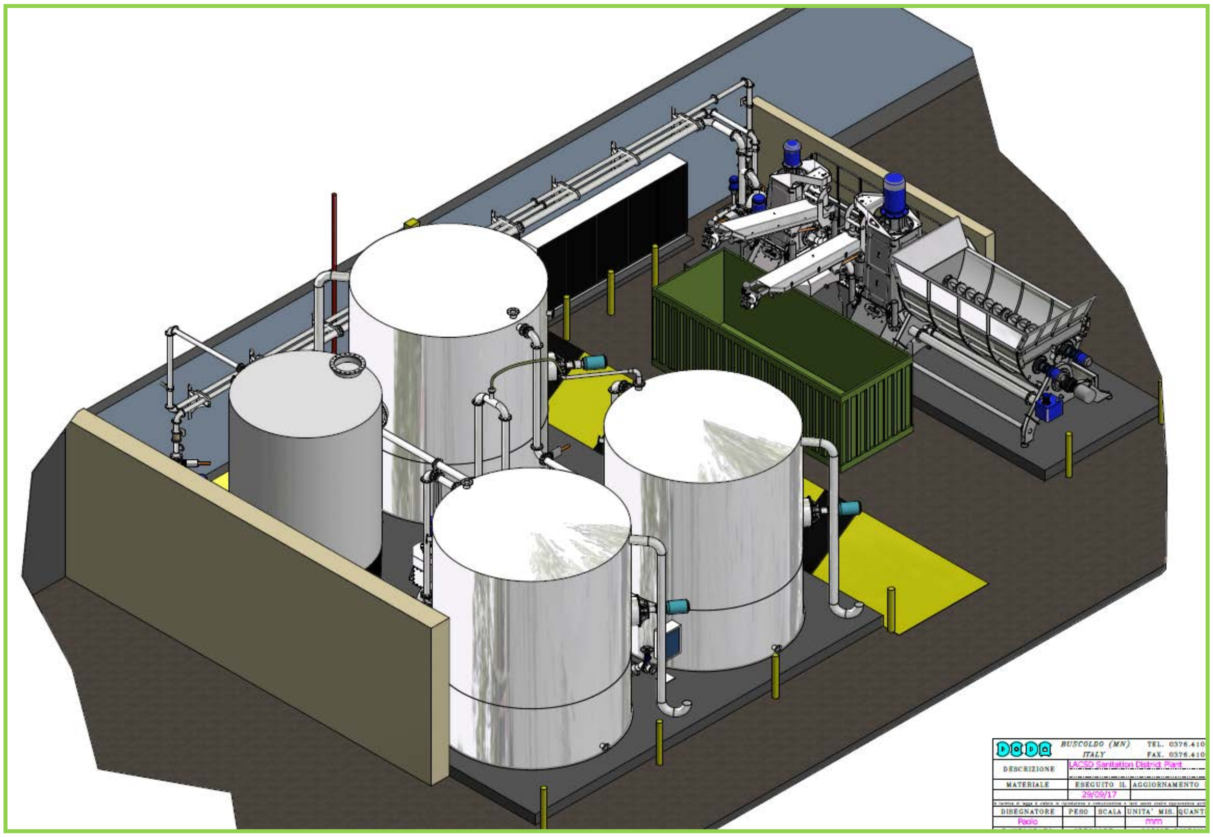

Figure 9-1. Rendering of DODA Food Waste Processing Facility at Puente Hill Materials Recovery Facility.
Source: https://www.laregionalagency.us/wp-content/uploads/2018/03/scan0001.pdf

CHAPTER 10

State Profiles: Policy Portfolios and WRRF Co-Digestion Adoption

The rate of adoption of co-digestion among all U.S. WRRFs with AD is low; indeed, in 2015, half of the states had no co-digesting WRRFs (U.S. EPA 2018). But adoption rates vary across the states: they are higher in states with market conditions and policies that enable a WRRF to achieve strong economic returns from co-digestion.

The focus of this chapter, however, is not on policy differences between states with high vs. low rates of co-digestion adoption. Rather, it first highlights the variation in policy portfolios among the states with the most co-digesting WRRFs. Though the sample of WRRFs is too small for statistical analysis, the researchers offer some qualitative observations. They compare the pattern of co-digestion in the states over time to the evolution over time of state policy portfolios, and report on interviews with WRRF managers who were asked about their drivers for adoption. The states in this group are: California (20, 12.8%), Wisconsin (nine, 11.1%), New York (six, 5.1%), Iowa (five, 9.4%), Ohio (four, 6.9%), and Pennsylvania (four, 4.9%).[7] (The first number in parentheses is the number of co-digesting WRRFs, and the second number is the percentage of WRRFs with AD that are co-digesting. See Table 10-1 and Figure 10-1.)

The research team notes that – while California is widely recognized as the state with the most aggressive and broadly focused policy portfolio – it is less well known that several of the Midwest states with less aggressive policies have achieved adoption rates among WRRFs with AD almost as high as those of California. Specifically, the team observed some facilities with highly favorable feedstock supplies and energy market access that are successfully co-digesting food waste without the support of an aggressive policy portfolio. Moving forward, however, the current climate for investment is clearly most dynamic in California, which continues to add new regulatory requirements and financial subsidies to promote greenhouse gas mitigation and food scrap diversion. In contrast, in the Midwest states, which generally lack regulations or incentives promoting food scrap diversion, growth has stalled. A factor in some cases is the decline in state renewable electricity market incentives, as well as in federal economic development incentives. See Table 10-2 for a summary of state policies.

Second, this research explores the pattern of adoption across alternative types of digesters (including on-farm, stand-alone and WRRF) among the five states with statewide organics recycling mandates or landfill bans in effect. (A sixth state, New York, just adopted a food waste recycling mandate, effective in 2022.) In addition to California, the other four states are in New England (Massachusetts, Vermont, Connecticut and Rhode Island). Each of them has one or no WRRFs co-digesting food scraps. The researchers highlight the intervening factors that influence the choices made in those states from among the range of options to recycle food scraps. One factor is simply the smaller area of the New England states – and the substantially fewer WRRFs. Another factor is the rural nature of much of the area in the two states with the most active promotion of the bans. Lack of economies of scale can disadvantage WRRF co-digestion relative to the other options.

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[7] The next state in terms of number of co-digesting WRRFs is Georgia, with three co-digesting WRRFs out of 20 WRRFs with digesters. AR, ME, and MA have a higher % of WRRFs with AD co-digesting, but they all have only one plant co-digesting and fewer than 20 WRRFs with AD.

Table 10-1. WRRF Adoption of AD or Composting to Process Food Wastes, for Selected States.

Table 10.1. WRRF Adoption of Co-digestion of Food Waste, for Selected States.		Greater Number of WRRFs Co-digesting						Organics Landfill Bans			
		CA (organics recycling mandate)	IA	NY	OH	PA	WI	MA	VT	CT	RI
WRRFs	#	497	768	597	815	846	592	126	87	89	20
WRRFs With AD \1	#	156	53	118	58	81	62	6	13	10	1
	%	31.4%	6.9%	19.8%	7.1%	9.6%	10.5%	4.8%	14.9%	11.2%	5.0%
WRRFs with AD Co-digesting Food Waste \2	#	20	5	6	4	4	9	1	1	0	0
	%	12.8%	9.4%	5.1%	6.9%	4.9%	14.5%	16.7%	7.7%	0%	0%
Farm AD Co-digesting Food Scraps \2	#	0	2	4	1	8	6	3	7	0	0
Standalone AD Digesting Food Scraps \2	#	11	0	3	8	2	5	5	2	1	0
Compost Facilities Processing Food Scraps \3	#	99	NA*	52	93	16	21	34 \4	9	4	1

* There are 80 composting sites in Iowa but the source does not provide breakouts based on feedstock.

Sources: \1. WRRFs with AD: http://www.resourcerecoverydata.org/biogasdata.php. \2. USEPA, 2018, Anaerobic Digestion Facilities Processing Food Waste in the US in 2015. \3. Biocycle, 2017, The State of Organics Recycling in the U.S. (The number is the sum of numbers reported for "Yard & Food Waste" and "Multiple Organics" Columns from table 2. \4. MA DEP, Sites Accepting Diverted Food Material, https://www.mass.gov/files/documents/2018/11/20/fdcomlst.pdf

10.1 California

California has been aggressively expanding its policies to mitigate climate change, promote renewable energy, and recycle commercial organics waste. Of all 50 states, California has the largest number of WRRFs that are co-digesting (20 out of 156 WRRFs with AD, or 12.8%). Co-digesting WRRFs in California range in size from 6 mgd (Millbrae WWTP) to 280 mgd (JWPCP in Carson). U.S. EPA (2018) estimates that there also were 11 stand-alone and one on-farm digester accepting food waste in California as of 2015. (See Table 10-1.)

Co-digesting WRRFs in California that were interviewed indicated that a variety of factors contributed to the economic feasibility of co-digestion in the state, including tip fee revenues, avoided high electricity costs, favorable electricity tariffs, and the availability of an extensive set of grant programs to support food waste and energy infrastructure investments. Some, including EBMUD, CMSA, and Victor Valley WRF, cited a desire to make good use of idle digester capacity (See Appendix B, Chapter 8, and Chapter 4). In addition, California's ever-tightening biosolids regulations and the rising costs of biosolids management are providing incentives for an alternative allocation of biogas to support the extra processing required to create Class A biosolids and marketable fertilizer products, which represent additional revenue streams. At least four (EBMUD, Victor Valley, CMSA, and JWPCP) WRRFs in California accept slurried food scraps that have been preprocessed by private haulers (see Appendix B and Chapters 4, 8, and 9).

California's constellation of regulatory and financial support policies surrounding organics recycling has thrust the state to the forefront for co-digesting food scraps.

California's Renewable Portfolio Standard (RPS) calls for 50% renewable energy use by 2030, and approves AD as an eligible source (DSIRE 2018). The state's BioMAT and ReMAT tariffs offer competitive prices for renewable electricity, with set-asides for WRRF biogas. Programs such as the Self-Generation Incentive Program (SGIP) administered by the California Public Utilities Commission provide rebates for qualifying energy systems installed on the customer's side of the electric utility meter and help to incentivize biogas use.

With the California Low Carbon Fuel Standard and the U.S. Renewable Fuel Standard providing attractive financial incentives for producing vehicle fuel from WRRF biogas, a number of WRRFs are currently evaluating converting their biogas to vehicle fuel for either direct sales or pipeline injection. The Biomethane Interconnector Monetary Incentive Program, established in 2015 by the California Public Utilities Commission, can contribute funding for up to 50% of pipeline interconnection costs, with a cap of $3 million per project (SoCalGas 2017). On the other hand, California has the most stringent rules in the country for pipeline injection, though it has commissioned research to evaluate the rules, and determine what is essential to maintain pipeline safety and quality control with biomethane injection. As of April 2018, only the Point Loma WWTP in California (which does not co-digest) has a fully implemented project injecting its conditioned biogas into a natural gas pipeline.

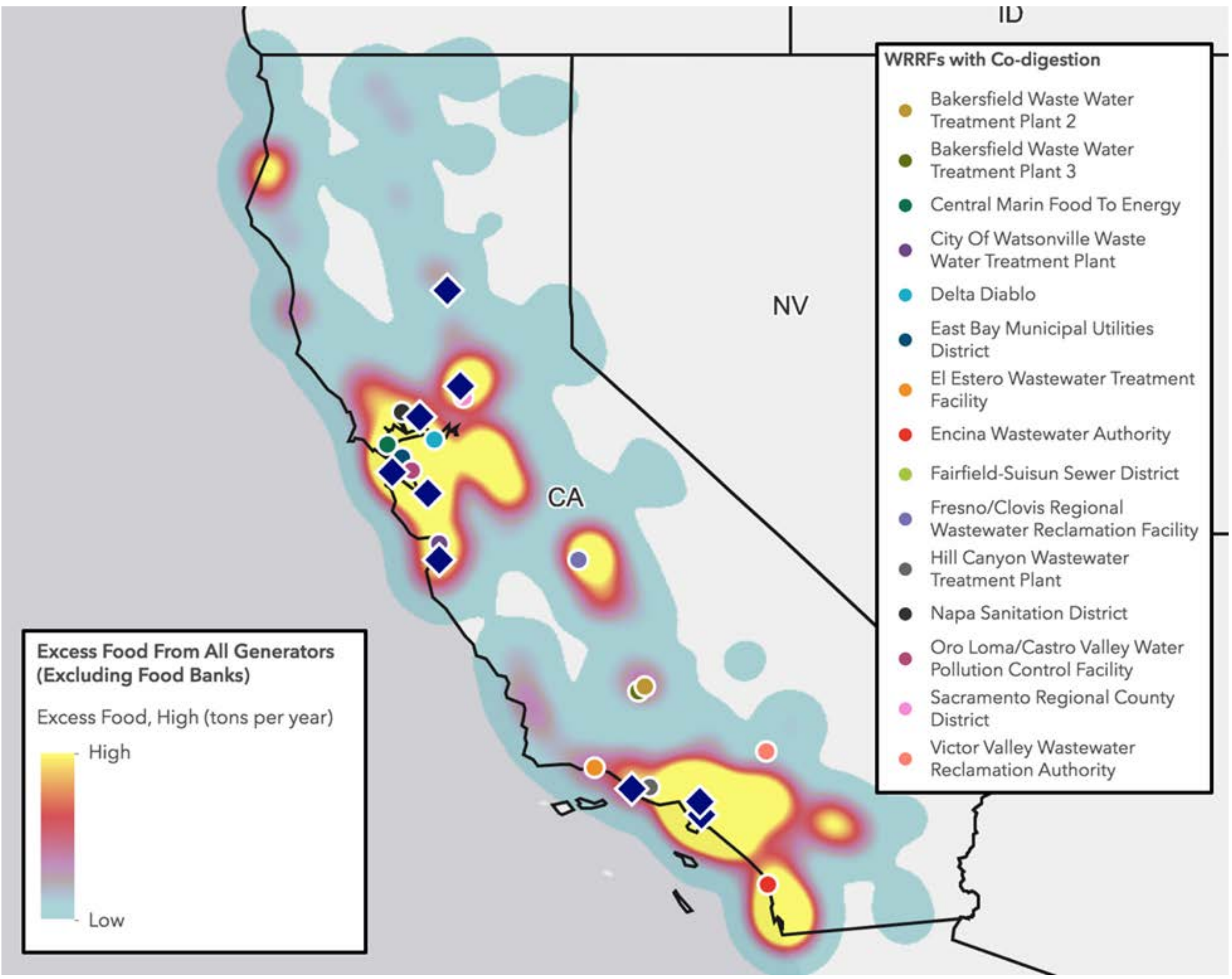

Figure 10-1. Co-Digesting WRRFs (Circles), Standalone ADs (Diamonds), and All Excess Food Waste in California (Tons per Year).

Source: U.S. EPA Excess Food Opportunities GIS Database, https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map.

10.2 Wisconsin

Motivated by limited sources of in-state fossil fuel resources and large expenditures on out-of-state energy sources, Wisconsin was an early adopter of energy efficiency and renewable energy programs, which provided an early impetus for co-digestion in the state. At one point, 11 of the 62 WRRFs with AD in the state were co-digesting food waste, including WRRFs in Stevens Point, West Bend, Fond du Lac, Wisconsin Rapids, Appleton, Sheboygan, Janesville, Milwaukee, Port Washington, Rice Lake and Kiel. (See Table 10-1 and Figure 10-2.)

Initially, the adopters indicated that co-digestion was financially feasible because it provided ample feedstock, strong tip fees, and electricity market benefits. These benefits included cost savings, revenues from electricity sales with favorable power-purchase agreement tariffs, and support from Wisconsin Focus on Energy, a utility-funded organization that aims to reduce Wisconsin's energy waste. For Stevens Point and West Bend WRRFs, diverting high strength wastes to digesters reduced energy costs associated with aeration. The West Bend WRRF added co-digestion to supply biogas demands for new cogeneration systems that became economic with favorable electricity tariffs (see Appendix B).

Wisconsin's Focus on Energy program provides technical assistance and grants to support energy efficiency and renewable energy. Focus on Energy has provided $8 million to support construction of 38 digesters (including on-farm, stand-alone and WRRF digesters), and has provided financial support to three of plants highlighted in this research: Stevens Point (Chapter 5), and Janesville and Sheboygan (Appendix B).

Wisconsin's Renewable Portfolio Standard, implemented in 1999, required the state to meet a goal of 10% renewable energy use by 2015. To facilitate market access by distributed energy sources, the state mandates that all investor-owned utilities (IOUs) and municipal utilities provide net metering for all distributed generation systems. Many Wisconsin utilities voluntarily set up feed-in tariffs with 10-15 year contracts at favorable prices, allowing WRRFs to invest in onsite energy production equipment. However, the low caps on participation have been met, and the utilities are no longer offering the favorable tariffs for new contracts. The reduction in energy revenues due to the loss of these tariffs has dampened the economic incentives for adding co-digestion.

Other biogas end uses face challenges. Local gas utilities have not been welcoming to the idea of pipeline injection, and none of the facilities in the state is doing pipeline injection. As elsewhere, the cost of converting city vehicles to CNG to enable biogas-to-CNG projects poses economic feasibility challenges. Nonetheless Janesville has installed a CNG vehicle fuel production facility, in partnership with BioCNG, a renewable compressed natural gas production company. A $125,000 grant from the Wisconsin State Energy Office covered part of the $880,000 cost (See Appendix B).

Moreover, in some areas of the state, competition from other organic waste disposal options has resulted in dramatic tip fee reductions, reducing revenue from co-digestion. The decline in tip fee revenues contributed to the City of Sheboygan's decision to terminate co-digestion in 2017. The Janesville Wastewater Treatment Plant (JWWTP) also stopped co-digestion in 2015 when it lost its single feedstock supplier, a chocolate producer in the area. The JWWTP, which earned limited revenue in tip fees, had no incentive to seek out other feedstocks because it did not require co-digestion to meet its renewable energy and fuel production goals.

In addition, Wisconsin lacks policy or financial incentives promoting recycling of food scraps, which makes the economics of implementing food scrap co-digestion challenging according to Matt Seib of the Nine Springs WWTP in Madison (Matt Seib, email correspondence with authors, October 11, 2018). As a result, the current food waste feedstocks for WRRF co-digestion are typically dairy wastes, other food processing wastes and/or FOG.

While co-digestion does not seem to be increasing in popularity due to the feedstock market and electricity price trends, Wisconsin remains one of the states with the highest number of co-digesting WRRFs.

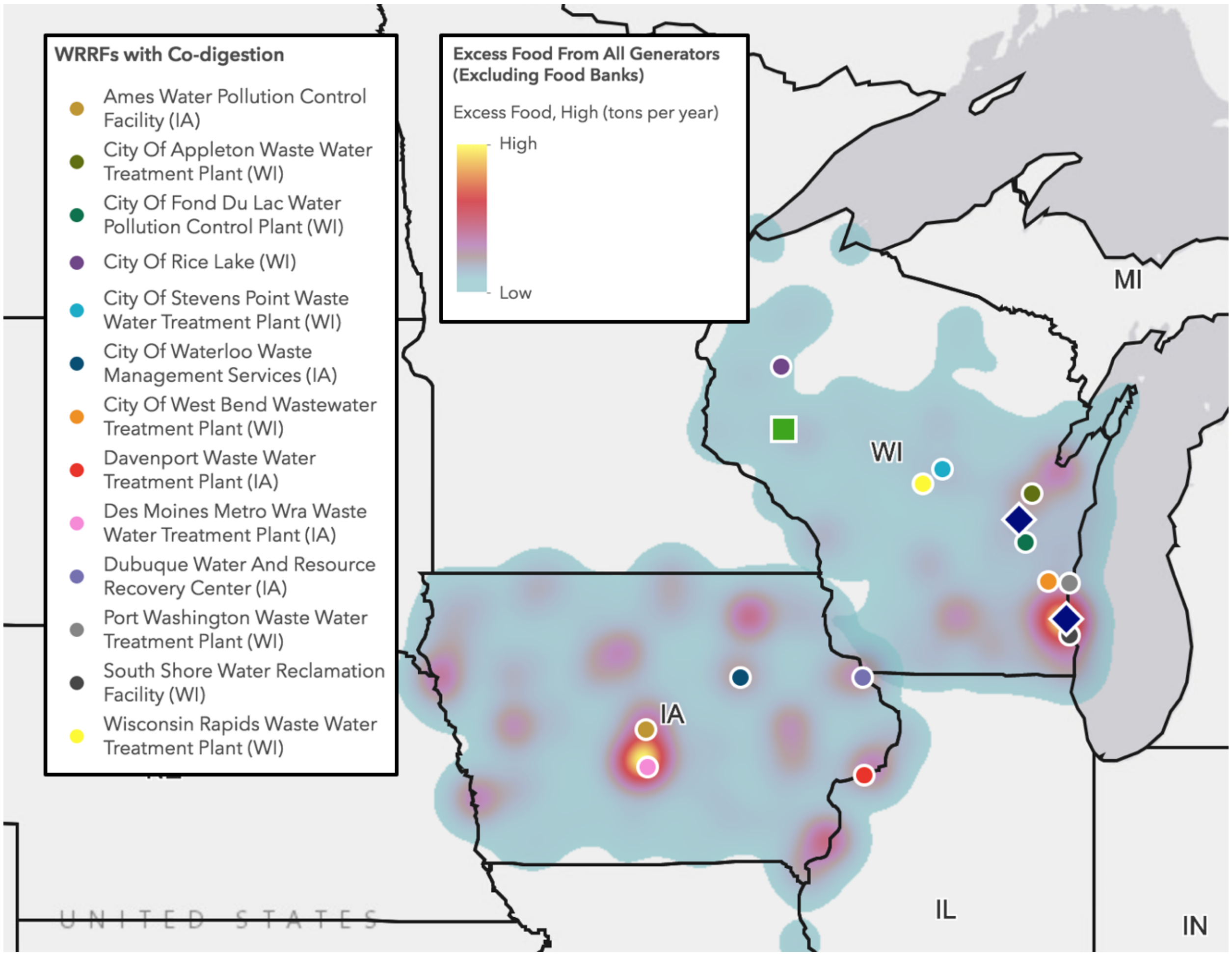

Figure 10-2. Co-Digesting WRRFs (Circles), Co-Digesting On-Farm Digesters (Squares), Standalone ADs Accepting Food Waste (Diamonds), and All Excess Food Waste in Iowa and Wisconsin (Tons per Year).
Source: U.S. EPA Excess Food Opportunities GIS Database, https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map.

10.3 Iowa

In 1983, Iowa was the first state to adopt a Renewable Portfolio Standard (RPS), though the standard did not explicitly designate anaerobic digestion as an eligible technology. Other Iowa renewable energy policies do list anaerobic digestion as an eligible source; however, they generally favor wind energy. Iowa does not have any solid waste policies promoting diversion of organics.

Five of the 53 WRRFs with AD in Iowa are currently co-digesting (9.4%) as of 2015. Two of these WRRFs currently inject biogas into a pipeline for private commercial or industrial use; one of those is developing a project for utility pipeline injection. Co-digesting WRRFs in Iowa include Des Moines Wastewater Recovery Facility, Ames Water Pollution Control Plant, Davenport Water Pollution Control Plant, and Dubuque Water and Resource Recovery Center. The city of Waterloo WRRF co-digests in its anaerobic lagoon. Three farm digesters also accept food waste in Iowa. Co-digesting WRRFs range in size from 10 mgd (Ames and Dubuque WRRFs) to 59 mgd (Des Moines WRF). Most feedstocks accepted are FOG or food processing residuals. Three farm digesters also accept food waste in Iowa.

The five co-digesting WRRFs in Iowa cite diverse motivations for pursuing co-digestion. Both Des Moines and Dubuque cite excess capacity in their digesters and a motivation to provide a disposal option for nearby industries as the motivations for implementing co-digestion. The Ames WRRF sends FOG to the digester in order to remove FOG from the sewer system and reduce sewer system O&M costs. Regulatory limitations on the land application of biodiesel and ethanol wastes drastically increased high-strength waste (HSOW) deliveries to the Des Moines WRRF.

The Iowa RPS requires the state's two investor-owned utilities to provide 105 MW of generating capacity for renewable energy, not including renewable energy used "behind the meter." The utilities have met the 105 MW target and are not required to produce more. In 2017, the Iowa Utilities Board mandated net metering for two major Iowan utilities, MidAmerican Energy and Interstate Power and Light Co. Biogas recovery also is eligible for the $0.015/kWh in tax credits that a renewable facility can receive (IUB n.d).

Currently, the Dubuque and Des Moines facilities inject biogas to a nearby utility and industrial pipeline, respectively. Des Moines is involved in a major project to upgrade its facility, and to expand its pipeline injection capacity from sending biogas to a nearby industrial partner to upgrading biogas for utility pipeline injection. It cites access to RFS credits as an important driver for this large investment project, which builds on its experience with pipeline delivery to an industrial customer.

In August 2018, Iowa published a report outlining strategies to expand the use of biomass energy, which included streamlined permitting for bioenergy facilities, funding for pilot projects, and increased access to pipeline transmission (Iowa Economic Development Authority 2018). While the electricity sector has met the state's RPS goal, Iowa's new strategies for biomass energy present a promising opportunity for anaerobic digestion development in the state, which may subsequently incentivize co-digestion.

10.4 Ohio

The presence of both Ohio's Alternative Energy Law (the state's RPS) and the voluntary Ohio Food Scrap Recovery Initiative suggests a policy landscape that facilitates co-digestion at WRRFs. However, state's commitment to the RPS has been on-and-off, and low natural gas prices and the low prices for RECs further limit the incentives to pursue renewable energy projects. In addition, WRRF operators note the lack of organic waste diversion regulatory requirements that would promote co-digestion.

Four out of the 58 WRRFs with anaerobic digestion in the state of Ohio co-digest (6.9%). As of 2015, these WRRFs include London WWTP, Newark WWTP, Struthers Water Pollution Control Facility (which stopped co-digestion in 2017 due to digester upsets from inconsistent feedstock), and Wooster WWTP. (See Figure 10-3.) Food processing residuals are the most common feedstock accepted. WRRFs range in size from 2 mgd to 7 mgd.

The AD and renewable energy company Quasar has contributed significantly to the proliferation of food waste digestion and co-digestion in Ohio. By keeping digester construction costs low and leveraging multiple incentive programs, the company has installed or upgraded 11 stand-alone, WRRF, and on-farm digesters in Ohio. Two of the three Quasar digesters serving WRRFs (including French Creek WWTP[8]) are stand-alone facilities, with service agreements to accept and digest local WRRF wastewater treatment solids as merchant processors. Primary drivers for co-digestion identified by the WRRFs include using excess AD capacity fully and providing a local disposal option that will save money for local industries and the municipalities. Biosolids restrictions also can influence co-digestion adoption. The director of

[8] Note that Quasar actually owns the AD. French Creek delivers their biosolids to the Quasar digester via pipeline.

the French Creek WWTP cites increasing requirements for managing biosolids as a driver for its partnership with Quasar.

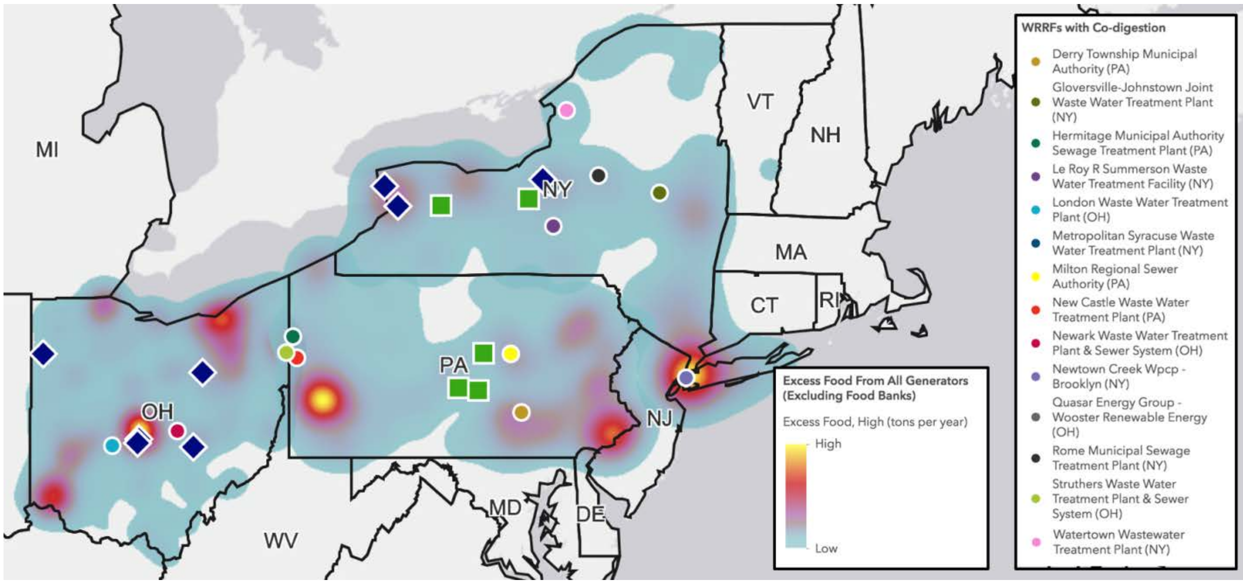

Figure 10-3. Co-Digesting WRRFs (Circles), Co-Digesting On-Farm Digesters (Squares), Standalone ADs Accepting Food Waste (Diamonds), and All Excess Food Waste in New York, Ohio, and Pennsylvania (Tons per Year).
Source: USEPA Excess Food Opportunities GIS Database,
https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map.

Starting in 1989, the state of Ohio has articulated solid waste reduction goals. At a stakeholder meeting in 2007, the state of Ohio unveiled the Food Scraps Recovery Initiative, designed to promote food scrap diversion from landfills to recycling. Since then, Ohio has restructured food waste tip fees so that recycling options are not charged the disposal fee (2010) and streamlined permitting for anaerobic digesters (2011) (Goicochea and Arroyo-Rodriguez 2012; OH EPA n.d.). Ohio Waste-to-Energy facilities are classified as recycling facilities and do not require a solid waste disposal permit. While this removes the burden of obtaining additional permits, it does make it difficult to track which WRRFs are currently co-digesting.

Ohio's Alternative Energy Law (SB 221), which passed in May 2008, articulated a goal of 12.5% renewable electricity generation by 2024. Biogas produced from anaerobic digestion is included as a renewable energy source, and the Public Utilities Commission of Ohio in 2016 promulgated pathways for biogas producers to obtain Renewable Energy Credits. The mandate was frozen in 2104 for two years, but reinstated in January 2017, after Ohio governor Kasich vetoed a proposed freeze extension. Then in 2019, the state passed new legislation that subsidizes uneconomic nuclear and coal plants, and removes financial support for renewable electricity and efficiency mandates; further, it shrinks Ohio's renewable portfolio standard goal of 12.5% to 8.5%, and cancels the program after 2026 (Siegel 2019).

The active period for developing AD and co-digestion in the state occurred around ten years ago. For example, Quasar's major expansion into AD occurred during 2008 and 2011, using a variety of economic development programs to subsidize construction costs extensively. American Recovery and Reinvestment Act funds reduced digester construction costs by 33%; grants from the USDA Rural Energy for America Program (REAP) and from the Ohio Department of Development reduced it by another 25%, and use of double depreciation rates reduced them further (Alan Johnson, interview with authors, October 17, 2018; U.S. Treasury, n.d).

10.5 New York

New York is actively engaged in promoting both renewable energy, including co-digestion to produce biogas for energy production, and food scrap diversion from landfills. The state has one of the most ambitious renewable energy goals, 50% by 2030. Funding from NYSERDA supports renewable energy production and AD. However, low energy prices in New York's deregulated energy grid, combined with a tariff fee structure with high demand prices and other fixed fees, limits the potential for WRRFs to capture energy cost savings from onsite energy generation, reducing the economic incentives for adoption of CHP (O'Brien and Andrews 2017). With the state enacting a food waste recycling mandate into law in April 2019 (effective for large facilities within 25 miles of a recycling facility in 2022), New York is poised for an increase in co-digesting WRRFs. Funding from New York Department of Conservation has provided support for food waste recycling programs across the state and at two WRRFs.

Of the 118 WRRFs with anaerobic digestion in New York State, six are co-digesting as of 2015. These WRRFs include Newtown Creek Wastewater Treatment Plant, LeRoy R. Summerson WWTF, Gloversville-Johnstown Joint WTF, Rome Water Pollution Control Facility, Metropolitan Syracuse WWTP (not co-digesting as of 2018 due to digester upset), and City of Watertown Pollution Control Plant. Newtown Creek WWTP is the only WRRF currently digesting food scraps, through a pilot program with Waste Management. Four stand-alone digesters and five on-farm digesters also accept food waste in New York State.

WRRFs in New York cite varying reasons for pursuing co-digestion. The Gloversville-Johnston WRRF and Rome Water Pollution Control Facility implemented co-digestion programs in partnership with municipal economic organizations in order to attract industry to their respective areas. The Oneida-Herkimer Solid Waste Authority has been developing a project with the Oneida County WRRF to implement food scrap digestion at the WRRF in anticipation of the recently approved statewide organic waste diversion mandate. Similarly, a driver for the Newtown Creek WWTP in Brooklyn, New York, to implement co-digestion was NYC's greenhouse gas emission reduction goals (Gilbride and Timbers 2013).

New York's Clean Energy Standard (CES), adopted in 2016 to replace the state's expired state RPS, and NYSERDA's financial and technical support of AD provide substantial incentives for renewable energy production at digesters (U.S. DOE 2018). Biomethane pipeline injection still faces barriers in the state due to a lack of consistent standards across the state. Currently National Grid and the Northeast Gas Association are working to establish consistency in interconnection standards across the Northeast (Dessanti and Wilson 2018). National Grid is currently working with the Newtown Creek WWTP in Brooklyn to develop a biogas to renewable natural gas project (RNG Coalition n.d.). With the newly approved organics recycling mandate and financial support from NYSERDA, New York is well-positioned to increase co-digestion at WRRFs in the state.

10.6 Pennsylvania

In Pennsylvania, renewable energy policy and funding incentives have supported WRRFs pursuing renewable energy generation. The state does not have requirements for organic waste diversion.

Four out of Pennsylvania's 81 WRRFs with AD are co-digesting as of 2015 (5%). These WRRFs are managed by the Hermitage Municipal Authority, Derry Township Municipal Authority (DTMA), Milton Regional Sewer Authority and New Castle Sanitation Authority. All four process under 10 mgd of wastewater. In addition, Pennsylvania has eight co-digesting farm digesters. Three out of four WRRFs in the state have leveraged partnerships with private industry to build successful co-digestion programs. Two of the WRRFs are co-digesting food scrap slurries despite the lack of organics waste diversion incentives. The Clearwater Road Treatment Facility operated by the Derry Township Municipal Authority successfully co-digested food scraps in partnership with Divert, a food waste management company producing a food scrap slurry that the WRRF was able to accept without making equipment changes. (When flood damage to the thermal dryer's ancillary systems in July 2018 reduced DTMA's capacity to process biosolids, DTMA suspended its acceptance of Divert feedstocks. See Chapter 7 for more information.) The Hermitage WRRF sources both food scraps and high strength wastes from food waste generators and carries out a successful food waste digestion program, including preprocessing food scraps onsite, with no private partner (See Appendix B).

Biosolid quality upgrades are a significant motivator to pursue co-digestion for PA WRRFs. Hermitage and Derry Township use the additional biomethane for producing Class A EQ biosolids. In addition, Derry Township cites market factors, such as the removal of electricity price caps and resulting electricity price increase, as a triggering factor for pursuing onsite renewable energy generation. Lastly, a motivation to seek out revenue-producing ventures from resource recovery has driven Hermitage and DTMA to seek out new resource recovery business lines. The Milton Sewerage Authority adopted co-digestion in tandem with upgrades to AD in order to reduce treatment costs, biosolid hauling costs and nutrient loading associated with wastes from a nearby industry (Kotrba 2007).

Policy motivators for co-digestion in Pennsylvania include the state's Renewable Portfolio Standard, which calls for 18% renewable energy use by 2021. Biologically derived methane and anaerobic digestion are explicitly identified as eligible sources. Net metering policy and available funding sources also provide incentives for renewable energy production. Pennsylvania's Alternative Clean Energy Program provides grants, loans and loan guarantees for the development of clean energy through the Pennsylvania Department of Community and Economic Development. Through the Growing Greener program and the Green Energy Loan Fund, Pennsylvania's Department of Environmental Protection has funded at least two combined heat and power projects at Hermitage and DTMA WRRFs. DTMA is the first co-digesting WRRF in the state to establish a PPP to enable RNG production, for sale via tube trucks or pipeline injection. The WRRF's natural gas utility, UGI, is becoming more open to pipeline injection as many other biogas generators such as landfills have requested interconnections for pipeline injection projects.

10.7 New England Organics Landfill Ban States

In this section, the researchers explore the pattern of adoption across alternative types of digesters (including farm, stand-alone and WRRF) among the five states with statewide organics recycling mandates or landfill bans. In addition to California (and very recently, New York), the other four states are in New England: Massachusetts, Vermont, Connecticut, and Rhode Island. Massachusetts and Vermont each has one WRRF co-digesting food scraps, the other two states have none. The researchers highlight the intervening factors that influence the choices among organics processing options to process food scraps in these four states.

One key difference is size. California is the third largest state by area (after Alaska and Texas) whereas the four New England states are among the eight smallest U.S. states by area. The New England states have substantially fewer WRRFs than California, and indeed than all of the six states highlighted for having the most co-digesting WRRFs (see Table 10-1). Once size of the wastewater sector in a state is taken into account, the New England rates of adoption of AD fall roughly within the same range as for the six states featured above. Given the small numbers of WRRFs with AD, the rates of adoption of co-digestion similarly are not out of line.

Another factor is that two of the states (the ones with no co-digesting WRRFs) only require generators to adhere to the ban if a facility is nearby, which has slowed the development of new processing capacity. In contrast, Massachusetts and Vermont are more active in providing policy incentives and promoting compliance with their bans. A third factor is that all of Vermont and large swaths of Massachusetts are very rural, and the resulting lack of economies of scale work against the economic feasibility of WRRF co-digestion. As a result, in those states, other organics processing solutions more suited to rural areas have been adopted, including on-farm digesters and composting. It should be noted, however, that the one co-digesting WRRF in Massachusetts, which serves the Boston metropolitan area, is processing 40% of the state organics.

10.7.1 Massachusetts

Massachusetts has implemented organic waste policies and renewable energy policies that support co-digestion. Massachusetts has the largest population (6.8 million) of the four New England states to enact a landfill ban, and disposes of the largest quantity of food waste (one million tpy). The Massachusetts organics landfill ban requires institutional, commercial and industrial food waste generators producing above one ton of waste per week, to divert their organics from the landfill. The state funded feasibility studies for co-digestion at the six WRRFs with digesters. These feasibility studies found that co-digestion would be financially infeasible at low feedstock acceptance and for most WRRFs, there are insufficient nearby feedstocks to justify a large-scale co-digestion project. Of the six, one WRRF is co-digesting food waste: the Greater Lawrence Sanitary District WRRF is very large (52 mgd) and will provide up to 40% of the capacity needed to process the additional 350,000 tons/year of organic waste projected to be diverted from landfills due to the ban (Cousens and Weare 2018). Originally the Deer Island WTP in Boston, the state's largest WRRF, was proposed to supply processing capacity for the Greater Boston area; however, residents near the facility protested against the proposed project due to concerns about increased truck traffic to the facility.

While there are few co-digesting WRRFs, on-farm and stand-alone digesters that accept food waste are prevalent throughout the state. Massachusetts has three on-farm digesters and five stand-alone digesters in 2015 (Pennington 2018).

10.7.2 Vermont

Vermont has a landfill disposal ban[9] that is the most expansive and ambitious of any state, as well as a robust system of energy incentives and revolving loan programs that allow for AD energy development. With the low population density in the state, the regulatory landscape of Vermont generally encourages distributed, smaller-scale processors of energy using anaerobic digestion (e.g., low caps on net metering, FITs, and tax incentives). The state RPS goal aims to achieve 75% renewable energy use by 2032, and specifically identifies anaerobic digestion as an eligible technology.

With the largest land area (nine times the size of Rhode Island and 20% larger than Massachusetts) and the smallest population (624, 600, or one-tenth that of Massachusetts), Vermont generates an estimated 60,000 tpy of food waste. While Vermont has one of the most far-reaching landfill bans, it also has substantially different solid-waste economics compared to other New England states. The low population density and high access to agricultural waste disposal may make it difficult for WRRFs to source the feedstock needed to invest in an organics processing facility. Existing renewable energy programs cater towards the state's farm digesters, which are smaller than a typical WRRF digester.

Only one WRRF in Vermont is confirmed to be co-digesting as of 2015 (Pennington 2018). Essex Junction WWTP (3.3 mgd) accepts food processing wastes on an ad hoc basis. For its co-digestion substrate, the WWTP focuses on brewers' waste and other HSOW, which other facilities cannot handle and which does not require a long term commitment that could compromise its ability to serve connected customers, its

[9] As per VT. Stat. Ann. tit. 10, §6602 and 6605, the ban includes:

- Coverage of ICI in 2014; coverage of ICI and households by 2020
- Sets up a distance threshold to processing facility: less than 20 mi in 2014; no threshold in 2020
- Sets up a generation threshold: 2017: more than 18 tons/yr; 2020: no threshold (all ICI and households)

core mission. Food scraps are processed at the solid composting facility, run by the local solid waste district. (See Appendix B).

10.7.3 Connecticut

Connecticut's 2014 food waste ban requires institutional, commercial and industrial (ICI) food waste generators within 20 miles of a facility to divert food waste from landfills (though restaurants and institutional food service are exempt). Beginning in 2014, ICI food waste generators producing more than 104 tons per year are potentially subject to the landfill ban, conditional upon a processing facility with available capacity being located within 20 miles. In 2020, generators producing more than 52 tons per year will be subject to the ban conditional on the distance threshold.

Connecticut is the second largest of the four New England landfill ban states in population (3.6 million) and quantity of food waste disposed (500,000 tpy) – about half that of Massachusetts. Its stated goal is to divert 60% of municipal waste away from incinerators and landfills, and the state estimates that it needs a minimum of 300,000 tpy of organic processing capacity by 2024. To reach its target, Chris Nelson of the Connecticut Department of Energy and Environmental Protection said the state is seeking a diversified portfolio of facility types. However, land application of biosolids faces regulatory barriers.

High energy prices and high landfill prices make renewable energy generation and food waste diversion via AD attractive, yet none of the 10 WRRFs with AD in Connecticut pursues co-digestion. This capacity has largely been fulfilled by developers of large AD facilities such as Quantum Biopower's merchant plant in Southington. In addition, while energy prices in Connecticut are high, RECs accessible through the state RPS are geared more towards solar, wind and fuel cells.

10.7.4 Rhode Island

Effective in 2016, the Rhode Island landfill ban requires covered ICI entities less than 15 miles of a permitted processing facility to divert their food waste from landfills. As of 2016, covered entities include sources generating at least 104 tons per year; in 2018, the coverage expands to include educational institutions generating at least 52 tons per year.

Rhode Island, the state with the smallest land area and highest population density (1.1 million people), generates an estimated 220,000 tpy of food waste. Its stated goal for diversion is 80%, or around 174,000 tpy. However, the state has very limited resource to support implementation of the ban.

Prior to the ban, commercial collection and processing of segregated food wastes was "practically nonexistent" (Rhode Island Solid Waste Management Plan 2038 2015). As of 2018, the primary outlet for foods scraps under development is a stand-alone food scrap digester by the Israeli-based Blue Sphere Corporation. The facility, which will be the largest in the New England when operational, is set to begin operations in Winter 2018/2019.

Table 10-2. Policies and Market Indicators Relevant to Co-Digestion for Key States

	States with Greatest Numbers of WRRFs Co-digesting						States with Organics Landfill Bans			
State	CA (organics recycling mandate)	IA	NY	OH	PA	WI	MA	VT	CT	RI
Water Quality Permit Policies										
% WRRFs with nutrient limits in NPDES permit	43%	15%	47%	52%	91%	100%	59%	0%	22%	63%
Food Waste/Recycling Policies										
Statewide scraps landfill ban/Recycling mandate (unless otherwise noted) (year enacted)	Organics waste recycling mandate for ICI generating: > 8 cu yd/wk, 2016; > 4cu yd/wk, 2019; >2 cu yd/wk, 2020 (2014)	No statewide requirement	Organics waste recycling mandate for ICI generating > 2 tons/wk within 25 mi of processing facility, 2022 (2019); NYC: large food waste generators, 2015 (2013)	No statewide requirement	No statewide requirement	No statewide requirement	Organics landfill ban for ICI generating > 1 ton/wk of food scraps, 2014 (2014)	Organics landfill ban for ICI generating: >2 tons/wk, 2014; >1 ton/wk, 2015; > 1/2 ton/wk, 2016; >1/3 ton/wk, 2017; all ICI & households, 2020 (2012)	Organics landfill ban for ICI (except restaurants and most institutional food services) generating: >2 tons/wk, 2014; >1 ton/wk, 2020 (2014)	Organics landfill ban for ICI generating: >2 tons/wk, 2016; >1 ton/wk fpr covered educational facilities, 2018 (2014)
Zero waste goal or organics diversion/disposal goal (in statute or regulations)	Disposal: -50% by 2020; -75% by 2025 (SB 1383, 2016)			Removed state disposal fee for organics diverted from landfills (2010)			Disposal: -30% by 2020; -80% by 2050 (regulatory)	Diversion: 50% Disposal: -25% by 2020 (statutory)	Disposal: -60% by 2024 (regulatory)	Diversion: 50% by 2012 (statutory)
Financial grants, technical assistance	CalRecycle Organics Grant Program		Municipal Recycling and Climate Smart Communities grants (NYDEC)	Ohio DNR grants for food waste recycling programs; removed state disposal fee for organics diverted from landfills (2010)			Commonwealth Organics-to-energy Program; Massachusetts Renewable Energy Trust Fund; Sustainable Materials Recovery Program; Energy Revolving Loan Fund	Clean Energy Development Fund	Green Bank loans for AD developers	None

Table 10-2. Policies and Market Indicators Relevant to Co-Digestion for Key States (cont'd).

Distributed renewable energy market access policies										
Interconnection limits	Up to 10 MW	Up to 10 MW	Up to 5 MW	Up to 20MW	Up to 5MW	Up to 15MW	No limit specified	No limit specified	Up to 20MW	No limit specified
Net Metering	Net metering up to 1 MW	Net metering kWh offset provides credit at costumer's retail electricity rate	Includes AD biogas (up to 2 MW, farm-based only), biomass, and micro-CHP	No capacity limit; including for biomass and landfill gas	Up to 50kW for residents, up to 3MW for nonresidents and up to 5MW for emergencies	20 kW (some utilities allow larger systems to net meter); provided by all IOUs and municipal utilities, CHP eligible	Up to 2MW for private and up to 10MW for public	Up to 2.2 MW for military systems, 500kW for general renewable energy systems	Standard net metering: 2 MW Virtual net metering: 3 MW	Up to 10 MW
Feed-In Tariffs (FIT)	CHP Feed-In Tariff: rate based on 12-mo avg spot price for hours	None	None	None	None	Utilities voluntarily offered Advanced Renewable Tariff	Exists only for solar; Solar Massachusetts Renewable Target (SMART) Program	FIT known as Standard Offer Program; up to 2.2MW	The Low and Zero Emissions Renewable Energy Credit Program requires Eversource and United Illuminating Company to procure renewable energy credits under 15-year contracts	The REG Program is a new system of performance-based incentives approved by the Public Utilities Commission
Renewable energy financial incentives and assistance										
Low Carbon Fuel Standard/ Alternative Fuel Standard (ID rates, eligibility)	LCFS	No	No	No	AFS	No	No	No	No	No
Financial Assistance	Self-Generation Incentive Program by California's Public Utilities Commission: 3 MW limit; tiered payments based on production	Renewable Energy Tax Credit: 2.5 MW limit; Alternative Energy Revolving Loan Program: low-interest loans for 20 years max	NY Prize: financial support for communities for stand-alone microgrid energy systems; NYSERDA CHP Program: to install CHP systems up to 3 MW; AD Gas-to-electricity program: 2MW limit	Ohio Energy Loan Fund	Alternative and Clean Energy Program: loans and grants; Public Utility Commission's Sustainable Development Fund; Metropolitan Edison/PECO Sustainable Energy Funds; Growing Greener and Green Energy Loan Fund	Focus on Energy (public benefit fund) provides financial and technical assistence	Commonwealth Organics-to-energy Program; Massachusetts Renewable Energy Trust Fund; SMRP: grants for composting equipment and organics capacity development; Energy Revolving Loan Fund: PACE financing for commercial properties	Clean Energy Development Fund; Renewable Energy System Sales Tax Exemption: 250 kW limit; 20kW limit on micro-CHP systems; GMP's Cow Power; Small Business Energy Loan Program; Commercial Energy Loan Profram; Agricultural Energy Loan Program	Green Bank loans for AD developers	None
Renewable Portfolio Standard (year enacted)	20% by 2010, 25% by 2016, 33% by 2020 (2002); 50% by 2030 (2015)	Capacity-based requirement of 105 MW; AD is eligible (1983)	29% by 2015 (2004); 50% by 2030 (2016)	12.5% by 2027 (2008)	18% by 2021 (2004)	10% by 2015 (1999)	Class I: 15% by 2020, + 1% per yr after; Class II: 5.5% by 2015, with formula-based increases per yr after; covers AD biogas	55% by 2017; + 4% every 3 years to 75% by 2032	H.B. 7413 enacted in 2016, extended RES to increase by 1.5% annually to 38.5% by 2035	Class I: 21% by 2020; 40% by 2030; Up to 29% by 2020 across all classes

Table 10-2. Policies and Market Indicators Relevant to Co-Digestion for Key States (cont'd).

	States with Greatest Numbers of WRRFs Co-digesting						States with Organics Landfill Bans			
State	CA (organics recycling mandate)	IA	NY	OH	PA	WI	MA	VT	CT	RI
Energy Performance Contracting (ESCOs) Authority										
(1)Is there clear legislative or executive authorization? (2) Is there a program or project administered by the state agency?	(1) Yes; (2) Yes; State facilities only	(1) No; (2) No	(1) Yes; (2) Yes; State agency implements for all public entities, including municipalities	(1) Yes; (2) Yes; ESPCs in public buildings and universities since 1994	(1) Yes; (2) Yes; State statute (GESA) authorizes similar provisions	(1) Yes; (2) Yes; Dept of Admin provides financing for ESPC projects in state facilities only	(1) Yes; (2) Yes; State agencies implement ESPCs for all facilities larger than 100,000 sq ft including municipal projects	(1) Yes; (2) Yes; Department of Buildings and General Services uses EPSCs within correctional facilities only	(1) Yes; (2) Yes; for state agencies and municipalities	
Energy market prices										
Electricity prices (industrial customers) - Cents/kWh (2018 $)	16.06	8.73	14.74	9.84	10.13	10.76	17.12	14.6	17.55	16.42
Natural gas prices (industrial customers)	7.22	5.34	7.81	6.87	8.58	5.14	9.9	4.55	6.63	8.69
Landfill tipping fees - $/ton	58.42	48.28	66.17	44.49	69.59	49.09	95.00	Not reported	Not applicable	90

CHAPTER 11

Lessons Learned

The first section of this chapter summarizes the findings from project research. The second section draws out the lessons learned for the design of successful business strategies for co-digestion, with a focus on solutions to financial impediments and risks, including low or uncertain market returns and challenging access to capital. The third section summarizes the research team's conclusions.

11.1 Findings

This section reports on findings about impediments and potential strategies to address them from facilities with co-digestion success, as well as facilities that decided not to co-digest, or that have cutback or suspended co-digestion. This section also reports on the contributions that innovation ecotem partners can make to facilitate WRRF co-digestion.

11.1.1 Successful WRRFs: Co-Digestion Strategies and Programs

Our findings draw on both the major case studies reported in Chapters 4 through 9, as well as the case study thumbnails in Appendix B. Table 11-1 summarizes key elements of the major case studies.

Drivers: The financial drivers for co-digestion most frequently mentioned by WRRFs were: rising energy costs, and financial support programs to promote greenhouse gas mitigation, renewable energy, and food scrap diversion. Some also cited their opportunity to add investments to support co-digestion as part of large facility upgrade investment projects, which allowed them to scale planned AD, energy, and/or biosolids management investments to accommodate co-digestion. Operational drivers included underutilized AD or energy infrastructure, more stringent requirements for biosolids management, and the need to preserve wastewater treatment capacity (and the ability to accommodate new business moving into the area) in the face of dramatically expanding pretreatment program wastes (e.g., brewery wastes) that would overwhelm the wastewater treatment capacity. Environmental and community benefits cited include: service to FOG, food processing and food scrap waste generators (particularly ones from their service area) seeking new outlets to comply with more stringent regulatory requirements; support for economic development; and support for achieving community goals for renewable energy, GHG reduction, and food scrap diversion.

Decision Criteria for Investments: Many co-digestion projects were required to meet return on investment or payback period tests, though the thresholds for approval varied widely. For non-core-mission projects, LACSD uses five to 10 years as a maximum payback target, whereas Stevens Point uses a 20-year payback threshold. Various WRRFs placed different requirements on these projects in non-core business lines, including: maintaining or improving water quality, no detrimental impact on facility operations, and no impact on taxpayers.

Scope and Costs of Co-Digestion Projects: Successful co-digestion programs are typically implemented over time in a series of projects or phases. In the first project to accommodate receiving HSOW, the scale of investment varies tremendously across WRRFs, depending upon the facilities currently available, the type and quality of incoming feedstock supply, and the stage of commitment to co-digestion. For example, VVWRA spent $10,000 to convert an existing tank to a FOG receiving station, whereas CMSA spent $2 million on a new organics receiving station, which includes a 300,000-gallon tank, mixing pumps, rock trap grinder, paddle finisher and odor control system. Among energy projects, the costs of RNG pipeline injection projects vary widely depending upon interconnection requirements, which vary across utilities and states, and pipeline proximity.

Table 11-1. Key Elements of Major Co-Digestion Case Studies.

Characteristic	VVWRA, VVWRF	City of Stevens Point, Stevens Point WTP	City of Dubuque: Dubuque WRRC	DTMA, Clearwater Road WWTP	CMSA, CMSA Treatment Plant	LACSD, JWPCP
Drivers	High electricity prices, Electric power instability, Financial support for renewable energy (subsidies, tariffs and grants)	Dramatic increase in brewery pretreatment wastes; WI Focus on Energy technical and financial assistance; Increasing restrictions on biosolids, effluents	Community sustainability goals, Large scale investment to upgrade outdated facility provided opportunity to add AD and resource recovery	Increasing biosolids management challenges, optimize beneficial uses of on-site generated biogas, and reduce energy costs	Organics recycling mandate, diversion goals; Financial support for GHG mitigation; Marin County's Zero Waste Goal by 2025	Organics recycling mandate, diversion goals; CA LCFS, US RFS, South Coast Air Quality Management District 1191 Vehicle Fleet Rules
Goals	**Initial Goals**: Energy efficiency and neutrality, Improved treatment process control parameters; **Later Goals:** Supply electricity to grid, and RNG pipeline injection	Energy neutrality and efficiency, Keep operating costs low, Service to brewery waste generators	Public health and environment, Energy efficiency and neutrality, Resource recovery, Service to waste generators, Revenue streams	Maintain reasonable customer rates, Energy neutrality, Provide reliable outlet for local or regional sources of FOG and HSOW	Support local solid waste hauler achieve food scrap diversion, Energy savings and neutrality, Underutilized digester and energy equipment	Provide food scrap diversion option for local haulers, Convert waste into renewable energy and soil amendments
WW Treatment (MGD) avg daily dry weather flow	11.3	2.8	7	4	7.5	280
Major Sources of Cost Savings	Energy	Wastewater treatment, energy	Staff, energy, biosolids management	Energy, biosolids management	Energy	Energy
Major Sources of Revenues	Tipping fees	Tipping fees	Tipping fees, RNG sales	Tipping fees for Septage, FOG, and High Strength Organic Waste (HSOW) receiving	Electricity sales (starting 2019), Tipping fees	Electricity sales, Vehicle fuel sales, Tipping fees
Tipping Fee Rates:						
FOG	$0.04/gal	(dropped FOG for more valuable feedstocks)	$0.06/gal	$1.16/gal	sliding scale: $0.06/gal (first 1500 gal.) to no charge (> 15,000 gal.)	--
Food processing residuals	$0.04/gal	$0.00606/gal, from service area, $0.03988/gal, from outside service area	$0.03- $0.06/gal	$0.0378/gal	NA	--
Food scraps slurry	$0.04/gal	NA	NA	$0.0378/gal	$0.0938/gal	$25/ton ($.021/gal) CY2020
Total tipping fee revenues for food waste	$249,693 (2017)	$110,000/year on average	$189,644 (FY 2019)	FOG = $387,400 (2018) HSOW = $50,000 (2018)	$150,000 (2017-2018)	$1.5 million (FY2019/2020)
Feedstock contracting	No contracts	Longterm agreement with brewery	No contracts	G2E; MOU for food scrap slurry with Divert	Longterm MOU for food scrap slurry with Marin Sanitary Services	Current: 1-yr contracts for food scrap slurries (multiple private haulers; county facility)
Onsite feedstock pretreatment equipment	No equipment	Bar screen, rock trap, grit sump pump, chopper pump	No equipment	Aerobic FOG conditioning, rock trap, grinder, chopper pump	Rock trap grinder, paddle finisher	Pending: grit and plastics removal
Food waste as share of total AD feedstock	10% of volume, 20% of TSS	34.1% of volume, 39.7% of TVS	22% of volume, 44% of TSS	12% of volume, 33% of TVS	20% of volume	9% of volume, 30% TSS (in the 1 codigesting AD out of 24 total for demo project)
Biogas production (% increase; Total with co-digestion)	120%; 685,000 scfd (2016)	100%; 100,000 scfd	33-78%; 300,000 to 400,000 scfd	78%; 267,000 scfd	80%; 280,000 scfd (2018)	33% in codigesting AD, 1.4% overall; 7,300,000 scfd (demo project)
Biogas uses (beyond boilers)	1) CHP; 2) [pending] microgrid/battery storage; RNG production	1) CHP; 2) [pending] biosolids thermal dryer	1) CHP; 2) RNG to pipeline injection	1) Biosolid thermal dryer, 2) CHP engine, 3) additional CHP [pending]	1) CHP; 2) [pending] new CHP for electricity sales	1) CHP; 2) CNG for onsite fueling station; more CHP or RNG pipeline injection [pending]
WRRF energy sales tariffs	1) No energy sales; 2) [pending] net metering sales	Wisconsin Public Service Renewable Energy Tariff: $0.10/kWh (peak) and $0.05/kWh (offpeak)	5% of gross RNG and RINS sales revenue	No energy sales	Electricity Sales to Marin Clean Energy at $0.105/kWh	Spot market sales to CA ISO Grid
P3 structure	1)PPA and lease with Anaergia; 2) Negotiating a DBFOM with Anaergia for RNG pipeline injection	P3 in which brewery and WRRF share costs of dedicated pipeline and HSOW receiving station.	DBFOM with BioResources Development for RNG pipeline injection	Future GESA for expanded co-digestion	PPA with Marin Clean Energy (10-year Contract)	NA
Biosolids: Change with codigestion	No change	12% Increase	Minimal change	15% Increase	Minimal change	No detectable change (demo project)
Financing and Grants	Private sector P3 funding, CA grants	1) Wisconsin Focus on Energy grants, Build America Bonds; 2) WI Clean Water Fund bonds	IA State Revolving Fund loans	1) municipal bonds, 2) municipal bonds, PA Green Energy Works Grant	Utility Capital Investment Accounts	Internal funds, CA grants

Key:
Numbers 1), 2) and 3) refer to separate codigestion projects.
G2E: Grind to Energy; MOU: Memo of Understanding; scfd: standard cu ft per day; CHP: combined heat and power; DBFOM: design-build-finance-operate-maintain; PPA: Power purchase agreement; GESA: PA Guaranteed Energy Savings Act; NA: not applicable
TSS: total suspended solids; TVS: total volatile solids; HSOW: high strength organic wastes; RINS: Renewable Identification Numbers (RINs) under the Renewable Fuel Standard (RFS) Program; LCFS: Low Carbon Fuel Standard

Major Sources of Cost Savings and Revenues: WRRFS most frequently cited as the major sources of financial gain: tip fee revenues (which contribute revenue streams to major AD upgrades as well as receiving station investments), energy cost savings and/or revenue, savings in wastewater aeration costs by diverting liquid wastes from the headworks to the digester, and savings in biosolids management costs by supporting thermal dryers to create Class A EQ biosolids. They also cited financial incentive programs providing grants or green payments.

Biogas and Biosolids Production: Biogas production increased substantially from the addition of co-digestion substrates, with rates of increase depending upon share of HSOW added to digesters, and share of total digesters involved in co-digestion. Biosolids did not increase with co-digestion in 4 out of 6 of the plants.

Evolving Trends: Resource Recovery Product Lines: More WRRFs are slowly beginning to address the relatively untapped potential to date of food scraps as an AD feedstock, as various innovative arrangements are introduced to supply food scrap slurries. Many WRRFs are now evaluating projects to produce biomethane for use as vehicle fuel or pipeline injection (typically for vehicle fuel) as an alternative, or as a complement, to producing renewable heat and power, as the relative values of subsidy programs have shifted more in favor of production of vehicle fuel a few years ago. Current uncertainties in RINS pricing has engendered a wait-and-see approach for WRRFs planning energy projects for a few years down the road.

Evolving Trends: Performance-Based Contracting: Though WRRFs have been reluctant, and in some cases prohibited by charter, to engage in Public-Private-Partnerships in the past, they are moving into performance-based contracting for new projects that are outside their core area of expertise, notably energy projects, and especially RNG projects. Benefits of entering into a Public-Private-Partnership include accessing expertise not available inhouse, shifting risks, and – infrequently – accessing private financing to circumvent a public capital constraints and, in some cases, long and politicized approval processes.

11.1.2 “No-Gos” and Co-Digestion Suspensions and Cutbacks: Barriers

Among WRRFs that evaluated co-digestion, the primary reason offered for not going forward with it is the lack of sufficient economic returns. Contributing factors cited include uncertain feedstock supply and revenues, low energy prices (and, as a result, low energy savings), scale too small to attain economics of scale, and lack of incentive programs to provide financial support. Many WRRFs cite use of payback periods as a decision criterion; it is not known to what extent the financial returns would have been positive if a net present value had been calculated over the lifetime of the equipment. Nonfinancial reasons offered for no-go decisions include NIMBY concerns and changes in political leadership, with different priorities.

Plants have suspended co-digestion because of problems with feedstock availability or quality or the need to invest in additional equipment not planned or budgeted for, reinforced by market changes that have reduced the available economic returns relative to time of adoption. In several cases, plants cited the loss of their sole food waste source, typically a local food processing plant that moved away, and limited incentives to pursue a replacement because the plant was close to capacity to generate energy and at risk of flaring, or because energy prices had plummeted since time of initial investment.

One facility, known as a nationwide leader in co-digestion, found itself facing a combination of aging equipment, reduced tipping fees and digester capacity limitations, which raised questions as to the cost-effectiveness of continuing to accept HSOW. Facing requirements for both near-term and long-term capital investments to continue co-digestion and competing priorities for capital, the municipality decided to suspend the co-digestion program for now, and to consider “refining the program when financing terms become more favorable.”

Some WRRFs continue co-digestion but cut back on the quantity of food waste feedstocks accepted. A primary reason is operational failures: the facilities experience extended periods of equipment failure that are reducing their capacity to use biogas, resulting in flaring, or to manage biosolids. Another reason is issues with the quality of some of their feedstocks, which the plant may address at a future time with investments in pretreatment equipment.

11.1.3 Role of Innovation Ecosystem Elements

The various elements of the innovation ecosystem are each contributing to the innovations required to achieve co-digestion at WRRFs.

Technology and development companies are serving an important role partners, in some cases with performance-based contracts, in all areas of investment and operations for co-digestion: AD, feedstock management, energy recovery, and biosolids management. Typically the WRRF retains ownership of the assets, but the contractor will build and operate the equipment and provide guarantees of revenues or cost-savings. Quasar, which has played a significant role in the proliferation of digesters accepting food waste in Ohio and nearby states, employs three different models at its facilities serving WRRFs – including the French Creek WRRF in North Ridgeville Ohio – where it builds, owns and operates the facilities, and supplies AD services and electricity at a discounted rate to contracted WRRFs. Alternatively, Quasar can construct and operate digester with their partners retaining ownership, or simply design and construct a digester that partners own and operate (a more traditional business model). Anaergia and ESG also are leaders in this area. Anaergia has developed multiple projects with Victor Valley, outlined in Chapter 4. ESG is currently developing a co-digestion project with DTMA, outlined in Chapter 7, and also has developed projects in Virginia, West Virginia and New York.

In the **solid waste sector**, a wide variety of innovative supply arrangements are arising to address the relatively untapped potential to date of food scrap as an AD feedstock. Their traction is greatest in areas with landfill bans or recycling mandates – either in place, or being seriously discussed. A number of private solid waste haulers and others in related sectors – both local and national – are supplying the new product line of food scrap slurries. Also solid waste agencies have initiated wastewater-solid waste partnerships to create AD co-digestion options for their organics waste stakeholders to comply with new landfill ban/recycling mandates. Finally municipal solid waste agencies have shares with wastewater agencies the expertise in RNG gas recovery systems they have accrued from prior use of this technology for its landfills.

Energy utilities operating under RPS requirements in concept have an incentive to support the supply of renewable power, though WRRFs find it can be difficult to negotiate interconnection agreements with utilities. Utility tariff structures also may limit the cost savings WRRFs can realize from onsite use. The federal RFS and California LCFS potentially provide strong incentives for eligible investments in pipeline injection of biomethane-based vehicle fuels. Stringent gas quality standards and interconnection requirements in California can impede these projects, though requirements are less onerous in other states.

The private capital **finance sector** is showing some interest in funding co-digestion investment, though their focus is primarily on stand-alone food scrap digesters. Among public sources of capital, there is now a precedent for the low-interest rate State Revolving Fund (SRF) program to allow alternative delivery approaches for contracting. The NJ SRF allowed the Rahway Valley Sewerage Authority to procure a long-term feedstock contract with a private partner prior to procuring SRF funding, a departure from the traditional process of submitting a completed design to SRF before receiving funding and issuing an RFP for bids to be awarded on a lowest-cost basis.

The policies of **state and municipalities** that regulate wastes are important for creating supplies of feedstocks; further, their policies providing green payments to support investments in sustainability can provide important financial support. Chapter 10 illustrates that, in some cases with highly favorable feedstock access and energy market access and the support of federal tax and energy policies, it has been possible for WRRFs to make a successful business case for co-digestion of food waste without the support of an aggressive state policy portfolio. However, reducing the impediments to energy market access for sales of electricity, and particularly for pipeline injection of RNG, will improve the economics of co-digestion, as will implementing strong policies to promote renewable energy supply. Further both establishing and enforcing food scrap diversion requirements will increase the currently limited supply of food scraps.

11.2 Lessons About Successful Business Strategies for Co-Digestion

11.2.1 Overview

For each WRRF, the specifics of a successful business strategy for co-digestion will vary because it will depend upon the policy and market environment in the region, as well as utility long-term strategic goals, organizational culture, and resources. As a corollary, the costs and economic contributions will vary. As a result, the research team does not offer economic rules of thumb for revenues or costs.

However they offer the following lessons.

1. **The right context is necessary to have a successful co-digestion program.**
   Every list of essential elements for a successful co-digestion program includes the need for a co-digestion champion in the utility or municipal government. This research identified five other elements as critical:

   - Enough site space for vehicles to deliver feedstocks and for other equipment needs.
   - A business mindset to resource recovery.
   - Visionary utility board or municipal decision makers who will support projects beyond the core wastewater mission that make economic sense to ratepayers.
   - Location with access to a sufficient supply of feedstock at a good price.
   - Location in an energy market where it is possible to generate energy cost-savings and/or energy revenues.

The first is a feasibility constraint; the next two are additional organizational attributes, ones that are associated with a UOTF orientation; and the final two pertain to the potential for achieving scale for the program, and generating revenues or cost-savings.

2. **A successful business strategy employs a life-cycle perspective, taking into account revenues and costs from the time of initial investments through replacement investments.**
   It is critical to assess whether the utility can establish the operational and financial capacity to support the program over the long-term, which requires a life-cycle perspective. This is because:

   - The full benefits of co-digestion typically will not accrue until the WRRF has achieved a mature program with a balanced set of AD, energy generation, and biosolids management capacity.
   - Identifying the full costs necessitates delineating the capital requirements for maintaining and upgrading the assets that support co-digestion.

3. **A successful business case leverages available drivers in sync with WRRF mission.**
   Drivers include market-based opportunities to generate revenues and cost savings, regulatory policies regulating wastes, policies providing green payments to support investments in sustainability, as well as utility and community commitments to environmental service and community service.

4. **A successful business strategy incorporates strategies to address financial risks.**

Risk management strategies include: diversifying sources and product outlets, establishing long-term contracts, building in equipment redundancies to allow for scheduled or unscheduled maintenance requirements, establishing long-term contracts for purchasing feedstocks or selling products, and using public-private partnerships/contracts to share construction ***and operating*** risks with the private sector.

(The next section of this chapter considers strategies to address financial impediments and risks in more detail.)

5. **A successful business strategy demonstrates the project will not compromise plant compliance with its environmental permits.**
   The wastewater sector has important responsibilities for public health and environmental quality, which are central to its mission. Violation of those responsibilities can result in substantial financial penalties.

6. **A successful business strategy typically will evolve over time, adding additional projects that build on past successes.**
   As a WRRF learns from experience over time and is able to improve economic performance from resource recovery, the strategic questions evolve. For example, for AD capacity, the focus evolves from identifying excess capacity, to rationing capacity to the highest value sources, and finally to examining the potential for co-digestion to support expansion in AD capacity. For energy, the focus evolves from achieving onsite energy neutrality, to breaking down barriers to accessing the power grid, to exploring the potential for supplying RNG to the market.

7. **A business case for investment capital that can be successful is to highlight the financial value co-digestion can contribute to larger investment projects required for regulatory compliance or for regularly scheduled maintenance and upgrades in the utility asset management plan**.

   Large WRRF investment projects motivated by core wastewater treatment requirements, for which the financial criterion is cost-effectiveness, can provide leverage for promoting investments to support co-digestion. It can be much more cost-efficient to scale new investments in energy and biosolids infrastructure to accommodate co-digestion, than at a later time. Also this approach creates greater economies of scale in procurement for the co-digestion investment.

8. **A business case for investment capital that can be successful is to highlight the contributions the project will make to achieving environmental and community goals, along with its financial contributions.**

   Stevens Point considered co-digestion to be essential to process the dramatic expansion in brewery wastewaters with the success of its local brewery, in order to preserve wastewater treatment capacity to enable other companies to move into the area.

9. **A business case for investment capital for projects outside the core mission of the wastewater sector that can be successful is to employ a Public-Private-Partnership**.

   In addition to transferring risks (as mentioned in #4 above), P3 can provide access to alternative financing, including tax incentives unavailable to the public sector. Further the WRRF can gain increased flexibility and adaptability by shifting the project to the operating budget from the capital budget.

11.2.2 Solutions for Co-Digestion Impediments and Risks

The findings from successful and unsuccessful co-digestion programs highlight the importance of conducting long-term planning and adopting risk management strategies. Table 11-2 provides a set of solutions to the financial risks a WRRF faces, including insufficient, or highly uncertain, economic returns for the project (or program) and impediments to accessing financial capital. In addition, it addresses the operational and economic risks associated with feedstocks, energy and biosolids. Finally it covers solutions to impediments related to making the business case to stakeholders outside and inside the utility.

Table 11-2. Solutions to Co-Digestion Impediments and Risks: Creating Value and Managing Risks.

Barriers	Solutions
Project: Lack, or High Uncertainty, in Economic Returns	• Explore the full set of business options to generate cost savings and/or revenues for the project through resource recovery (tip fees, energy cost-savings, energy and nutrient product sales) • Explore the full set of options for grants and green payments from federal, state, and local government sustainability programs • Explore risk-sharing and cost-saving/revenue generating potential through an ESCO or other public-private partnership arrangement
Access to Financial Capital • Scarce financial capital (high debt load)	• Evaluate potential for use of internal capital reserve funds • Explore availability of incentive program grants and loans • Consider below-market Clean Water State Revolving Fund loans. • Consider a Public-Private-Partnership to provide financing
• Low priority for "non-core-wastewater" projects	• Leverage capital investment programs to comply with regulatory requirements or to perform needed maintenance/upgrades • Highlight the full set of financial, environmental and community benefits
Feedstock: Operations and Economics • Variable and uncertain quantity, quality and price (tip fees) of feedstock supplies	• Conduct market assessment of potential feedstock supplies, and implement a program for market development and supplier retention. • Leverage regulations for more stringent requirements for FOG, liquid industrial wastes, and food scraps to attract more suppliers. • Partner with haulers or generators of food wastes in order to reduce contamination and ensure a reliable supply. • Explore new options for supplying pretreated food scrap slurries. o Private market sources, including Waste Management, Divert, Grind2Energy, as well as regional solid waste companies o Collaborations with solid waste agencies o WRRF onsite depackaging and slurrying • Use feasibility studies, pilots and/or demonstration projects to evaluate impacts of feedstocks before full implementation. • Invest in onsite pretreatment equipment to reduce operational challenges and O&M costs. • Establish long-term contracts where possible (most likely when supplier does pretreatment), establish collaborative customer relationship when not. • Diversify food waste sources to avoid reliance on a single anchor supplier and to allow continuity in co-digestion if a source moves away or hauler drops out
• Landfill tip fees for food scraps lower than costs to supply food scrap slurry	• Encourage solid waste agencies to establish pricing across generator disposal options that incentivizes recycling scraps • Encourage solid waste agencies to enforce recycling mandates where they exist

Table 11-2. Solutions to Co-Digestion Impediments and Risks: Creating Value and Managing Risks, cont.

Energy: Operations and Economics • Cogeneration equipment difficult to maintain, prone to shutdowns • Access for selling electricity to the grid may be constrained • Access for injecting biomethane into pipeline may be constrained	• Explore all energy products and onsite/external sale options, taking into account evolving market access, tariff structures, and incentive programs, including the following products: o Electricity o Pipeline injection of biomethane o Biomethane for vehicle fuel production for local government fleets, direct sales, or through RNG brokers o Onsite use to support turning biosolids into valuable products (e.g., a dryer to produce Class A biosolids) • Diversify products and/or product outlets (onsite use and market sales). • Build in equipment redundancy to provide resiliency for downtime for maintenance. • Consider public-private partnerships to provide expertise and take on risks
• Air permits may be required when biogas used for incineration, drying, boilers, co-generation	• Impose air quality performance standards on private energy developers • Develop a collaborative approach with regulators
• Cost savings/revenues maybe low and/or uncertain due to: o Low energy prices o Tariffs with high fixed and demand fees	• Negotiate Power Purchase Agreements, setting long-term prices • Negotiate as a class with utilities/regulators for better contract terms
Biosolids: Operations and Economics • May not have capacity to handle an increase in biosolids in current management approaches • Accepting food waste may change quality of biosolids, e.g., increase nutrient loading in biosolids (as well as effluent)	• Optimize feedstock types and solids processing to manage impact on quality and quantity of biosolids produced. Not all cases of co-digestion result in additional biosolids, it will depend upon the relative share of co-digestion feedstock. • Evaluate opportunities for producing new products for nutrients
Stakeholders: (Board, feedstock sources, ratepayers, neighbors) • Political leadership promoting renewable energy and food waste recycling may be lacking • Stakeholders are concerned about impact on utility performance, future rates, neighborhood nuisances	• Work closely with utility decision makers and local political leadership. Make certain that decision makers are aware of the benefits as well as the costs. • Identify a champion from each stakeholder group to promote co-digestion. • Conduct public meetings and consultations with stakeholders to make benefits more understandable and tangible, and to learn about concerns • Develop solutions to mitigate potential public nuisances
Organizational Culture: • Risk-averse sector culture • Lack of information on financial aspects of co-digestion • Uncertainty about how to capture and communicate non-monetary benefits • Wastewater and solid waste cultural differences	• Appeal to a "do the right thing" perspective • Develop a "Utility of the Future" perspective • Highlight experiences of peer utilities that are co-digesting • Highlight local benefits that will accrue, including jobs, economic development, and community sustainability • WRF, WEF and U.S. EPA can facilitate information sharing through publication of co-digestion best practices and other technical information transfer (workshops, training, resources) • Conduct feasibility studies, and implement co-digestion project in stages, with pilot and demonstration projects providing an opportunity for stakeholders to provide feedback to improve processes and create buy-in • Involve employees in implementation of co-digestion and improving the process

11.3 Conclusions

Co-digestion at WRRFs can be successful where there is a fit with the organization culture, support from the utility decision makers for projects outside of the core mission area, and market and policy opportunities to create economic value. A successful business strategy will identify the opportunities to create value and achieve mission goals that co-digestion can unlock over time, while ensuring that the utility can establish the long term operating and financial capacity to support co-digestion. A successful business strategy will employ a a life-cycle perspective, leverage all available drivers, and structure co-digestion-related activities and contracts to manage financial risks. Public-private partnerships (PPP) can be part of the solution to insufficient or uncertain financial returns, by generating cost-savings or revenue streams to improve the economics relative to what the WRRF could achieve.

It is important to recognize that co-digestion does not fit in all contexts: in some contexts, the business case will indicate that the best option, under the current understanding of life-cycle potential, is to not move forward at this time.

To aid WRRFs in conducting preliminary assessments prior to contracting consultants to carry a formal evaluation, the researchers have presented a framework for WRRFs to analyze the opportunities co-digestion could provide in their own organizational, market and policy contexts. Such a framework is intended to help WRRFs develop a long-term business strategy and implementation plan that leverages those opportunities in a way that advances their mission and long-term goals. Ths research also provides six major case studies in this report in Chapters 4 through 9 and 25 thumbnail case studies of WRRF co-digestion programs in Appendix B. These thumbnail sketches offer a diverse range of approaches to co-digesetion and represent diversity in WRRF size, geographic distribution, and co-digestion feedstock.

The Appendices also provide a variety of resources to assist WRRFs in conducting preliminary analyses of the economics and environmental implications of co-digestion projects. As a supplement to the discussion in Chapter 2, Appendix A provides a summary of key policies that affect co-digestion in the wastewater sector, including regulations permitting wastewater treatment facilities, as well as policies that create, expand or impeded access to ptoential co-digestion product or feedstock markets. Appendix B provides thumbnail sketches of the 25 WRRFs that were studied in addition to the six major case studies, to illustrate a greater range of WRRF characteristics, policy and market contexts, and WRRF co-digestion strategies. Appendix C provides profiles of innovative food waste feedstock suppliers, supplementing the discussion in Chapter 3.

Appendices D-G are intended to provide resources for WRRFs in their preliminary assessment of co-digestion, supplementing discussions in Chapter 3. Appendix D lists a variety of models and tools WRRFs may find useful for doing a preliminary screening of their business case. Appendix E provides a primer on investment decision-making criteria and metrics, focusing on the use of triple-bottom line analysis as a complement to traditional financial analysis. Appendix F provides a list of funding sources that WRRFs may find useful when doing a preliminary screening of their business case. Appendix G lists the studies in the program of research exploring the technology and economics of implementing co-digestion commissioned by The Water Research Foundation.

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APPENDIX A

Policy Context for Co-Digestion at Wastewater Resource Recovery Facilities

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Map A-7: State and Local Food Waste Landfill Bans or Recycling Mandates

Map A-8: Average Price to Landfill a Ton of Municipal Solid Waste by Region, May 2017

Map A-9: Average Price of Electricity to All Sectors, November 2017

A.1 Introduction[1]

This appendix highlights two major classes of policies: regulations permitting wastewater treatment facilities; and policies that create, expand, or impede access to potential co-digestion product or feedstock markets.

Section A.2 reviews policies pertaining to permitting anaerobic digestion and energy technologies at wastewater resource recovery facilities (WRRFs), with particular attention to how the introduction of co-digestion with food waste may affect their applicability. The National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act represents the primary, water quality-based regulatory program for WRRFs. Anaerobic digesters are covered by the plant's NPDES permit. Federal and state water quality standards impose limits on the pathogen and nutrient content of the effluent that is discharged from the plant and on bioliquids or biosolids that are applied to farmland.

Anaerobic digesters and the related processes of energy production and biosolids management also may be subject to federal and state permitting requirements for emissions to the air and for solid waste disposal/management. Permits required by state and federal statutes are generally managed at the state level, and regulations will vary by state. The multiple permitting requirements, which may be complicated, expensive, and uncertain, are often cited as barriers to wider adoption of anaerobic digestion and co-digestion.

In some states, acceptance of food waste as a feedstock may result in the designation of the digester as a waste processing facility and as such, may trigger the states to develop solid waste regulations under the Resource Conservation and Recovery Act Subtitle D (for non-hazardous solid wastes). Because developing state-level solid waste permits for food waste digesters requires a new area of expertise among permitting officials, establishing the requirements and procedures can take an extended time period. Local permitting and zoning challenges also may arise when installing new digesters and energy production equipment; however, these issues are beyond the scope of this appendix.

Emissions from combustion-related equipment used for onsite energy production are regulated by both federal and state air quality regulations. Federal emission standards from the Clean Air Act are a minimum threshold; state standards may be more stringent.

Section A.3 of this appendix reviews policies designed to create or expand market demand for the energy and nutrient/soil amendment end-products of anaerobic digestion (co-digestion), or market supply of the food waste feedstocks for co-digestion.

For energy markets, whether and how states implement various "market-access" policies has a substantial effect on the ability of distributed power sources (such as WRRFs) to achieve positive economic returns from energy production in-house, particularly in this period of low market prices for natural gas. Returns from heat and power generation may be in the form of cost savings from reducing purchases from the electricity utility (which may be limited by tariff structures) or revenues from selling

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[1]This appendix draws extensively from the discussions of relevant law in several recent reports: Hammond, Emily, Sean McGinis, and Bruce Tobey. 2017. "Public-Private Partnership Opportunities for Water and Water Resource Recovery Utility Energy Projects." Water Research Foundation (WRF); Carr, Scott, Dan Collins, Sarah Deslauriers, Patrick Dube, Lauren Fillmore, Lisa McFadden, Lynne H. Moss, Lori Stone, and Jason Turgeon. 2017. "Accelerating Resource Recovery: Biosolids Innovation and Opportunity." WEF, National Biosolids Partnership; Willis, J., Andrews, N., Stone, L., Cantwell, J., & Greenwood, R. 2015. "Identification of Barriers to Energy Efficiency and Solutions to Promote these Practices." WRF; and U.S EPA. 2012. "Case Study Primer for Participant Discussion: Biodigesters and Biogas". EPA 190S12005, Technology Market Summit, May 14.

electricity to the power grid (through mechanisms such as net metering, feed-in tariffs, and interconnection to the grid). Returns from renewable gas sales may be in the form of revenues from either selling it directly as vehicle fuel, or distributing it through natural gas pipelines (which will be controlled by interconnection standards and utility rate structures).

Another set of energy policies that can be critical to achieving positive economic returns are financial incentive programs for environmental sustainability activities – notably renewable energy (in electricity or fuel form), energy efficiency, or greenhouse gas mitigation. In particular, state renewable portfolio standards (for electricity generation) can provide incentives for utilities to offer favorable tariffs for renewable energy sources. Since the U.S.EPA qualified biogas from anaerobic digestion (AD) as a new pathway for cellulosic biofuel in 2014 (and the associated credits have been rising in value), the federal renewable fuel standard has become a potentially significant revenue stream for biogas energy projects, complemented by the development of state low carbon fuel standards. Various federal and state agencies also provide grants or low interest loans for renewable energy projects.

For nutrient and soil amendment markets, various policies create both public, and in some cases, private demand for digestates, or compost made from digestate.

Finally, various policies promote – either directly or indirectly – a reliable supply of food waste feedstocks for organic processing, such as AD. Organics landfill bans and recycling mandates are designed to create a reliable supply of food scrap feedstocks for organic processing, as well as to promote the reduction and reuse of wasted food. States or local governments may also provide grants or low interest loans for the development of composting or anaerobic digestion infrastructure to recycle food waste. Further, local or state policies increasing the stringency of requirements for managing fats, oils and grease (FOG) or industrial food processing wastes may provide a stimulus to co-digesting those feedstocks.

A.2 Permitting Requirements

A.2.1 Water

A.2.1.1 Federal: National Pollutant Discharge Elimination System Permit and Beyond

The Clean Water Act (CWA) prohibits the discharge of 'pollutants' from a 'point source' into a 'water of the United States' unless the discharger has a National Pollutant Discharge Elimination System (NPDES) permit. Because wastewater resource recovery facilities (WRRFs) discharge pollutants from a point source into a water of the United States, they are each required to have an NPDES permit.

A WRRF's NPDES permit contains limits on what can be discharged, requirements for monitoring and reporting, and other provisions to ensure that the discharge does not harm water quality or people's health (U.S. EPA 2019). The implications of adding high-strength organic wastes (HSOW) at the headworks of a WRRF would need to be addressed in the facility's NPDES permit and falls under the Pretreatment program portion of the permit. Increased nutrient levels in wastewater discharges where high-strength food wastes are feedstocks can pose challenges in meeting effluent requirements because of the high nutrient content of certain food wastes (Carr et al. 2017). These are food wastes that have high protein content, such as dairy and meat/poultry processing wastes.

A.2.1.2 Pretreatment Standards

Pretreatment standards are limits on pollutant discharges from industrial and commercial facilities (see 40 C.F.R. 403.5) that emit an effluent to be processed by a publicly owned wastewater treatment plant (POTW). The standards are designed to protect the POTW from receiving a pollutant that would not adequately be treated or removed by the plant and that would constitute a violation of the POTW's NPDES permit. Such standards would also protect the treatment plant from receiving substances that could interfere with the plant's operations (including wastewater solids management) (U.S. EPA 2017a).

The standards include general and specific prohibitions, as well as national effluent guidelines for specific sectors. For example, 40 C.F.R. 403.5(b)(2) limits the acidity of waste that can be accepted at a WRRF, prohibiting anything with a pH lower than 5.0 “unless the [WRRF] is specifically designed to accommodate such discharges.” They also include local limits, which are set based on the capabilities of a specific POTW, its solids, and its receiving waters.

The wastewater utility will issue industrial pretreatment discharge permits, provided the state has received delegated authority to administer the CWA from the EPA, and the state has approved the WRRF pretreatment program. See https://www.epa.gov/npdes/npdes-state-program-information for states authorized with delegated authority to administer the CWA. Pretreatment limits usually address biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), oil and grease, and heavy metals. Utilities may recruit participants in the industrial pretreatment program to alternatively supply high-strength organic wastes with problematic characteristics for the treatment process to supply them as feedstocks for their AD. Tests are usually used to determine if new wastes are digestable and to identify any potential operations concerns for the digester.

The entity or authority in charge of the POTW is responsible for identifying industrial users in the service area, and new industrial/commercial development projects are often brought to the POTW’s attention during the local government’s land development approval processes. Permits must be in place before the new development is allowed to begin wastewater discharges to the sewer system. Pretreatment limits for sources of FOG or food processing residuals (FPR) often include Biological/Chemical Oxygen Demand (BOD/COD), Total Suspended Solids (TSS), Total Nitrogen, Total Phosphorus, and Hexane-Extractable Materials (HEM, formerly Oil & Grease).

Co-digestion substrates, like FOG and FPR, along with HSOW, can be delivered to the POTW in non-pipeline carriers, like trucks. The discharge prohibitions listed at 40 CFR 403.5 apply to all wastes received at the POTW, including domestic and nondomestic hauled waste, regardless of delivery method. NPDES permits issued to POTWs contain standard requirements for the permittee to notify the permitting authority when accepting any new or substantially changed waste (including hauled waste).

Smaller POTWs may not have Industrial Pretreatment Programs in place but may still be candidates for receipt of co-digestion substrates via trucked-in wastes. Guidance has been published to provide information for smaller POTWs on how to develop and implement hauled waste controls. The guidance discusses collection of information on waste haulers, characterization of hauled waste received, evaluation of potential impacts, and the development and implementation of controls. The guidance also includes case studies of successful waste hauler programs and example forms (U.S. EPA 1999).

A.2.1.3 Wastewater Sector Effluent Limitations

Effluent limitations, which serve as the primary mechanism in NPDES permits for controlling discharges of pollutants, fall into two categories: technology-based effluent limitations (TBELs) and water quality-based effluent limitations (WQBELs). TBELs represent the minimum level of pollution control technology that must be imposed in a permit, with the ultimate goal of achieving zero discharge of pollutants. When TBELs are not sufficient to protect water quality, an NPDES permit also may impose a WQBEL based on the most stringent effluent limits needed to achieve all applicable water quality criteria for a specific point source to a specific receiving waterbody.

Water quality criteria are set at the state level. States have begun to adopt numeric nutrient water quality criteria for nitrogen and phosphorus, and effluent nutrient regulations are generally expected to become more stringent in the future. Nutrient removal from wastewater is a major demand on resources and source of expenses for WRRFs. These needs are expected to increase as more stringent effluent nutrient limits are promulgated. Co-digestion of specific feedstocks can add nutrients to the digestion process, and so can pose challenges for compliance with any nutrient restrictions in the WRRF permit.

As discussed further below, anaerobic digestion can be used to accumulate and produce a nutrient product that has value in a secondary market. Therefore, effluent limitations can play a factor in motivating WRRFs to explore anaerobic digestion as one element of a nutrient management strategy.

A.2.1.4 Biosolids Management

Beneficial reuse of the biosolids product from wastewater treatment can provide financial, social, and environmental value. Land application of liquid, dewatered, or dried biosolids or of composted biosolids can improve soils by providing nutrients, but also is now recognized to provide a range of other benefits such as promoting carbon sequestration, reducing water use, helping manage storm water, and preventing soil erosion and nutrient run-off. The liquid effluent from wastewater treatment can be used to make liquid fertilizer products. The use of biosolids or bioliquids for land application, either directly or following further processing, can reduce demand for manufactured fertilizers.

Both federal and state regulations influence how biosolids can be managed.

A.2.1.4.1 Regulation 40 C.F.R. Part 503

Implementing provisions of the Clean Water Act, the regulation at 40 C.F.R. Part 503 sets out the "standards for the use or disposal of sewage sludge." Subpart D outlines the requirements for "sewage sludge" disposal and the quality controls necessary for land application. Biosolids are classified as "Class A" or "Class B" based on the pathogen reduction techniques used in biosolids post-processing to meet the 40 C.F.R. 503 standards. The distinction has significant implications for the marketability of the end product as fertilizer or soil amendments. (Except when referring to the regulatory language, the research team uses the terms "wastewater solids", or simply "solids", rather than "sewage sludge", elsewhere in the report.)

For Class A biosolids, pathogens must be reduced to virtually non-detectable levels and the material must adhere to strict limitations on heavy metal concentration, odors, and vector attraction reduction (VAR). In contrast, Class B biosolids can have a detectable level of pathogens; further, cumulative heavy metals concentration is tracked differently in land application of Class B biosolids. Other than the less strict pathogen requirement, the regulations for Class A and Class B biosolids are identical. The more lenient pathogen regulation can make Class B biosolids less costly to produce, but they may not be applied to home lawns and gardens. Further, regulations restrict when crops can be harvested, animals can graze, and the public can access land on which Class B biosolids have been applied (U.S. EPA 1994, 38). These restrictions make it more difficult to market Class B biosolids as fertilizer or land cover.

The introduction of highly processed nutrient fertilizers derived from wastewater treatment bioliquids poses a regulatory question: Should these fertilizers be regulated under Part 503 like "sewage sludge"?

A clear example is the regulatory debate surrounding struvite fertilizers. Wastewater treatment plants digesting anaerobically their wastewater solids often encounter phosphate-based formations that clog piping, valves, and pumps, reducing the efficiency of the treatment plant. Among the many possible phosphate-based precipitates, struvite is the most common. Removal of struvite increases digestion efficiency and also reduces the water quality impacts associated with total phosphorus levels in the final biosolids product and/or wastewater discharge. As such, there are significant incentives to produce and market struvite fertilizers, which are created by engineering the precipitation of struvite from thickened and/or digested solids or centrate/filtrate, as a byproduct of anaerobic co-digestion at WRRFs.

Wastewater industry participants engaged in nutrient recovery have advocated that struvite does not meet the regulatory definition of sewage sludge: it is not a residual of the wastewater treatment process or a material derived from sewage sludge, and it does not share the characteristics of sewage sludge. Nonetheless, in January 2017, EPA decided that struvite and highly processed nutrient fertilizers made for land application are, by default, 'derived from sewage sludge' and, thus, subject to the requirements of 40 C.F.R. Part 503. The agency stated it was "willing to consider on an individual case-by-case basis whether a particular product recovered from sewage sludge is [sufficiently refined such that it is] beyond the scope of Part 503." (U.S. EPA to NACWA 2017). Requiring labeling of struvite products as derived from biosolids will reduce the marketability of the product. Making the determination that a product is not derived from sewage sludge is a case-by-case process based on product-specific data that will limit the number of products for which such determinations are sought.

A.2.1.4.2 USDA Nutrient Management Revision Code 590[2]

The USDA Natural Resource Conservation Service (NRCS) revised its Code 590 Nutrient Management Standard to bring more uniformity to state standards for managing nutrient sources such as manure and biosolids that are applied to the land, particularly in the development and application of the primary tool used to assess risks from the over-application of phosphorus (P), the phosphorus index (PI). The federal standard is essentially a template that the states are to tailor to their unique situation. While Code 590 was originally intended for farmers participating in NRCS assistance programs, it has been incorporated into regulations governing manure management and in some states (especially in the Mid-Atlantic region) into biosolids land application regulations and/or permits (Moss et al 2013).

The move toward P-based management of land-applied biosolids poses a significant challenge to biosolids land application programs because it can result in lower application rates per acre of biosolids in certain areas due to P restrictions. The issue is exacerbated by the fact that most state PIs do not account for the different P availabilities from nutrient sources; this can be highly disadvantageous to biosolids products which have a substantially lower P availability than manures, and *a fortiori*, from manufactured fertilizer. The adoption of phosphorous source coefficients (PSCs), which capture available P (rather than total P), into USDA Code 590 implementation can help establish agronomically suitable application rates that, as a side effect, will lessen the restrictions on biosolids land application. To date, approximately 12 states include PSCs in evaluating their P Index, and several of them include a biosolids PSC of some kind (Moss et al 2013).

A.2.1.5 State Clean Water Law

State regulation of biosolids can create more stringent limitations on their beneficial reuse. Regulations focusing on odor and phosphorus application are the most common biosolid regulations. For example, in Idaho, biosolids rules that are more stringent than the federal regulations of 40 C.F.R. Part 503 force WRRFs to work with both wastewater and solid waste regulators.[3]

Odors: In Texas, only three out of six EPA-approved methods for generating Class A biosolids can be used to qualify biosolids as Class A. The limitations on biosolid processing help to reduce biosolid odors. If the other three EPA approved methods are used for processing, Texas qualifies the biosolids as Class AB (Moss et al 2013).

Nutrients: In addition to limiting P application to agricultural land (see USDA code 590), at least 11 states, mostly located in the Northeast, Mid-Atlantic, and Great Lakes regions, ban the application of

[2] This section draws extensively from Moss, L. et al. 2013. "Enabling the Future: Advancing Resource Recovery from Biosolids." WRF, WEF, National Biosolids Partnership.

[3] For example, IDAPA 58.01.16 "Waste Water Rules" require Idaho Department of Environmental Quality (DEQ) approval of a biosolids/sludge management plan; *see also* IDAPA 58.01.17 "Recycled Water Rules" *and* IDAPA 58.01.06 "Solid Waste Management Rules"

phosphorous fertilizers to lawns. Other phosphorous fertilizer regulations limit fertilizer to specific uses, or require labeling of fertilizers containing phosphorus (Moss et al 2013).

Quantity: WRRFs need to be aware of the potential regulatory implications of increased biosolids production with co-digestion. For example, Wisconsin prohibits the land application of biosolids during winter months and requires WRRFs to have 180 days of onsite biosolid storage (Ely and Rock 2015). If additional biosolids are generated due to co-digestion, they may increase the required storage capacity.

A.2.2 Solid Waste

Adding solid waste to treatment processes at WRRFs may trigger additional permitting requirements. Some states have worked to streamline permitting for food waste in order to facilitate co-digestion.

A.2.2.1 Federal Solid Waste Law: Resource Conservation and Recovery Act

The acceptance of organic feedstocks such as fats, oils, and grease (FOG), food processing residuals, and source-separated organics (SSOs) may result in the designation of the digester system as a waste processing facility in some states. Waste processing facilities are required to meet federal regulations under the Resource Conservation and Recovery Act (RCRA) Subtitle D (for non-hazardous waste). Under Subtitle D, state and local governments serve as the primary planning, regulating, and implementing entities for the management of non-hazardous waste. The trend toward WRRFs digesting food scraps traditionally managed through the municipal solid waste system has led to new concerns about triggering RCRA regulations under state implementation of Subtitle D (Moss et al 2013).

A.2.2.2 State Solid Waste Law

State solid waste permits for food waste digesters are a new program in many states, so the permitting requirements and procedures will be uncertain as new policies and procedures are developed. Solid waste regulators are often from a different agency than wastewater regulators and the permitting requirements may not be coordinated. For example, until recently, a WRRF in California that wanted to receive food waste needed both an NPDES permit from the State Water Resources Control Board and a solid waste permit from the California Department of Resources and Recovery (CalRecycle) (Ely and Rock 2015). In January 2016, CalRecycle adopted regulations excluding POTWs (like WRRFs) that receive vehicle-transported digestible solid waste for the purpose of anaerobic co-digestion with POTW wastewater from its solid waste transfer/processing and in-vessel digestion regulations (14 CCR § 17896.6(a)(1)).

Ohio has taken a different approach, opting for collaboration among agencies instead of eliminating regulatory overlap by designating one responsible agency. The digestion of wastewater solids at Ohio WRRFs is regulated by the Ohio EPA's Division of Surface Water through the NPDES program, while food waste processing is regulated through the Division of Solid Waste and Infectious Waste Management (Moss et al. 2013). The state has assigned primacy to the Surface Water Division for permitting involving biosolids, but provides for feedback from other relevant divisions during the permitting process (Moss et al. 2013).

A.2.3 Air

Energy production from the combustion of digester-generated biogas can generate emissions of criteria air pollutants and greenhouse gases (especially nitrogen oxides and methane), as well as odors, and can involve combustion equipment – all of which can create issues with air emission standards and regulations.

A.2.3.1 Federal Air Quality Law: Clean Air Act

Combustion devices used for energy generation may require air permits if the devices operate over federal *de minimis* thresholds for the emission of certain pollutants. For example, 40 C.F.R. Part 60 Standards of Performance for New Stationary Sources and 40 C.F.R. Part 63, Subpart ZZZZ Stationary

Internal Combustion Engines could be implicated if new energy equipment, such as combustion engines, turbines, microturbines, or fuel cells, are added to use the additional biogas created by co-digestion. EPA may certify an engine to meet the air quality standards or the engine manufacturer may provide a "not-to-exceed" guarantee. If the engine is not certified, it is subject to emissions testing, which can cost around $8000 per year. No engine manufacturers have certified their engines to run on biogas, so all digester systems require testing (U.S. EPA 2012). Microturbines and fuel cells typically produce electricity with lower air emissions; however, the cost of fuel cell systems can be prohibitive.

Under the National Ambient Air Quality Standards (NAAQS) of 40 C.F.R. Part 50, the EPA sets standards for six "criteria" air pollutants, including nitrogen dioxide and sulfur dioxide (potentially prevalent in anaerobic co-digestion) (Kuo 2015). The NAAQS contain primary standards to protect public health and secondary standards to protect public welfare. If a WRRF is operating in an area of nonattainment for ambient air concentrations for a given pollutant, the restrictions are heightened on any activity that would emit that pollutant, such as internal combustion (IC) engines or venting and flaring biogas. As a result, additional emissions control technology may be required, the IC engine permissible operating hours may be limited, or the IC engine technology may not be allowed. For areas designated as "nonattainment" see Map A-1 in the appendix.

A.2.3.2 State Air Quality Law

In some cases, state air regulations are more stringent than federal regulations and may further restrict the options available for producing energy. For example, a combustion unit generating energy could conflict with state-mandated greenhouse gas reduction policies. In this case, WRRFs are exploring options to generate renewable natural gas for vehicle use or sale to natural gas pipelines.

Also, if odors in a particular state are regulated under a "nuisance" standard, a WRRF could be opening itself to liability unless the odors from the waste handling component of the anaerobic co-digester are properly managed (Lebrero et al. 2011).

A.3 Policies that Create, Expand, or Impede Access to Product or Feedstock Markets

A.3.1 Renewable Energy Markets

WRRFs can potentially achieve internal energy cost-savings by recovering energy from biogas to generate power for onsite electricity and heat use or by producing electricity for sale to the power grid. Such projects typically include a biogas treatment and conditioning system and new generating equipment such as IC engines, fuel cells, micro-turbines, or turbines. An alternative, which has gained substantial traction since the EPA declared renewable natural gas from AD qualified as a cellulosic pathway under the Renewable Fuel Standard, is to produce renewable natural gas (RNG) for vehicle fuel either through direct use and/or sales or via injection into natural gas pipelines. This option is particularly attractive in areas with low electricity pricing and/or restrictive air pollution requirements.

A.3.1.1 Access to Electricity Markets and Utility Rate Structures

A variety of policies at the federal and state level affect the ability of distributed renewable power sources to achieve cost savings from onsite use or to generate revenues from external sales. The eligibility of WRRFs as renewable energy sources varies across the programs and the states implementing them.

A.3.1.1.1 Federal Policies

Public Utility Regulatory Policies Act Qualifying Facilities

Enacted in 1978 and amended in 2005, the Public Utility Regulatory Policies Act (PURPA) ensures that qualified renewable energy project developers ("qualified facilities, or QFs") have the ability to send energy to the grid. QFs may be small cogeneration, solar, or wind installations. PURPA also imposes on power utilities an obligation to purchase renewable energy at a rate based on the utilities' avoided cost (which is based on the utility's cost-of-generation). As of 2017, WRRFs have not yet taken advantage of this purchase obligation. This PURPA provision remains in effect primarily in Southeastern and some Western states (Hammond et al. 2017). While PURPA has had success in opening up renewable energy markets, industry argues that the law is now outdated and pits customers, utilities, and renewable energy producers at odds with each other by requiring utilities to purchase renewable energy, even if it is not needed. In 2017, the PURPA Modernization Act was introduced to the House in order to address the requirement to purchase. The Bill did not move forward (Kuckro 2017). A second bill updating PURPA was proposed in the House and Senate in 2019 (S. 1760 June 10, 2019).

Demand Response and Other Market Incentives

For WRRFs operating within competitive wholesale electricity markets, WRRFs can take advantage of a number of incentives which provide services to the grid. The Federal Energy Regulatory Commission (FERC) has issued Order 745, which permits aggregated demand response to be bid into competitive wholesale energy markets at the same price as electricity (CFR Title 18 Part 35). Under such programs, the WRRFs would receive payments for limiting grid demand for electricity by relying on onsite generation when called upon to do so. Due to air emission requirements, however, WRRFs' backup generators may not be suitable for providing demand response. Even without demand, response incentives, rebates, other incentives, and the ability to provide other monetizable grid services like frequency regulation can all motivate onsite energy production at WRRFs (Hammond et al. 2017).

A.3.1.1.2 State Policies

Electric Utility Rate Structures

Electric utility rate structures can provide either incentives or disincentives for energy-related projects at WRRFs. For example, when the Enron scandal led the California Independent System Operator (CAISO) to revise its regulation of the wholesale electricity market, higher energy costs (for both electricity and natural gas) directly motivated many WRRFs to pursue energy efficiency or energy generation projects. By contrast, Pennsylvania's electricity rates were structured to maintain low prices, thus the incentive for WRRFs to implement energy projects was very low. WRRFs such as Philadelphia's wastewater treatment plant and the Derry Township Municipal Authority's Clearwater Road Treatment Facility (DTMA) only began to consider energy projects when the electricity price caps were removed due to the state's transition to a new pricing structure. Both DTMA and Philadelphia specifically pointed to this change in rate structures as a major driver for adopting cogeneration systems (Hammond et al. 2017).

Similarly, in New York, WRRFs have negotiated different electricity rate structures due to a deregulated energy market. Where WRRFs have negotiated highly competitive rates, they have reduced the cost-savings that would be generated by substituting on-site production for purchase from the utility.

Recent research has identified the structure of utility rates as a significant additional impediment to realizing cost-savings (O'Brien and Andrews 2017). For example, WRRFs in New York pay two different bills for electricity: one for generation and one for distribution. Electricity distribution bills include a minimum monthly fee and a demand fee, which is based on the highest level of demand, often based on 15 minute intervals. Demand fees range from 8% -77% of distribution bills for New York WRRFs and can influence payback schedules for renewable energy generation projects. For WRRFs with combined heat and power (CHP) generators, outages due to regular maintenance (CHP requires maintenance four to eight times a year) can increase demand fees even if the maintenance is short in duration.

Several utilities have increasing rate demand structures in place, with a minimum monthly demand fee that increases with high variability in electricity demand. For example, one WRRF's minimum demand fees are 75% of the highest electricity bill of the past 12 months. WRRFs with frequent planned or unplanned outages of their energy generation machinery can rack up significant electricity with this rate structure due to spikes in electricity demand during machinery downtime, thus impeding the realization of cost savings with in-house energy production (O'Brien and Andrews 2017).

Net Metering

Net metering allows electricity customers to send electricity generated onsite back into the distribution grid. If a home or business is net-metered and is producing energy, the electricity meter will run backwards to provide a credit at the retail price against the amount of electricity consumed at night or during other periods in which the home's electricity use exceeds the system's output. Customers are only billed for their "net" energy use. Forty states plus D.C. have mandatory net metering policies, while five states have other distributed generation (i.e., power generated at the point of consumption) policies, and two others allow utilities to decide whether to permit net metering (DSIRE 2019). Electric utilities are leading a movement to roll back net metering policies and increase charges on distributed energy generators (Stanton 2019). States with net metering rules are identified in Map A-2 at the end of this appendix.

Feed-In Tariffs

Feed-in tariffs (FITs) have been associated with well-established European models in which the government mandates that utilities enter into long-term contracts with generators at specified rates, typically well above the retail price of electricity. In the United States where FITs are comparatively new, a limited number of states, including California, Oregon, Washington, Vermont, Maine, Rhode Island, and Hawaii, mandate FITs or similarly structured programs to varying degrees. However, a different model has also emerged in which utilities independently establish a utility-level FIT, either voluntarily or in response to state or local government mandates (USEIA 2013). With long-term contracts (typically 10-20 years) at a fixed price, FITs provide a revenue stream that can be leveraged for financing and in public-private partnerships (PPPs). States with feed-in tariffs are identified in Map A-3 at the end of this appendix.

A.3.1.2 Access to Renewable Natural Gas Markets and Utility Rate Structures

A.3.1.2.1 Natural Gas Utility Rate Structures

WRRFs use natural gas to provide heat for buildings and anaerobic digesters. At some WRRFs with AD, the quantity of biogas produced can be sufficient to heat digesters and supplement natural gas use for building heating, thus reducing natural gas purchases.[4] Natural gas rates vary based on a number of factors including location, the age of the system, number of customers served, employee wages and benefits, the local regulatory environment and philosophy, location-specific costs to install mains, and the frequency of rate cases. Generally, rates for natural gas are higher in colder areas. New England, the Mid-Atlantic and Central regions have the highest natural gas rates (AGA 2017).

Natural gas bills typically consist of the cost of the gas delivered, a delivery charge, and a "customer charge." The cost of gas itself makes up the majority of the customer's bill and varies with natural gas use. Customer charges are fixed costs, which cover meter reading, natural gas storage, administrative expenses, customer service, and fixed plant costs. Utilities can charge the customer even if no natural gas is used onsite (AGA 2015). Natural gas utility customer charges are determined by regulatory entities that consider the cost of service for utilities and are settled in rate cases. Across 197 localities, a 2015 survey found that the median customer charge for small commercial customers was $22 per month (AGA 2015).

[4] For more information, see VVWRA Case Study and Stevens Point Case Study, Chapters 4 and 5 in this report.

A.3.1.2.2 Pipeline Interconnection Standards and Infrastructure Requirements

Interconnection standards for biomethane quality vary by region and utility. Interconnection standards can mandate a combination of limits including minimum heating value, maximum siloxane content, maximum sulfur content, and maximum concentrations for other nutrients. California has particularly stringent requirements for pipeline-quality biomethane. Recently, the California Council on Science and Technology published recommendations for lowering California's minimum heating value for biomethane from 990 BTU/scf to 970 BTU/scf. The report also considered loosening limitations on siloxane concentrations but found that more research was needed before recommending a new standard. While California hosts many funding sources and support programs for RNG production (see Section A.3.1.2.3 RNG Production Incentives and Grants), these stringent guidelines have made it costly to upgrade biogas to pipeline quality, thus inhibiting investment in RNG. By contrast, biomethane pipeline injection requirements in other states are much less stringent. Minimum heating values landfill gas and WRRF pipeline injection agreements outside of California range from 950 BTU/scf - 967 BTU/scf (RNG Coalition 2016). In Ohio, the Newark WRRF has been injecting biomethane into a local rural energy cooperative pipeline since 2011. The agreement between the energy cooperative and the WRRF stipulates a minimum heating value of 960 BTU/scf. The cooperative treats the WRRF like one of its natural gas producing wells and tests the gas for quality before it enters the pipeline (See Appendix B for more information).

There are no national requirements for natural gas or compressed natural gas infrastructure or quality. FERC regulates tariffs on natural gas travelling across state lines, but does not regulate gas quality. Infrastructure requirements for pipeline natural gas and compressed natural gas (CNG) equipment follow standards developed by the National Fire Protection Association, CSA America, The Compressed Gas Association, and SAE (USDOE 2010).

A.3.1.2.3 RNG Production Incentives and Grants

Green payment programs for low carbon fuels and renewable fuels (discussed in Section A.3.1.3), as well as air quality requirements, can incentivize the production of renewable natural gas at WRRFs (Dougherty and Nigro 2014). For example, in Los Angeles County, stringent air quality requirements for vehicle emissions have supported renewable natural gas infrastructure at the Joint Water Pollution Control Plant. The Los Angeles County Sanitation District is expanding an existing CNG station at the WRRF to provide CNG for the county's vehicle fleet. The use of CNG will help the county adhere to South Coast Air Quality Management District 1191 Fleet rules, which require public agencies to lower emissions associated with vehicle fleets and convert to alternative fuel use.

In California, several initiatives such as tariffs and grants can assist in funding RNG projects. Southern California Gas (SoCalGas) offers tariff agreements for biogas conditioning for end uses including biogas to pipeline, biogas to vehicle fuel and biogas to CHP (SoCalGas 2018). Under the program, participating biogas producers would pay a tailored monthly fee to SoCalGas to manage the biogas cleaning process.

The Biomethane Interconnector Monetary Incentive Program, established in 2015 by the California Public Utilities Commission, can contribute funding for up to 50% of pipeline interconnection costs, with a cap of $3 million per project (SoCalGas 2017). Statewide funding is capped at $40 million.

A.3.1.2.4 Private Funding

Costs for RNG production include biogas upgrading and cleaning equipment, compression equipment (if producing compressed natural gas) or pipeline extension and interconnection (if injecting biomethane to a natural gas pipeline). WRRFs have used PPPs to provide creative financing solutions that help alleviate the risks and barriers associated with RNG development (Dougherty and Nigro 2014). Private gas utilities such as Ameresco (San Antonio, Texas) and National Grid (Brooklyn, NY) have funded or plan to fund the construction of biogas upgrading infrastructure and interconnections. The sale of renewable natural gas and associated renewable fuel credits pay off the costs of construction for the gas utility. In some cases, WRRFs receive royalties from gas sales resulting in a financial benefit for both the WRRF and the gas utility.

A.3.1.3 Federal and State Policies: Sustainability-based Financial Drivers

Other energy policies provide financial support for the environmental sustainability goals of producing renewable energy (in electricity or fuel form), increasing energy efficiency, or reducing greenhouse gas emissions. The existence of some policies that are only available to private investors, such as investment tax credits, provides incentives for the development of PPPs for investments in co-digestion and energy production. PPPs are subject to their own regulation, which is discussed below.

A.3.1.3.1 Federal Tax Policies and Grant Funding

Federal support for renewable electricity generation is largely achieved through tax policy and includes: 1) accelerated depreciation rates; 2) investment tax credits for solar power, qualified fuel cell, micro-turbine, and CHP systems; and 3) production tax credits for wind power and other qualifying technologies (set to be phased out in 2020). Typically, renewable project developers monetize their tax credits by bringing in tax equity investors. For PPP energy projects, the private partner (rather than the WRRF) would be the most likely entity to leverage the tax incentives.

The Bipartisan Budget Act of 2018 was passed and signed into law February 9, 2018. The Production Tax Credit (PTC) for biomass as well as the excise credit for renewable fuels was given a retroactive extension through December 31, 2017. For anyone considering developing a biogas project or producing RNG for 2018 and beyond, the future of these credits is still uncertain but the opportunity to further extend these credits is still alive. 30% Investment Tax Credit (ITC) for microturbines and fuel cells that had lapsed in 2015 was not only retroactively extended for 2016 and 2017 but also now continues through 2022. The 10% ITC for CHP was similarly extended. In August 2019, H.R. 4186 was introduced to extend both the PTC and ITC to projects beginning construction before 2025 (Li 2019). Another bill introduced in July 2019, H.R. 3744 aims to create a 30% ITC for biogas and nutrient recovery projects (Li 2019).

Although no longer available, a notable driver of numerous WRRF co-digestion and energy projects was a cash grant provision in the American Recovery and Reinvestment Act (ARRA) of 2009, known as "section 1603" grants.[5] The section 1603 grant program, available for projects that undertook construction or began operation through 2011, permitted project developers to receive up to 30% of their qualifying costs as a grant in lieu of the other tax credits.

The U.S. Department of Energy (DOE) administers renewable energy and energy efficiency grants for which WRRF co-digestion-related energy projects are eligible (USDOE n.d.). The U.S. Department of Agriculture (USDA) also provides grants and low-interest loans for rural renewable energy infrastructure through the Rural Development Utilities Program.

A.3.1.3.2 Federal Renewable Energy and Climate Change Regulation

Renewable Fuel Standard Program

The federal Renewable Fuel Standard (RFS) Program, initiated in 2005 and expanded in 2007, is administered by EPA in collaboration with USDA and DOE. The program mandates increasing quantities

[5] For example, Philadelphia's Northeast Water Pollution Control Plan leveraged a PPP arrangement in conjunction with ARRA funding to install a biogas cogeneration system that came online in 2013. The site generates over 134,000 kWh of electricity per day and has reduced the need to purchase electricity by 81%; combined with the heating provided by this system, the site reports 54% energy neutrality.

of renewable transportation fuel to replace fossil fuels through 2022, when a 20% share of renewable sources is to be achieved. To comply, refiners or importers of fossil transportation fuels must either blend their fuels with renewable sources, or purchase credits called Renewable Identification Numbers (RINs).

Under the program, both renewable natural gas and – in concept – electricity for electric vehicles that are generated from WRRF biogas can qualify as renewable fuel feedstocks and earn a revenue stream from the associated RINs, in addition to the energy market sales revenue. However, several wrinkles exist.

First, the RFS electricity pathway has been approved but not yet implemented. In February 2019, the RFS Power Coalition, newly formed by the American Biogas Council, Biomass Power Association, and Energy Recovery Council, filed suit against U.S. EPA over non-action in activating the electric fuel pathway for RINs (Walsh 2019).

Second, a major impetus for use of WRRF biogas came in 2014, when the EPA upgraded biogas produced at municipal WRRFs from an "advanced fuel" (D5) to a cellulosic fuel (D3), which currently earns a significantly higher value RIN. (Up to that point the supply of cellulosic renewable fuels had been significantly lower than the statutory target set by Congress.) The values of D3 and D5 RINs during 2017-2019 have ranged $1-$3/D3 RIN (or $13-$39/MMBTU) and $0.2-$1.0/D5 RIN (or $2.60-$13/MMBTU). The statutory mandate in the RFS requires the use of 36 billion gallons of renewable fuel, 16 billion of which will be cellulosic fuels as of 2022 (U.S. EPA 2017b). This presents a significant market opportunity for additional revenues from biogas production for vehicle fuel use.

U.S. EPA approved the D3 RIN pathway for landfills, municipal wastewater treatment facility digesters, agricultural digesters including agricultural residues and manures, and separate municipal solid waste digesters (CFR Title 40, Part 80). However, because food scraps typically contain substantial non-cellulosic components, such as fats, oils, sugars and starches, the EPA determined that when biosolids are co-digested with food scraps, the biogas qualifies only for D5 RINs. This determination provides a disincentive to co-digest (Carr et al. 2017). The American Biogas Council and others are in negotiations with the EPA to identify methods for a simplified methodology to identify a D3/D5 split for co-digesting WRRFs in order to increase revenue potential (Pleima 2019).

After 2022, the RFS does not expire, but there is uncertainty about what annual obligations will be set for year 2023 and beyond.

Clean Power Plan

Under the Clean Air Act's Clean Power Plan (CPP), promulgated during the Obama Administration, states were required to set emission targets for existing fossil fuel-fired electricity generators, and new renewable and efficiency measures could be credited toward state compliance. In 2017, President Trump directed the EPA to reexamine all climate-related rules including the CPP. In June 2019, The EPA replaced the Clean Power Plan with the Affordable Clean Energy plan. The plan significantly reduces emissions reductions and repeals the Clean Power Plan. Nevertheless, some states are continuing to develop greenhouse gas mitigation policies and many scholars expect climate policies to continue to gain traction in the longer term.

A.3.1.3.3 State Renewable Portfolio Standards

A Renewable Portfolio Standard (RPS) is a state mandate that a certain portion of electricity be generated from renewable sources by a certain date. Twenty-nine states plus D.C. currently have some form of RPS, and an additional eight states have voluntary renewable portfolio goals (See Map A-4 at the end of this appendix) (NCSL 2019). As of November 2018, only a few states (including D.C., New Hampshire, New Mexico, and Illinois) have missed their interim targets for their renewable portfolio standards. The set of technologies counted as "renewable" vary across the states, and may change over time. As a result, the inclusion of AD biogas-related energy needs to be confirmed on a state-by-state basis at the time of decision.

Electricity suppliers can comply with RPS requirements by owning renewable generation resources, purchasing Renewable Energy Credits (RECs), or purchasing both power and RECs from a renewable power source. RECs are typically bought and sold in secondary markets, and their value varies significantly from one market to another. Thus, an RPS creates a market for renewable power as well as for the RECs associated with generation. In PPP energy arrangements, the private partner typically retains the RECs associated with any renewable power generation, but this is a contract element that can be negotiated.

A.3.1.3.4 State Energy Efficiency Resource Standards

By contrast, Energy Efficiency Resource Standards (EERS) are state mandates that electric utilities meet particular energy-savings goals by a given date. Twenty-five states have EERSs or goals (See Map A-5 at the end of this Appendix) (DSIRE 2019). For example, New Jersey adopted an EERS in May 2018 which requires 2% electric and 0.75% gas savings goals (ACEEE).

A.3.1.3.5 State Low Carbon Fuel Standards

Low Carbon Fuel Standards (LCFS) prioritize the use of low carbon footprint fuels in an effort to reduce statewide carbon emissions. These standards help to increase the diversity of fuels and allow for competition with fossil fuels that dominate the market. Low Carbon Fuel Standards favor biogas produced from AD due to its low carbon footprint. To date, only Oregon and California have implemented an LCFS. California's LCFS requires a 10% reduction in the carbon intensity of fuels by 2020. Energy providers can meet the CA LCFS by buying and selling more low carbon fuels such as CNG from biogas, using technological advancements to reduce the carbon intensity of existing fuels, or by purchasing low carbon credits from other suppliers. Out-of-state projects can qualify their RNG for LCFS credits if the gas is injected into a natural gas pipeline with the ability to flow to California. Wastewater biomethane can earn between $11-$12/MMBTU or $1- $2/GGE at the current price for California's Low Carbon Fuel Standard credits of $193.54 (March 10, 2019). In addition, wastewater biomethane can earn between $11-$12/MMBTU or $1- $2/GGE at the current price for California's Low Carbon Fuel Standard credits of $193.54 (March 10, 2019).[6]

Eleven states in the Northeast and the Midwest are considering LCFS policies (National LCFS Project n.d.). As of June 2019, an LCFS bill passed in the State of Washington House of Representatives and has stalled in the Senate (Gentzler 2019). For an illustration of states with LCFS policies and states considering LCFS policies, see Map A-6 at the end of this appendix.

A.3.1.3.6 State and Municipal Tax Incentives and Grant Funding

In a number of states and municipalities, incentives are available to support elements of a co-digestion project that may help the WRRF to finance the project itself, or provide leverage to attract private investors. There are numerous examples of state grant funding, often conducted in conjunction with EERS or the Clean Water State Revolving Fund (CWSRF). The Green Project Reserve, created under American Recovery and Reinvestment Act (ARRA) and continued through annual appropriations from FY

[6] Author calculations using CI values from the CARB Fuel Pathways Working Table, (https://www.arb.ca.gov/fuels/lcfs/fuelpathways/lcfspathwaytable_working1.htm) and the CARB Credit Price Calculator (https://www.arb.ca.gov/fuels/lcfs/dashboard/creditpricecalculator.xlsx). Credit Price set at $193.54 (average value week of March 4-10, 2019) and CI set to the upper end of CI for AD wastewater sludge (40). Reference Fuel: Gasoline

2010-2014, requires each state to provide a portion of funds to green projects through the CWSRF. Green projects can include energy efficiency and CHP (U.S. EPA 2014).

Finally, a number of nonprofits also provide funding and interact with the state's environmental agency or public utility commission. Efficiency Vermont, for example, is a program operated by a nonprofit organization appointed by the Vermont Public Service Board; it provides rebates to WRRFs that install new energy-efficient equipment. As another example, the Illinois Community Clean Energy Foundation provided 60% of funding for the City of Galena's solar project at its WRRF. Wisconsin's Focus on Energy has played a role in providing technical assistance to Stevens Point and has provided grant funding to WRRFs in Janesville and Sheboygan to construct renewable energy generation facilities. Focus on Energy is a public benefit fund financed by a surcharge on Wisconsin residents' utility bills. As of 2017, the program has provided $8 million to assist in the construction of 38 digesters (this includes on-farm, standalone and WRRF digesters) (Lydersen 2017).

Commonwealth Organics-to-Energy Program**,** administered by the Massachusetts Clean Energy Center, supports the development of facilities that convert source-separated organic materials and wastewater solids into heat, electricity and/or compressed natural gas (MASSCEC n.d.). It operates by providing funding from the Massachusetts Renewable Energy Trust Fund, mentioned above, which is paid into by electric distribution companies, and thus the funding is available to projects within the service territory of those companies. The program provides funding to public and private entities for implementation and pilot projects, and also provides funding to public entities for feasibility studies for co-digestion at WRRFs.

A.3.1.4 State Public-Private Partnership Enabling Legislation

Public-private partnerships have been an important source of private financing for infrastructure projects in transportation, but are just beginning to be applied for water/wastewater projects.

Public-Private Partnership (PPP) Authorizations

As of January 2017, 37 states including Washington, D.C. and Puerto Rico have state enabling PPP legislation, and in some states compliance with statutory requirements may be a prerequisite to entering into PPP arrangements.[7] There is significant variation among the authorizing states, however, and the U.S. Department of Treasury reports that about 18 states have broad enabling statutes (UST 2014).

Power Purchase Agreement (PPA) Authorizations

PPAs are simply contracts between buyers and sellers of electricity. They have developed a specialized meaning in the context of renewables, however, as a way of financing small renewable projects. It is important to note that the availability of PPAs for this purpose is governed by state law. For example, at least twenty-eight states, plus D.C. and Puerto Rico, authorize some form of third party PPA for solar photovoltaic (PV) technology (DSIRE 2019). At least seven states, however, expressly disallow PPAs for solar PV. The status of PPA authorization in a WRRF's state should be carefully examined for what technology it covers and for any specific terms it requires.

A.3.2 Nutrient and Soil Amendment Markets

Regulations imposing restrictions on uses of nutrient and soil amendment products from WRRFs to address pathogens and nutrient impacts on land and water quality were discussed in Section A.1.2. At

[7] Up-to-date, state-by-state information is available by National Council for Private-Public Partnerships at ncppp.org.

the same time, there is growing recognition of the important role that organic soil amendments play in promoting carbon sequestration in the soil, improving plant growth, reducing water use, preventing soil erosion and nutrient run-off, helping manage storm water, and reducing reliance on chemical pesticides and fertilizers.

As a result, government agencies, businesses, and institutions in various states and localities are developing environmental procurement guidelines and policies that require the purchase of compost to enhance their construction and/or landscaping operations and to “close the loop” by turning waste into a recycled, value-added product. In addition, more of these entities are specifying that the compost be purchased locally, which minimizes transportation impacts and creates demand in the local market for a sustainable compost product.

A.3.2.1 Public Sector Procurement Policies

A primary vehicle for creating markets for soil amendment products is public sector procurement policies. For example, the NY State Department of Transportation (NYSDOT) requires the use of compost as a best management practice in their specifications for state construction projects that require landscape restoration. NYSDOT has recently expanded the scope of acceptable feedstocks for compost products, which now includes biosolids and composted wastewater solids, as well as source-separated organic waste (SSOW), yard and leaf waste, and agricultural sources (i.e. compost from manure and bulking agents) (NYSDOT 2019). King County in Washington state also requires government agencies to purchase “environmentally preferable products whenever practicable” through their Environmental Purchasing Policy (EPP). During construction projects, the county’s Wastewater Treatment Division uses compost generated from biosolids at the county’s three WRRFs to fulfill EPP requirements (ILSR 2016a).

A.3.2.2 Surface Water Runoff Regulations

Some communities, particularly ones affected by drought, are imposing requirements on private landowners as well. For example, Denver is one of several communities to mandate the use of compost in disturbed soil and new landscaping as a means of improving the ability of the soil to conserve and manage water (ILSR 2016b).

A.3.3 Regulatory or Subsidy Programs Incentivizing Food Waste Recycling

The adoption of local or state policies that increase the stringency of requirements for managing fats, oils and grease (FOG) or industrial food processing wastes may provide a stimulus to co-digesting those feedstocks. Both of these feedstocks are typically managed through the wastewater system, unlike food scraps, which are managed through the solid waste system.

In recent years, five states and several localities have implemented organics waste bans to promote the reduction and reuse of wasted food and the recycling of food waste scraps (See Map A-6 at the end of this appendix). In April 2019, New York State became the sixth state to adopt such requirements, which will be effective as of 2022. Organics disposal bans went into effect in 2014 for Vermont, Connecticut and Massachusetts, and in 2016 for Rhode Island. In Rhode Island, Connecticut, and Vermont, the size thresholds of food waste generators covered by the bans decline over time (except in Massachusetts), achieving maximum coverage of generators in 2018 (Rhode Island) and 2020 (Connecticut, Vermont). The laws in Connecticut, Rhode Island and Vermont include a waiver of coverage if there is no processing facility permitted by the state within 15 or 20 miles of the generator. Distance exemptions expire in 2020 in Vermont, but have no expiration date in Rhode Island and Connecticut (Jones 2017a; 2017b). New York’s Food Donation and Food Scrap Recycling Act requires food waste generators producing an annual average of two or more tons per week of food waste to donate excess edible food. Any other food waste must be recycled if a recycling facility exists within 25 miles of the entity (NYDEC n.d.).

In California, several regulations motivate organic recycling. Most directly, the Mandatory Commercial Organics Recycling law (AB 1826) requires organic waste generators of a certain size to recycle organic waste produced. The size thresholds of participating generators step down to generators producing two tons of food waste per week by 2020 (AB 1826 2014). In addition, SB 1383 (2016) requires California to reduce organic waste by 50% by 2020 and 75% by 2025 using a 2014 baseline levels in order to reduce methane emissions (SB 1383 2016).

Cities with organic waste recycling mandates or landfill bans include Seattle, Portland, San Francisco, New York City, Austin and Boulder (see Map A-7).

The states and cities with the landfill bans/recycling mandates share some underlying drivers for recycling food waste, including high tipping fees for solid waste disposal, high electricity costs, and a strong conservation ethic. (See Map A-8 of tipping fees and Map A-9 of electricity costs at end of document.) Such policies provide an incentive for municipal solid waste agencies and/or private solid waste companies to establish source-separated-organics (SSO) hauling, and to establish organics processing capacity for the SSO food scraps, including composting and anaerobic digestion.

Short of organics landfill bans or recycling mandates, many municipalities have identified solid waste recycling as a community goal, with a number establishing zero waste goals, and are focusing community resources to that end. Food waste recycling is a critical component of achieving such goals because in most communities, food waste represents the largest or second largest component of the solid waste stream and has the lowest recycling rate.

States or local governments may adopt a variety of complementary policies – including providing technical assistance and/or grants or low interest loans for the development of composting or anaerobic digestion infrastructure to recycle food waste.

A.4 Summary

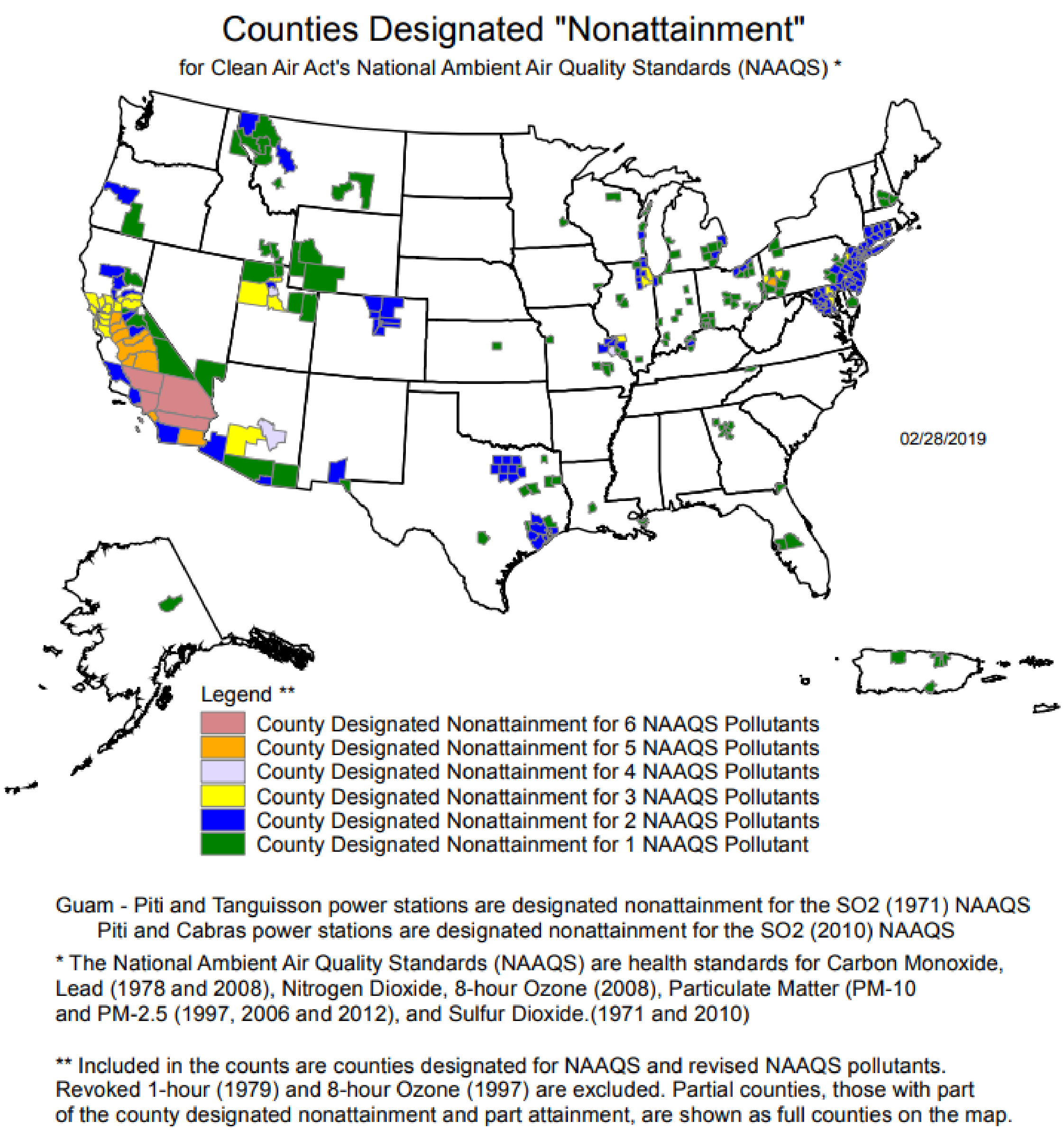
Understanding and leveraging the federal, state and local water, renewable energy, solid waste, and air policies that affect the opportunities and returns for co-digestion at WRRFs is critical for the success of co-digestion projects.

First, co-digesting WRRFs need to understand how the addition of nutrients to their digesters and the use of energy production equipment will impact their compliance with water, air and solid waste regulations in order to manage the choice of feedstocks and reduce digester operational impacts, the choice of energy generation technologies, and the choice of biosolid management options.

Second, WRRFs need to understand how policies affect the cost-savings or revenue that they can accrue from co-digestion end products. For energy markets, utility rate structures have a substantial effect on the ability of distributed power sources (such as WRRFs) to achieve economic returns from in-house energy production, and state (or utility) “market-access” policies, including interconnection standards, net metering, and feed-in tariffs have a substantial impact on utilities to earn revenue from energy sales. In addition to the Federal Renewable Fuel Standard incentive payments for vehicle fuel, a number of states have financial incentives for environmental sustainability activities – notably renewable energy (in electricity or fuel form), energy efficiency, or greenhouse gas mitigation – that can provide an important source of revenue for WRRF energy projects. For biosolid/bioliquid/nutrient products, state or local environmental purchasing policies that require the purchase of environmental beneficial products can provide markets for soil and nutrient amendment end products.

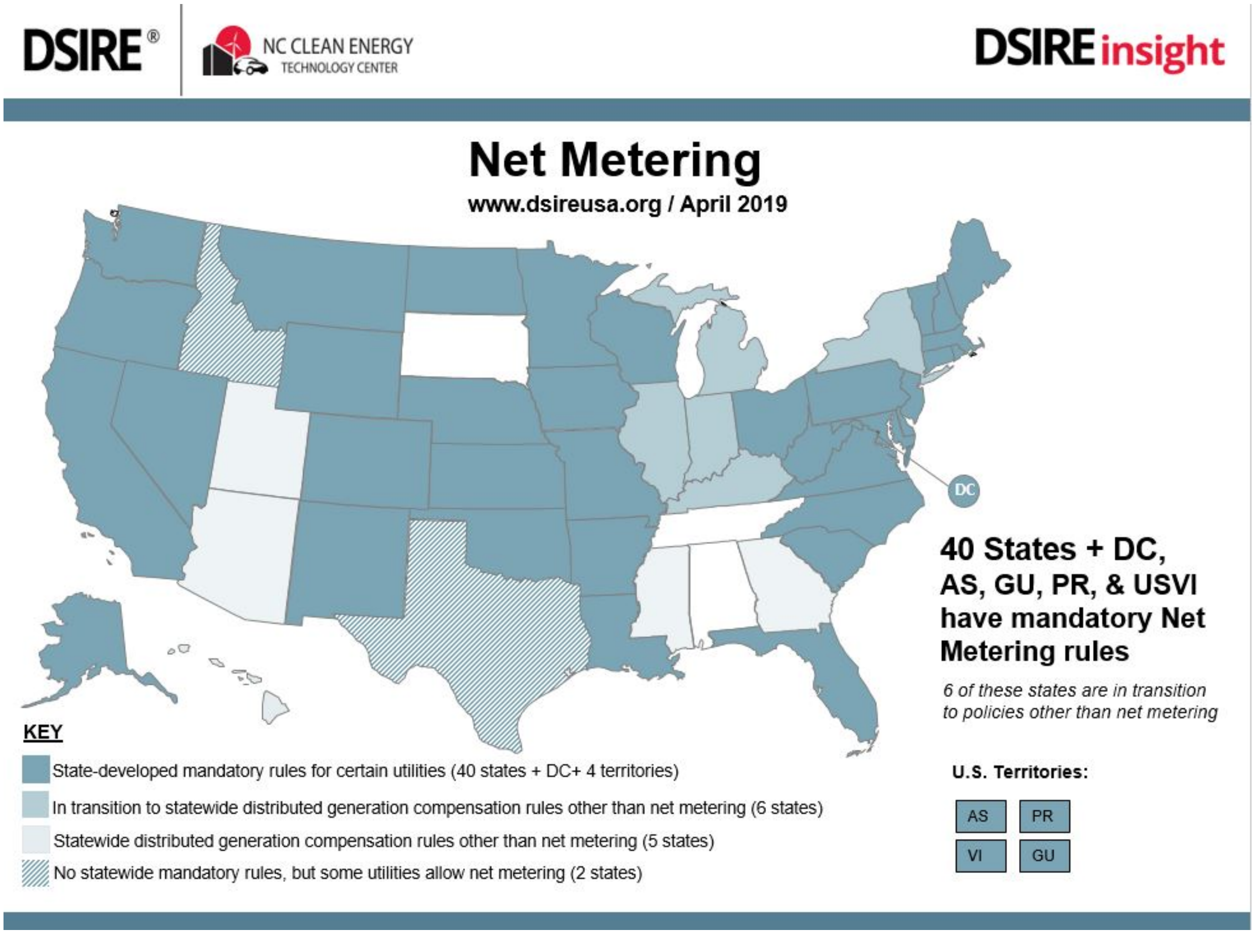
Third, WRRFs need to understand how policies such as organic waste landfill bans, pretreatment standards for industrial users, and restrictions on FOG may generate feedstock supplies for their digesters.

Maps

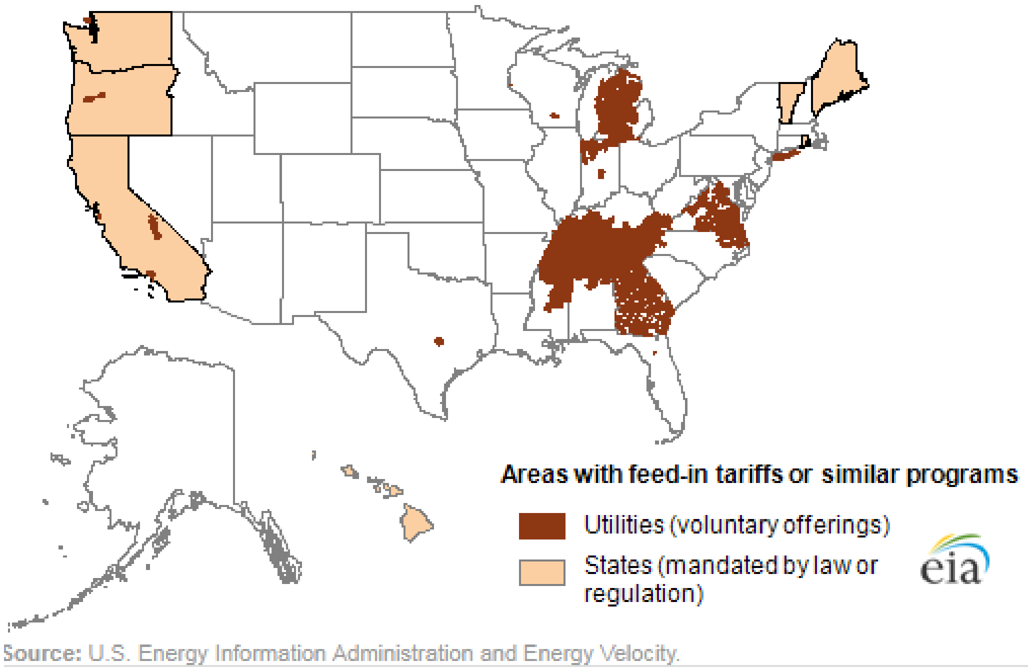


Map A-1. Counties Designated “Nonattainment” for Clean Air Act's National Ambient Air Quality Standards (NAAQS), February 2019.

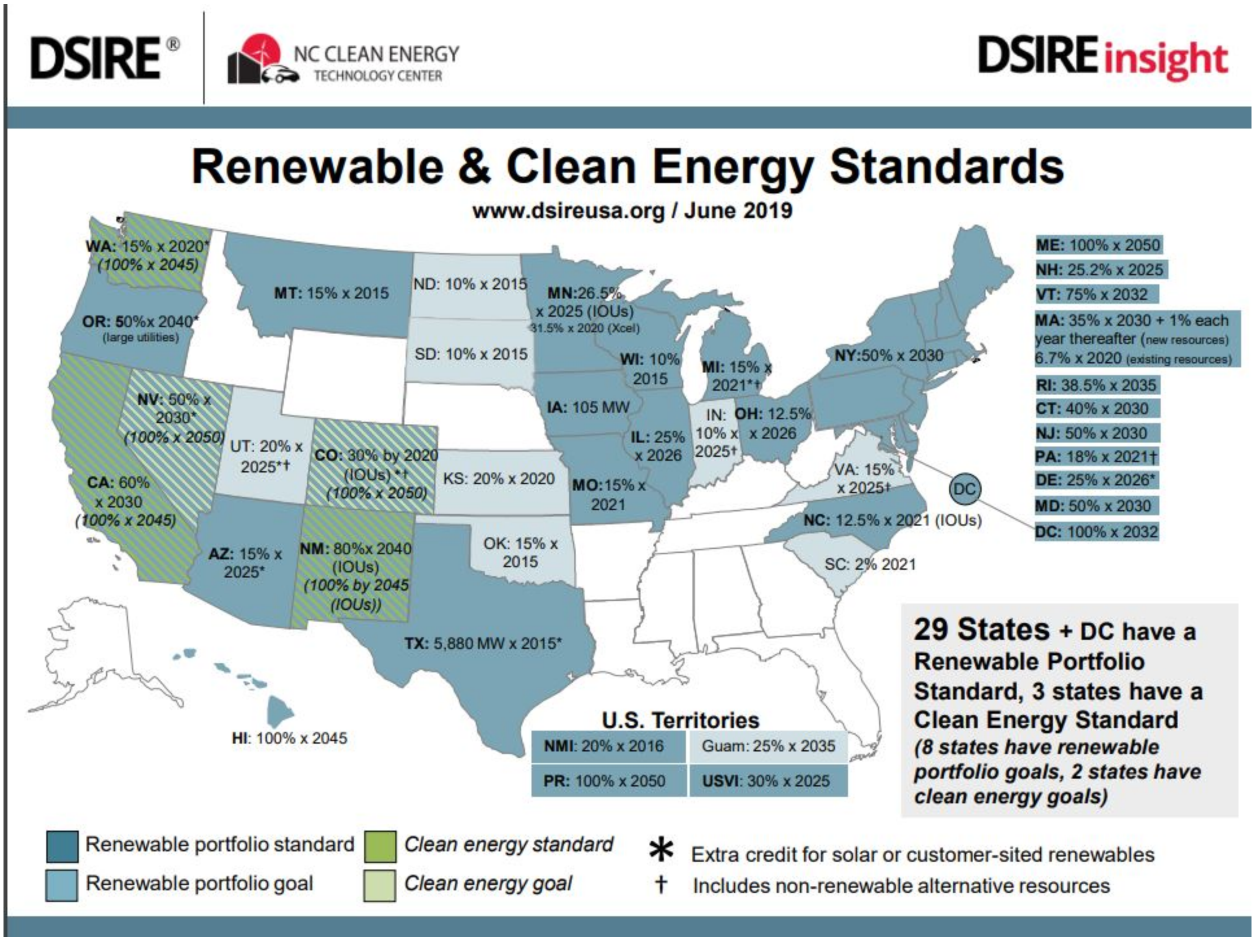
Source: U.S. EPA website: https://www3.epa.gov/airquality/greenbook/mapnpoll.html. Last accessed March 11, 2019.



Map A-2. Net Metering Rules in the United States, April 2019.
Source: DSIRE (https://s3.amazonaws.com/ncsolarcen-prod/wp-content/uploads/2019/07/DSIRE_Net_Metering_April2019.pdf). Last accessed September 5, 2019.

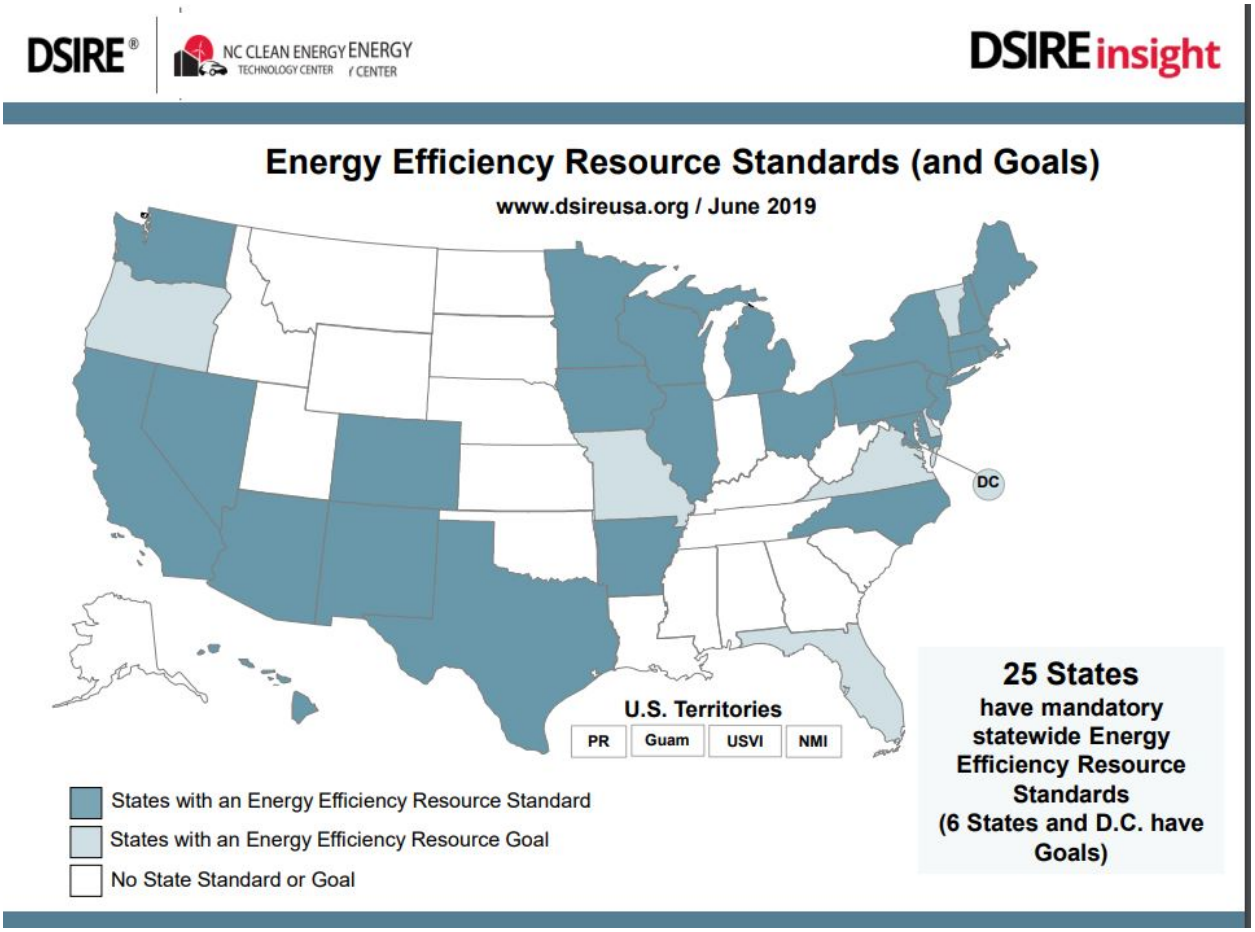


Map A-3. U.S. States and Utilities with feed-in tariffs or similar programs (2013).
Sources: EIA https://www.eia.gov/todayinenergy/detail.php?id=11471. Last accessed March 11, 2019.



Map A-4. Renewable Portfolio Standards (2019).

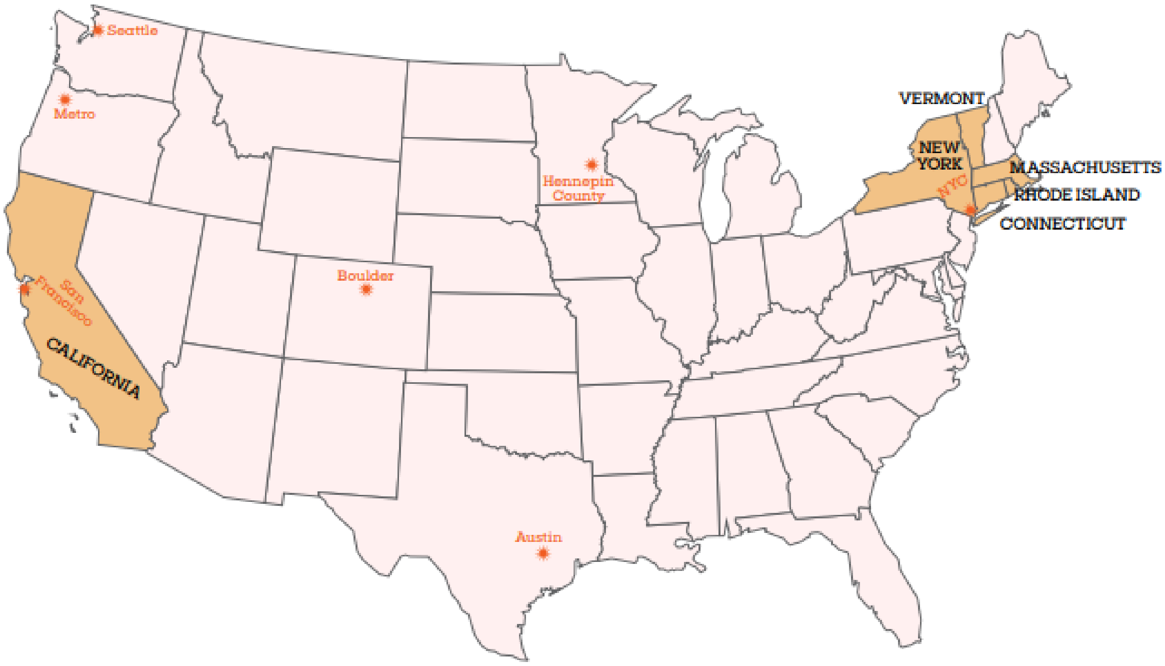
Source: dsireusa.org (https://s3.amazonaws.com/ncsolarcen-prod/wp-content/uploads/2019/07/RPS-CES-June2019.pdf). Accessed September 5, 2019.



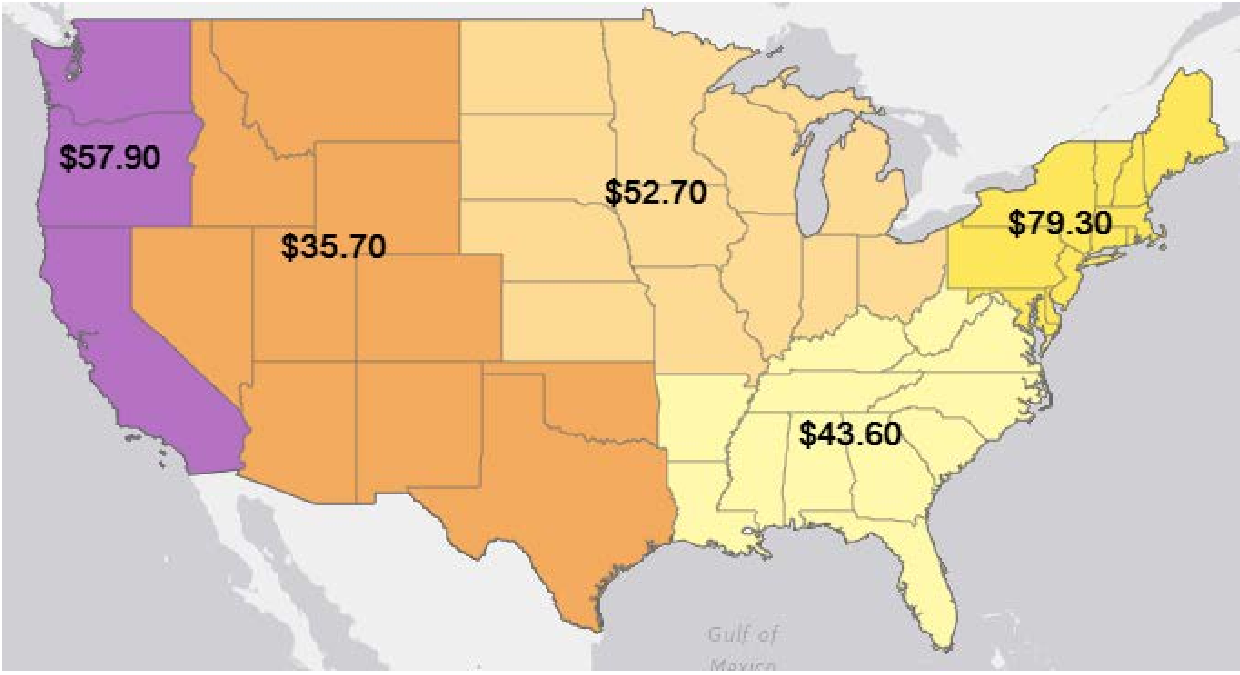
Map A-5. Energy Efficiency Resource Standards (2019).

Source: dsireusa.org (https://s3.amazonaws.com/ncsolarcen-prod/wp-content/uploads/2019/07/Energy-Efficiency-Resource-Standards.pdf). Accessed September 5, 2019.

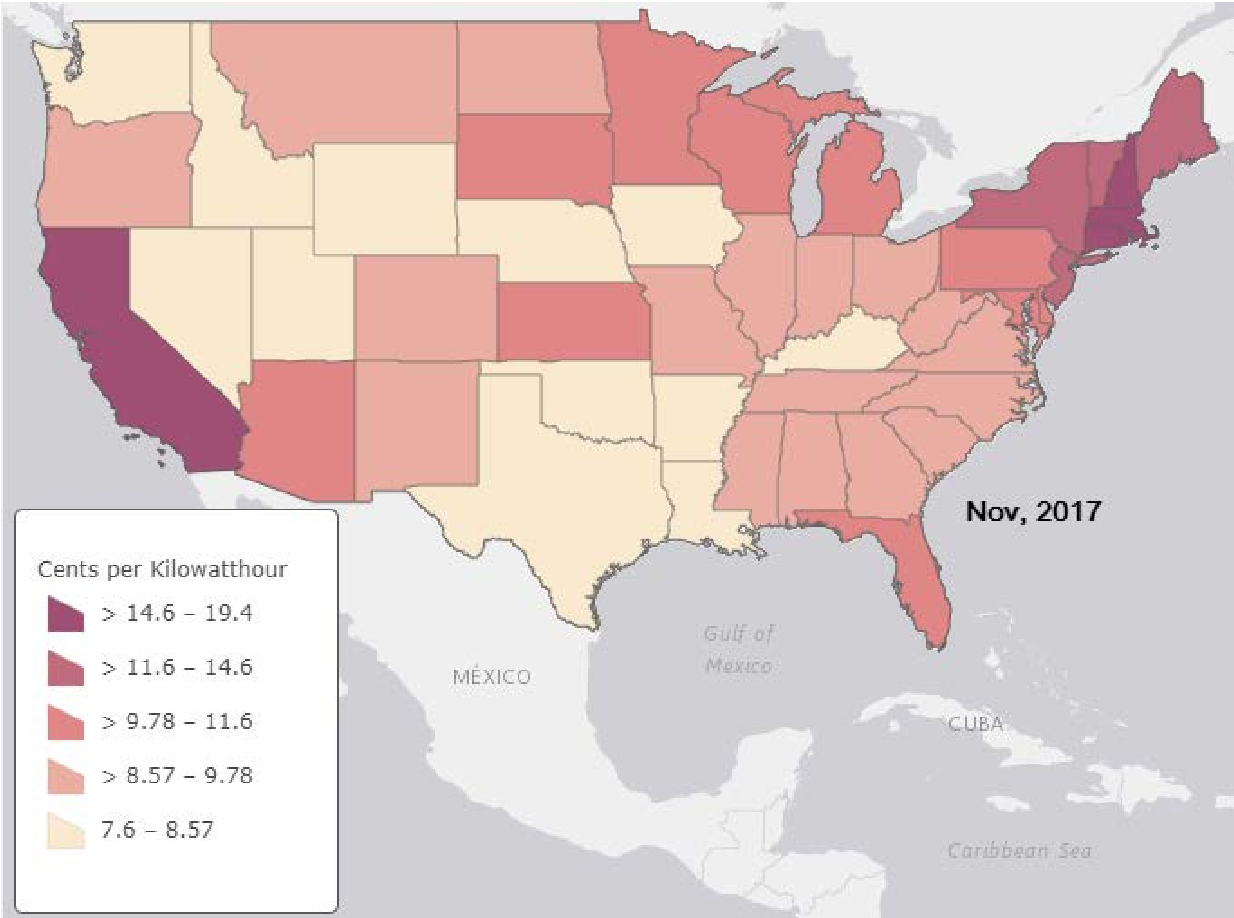
Map A-6. Low Carbon Fuel Standards and Alternative Fuel Standards.
Sources: Center for Climate and Energy Solutions (https://www.c2es.org/document/low-carbon-fuel-standard/).
AFS: Alternative Fuel Standard; LCFS: Low Carbon Fuel Standard.



Map A-7. State and Local Food Waste Landfill Bans or Recycling Mandates (2019).
Source: BANS AND BEYOND: Designing and Implementing Organic Waste Bans and Mandatory Organics Recycling Laws. Harvard University Food and Law Policy Clinic and Center for EcoTechnology. https://www.chlpi.org/wp-content/uploads/2013/12/Organic-Waste-Bans_FINAL-compressed.pdf Last accessed September 5, 2019.



Map A-8. Average Price to Landfill a Ton of Municipal Solid Waste by Region, May 2017.
Source: SWEEP (Solid Waste Environmental Excellence Protocol), http://nrra.net/sweep/the-cost-to-landfill-msw-in-the-us-continues-to-rise-despite-soft-demand. Last accessed March 11, 2019.



Map A-9. Average Price of Electricity to All Sectors, November 2017.
Sources: U.S. Energy information Administration, Form EIA-861M (formerly EIA-826), Monthly Electric Power Industry Report, Table 5.3. Average Price of Electricity to Ultimate Customers: Total by End-Use Sector https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a. Last accessed January 23, 2018.

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APPENDIX B

Thumbnail Sketches of Minor Case Studies

Introduction

EPA estimates that 78 WRRFs have adopted co-digestion in the United States. Chapters 4-9 highlight six of these WRRFs in detail and demonstrate diverse approaches to co-digestion. This section provides details on 17 additional co-digesting WRRFs and the innovative strategies they have used to implement co-digestion. Sections B.6 and B.7 also highlights eight WRRFs that have cutback or suspended co-digestion or that have done a formal assessment and decided not to adopt co-digestion.

B.1 Feedstock Partnerships

One of the most significant risks of investing in co-digestion infrastructure is ensuring a consistent feedstock stream. Partnering with local solid waste authorities or private waste management companies can mitigate that risk and provide long-term stability for co-digesting WRRFs. Moreover, WRRFs can require that feedstock providers meet certain feedstock quality standards, thus mitigating contamination risk and reducing variation in feedstock quality.

B.1.1 East Bay Municipal Utility District WRRF, CA: Evolving Food Scrap Feedstock Partnerships

Note: The research team did not select East Bay Municipal Utility District (EBMUD) as one of their major case studies because – as one of the largest and longest co-digesting facilities in the U.S. – extensive reports on it have appeared previously in the literature. Nonetheless, there is much to be learned from the EBMUD WRRF's strategies to adapt to changing feedstock market and regulatory environments.

Located in Oakland, California, the EBMUD WRRF (with an average dry weather flow of 50 mgd) was one of the first to adopt co-digestion and to produce more energy than it uses onsite. This section focuses on its long experiences accepting a wide variety of feedstocks, with particular attention to its partnerships for food scrap supply and preprocessing.

The facility currently accepts hauled-in liquid and solid HSOW for co-digestion at 11 anaerobic digesters. Over the course of its experience with co-digestion, EBMUD has pursued various partnerships both with the food manufacturing sector, as well as with solid waste suppliers, including both private haulers such as Recology, and public agencies, such as Central Contra Costa Solid Waste Authority, and South Bayside Waste Management Authority.

B.1.1.1 Co-Digestion and Energy Strategy

Resource Recovery Program Investments

The loss of the nearby canning industry in the early 1990s opened up capacity in EBMUD's digesters. To circumvent rising energy costs, the WRRF initiated a Resource Recovery Program in 2002 to haul in HSOW feedstocks to use available digester capacity for co-digestion. Over the years since then, it has made a series of investments in receiving facilities to accommodate co-digestion feedstocks. In 2002, EBMUD spent $1 million to begin accepting septage wastes (Hake 2017). When food scrap co-digestion began in 2004 through a pilot with a San Francisco hauler, Recology, EBMUD spent $7 million installing solid and liquid receiving facilities to accommodate this new waste. In 2014, EBMUD spent $13 million to install a new HSOW receiving facility. One component of the facility was blend tank infrastructure designed to ensure a uniform feed for the WRRF's digesters (Hake 2017, Goldstein 2018).

Since EBMUD was one of the first WRRFs to accept separated food scraps before good separation practices became more mainstream, contamination has been a significant operational issue from the beginning. Contamination has become more of a problem over time, as more sources have been added (U.S. EPA 2018). While most of the WRRF's food scrap suppliers preprocess waste before bringing it to EBMUD, EBMUD uses a patented pretreatment system to further reduce waste contamination. Foods scraps are passed through a rock trap/grinder, allowing large pieces of debris to settle out. Food scraps are then extruded through a screen with rotating blades. The system can reasonably process up to 50 tons of food scraps per day (Hake 2019).

Current Feedstocks and Revenues

Currently the WRRF receives approximately 100-150 trucks of liquid waste per day sourced from 250 different generators (Goldstein 2018). Two-thirds of the trucked-in waste has low COD [chemical oxygen demand] and goes to the head of the plant; the remaining one-third of accepted waste that is high COD is sent directly to the digesters. Of the food waste directed to digesters, 15% is FOG, 1% is food scraps, 10% is animal protein waste and 74-75% are various types of process effluents from dairy and wine industries (Goldstein 2018).

Hauled-in liquid wastes are accepted 24/7 through a semi-automated system, and are charged tip fees of $0.04/gallon - $0.09/gallon. Hauled-in solid HSOW can only be delivered 9-5:00 pm, five days a week, because staff must be present to operate pre-digestion processing and screening equipment (U.S. EPA 2018). Tip fees for solid organic wastes range from $30-$75/ton, depending upon factors influencing their financial impact on the facility, including treatment costs, gas production, and volumes (Hake2019).

Annual income from tip fees has increased substantially since the introduction of the co-digestion program in 2002, but has levelled off in the last few years as more processors are competing for organics. In FY2018, EBMUD earned $5.1 million in high-strength organic waste tip fees and a total of $12 million for all hauled-in wastes (Hake 2018). EBMUD is looking to expand its acceptance of food scraps, and anticipates more will become available as enforcement of B1383 activates in 2024.

Energy Production

EBMUD began beneficially using biogas in 1985 with the installation of three 2.2-MW CHP engines. In 1986, EBMUD arranged a power purchase agreement (PPA) with Pacific Gas & Electric to sell the electricity generated from their engines on an as-available basis. The PPA limited EBMUD's ability to receive revenues from RECs.

With its investment in a new 4.5-MW turbine in 2012, EBMUD added enough capacity to become energy positive, and began looking for opportunities to fully maximize revenues from energy sales. In 2012, EBMUD terminated its agreement with PG&E and moved to develop a PPA with the Port of Oakland. Over the last five years, with roughly two-thirds of the facility's biogas production from co-digestion wastes, the facility produced between 130% -140% of its electric power needs (Hake 2019). In FY2018, EBMUD received $900,000 in revenues from renewable electricity sales (EBMUD 2018).

However, in 2018 EBMUD flared 12% of its biogas due to the unscheduled nature of biogas production on a day-to-day basis. As a result, EBMUD continues to look at new ways to fully use its biogas beneficially.

B.1.1.2 Partnerships for Food Scrap Feedstock Supply

EBMUD has one long-term public partnership for the supply of food scrap feedstocks, just concluded a pilot with a private partner, and is anticipating participating in another pilot in the near future.

CCCSWA Program: In 2008, the WRRF pursued a pilot project with Central Contra Costa Solid Waste Authority (CCCSWA) in Walnut Creek, CA. CCCSWA and its franchised hauler Allied Waste Services (which was merged into Republic Services later that year) began a two-year pilot for food waste diversion, funded by a grant from the Diversion Incentive Fund. The pilot project hauled food waste from commercial generators to a pretreatment facility in Martinez and then to EBMUD. Republic Services and CCCSWA procured 100 customers for the initial pilot.

The program is now in full-scale implementation, with a 10-year contract that runs through 2025. In the contract, CCCSWA commits to deliver all of its commercial source-separated organics (CSSO) collections to EBMUD, and EBMUD agrees to process them. The operational costs of the program are funded by the 140 commercial entities that participated in the program. The CCCSWA program collaborates closely with food waste generators in order to reduce contamination. EBMUD currently receives one truck per day (15 tpd) from CCCSWA, with feedstock quality continuing to improve (EBMUD 2018). Republic Services is now considering upgrading their transfer station in Martinez to further improve feedstock quality and quantity (EBMUD 2018).

Recology: Recology is a local waste hauler serving the San Francisco area that began a food scrap co-digestion pilot at EBMUD in 2004. In 2011, Recology and EBMUD proposed the construction of a pretreatment facility at the WRRF. The pretreatment facility would have allowed both Recology and the WRRF to accept a wider variety of feedstocks, such as those that might require depackaging, and was intended to address the contamination issues that have been problematic since the beginning of food scrap co-digestion. However, construction of the facility was delayed by a complex permitting process (Hagey 2011).

In 2015, Recology received a $3 million Cal Recycle grant to install an organics extrusion system at their San Francisco Transfer Station as well as an organics polishing system at their Alameda processing facility (CalRecycle 2014-15). During 2016 and 2017, Recology and EBMUD piloted the use of Anaergia's OREX 500 press extruder, which is designed to expand potential digester feedstock sources by extracting organic materials from mixed solid waste (Schneider 2016). At the peak of the pilot, Recology delivered 35 tons per week to EBMUD (Recology 2018). Because San Francisco has SSO collection, the quantities of food waste generated from the mixed solid waste were small and were insufficient to justify investing in a polisher for the system.

Recology discontinued the pilot in 2018, and is planning to participate in another pilot in San Mateo County, which will employ the full organics extrusion and polishing system (see below.)

South Bayside Waste Management Authority (SBWMA): SBWMA is a joint powers waste management authority in San Mateo County. The authority is planning to implement an "urban organics" project similar to the one that was planned for San Francisco, also involving Recology and EBMUD. The project will include an Anaergia Press and a polishing system to further reduce contamination (Hake 2019).

B.1.2 Solid Waste and Wastewater Treatment Partnership in Oneida County, NY

The Oneida-Herkimer Solid Waste Authority (OHSWA) in upstate New York is working to reduce food waste sent to landfill by diverting it to the nearby Oneida Water Pollution Control Plant (WPCP). OHSWA is constructing a $3.4 million facility to depackage and blend food waste into a slurry that can easily be digested at the WPCP's digester, which will be located next to the authority. The county's WPCP and sewerage system itself is undergoing a $330 million upgrade, $27 million of which is allocated to the installation of a new digester that will facilitate the Solid Waste Authority's Food2Energy program. The digester is expected to be completed in October 2018.

The project was in part motivated by a proposed state mandate for organic waste diversion for institutions producing more than two tons per week of organic waste within 40 miles of a disposal location, which was enacted in 2019 and will be effective as of 2022. OHSWA aims to ensure that local institutions have an affordable option for disposal with the passage of the state mandate. OHSWA is offering tipping fees for organic waste at $20 less than the normal $62/ton landfill tipping fee. OHSWA has already begun reaching out to local schools and other food waste-generating institutions to identify sources for its feedstocks (Mason 2018).

The WPCP service area is a subset of that of OHSWA: OHSWA serves both Herkimer and Oneida counties, and WPCP serves Oneida County and two municipalities within Herkimer County (Oneida County n.d.).

B.1.3 Onsite Food Waste Depackaging at Hermitage Municipal Authority, PA

The Hermitage Municipal Authority (HMA) operates a 3.5 mgd Food Waste to Energy and Wastewater Reclamation Facility (WRF) with a unique food scrap co-digestion program in Western Pennsylvania. With no long-term contracts, the WRF provides a sustainable disposal method for local and regional industries while also bringing in enough revenue to fund four full-time organics waste management staff.

The food scrap digestion program at the Hermitage WRF was implemented to support a $32 million upgrade to the WRF’s anaerobic digesters and other treatment processes. Championed by the Water Pollution Control Superintendent and HMA Manager, Tom Darby, WRF staff made the decision to use biogas while still in the design phase of the digesters. After discussion, WRF staff concluded that a CHP engine seemed like the most feasible option with the lowest operational cost. The addition of a $1.5 million food waste receiving station allowed the WRF to accept food waste to the digesters (though Darby notes that some of the receiving station infrastructure is redundant and would have been constructed without co-digestion). This food waste would help to increase biogas production, allowing the WRF to sell electricity to the grid. Final upgrades to the WRF also included temperature-phased digestion, which the WRF chose in order to satisfy EPA and PA DEP requirements for the production of Class A EQ biosolids.

Energy Strategy: Co-digestion was implemented in 2013 during the second phase of the Hermitage WRF’s $32 million upgrade. The food waste accepted at the WRF produces additional biogas, which is sold to the grid through a net metering agreement with the WRF’s electricity provider, First Energy. The cogeneration system, which was funded in part by a Pennsylvania Growing Greener grant from the Pennsylvania Department of Environmental Protection, runs on 70% biogas and 20-30% natural gas. The co-digestion system requires substantial maintenance. Darby notes that if he had to redo the biogas project, he would have chosen a pipeline injection process, though the local gas company is reluctant to facilitate a project of this nature.

Feedstock Strategy: Originally, the Hermitage WRF was prepared to accept only liquid wastes. To solicit feedstock providers, Hermitage WRF staff began speaking with local manufacturers and the Chamber of Commerce. The WRF initiated co-digestion by accepting wastes from a local dairy industry located six miles away. Darby knew that the industry was hauling wastes further than the WRF and offered a more convenient disposal option. After accepting wastes from additional feedstock generators, the WRF found that feedstocks were mostly solid. After conducting some research, WRF staff identified and purchased Minnesota-based Scott Equipment Company’s solid waste depackager, which removes packaging and slurries the food waste. The WRF also converted an open-air pavilion previously designated for biosolids storage to a food waste storage facility.

Hermitage WRF does not currently solicit feedstocks, but it receives several calls per week for food waste disposal. When determining whether to accept a new waste, WRF staff will evaluate BOD, TSS, VSS and pH of the waste. The WRF then will determine a tipping fee for the waste based on the labor required to break down packaging. On average, the WRF charges $30 per ton of liquid and slurried waste. The amount charged includes the cost of depackaging solid waste items. Over time, WRF staff have mastered mixing organic wastes with different characteristics to create desirable slurry properties. Hermitage has accepted a range of food wastes, including off-spec honey, frozen French fries, and salad dressing. The initial dairy industry client remains an anchor feedstock provider. In 2018, the WRF accepted between 60 and 100 tons per week of food waste.

In addition to providing a disposal service, Hermitage also provides companies with a certificate of sustainable disposal, which in some cases is needed to comply with FDA disposal requirements. The WRF can also provide an estimate of how much biogas a given product produces through digestion, demonstrating to disposal companies and their clients the beneficial impact of their waste.

Financial Impacts: In 2018, the WRF received $246,000 in 11 months from tipping fee revenue, saved an average of $27,000 in energy costs, and saved $8,000 in biosolid costs on a monthly basis. Packaging materials are sold, providing an additional source of revenue. Tom Darby views organic waste recycling as an entirely separate operation at the WRF. The WRF has four staff members dedicated to organics recycling (out of 18 total staff at the plant). Their salaries are paid from revenues from the co-digestion program. Due to the addition of food waste, Hermitage WRF expects the payback for their $32 million upgrade to take somewhere between 8 to 10 years (Thomas Darby, interview with the authors, December 18, 2018).

B.1.4 Rahway Valley Sewerage Authority, Rahway, NJ: Partnership with a Private Organics Processor

Rahway Valley Sewerage Authority (RVSA) in Rahway, New Jersey operates a WRRF with 60 mgd capacity for tertiary treatment (and peak load capacity up to 105 mgd). In 2015, RVSA negotiated a 10-year contract for feedstock slurry supply with WM, with an option for a 10-year renewal. The contract takes advantage of unused capacity in the WRRF’s three digesters and in the WRRF’s combined heat and power engine (Biocycle 2016). The WRRF aims to optimize digester operations, provide a steady and consistent feedstock supply, and reduce the need for natural gas purchases through increased biogas production. WM has designed and constructed a receiving tank from an existing gravity thickener tank at the WRRF. A NJ State Revolving Fund financed the retrofits needed to upgrade the gravity thickener into a receiving tank. WM delivers slurry from its northern New Jersey CORe® facility recently constructed in Elizabeth, New Jersey. WM ramped up deliveries from 6,000 gallons of Engineered BioSlurry (EBS®) per day to start to its current delivery rate of 20,000 gallons per day. Feedstock quality standards, including *de minimus* levels of contamination, are specified for the EBS product in the agreement. WM pays a tipping fee and is financially responsible for any expenses for potential increases in biosolids production beyond a stipulated level. In addition, RVSA and WM will share any additional value generated from renewable energy credits once gas production exceeds a 100% increase from pre-contract gas generation levels.

B.1.5 Industrial Food Waste in Appleton, WI

The Appleton Wastewater Treatment Plant (WWTP) began accepting high strength organic wastes in the early 2000s, after nearby industries left the area, opening up digester capacity. The WWTP accepts 200,000 gallons of hauled waste per day. Approximately 25% goes to the digesters and 75% goes to the WWTP headworks. Like many resourceful plants, Appleton made minimal investments to initiate co-digestion -- converting two tanks onsite into HSOW receiving stations. Feedstocks include cheese manufacturing wastes and other food processing wastes. Co-digestion can put stress on the WWTP system and staff conduct frequent sampling to ensure low contamination.

While Appleton has a CHP engine, it is currently not in use due to the low cost of natural gas. As a result, much of the WWTP's biogas is either sent to one of three waste gas boilers or flared. The waste gas boilers are used to heat the mesophilic digesters to 95°F. Tipping fees are tiered based on the concentration of wastes brought to the WWTP. The WWTP generates a substantial amount of revenue from tip fees through their hauled waste program (Chris Shaw, interview with authors, December 13, 2018).

B.2 Internal WRRF Management of Onsite Heat and Electricity Production

Many WRRFs use electricity and heat onsite only, and do not have energy utility contracts for energy sale or distribution. Onsite energy generation is particularly attractive in areas with high or rising electricity rates. Local climate change mitigation plans that call for carbon emission reductions and WRRF-driven net zero energy use initiatives have also motivated onsite use of digester biogas. Co-digestion is often a means to increase biogas use in order to achieve energy efficiency or net zero energy use goals.

B.2.1 Energy Efficiency at Durham Water Resources Recovery Facility Clean Water Services, OR

The Durham WRRF (22 mgd) operated by Clean Water Services has a dedicated energy management team that works with the Energy Trust of Oregon to identify areas for improved energy efficiency and energy production. Energy Trust of Oregon is a nonprofit that helps facilitate sustainable energy efficiency and renewable energy projects throughout the state. One of the projects developed at the Durham WRRF was the construction of a FOG receiving facility to enable the addition of FOG to the digesters. Clean Water Services also has a business opportunity manager who procures contracts for FOG acceptance and biosolid disposal (Willis et al. 2015). With the increase in biogas production from the addition of FOG, the total biogas produced and onsite solar panels provide 60% of the plant's energy needs (Clean Water Services n.d.).

B.2.2 FOG Co-Digestion at Gresham WWTP, OR

The 2005 addition of a new 400 kW cogeneration engine at the 13 mgd Gresham WWTP motivated staff to consider new opportunities for increasing biogas production. In 2008, the Oregon Department of Energy supported a study to assess the economic feasibility of FOG acceptance at the WWTP. The study found that the payback for investment in a receiving station and other infrastructure would be seven years if grant funding were included. This financial analysis played a crucial role in convincing city officials to pursue the co-digestion. In addition, a citywide sustainability plan with a focus on energy neutrality helped increase support for the project. The co-digestion project cost the city $2.8M, after receipt of $1.6M in Oregon Department of Energy and Oregon Energy Trust grants. The program started as a pilot in 2012 and has since expanded the FOG receiving station and added a second 400 kW cogenerator engine in 2014 and 2015 respectively (NW Biosolids 2015). Gresham has been energy neutral since 2015.

Gresham currently receives 13,000 gallons per day of FOG from five different haulers priced at $0.08 per gallon. WRRF staff consistently update the original cost estimates for the plan with actual costs. The consistency with prior estimates instills confidence in the project's success. FOG maintenance costs are higher than expected due to corrosiveness of FOG; however, WRRF staff are now adept at handling these maintenance issues. With biogas and an onsite solar panel installation, the WRRF now produces biogas in excess of its needs and net-exports 10% of its electricity to the grid (Alan Johnston, interview with authors, February 1, 2018). Oregon prohibits any public utility from avoiding retail utility rates by selling their power through the grid. Electricity produced in excess of onsite needs may contribute to electricity bill reduction over a 12-month period. At the end of 12 months, excess electricity generation is donated to help subsidize renewable energy for customers in low income programs (Public Utility Commission of Oregon 2016).

B.2.3 Net Zero Energy Use at Essex Junction WRRF, Essex Junction, VT

Essex Junction WRRF (3.3 mgd) used funds from Efficiency Vermont, the state's energy efficiency utility, from the Vermont Energy Investment Corporation, and from public bonds to upgrade its CHP and implement a system to control feedstock flow to its digesters. Efficiency Vermont incentivizes its utility customers to adopt net zero energy use by providing technical assistance and funding (Johnston 2015). The WRRF also generates onsite energy from a solar panel facility, effluent heat recovery and geothermal well. The plant accepts -- on an ad hoc basis -- food processing wastes that other processing facilities cannot handle (Johnston 2015). These renewable energy sources and the continuous evaluation and implementation of energy efficiency improvements have brought Essex Junction close to net zero energy use.

B.2.4 Energy Cost Savings and Co-Digestion in Fond Du Lac, WI

The Fond du Lac Regional Wastewater Treatment and Resource Recovery Facility (WTRRF) is an 8-mgd plant with a mission to recover valuable energy, biosolids, and nutrients. Using temperature phased anaerobic digestion, the WTRRF has co-digested high-strength organic wastes (HSOW) from nearby industries since 2013. Using their own financial reserves, Fond du Lac installed two HSOW receiving tanks with pumps to transfer wastes to the thermophilic digester. Hauling wastes to the WTRRF saves nearby industries money in disposal costs. Diverting HSOW from the primary treatment train to the digester saves the WTRRF money in energy required to aerate the wastes. On average, the WTRRF receives 20,000 to 25,000 gallons of waste per day, mainly from dairy waste producers, and charges a tip fee of $20 per 1000 gallons. Excess biogas from these wastes provides fuel for a cogeneration engine which provides 40-50% of the WTRRF's electricity needs (Cody Schoepke, interview with the authors, December 11, 2018).

B.3 Energy End Products from Co-Digestion for Sale

B.3.1 Biogas to Electricity Sales

WRRFs can generate revenue from electricity produced from biogas by selling the electricity to third parties and by selling Renewable Energy Credits (RECs) for compliance with state Renewable Portfolio Standard requirements. If the federal Renewable Fuel Standard activates the proposed renewable fuel pathway for electricity generated from renewable sources used in electric vehicles, they also may generate revenues from Renewable Identification Number (RIN) sales in the future (Greene 2017).

The East Bay Municipal Utility District (EBMUD) has changed its electricity sale contracts over time to maximize the revenue generated. EBMUD began beneficially using biogas in 1985 with the installation of three 2.2-MW CHP engines. In 1986, EBMUD arranged a power purchase agreement (PPA) with Pacific Gas & Electric to sell the electricity generated from their engines on an as-needed basis. The PPA limited EBMUD's ability to receive revenues from RECs. As electricity production was set to increase in 2013 to the point where it would be energy positive with the addition of a new 4.5-MW turbine, EBMUD began looking for opportunities to fully maximize revenues from energy sales. In 2012, EBMUD terminated its agreement with PG&E and moved to develop an agreement with the Port of Oakland (Hake 2019). EBMUD receives revenues from RECs and electricity sales to earn $900,000 annually (EBMUD 2018). However as of 2018, EBMUD still flares 12% of its biogas due to the unscheduled nature of biogas production. As a result, EBMUD is considering options for additional biogas end uses. In 2018, EBMUD submitted a preproposal to the California Energy Commission for upgrading biogas for use as vehicle fuel in order to create value from biogas that otherwise would be flared (EBMUD 2018).

At the Janesville Ohio Wastewater Treatment Plant (JWWTP), biogas is used for electricity generation or compressed into renewable natural gas for vehicle fuel. JWWTP is able to strategically direct biogas to either electricity production or compressed natural gas (CNG) production depending on the grid demand for electricity (Greene 2017). Through a net metering agreement with Alliant Energy, the plant generates $186,000 annually in revenue from electricity sales (U.S. EPA 2018). JWWTP found that it was more financially attractive to sell biogas to Alliant than to use it onsite due to Alliant's competitive renewable electricity tariff rates. (Note that Janesville dropped co-digestion in 2015. See discussion in Section B.6.2 for more details.)

B.3.1.1 Renewable Energy Tariffs Motivate Co-Digestion in West Bend, Wisconsin

The West Bend Sewer Utility in Wisconsin illustrates the importance of renewable energy policies such as high tariff fees as a catalyst for co-digestion. (See Chapter 10 for further details on renewable energy policies in Wisconsin.) In 2013, West Bend Sewer Utility entered into a 20-year renewable tariff agreement with We Energies. At the time, We Energies was offering high prices for renewable electricity. The West Bend Sewer Utility began accepting FOG and dairy waste to their digesters to boost biogas production for their newly installed microturbines. The West Bend Sewer Utility receives approximately $10,000 per month from selling electricity to We Energies.

While these revenues offer a substantial incentive for continuing co-digestion, the West Bend Sewer Utility notes that clogging and contamination present significant operational issues. Moreover, the cogeneration microturbines are becoming difficult to operate and require increasing maintenance. Lastly, as several utilities in Wisconsin have observed (See B.6 below), competition for feedstocks is increasing in some locations in the state. Already, the plant's tip fee rates have fallen from $200-$300 per 6,000 gallons to $70 per 6,000 gallons. West Bend is only in the 5th year of its tariff agreement and intends to continue co-digestion to generate tip fee revenues (Steve Randall, interview with the authors, December 12, 2018).

B.3.2 Biogas to Renewable Natural Gas (RNG)

Renewable natural gas is an emerging end use for WRRF biogas, particularly as vehicle fuel for which WRRFs can receive considerable revenue streams from the sale of RNG and from the associated RINs through the federal Renewable Fuel Standard (RFS) program. RNG fuel from biogas can be sold directly in fueling stations, or can be injected into pipelines and directed to fuel uses elsewhere. While biogas from anaerobic digestion of solids is classified as a D3 fuel, biogas from co-digesting WRRFs is classified as the less lucrative D5 fuel under the RFS. The U.S. Environmental Protection Agency and stakeholders are currently developing methods to allocate credits between D5 RINs and D3 RINs for RNG produced from co-digesting WRRFs.

B.3.2.1 RNG to Direct Vehicle Fuel Usage

At noted above, the Janesville WWTP can strategically direct biogas to either electricity production or compressed natural gas (CNG) production depending on the grid demand for electricity. For the latter, JWWTP has partnered with BioCNG, a renewable CNG production company, to design and build the CNG production facility. Currently, CNG production fuels eight city vehicles. The WRRF plans to eventually expand the program to fuel 40 vehicles. The facility is expected to initially save $8,000 in fuel costs and will save $60,000 per year in fuel costs after all city vehicles are converted to natural gas.

B.3.2.2 RNG to Pipeline Injection

Biogas to pipeline injection requires less onsite compression than vehicle fueling (50-1000 psig vs. 3500 psig for onsite vehicle fueling and 4000 psig for tube trailer transportation), and it limits the need for hauling fuel or creating onsite vehicle fueling stations (and the extra emissions that come from these options) (American Biogas Council n.d.; Holland et al. 2016). The case study of the Dubuque, Iowa Water and Resource Recovery Center highlights its experience with adoption of pipeline injection in 2018. Highlighted below are the experiences of the Newark WWTP in Newark, Ohio, which has injected biogas to a nearby gas utility since 2011. Guild Associates' Molecular Gate technology cleans biogas generated by digesters at the WRRF to standards set by the local utility.

RNG to Pipeline Injection at the Newark WWTP
Prior to the proliferation of RINs and the RFS, the City of Newark WWTP implemented a biogas-to-RNG system at their plant in 2011. Over the past eight years, WWTP has had mixed success in producing a consistent RNG product; however, the WWTP is one of the earliest adopters of RNG production for pipeline injection.

The City of Newark operates an 8-mgd wastewater treatment plant in central Ohio. The plant has leveraged local resources to engage in both renewable natural gas production and a limited form of co-digestion. (Both are currently on pause while the digesters are offline for a major overhaul). Starting initially with FOG in 2008, Newark has accepted a variety of other high-strength food wastes, usually on an ad hoc basis. WWTP Superintendent Brian Curry describes the plant's engagement with co-digestion as minimal, where the WWTP acts as an emergency disposal site when other plants reach their capacity for feedstock acceptance or when food processors need a temporary disposal site. WWTP staff determine whether to send wastes to the digesters or the headworks depending on waste characteristics.

In determining an end use for their biogas, the City of Newark first considered investing in a CHP engine to generate onsite power along with heat. Due to demanding maintenance requirements, however, Newark found that the combined capital and maintenance costs for the engine and the equipment to condition biogas for use in the engine were too high relative to the returns. The city also considered using biogas to supply vehicle fuel to a nearby solid waste transfer station. That project fell through because the solid waste company wanted a high-rate fill system for filling their vehicles, which would have been economically infeasible.

In 2008, Guild Associates, a supplier of biogas conditioning equipment, approached the Newark WWTP as a potential candidate for testing entry into the wastewater treatment market, with new biogas upgrading technology operating at a smaller scale than their previous landfill-based projects. Guild found Newark's high quality biogas and location near a natural gas pipeline to be ideal for a pilot pipeline injection project at a small wastewater plant. Using financial support from a federal Department of Energy grant and a local Community Block Development grant, the WWTP installed a 108,000 scfd (75 scfm) biogas upgrading system and began selling biomethane to the local energy utility, The Energy Cooperative (TEC), in 2011. Prior to pipeline injection, the biomethane is processed to achieve a compression of 90 psi, the pressure level in the nearby TEC distribution pipeline, and a minimum heating value of 960 MMBTU/scf (City of Newark 2010).

TEC estimates that they receive from 100 to 300 decatherms[8] of natural gas per month (100-300 MMBtu per month), which is substantially less than projected during the initial project evaluation. One source of variability in the quantities of biogas directed to the pressure swing adsorption (PSA) system is the

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[8] One decatherm is equal to *1,000,000* British thermal units (MMBtu) or *1.055* GJ. It is also approximately equal to *one thousand* cubic feet (MCF) of natural gas or exactly one MCF of natural gas with a heating value of *1000* BTU/cf.

seasonal variation in onsite requirements for biogas to heat the digesters. Digester heating needs are satisfied first, then excess biomethane is sent to the pipeline or directed back to heat buildings in the facility. Over time, maintenance issues with the PSA system, and associated system shutdowns, have become a more significant source of variability. Biogas sales to the utility are temporarily paused as the plant upgrades its anaerobic digesters.

In current wastewater sector applications, the Guild rule of thumb is that 400 scfm systems are the minimum size system for creating economies of scale and economic feasibility (Paul Baker, Interview with authors, Oct. 30, 2019).

B.3.2.3 Future Pipeline Injection Projects

Several other case studies are considering pipeline injection, including Victor Valley Water Reclamation Authority, Los Angeles County Sanitation Districts, Des Moines Wastewater Reclamation Authority, and the Derry Township Municipal Authority. Newtown Creek WWTP in Brooklyn, NY is accepting food slurry from WM and is also planning to implement pipeline injection. These utilities are negotiating PPP contracts where third parties will be responsible for biogas cleaning and preparation for injection, thus removing liability and the technical burden of biogas processing. Victor Valley is working with the energy company, Anaergia, to inject biogas to the Southwest Gas pipeline. Anaergia will be completely responsible for cleaning the gas (Logan Olds, interview with authors, July 3, 2018). Newtown Creek is partnering with National Grid to send excess biogas generated from their food waste co-digestion program to the National Grid pipeline. National Grid will operate the equipment to clean the biogas to pipeline quality standards (Chahbazpour, 2017). DTMA is working with ESG on a pipeline injection project that will likely rely on truck transport of gas to a nearby pipeline.

B.3.3 Biogas to a Private Partner at Des Moines WRA, Des Moines, IA

The Des Moines Metropolitan Wastewater Reclamation Authority (WRA) is a joint authority of seventeen member communities in the Des Moines metropolitan region. The City of Des Moines operates the WRA, including the Authority's 60-mgd Wastewater Reclamation Facility (WRF). WRA is an early adopter of both co-digestion and innovative biogas use. Excess capacity in the WRF's six 2.7 million gallon digesters was a factor in WRA's decision to start co-digestion, as with EBMUD (Greer 2011).

B.3.3.1 Co-Digestion and Biogas End-Use Investments

The WRF began accepting whey waste from nearby industries for its digesters in 1991. Since then, the WRF has added wastes from local industry and nearby restaurants. The co-digestion program rapidly expanded when Iowa implemented stringent regulations for the land application of biodiesel and ethanol production wastes. Anaerobic digestion offered an affordable and legal method for the disposal of waste from these industries.

Project 1: Biogas to Cargill

Prior to the addition of biodiesel wastes, biogas production only powered one or two of the three WRF 600-kW cogeneration engines. With the addition of these new high-strength organic wastes (HSOW), digesters produced biogas in excess of the capacity of the WRF's previously underutilized cogeneration engines. As a result, WRA began looking for additional biogas end uses. Due to a long-term electricity price cap, electricity prices were too low to make the addition of another cogeneration engine economically favorable. Thus in 2007, the utility entered into a partnership to deliver biogas to nearby Cargill vegetable oil refinery. WRA invested approximately $1 million in a biogas conditioning system and contributed to funding the 600-foot pipeline to the Cargill plant. Cargill invested $750,000 for the rest of the pipeline. Estimated payback periods were 3.9 years for WRA and 1.5 years for Cargill. Cargill is billed monthly based on the cost of natural gas and the share of methane in the biogas (62%) (Willis et al. 2012).

Project 2: Receiving Station and Storage

In addition to the biogas-to-Cargill project, the plant has gone through two additional phases of upgrades as a result of the success of the co-digestion program. Originally, trucked-in wastes were delivered directly to WRA headworks. WRA began experimenting with adding a pipe to deliver feedstock to the digesters, but found that pipe blockages were an issue during Iowa winters. Subsequently, WRA added a $1.75 million receiving and storage station for hauled waste (Greer 2011). The 140,000-gallon tank allows WRA to manage the feed-in rate of hauled wastes regardless of delivery time. They have also added three polymer precast concrete boxes with resin binders to remove debris such as rocks and silverware. Heavy items fall to the bottom of the boxes while liquid wastes flow into a storage tank. WRA constructed the boxes with a corrosion-resistant lining to manage the different chemical qualities of wastes (Greer 2011).

Project 3: Digester Mixing and Cogeneration

In 2010, WRA began a $19 million upgrade project to increase the mixing capabilities of their digesters. In-depth evaluations of digester operations found that upsets caused by corn oil and isopropyl alcohol feedstocks could be reduced with better mixing. WRA also added two 1.4-MW Jenbacher CHP engines to the WRF's existing 1.8 MW of capacity. The engines became economically feasible because of an expected increase in electricity prices when the Iowa Utility Board electricity price caps were removed (Greer 2011).

Future Project 4: Biogas to RNG

WRA is pursuing a project to inject biogas to a pipeline as Renewable Natural Gas (RNG) with CDM Smith. The project is slated to be completed by 2019 (Paul Ebert email correspondence with authors, July 11, 2018). (They demurred at being a major case study until their project is completed.)

B.3.3.2 Feedstocks

To initiate co-digestion, WRA contacted industries sending their waste through the WRA's pretreatment program to inquire about their interest. Currently, the WRF accepts HSOW from over 50 industries – ranging from biodiesel plants to food processors – in a four-state region and FOG waste from over 2000 commercial food service establishments throughout Iowa. Food wastes accepted at the WRF must have a total solids content greater than 2.5% and volatile solids content greater than 70% (Van Horne et al. 2017). The facility receives, on average, over 50 tankers per day. Over the course of the year, Des Moines accepts 11.2 million gallons of FOG and 41.6 million gallons of other high-strength organic wastes (Van Horne et al. 2017).

B.3.3.3 Starting Co-Digestion and Motivation

Des Moines takes a very methodical approach to improvements at the WRF. The Bioenergy Master Plan developed in 2008 outlines tasks. WRF staff evaluate various options using an economic model to estimate biogas output and present discounted net value of the project. Inputs include estimates for the quantity of solids and HSOW feedstocks, costs of power and natural gas, and revenues from tip fees and land application. To evaluate options, WRA also considers 11 non-economic criteria, including ease of use and the reliability of technology.

B.3.3.4 Strategies to Mitigate Risks

The Des Moines WRA has identified several strategies for mitigating operational and financial risks, including:

1. Experiment with adding waste to digesters using pipeline.
2. Use anti-corrosive materials to mitigate feedstock chemical characteristics.
3. Use a storage tank to manage feed-in rates.
4. Develop a Bioenergy Work Plan to guide tasks for biogas end use.
5. Establish innovative partnerships to finance biogas end use.

B.4 Public-Private Partnerships for AD Management

Utilities can partner with private companies that can assume the financial, regulatory and performance risk associated with new infrastructure. Co-digestion can be woven into these private contracts as a method for generating additional revenue for the private company or improving biogas production to increase energy savings for the WRRF.

B.4.1 Using Design, Build, Own, Operate Contracts: Quasar Case Study

Quasar is an Ohio anaerobic digestion (AD), waste management, and renewable energy company founded in 2006 by Mel Kurtz. In addition to digester management, Quasar manages a regional feedstock collection network to supply its anaerobic digesters. For digester development, Quasar works with WRRFs, private real estate companies, and industries in several different partnership structures. At the French Creek WWTP and Wooster WWTP, Quasar implemented a Design-Build-Finance-Own-Operate model; Wooster has subsequently exercised its option to purchase the AD on its property, and operates it in-house. Alternatively, Quasar can construct and operate digester with their partners retaining ownership, or simply design and construct a digester that partners own and operate (a more traditional business model).

Low Construction Costs: Quasar has played a significant role in the proliferation of food waste digesters in Ohio. By keeping digester construction costs low and leveraging multiple incentive programs, the company has installed or upgraded 11 stand-alone, WRRF, and on-farm digesters in Ohio. Quasar’s easy-to-assemble digesters are manufactured in Ohio, which reduces transportation costs (Angel Arroyo-Rodriguez, interview with authors, April 2, 2018). Quasar’s use of available American Recovery and Reinvestment Act funds between 2012 and 2014 reduced digester construction costs by 33%; grants from the USDA Rural Energy for America Program (REAP) and from the Ohio Department of Development reduced it by another 25%, and they also were able to use double depreciation rates (Alan Johnson, interview with authors, October 17, 2018; U.S. Treasury, n.d).

Regional Feedstock Management: Quasar has developed a regional feedstock collection network in Ohio. Due the geographical concentration of their digesters, Quasar typically has a choice of nearby Ohio digesters to deliver food waste collections and can optimize its choice based on digester operations, hauling costs and other factors affecting economic returns. Feedstocks accepted include biosolids from other WRRFs, food processing residuals, FOG, and food slurry from Grind2Energy equipment installed at organizations around the state.

Digester Products: The Class A and Class B biosolids generated from Quasar digesters are used at land reclamation sites or as fertilizer (Alan Johnson, interview with authors, October 17, 2018). Liquid effluent from digesters is processed into Quasar’s patented “equate” fertilizer and is land-applied on Ohio farms (Quasar n.d). Energy products produced by Quasar AD facilities include heat, electricity and Quasar’s patented renewable compressed natural gas (CNG) for vehicle fuel. Quasar uses the electricity onsite, and in some cases sells it to the grid or to their AD development partner (see French Creek case study below). CNG is sold to the public at fueling stations near the digester (Quasar n.d).

B.4.1.1 Wooster Wastewater Treatment Plant, Wooster, OH

In 2013, the City of Wooster’s wastewater treatment plant (7.5 mgd capacity, with average flow of 3.5 mgd) was facing regulatory non-compliance fines for its effluent quality. With limited funding available, Wooster opted to enter into a 20-year contract with Quasar in order to improve wastewater treatment to meet the regulatory requirements for its effluent. As part of the contract, Quasar improved the capacity and mixing capabilities of the WRRF’s existing digesters, constructed a cogeneration system, and managed feedstock collection, energy production, and biosolids disposition at the facility. Quasar provided approximately 90% of the capital for the $7.1 million project, while the city spent $1.5 million.

The contract specified that the Wooster plant would pay Quasar a tip fee for managing biosolids and would purchase electricity from Quasar's biogas energy generation system.

With Quasar's upgrades, Wooster expanded the capacity of the digesters and achieved regulatory compliance. The increase in plant capacity has also opened the door for Wooster to accommodate more industry moving into the area (Johnston 2014).

In March 2017, the Wooster City Council unanimously voted to invoke the contract option to purchase Quasar's renewable energy facility (AD and cogeneration equipment) for $4.58 million (Huszai 2017). Though repurchase was planned from the beginning, the timing may have been expedited due to public concerns with odors emanating from the site (Huszai 2017). Since June 2017, the Wooster WWTP has been accepting feedstock from nearby industries and procuring feedstock suppliers on their own. In the first six months of accepting feedstocks, the WWTP collected $80,000 in tip fees. For 2018, the utility plans to expand feedstock revenue by 25%, while maintaining regulatory compliance (Givens 2018).

B.4.1.2 French Creek WWTP, North Ridgeville, OH

French Creek WWTP is an 11.3 mgd plant operated by the city of North Ridgeville. The plant was facing $800,000 of necessary upgrades in order to comply with the new Ohio EPA biosolids regulations that went into effect in 2011, which included storage capacity for 120 days of biosolids (Ohio Administrative Code 3745-40-10). The utility concluded that a public-private partnership (PPP) with Quasar to manage biosolid disposal would be more economical than implementing upgrades using public financing (Alan Johnson, interview with authors, January 11, 2018).

Under the PPP agreement, Quasar was authorized to design, build, finance, own, and operate a digester on land leased from the French Creek WWTP site. The cost of construction was $6 million, $1 million of which was provided by American Recovery and Reconstruction Act funding (Alan Johnson, interview with authors, January 11, 2018). Feedstocks accepted at the digester include food wastes from Quasar's regional food waste network, and solids piped to the digester from French Creek WWTP (Alan Johnson, interview with authors, January 11, 2018). The WWTP also receives energy produced from the digester at a discounted price.

B.4.2 Energy Savings Performance Contract: North Regional WWTP, Broward County, FL

North Regional WWTP is a 95-mgd plant located in Pompano Beach, Florida. Broward County owns and operates the plant, which is one of the area's largest energy consumers. Broward County's climate change plan motivated the plant to reduce energy consumption in order to contribute to the plan's goal of reducing carbon emissions to 1997 levels by 2015. In 2012, the utility partnered with OpTerra Energy (formerly Chevron Energy Solutions Company) through an energy savings performance contract (ESPC) to implement a project that would use the biogas produced at existing digesters. The resulting facility features a 2-MW CHP engine and a FOG receiving station. Prior to the project, FOG was trucked to the plant and added through the headworks, which increased the plant aeration costs. With the new facility, the plant diverts FOG directly to the digesters, reducing the energy costs associated with aeration and increasing biogas production. Approximately $800,000 in energy cost savings were calculated for the first year of the project, along with a 50% reduction in carbon emissions. The returns of investment accrue to the project in the form of energy cost savings over the course of 20 years (Pfeffer et al. 2016).

B.5 Biosolids Management as an Incentive for Co-Digestion

As restrictions on land application of biosolids increase, WRRFs must find new disposal locations and methods for their biosolids. As a result, biosolids management is becoming an increasingly costly part of operations for WRRFs. Some WRRFs have used the additional biogas generated as a result of co-digestion to power various technologies to produce higher quality biosolids that can be used in more contexts and can earn revenues.

B.5.1 Innovative Biosolid Management and Co-Digestion at Columbus Water Works, GA

South Columbus Water Resources Facility (WRF) in Columbus, Georgia is a 40-mgd facility owned and operated by Columbus Water Works (CWW). A 46% increase in electricity costs between 1990 and 2013 spurred CWW to create an Energy Management Program (EMP) to increase energy efficiency at the WRF. Increasingly stringent biosolid regulations inspired CWW to tackle increasing energy efficiency along with producing higher quality biosolids in the biosolids at the WRF, which resulted in the development of a unique new AD technology called the Columbus Biosolids Flow Through Thermophilic Treatment Technology (CBFT3). The plant has the first thermophilic digesters heated entirely by digester gas in the United States. The digesters heat solids to 55°C in 30-minute batches to create Class A biosolids. With this technology, the WRF is able to reduce carbon emissions by 9600 metric tons of carbon dioxide per year and, even in a low electricity cost scenario ($0.053 per kWh), to accrue $490,000 in energy cost savings (Wiser et al. 2012).

In 2011, CWW added two 1750-kW CHP engines and a FOG receiving system in order to boost energy production (Wiser et al. 2012). FOG additions to the digester increased biogas production by 50% and ensured sufficient biogas was produced to heat the AD facility. The digester upgrades, CHP technology, and FOG receiving station cost the WRF $15 million with approximately half attributable to the CHP engines (Wiser et al. 2012). Assuming energy electric savings at $0.07/ kWh, the WRF expects to pay off the CHP engine in 10 years or less (Wiser et al. 2012).

B.5.2 PPP for Biosolids Management leads to Co-Digestion at Fairfield-Suisun Sewer District, CA

The Fairfield-Suisun Sewer District (FSSD) in Solano County, CA serves over 135,000 people in the San Francisco Bay Area. The District has capacity to treat 23.7 mgd of wastewater and has capacity to produce 1.3 MW of electricity. FSSD historically used its biosolids for Alternative Daily Cover at a landfill. Faced with California's ever-tightening biosolids regulations and the rising costs of biosolids management, the District entered into a Public-Private Partnership (PPP) with the Canadian company Lystek International. Finalized in June of 2015, the PPP included a lease agreement allowing Lystek to build and operate their Organic Materials Recovery Center (OMRC) at the FSSD treatment facility. The OMRC has a capacity of 150,000 U.S. tons per year and can convert Class B biosolids into a Class A EQ fertilizer marketed as LysteGro (Lystek n.d.). The lease agreement allows FSSD and Lystek to share profits from the sale of LysteGro. In 2018, nine million gallons of LysteGRO fertilizer were sold to farmers and applied to over 2,800 acres of land in Solano County.

Lystek also provides as a service their optimized digestion process, Lystemize. In using the Lystemize process, biosolids are re-fed to the digesters in order to increase biogas production and reduce biosolid production (Baatrup and Dunbar 2016). Through the partnership, FSSD complies with California's Clean Water Act Healthy Soils Initiative and numerous other organics regulations. The FSSD and Lystek are researching product differentiation and expansion (Baatrup and Dunbar 2017).

B.6 WRRFs Suspending Co-Digestion

Facilities drop co-digestion for a variety of reasons. The highly touted example of co-digestion, Sheboygan WWTP, dropped co-digestion due to changing economics, including declining tip fee rates due to feedstock competition and increasing capital investment requirements to support co-digestion. In the researchers' review, they came across several cases in which plants cited the loss of their sole food waste source, typically a local food processing plant that moved away, and limited incentives to pursue a replacement because the plant was close to capacity to generate energy and at risk of flaring, or because energy prices had plummeted since time of initial investment. Among that set of cases, the Janesville WWTP in Wisconsin is profiled below. In the two other examples, the facility dropped co-digestion due to problems caused by contamination.

B.6.1 Sheboygan, WI

The Sheboygan Regional Wastewater Treatment Facility (SRWWTF) has been a leader nationwide in the development of co-digestion and associated energy generation, as part of a strategy initiated in the mid-2000s to move toward energy neutrality in response to energy price increases. Other facilities with anaerobic digesters in the area have followed Sheboygan's lead, which has increased competition for high strength organic wastes (HSOW) and resulted in declining tip fee rates. In 2017, the combination of aging equipment, reduced tipping fees and digester capacity limitations raised questions as to the cost-effectiveness of continuing to accept HSOW. Facing requirements for both near-term and long-term capital investments to continue co-digestion and competing priorities for capital, the City decided to suspend the co-digestion program for now, and to consider "refining the program when financing terms become more favorable" (Vandersteen 2017).

Driver: Reducing Energy Costs, Moving toward Energy Neutrality

Between 2002 and 2008, prices for natural gas and electricity at the SRWWTF rose 108% and 72%, respectively. In 2005, Dale Doerr, the plant's superintendent, identified a two-part strategy to reduce dependence on energy purchases: increasing energy efficiency and expanding biogas generation to supply onsite energy needs (Greer 2009). To save energy costs for wastewater treatment and increase biogas production, the 10.9-mgd facility shifted some of the HSOW from entering the plant at the headworks to feeding them directly to the digesters. Cheese processing wastes were the first test case. The plant made minor operational modifications to incorporate the HSOW at a cost of $75,000: an old, unused digester tank was repurposed as a receiving tank, and a pump system was added to prevent settling. Successful in expanding biogas production, the facility addressed its next challenge -- developing energy generation capacity to beneficially use the biogas.

A PPP for Cogeneration

The SRWWTF staff initially conducted a feasibility study to adopt cogeneration in 2002. However, the study found that biogas processing costs due to siloxane contamination would render the project economically infeasible (Greer 2009). In 2006, the opportunity for a partnership with Alliant Energy offered a more affordable means for cogeneration at the WRRF. Alliant had entered into a distributorship agreement with Capstone Turbine Corp., which required Alliant to purchase a set number of microturbines. The utility found that the price of electricity in the MidWest was too low to support natural-gas fueled turbines, but using biogas, a free fuel, made more sense economically.

Under its agreement with SRWWTF, Alliant installed at SRWWTF biogas processing equipment to remove the siloxanes and 10 30-kW microturbines (with a market price of about $1 million), which Alliant would continue to own. Sheboygan provided the biogas for the microturbines at no charge, and Alliant provided the heat from the microturbines to the plant at no charge. The electricity was fed to the grid and sold back to Sheboygan at the normal tariff rates (Greer 2009).

Project costs for the cogeneration system were $1.2 million. SRWWTF invested $200,000 for the heat recovery equipment, which included adding two Cain heat exchangers and replacing three antiquated boilers. At the end of six years (in 2012), SRWTTP purchased the microturbines for $100,000 (Greer 2009). The Wisconsin Focus on Energy program provided a $20,000 grant to the project and Alliant Energy covered the rest of the costs. The city recovered its costs for the heating system in two years. The payback period for the entire project was estimated at six years (Greer 2009).

Expanding Co-Digestion and Energy Generation
After the installation of the 10, 30-kW microturbines, Sheboygan expanded its co-digestion program to ensure it could produce sufficient biogas to power the new microturbines. The feedstock supply was predominantly dairy wastes. In 2010, with biogas production in excess of microturbine capacity, the City added two 200-kW microturbines, two additional Cain heat exchangers, and gas conditioning capacity, at a net cost to the city of $1,295,000. The City spent a total of $1,671,000 on co-digestion and the two phases of CHP implementation.

CAPITAL INVESTMENTS			
Project	Project Cost	Funding Assistance	City's Cost
Co-digestion	$75,000	$0	$75,000
CHP Phase I	$1,200,000	$899,000 Alliant Energy	$301,000
CHP Phase II	$1,500,000	$205,000 Grant	$1,295,000
Total	**$2,775,000**	**$1,104,000**	**$1,671,000**

Figure B-1. Capital Investments for Co-Digestion and CHP Improvements.
Thieszen 2015.

The volume of HSOW feedstocks increased fourfold (from five million to 20 million gallons) from 2010 to 2014. With the resulting increase in biogas, the plant was able to supply 90% of its electrical needs and 85% of its heating requirements. Annual energy savings in 2013 were $270,000 (Thieszen 2015).

However, despite a quadrupling of HSOW volume, tip fee revenues peaked in 2011, and declined back to 2010 level in 2014 ($100,000). By 2016, increased feedstock competition from a growing number of organic waste acceptance programs at farm digesters and other WRRF digesters had driven SRWWTF tipping fee revenue below $50,000 (Vandersteen 2017).

Stopping Co-Digestion
In 2017, SRWWTF terminated co-digestion. It was experiencing declining tip fee rates due to feedstock competition and facing requirements for immediate and future capital investments to support co-digestion. In addition, the consultant evaluating the overall cost-effectiveness of the program found that the economic benefits had declined, and would not support the capital investments that would be required to maintain the co-digestion and energy generation program. Continuing co-digestion would require an immediate upgrade to the HSOW receiving equipment at a cost of $1,814,000. Other investments needed over the next years would include replacement of the aging 30-kW turbines in five years (costing $1,000,000), replacement of the 200-kW turbine in 10 years (costing another $1,000,000) and conversion of a secondary digester to a fourth primary digester (costing $1,548,000) (Vandersteen 2017). Given other critical capital improvement needs of the city, the City Council decided to forego the immediate improvements required for continuing feedstock acceptance and to suspend the co-digestion program for now. At the time, the mayor indicated the city would consider refining the program when financing become more favorable (Vandersteen 2017).

A preliminary financial review two years after suspending co-digestion suggests that operating costs have not increased as a result of dropping co-digestion: the increase in energy costs has been offset by the reduction in costs for solids hauling and wastewater chemicals (Jossart 2019).

B.6.2 Janesville, WI

The Janesville Wastewater Treatment Plant (JWWTP) stopped co-digestion in 2015 when it lost its single feedstock supplier, a chocolate producer in the area. The JWWTP, which earned limited revenue in tip fees, had no incentive to seek out other feedstocks because it did not require co-digestion to meet its renewable energy and fuel production goals.

Energy Generation and Cost-Savings/Revenue Generation

In 2010-2011, Janesville WWTP (with an average dry weather flow of 12.5 mgd) underwent a $30-million upgrade and expansion, including an anaerobic digester upgrade to expand capacity, upgrades to its biogas-to-energy system, and the addition of a high strength organic waste (HSOW) receiving station. It replaced its existing reciprocating engines with four 65-kW microturbines at a cost of $1,996,752 (USDOE 2015), partially funded by a grant from the Wisconsin Focus on Energy program. After entering into a 10-year contract (through 2020) with the local energy provider Alliant Energy to supply electricity back to the grid, it added a 200-kW microturbine, a receiving station for concentrated industrial waste, and a CNG vehicle fuel production facility, for a total cost of $880,000. The cost was partially covered by a $125,000 grant from the Wisconsin State Energy Office (Ely and Rock 2015). The utility partnered with BioCNG, a renewable compressed natural gas production company, to design and build the CNG production facility, which includes a biogas conditioning system. About 90% of the biogas produced at JWWTP is used to generate electricity, with the remaining going to CNG production (Ely and Rock 2015). CNG production is limited by the size of the gas skid (140 SCFM), which limits the amount of biogas that can be used for fuel production (U.S. EPA 2018).

Through the tariff agreement with Alliant Energy, JWWTP generates on average annual revenues of $186,000 from electricity sales (U.S. EPA 2018), as well as energy cost savings from using microturbine heat to regulate digester temperature and from replacing gasoline with CNG fuel for 10 fleet vehicles and a lawnmower (U.S. EPA 2018).

Co-Digestion

Initially, Janesville co-digested wastes from an off-spec beverage processor. However, contamination in the feedstock led the WRRF to discontinue acceptance of that waste product and switch to hauled-in chocolate waste from a single source in Illinois (U.S. EPA 2018).

When this supplier shifted to sending their wastes to a Chicago location closer to the supplier's operations in 2015, the WRRF ended co-digestion. Joe Zakovec, the JWWTP Superintendent, said he would consider restarting the co-digestion program if the ideal feedstock became available. However, for a variety of reasons, the WRRF has little incentive to seek out additional feedstock suppliers. The WRRF still has sufficient biogas for its energy generation through CHP and CNG production and reduces the risk of producing excess biogas that would require flaring. Further the tip fee revenue potential is limited, given the competitive market for feedstocks in the area and the limited storage capacity (7,500 gallons) for receiving HSOW, which limited hauled-in waste to one truckload per week (U.S. EPA 2018).

B.6.3 Metropolitan Syracuse, NY

The Metropolitan Syracuse WWTP in Onondaga County recently stopped co-digestion. It dropped the dairy wastes it had been receiving because they caused digester upset. The WWTP successfully co-digested waste from another industrial food processor; however, the industry has since reduced output and no longer has disposal needs (Dean Ellsworth, interview with the authors, December 12, 2018).

B.6.4 Contamination at Struthers Water Pollution Control Facility, OH

Struthers Water Pollution Control Facility in Ohio halted co-digestion in November 2017 due to low quality whey and FOG feedstocks. Contamination in the wastes led to plugging of two of the plant's digesters. The utility manager has now shut down co-digestion to clean the plugged digesters. The manager says he will reconsider co-digestion only if staff trust the feedstock sources to supply clean feedstock and if sufficient technology becomes available to remove contamination (Guy Maiorana, interview with the authors, December 11, 2018).

B.7 Co-Digestion No Go's

WRRFs have considered, but not pursued, co-digestion for various reasons. In a survey of 104 WRRFs conducted in 2015, 10.9% of WRRFs considered co-digestion but did not move forward with a co-digestion project due to "insufficient life cycle cost savings" (12 out of 110). An additional 24.5% considered co-digestion but did not move forward due to "other factors" (27 out of 110) (Van Horne et al. 2017).

The WRRFs profiled below have considered but not pursued co-digestion because of economic or operational risk, changes in political motivation, or a lack of policies and incentives.

B.7.1 Massachusetts

Pursuant to 310 Mass. Code Regulations 19.006 and 19.017, industrial, commercial and institutional food service sectors that generate one ton or more of food waste per week are required to recycle their food waste. To support the development of organics processing capacity, Massachusetts Clean Energy Center (CEC), a quasi-public agency funded via the Massachusetts Renewable Energy Trust Fund, supported feasibility studies for co-digestion of food waste at all six WRRFs with AD in the State. In only one of the six WRRFs was co-digestion implemented – the Greater Lawrence Sanitation District (GLSD) WRRF in Lawrence, Massachusetts.

The original option considered for serving the Boston area, with the greatest population density in the state, was the Deer Island Treatment Plant just outside of Boston. With its 12 three-million gallon digesters, it at offered a significant amount of food waste processing capacity. A feasibility study conducted by the Massachusetts Water Resource Authority (MWRA) determined that the financial benefit of additional biogas would exceed the cost of processing food waste (Parry 2014). For a pilot program to further explore project feasibility, Waste Management was planning to deliver food waste to the plant via truck. However, the Town of Winthrop opposed additional truck traffic through their already busy neighborhood during the pilot period and halted the project. (The full-scale project would have delivered food waste by barge; however, MWRA did not want to invest in barge transport prior to confirming the success of the co-digestion pilot.) Waste Management is now delivering its pretreated food scraps for digestion at the GLSD WRRF (John Fischer, personal communication with authors, October 10, 2017).

The Massachusetts CEC also conducted feasibility studies for the other WRRFs with in Massachusetts including the ones in Ayer, Easthampton, and Millbury. In Ayer, MA, the feasibility study found that accepting 1-5% of the food waste in the region would result in a tip fee higher than the area's landfill tip fees, thus rendering the project economically infeasible at this scale. Accepting 10% of the area's food waste would result in a reasonable tip fee, but would require managing upwards of 250 food waste suppliers. The feasibility study concluded that both cases were risky and recommended pursuing a private partnership to implement the project (CDM Smith 2014).

The feasibility study for Easthampton considered a public and private ownership scenario for adding an AD and implementing co-digestion. The study found that an AD would be feasible if revenues could be generated from beneficial digestate use (Tighe and Bond 2014).

The feasibility study for implementing co-digestion at the WRRF in Millbury considered feedstock acceptance at 10% and 50% of the area's available source-separated organics. Similarly to Ayer, the study found that at 10% acceptance, the tip fees to cover the investment would be above the region's landfill tipping fee. At 50% acceptance, the risk of procuring sufficient food waste to cover the WRRF's investment increases. The study recommends that the Town pursue a public-private partnership if co-digestion is important to the town (CDM Smith 2013).

B.7.2 New York State

In the New York State Energy Research and Development Authority 's 2017 report on biogas use at WRRFs in New York, two WRRFs evaluated but chose not to pursue co-digestion. One WRRF (processing less than 5 mgd) was concerned that costs for biogas and CHP systems would require a rate increase for their customers; however, the New York state tax cap would make it difficult to increase rates for customers if sufficient revenues were not received from biogas production (O'Brien and Andrews 2017).

A second WRRF (processing between 5 and 20 mgd) was planning on pursuing co-digestion and biogas use with combined heat and power. Co-digestion was viewed as an opportunity to work with and support local industries. The co-digestion project still has strong support from WRRF staff (O'Brien and Andrews 2017).

Bath Electric, Gas & Water Systems (BEGWS) attempted to incorporate resource recovery upgrades with upgrades required for nutrient permit compliance. However, the resource recovery upgrades were ultimately dropped due to a combination of regulatory barriers, lack of political and institutional support, and a rushed process for implementing the nutrient reduction upgrades due a restricted timeline for permit compliance (Stone 2019).

B.7.3 Orange Water and Sewerage Authority, Carborro-Chapel Hill, NC

The Orange Water and Sewerage Authority (OWASA) considered six biogas end use options to meet a board-imposed 2022 deadline to achieve beneficial use of biogas and reduce the amount of biogas flared to the atmosphere and. The first two options were CHP systems at different sizes and configurations. The third was CHP with co-digestion and the fourth, fifth and sixth options were use of biogas for renewable compressed natural gas (rCNG) or pipeline injection, with future opportunities for co-digestion. OWASA determined that while co-digestion offered significant revenue opportunities, the risk associated with co-digestion was too high to justify immediate action. OWASA was concerned that the upfront investment of a receiving station might not be worthwhile if sufficient feedstocks were not procured by 2022. OWASA staff determined that based on risk and financial feasibility, pipeline injection to a utility pipeline would be the most easily implemented biogas end use. Staff noted that co-digestion could be considered at a later point in tandem with the pipeline injection project (Rouse 2017).

B.7.4 Madison Metropolitan Sewerage District, Madison, WI

The Madison Metropolitan Sewerage District (MMSD) operates the 41-mgd Nine Springs Wastewater Treatment Plan (NSWWTP). MMSD previously co-digested whey waste at NSWWTP in the 1990s, but stopped when the industry supplying the feedstock left the area. Viewing co-digestion as an exciting opportunity, MMSD has expended efforts to assess the feasibility of co-digestion at their plant, including a bench scale study starting in 2014 (Matt Seib, interview with authors, August 22, 2018; MMSD 2016). Moreover, in their 2014 Energy Baseline and Optimization Study, co-digestion was considered a key step in achieving energy independence across MMSD operations (including the pumping stations as well as the WRRF) (Schroedel and Wirtz 2014).

Both the lack of community goals for greenhouse gas reductions or solid waste diversion, as well as the absence of funding sources, have created barriers to incorporating a broader supply of food scraps as co-digestion feedstocks and investing in energy production equipment.

According to MMSD staff, the lack of financial incentives for landfill diversion and the low cost of energy result in limited economic returns to onsite power generation. Historically, other biogas end uses also have not been considered viable: the local utility has not been welcoming to the idea of pipeline injection, and the complexity and cost of converting customer community municipal vehicle fleets to CNG has been an impediment to a biogas-to-CNG project.

MMSD does accept from Grind2Energy a small quantity of slurried food waste from grocery stores. However, the slurry enters the WRRF at the primary sludge thickening process and has limited impact on their biogas production. MMSD has considered other substrates such as FOG and ran a trial run for FOG acceptance in 2000. However, the FOG-rendering site located nearby has captured that supply. While MMSD is enthusiastic about Grind2Energy and co-digestion in general, there are concerns about increasing nutrients in wastewater effluent and the impact on biosolid quality.

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APPENDIX C

Thumbnail Sketches: Selected Food Waste Suppliers

C.1 Food Scrap Slurry Suppliers

C.1.1 Waste Management, Inc./CORe®

Waste Management (WM), through its subsidiaries, is a provider of waste management environmental services, organized into solid waste collection, solid waste disposal, landfill gas-to-energy, recycling management and brokerage, and renewable energy services, along with contract administration and specialty waste management operations. As of December 31, 2016, the company owned or operated 243 solid waste landfills, five secure hazardous waste landfills, 131 landfill gas beneficial use projects, 310 transfer stations, 95 materials recovery facilities, and 40 composting facilities in North America. In 2015, WM recycled 2.47 million tons of source-separated organic materials, including yard trimmings, food wastes, and biosolids (Waste Management 2018).

C.1.1.1 Role in Co-Digestion Feedstock Supply

To address the growing trend to mandate for source-separated organics (SSO) collection and diversion from landfills to other processing facilities, WM continues to make investments in composting facilities, but has also recognized the need to provide more efficient food waste recycling services to serve the needs of more urbanized areas. WM also understands the potential value to create renewable energy from wasted food.

In 2009, seeing that many existing wastewater treatment facilities had underutilized capacity, they decided to pursue a concept to create a turn-key feedstock for existing Water Resource Recovery Facilities (WRRFs), rather than to build new AD facilities. WM created a patented centralized organics recycling process (named CORe®, U.S. Patent 8,926,841) that creates a feedstock to facilitate the digestion of food wastes to create biogas that can, in turn, be converted into fuel or electricity. With CORe®, WM collects commercial food waste from restaurants, schools, food processing plants and grocery stores, screens it to remove physical contaminants such as plastic, packaging and bones, and blends the waste into an engineered slurry that has a consistency similar to cooked oatmeal. Through targeted research and numerous full-scale projects, the slurry has been demonstrated to significantly increase the production of biogas in anaerobic digesters.

The WM CORe® system takes a combination of pre- and post-consumer food wastes and produces a high-quality organics product suitable for co-digestion in municipal wastewater anaerobic digesters as well as in other biogas production facilities. The system uses custom-built food waste processing equipment that can efficiently remove non-degradable contaminants from source-separated food waste streams. The technology uses separation equipment (e.g., Doda Separator, Ecoverse Tiger, Scotts Turbo Separator, etc.) and wet extrusion equipment (similar to an industrial-scale pasta machine) in combination with other unit processes to produce a blended, high energy, consistent slurry which is effectively free of any significant physical contamination. WM has trademarked the resulting Engineered BioSlurry product as EBS®.

C.1.1.2 Locations Receiving Their CORe® Technology

Typically, CORe® facilities are located within a few miles of the receiving digester facility. Sources of food wastes to make EBS® include residential and commercial generators, grocery stores, colleges and universities, institutions, food processors, and restaurants. CORe® facility capacities vary from 30,000 to

75,000+ tons/year. Contracts with digester receiving facilities are customized depending on generating and off-take customer specifications.

WM began bench-scale testing a processed food waste material for co-digestion at the Orange County Sanitation District in 2011, followed by pilot-scale testing at the Victor Valley Wastewater Reclamation Authority. In 2012, it began negotiations with LACSD to pilot test its system at the Joint Water Pollution Control Plant (JWPCP), located in Carson, CA.

JWPCP, Carson, CA (See Chapter 9)

The Sanitation District of Los Angeles' (LACSD) Energy Recovery team has led the JWPCP's effort over the last decade to explore the potential of co-digestion at the plant. A sequence of studies culminated in a 4-year demonstration project (2014-2018) with WM's EBS® feedstock. Following the project's success, LACSD initiated a large scale co-digestion program and Phase I of an energy strategy for the additional biogas. The WRRF currently produces more than enough electricity to meet plant needs most of the time. In Phase I, the utility will produce RNG for direct sales at the local fueling station on JWPCP property. LACSD is still evaluating options for Phase II of the energy project. In February 2019, the utility suspended the food waste receiving station operations while it re-evaluates options to reduce costs and waits for market demand to develop.

Newtown Creek WRRF, New York City, NY

WM entered into an agreement with the New York City Department of Environmental Protection (DEP) to provide EBS® to the Newtown Creek WRRF in 2013 under a demonstration agreement. The plan is for the WM CORe® facility (at DEP's Varick Ave. transfer station) initially to process 48 tons per day of food waste. Over the course of the three-year demonstration project, WM expects to ramp up processing to handle 250 tons per day of organic waste. WM is responsible for sourcing all organics. After the completion of a small pilot, WM constructed the full-scale facility for the demonstration project, which began operation in 2016. The program continues to run successfully today. The WRRF has separately contracted with National Grid to develop a project to inject RNG to its pipeline from the excess gas produced through co-digestion.

Separately, WM has a contract with the Department of Sanitation of New York (DSNY) for processing source-separated organics. WM is processing organics collected by DSNY's residential collection program (now serving over three million residents) and public schools.

Rahway Valley Sewerage Authority, Rahway, NJ (See Appendix B)

Rahway Valley Sewerage Authority (RVSA) in Rahway, New Jersey operates an 80-mgd WRRF. In 2015, the WRRF negotiated a 10-year contract for feedstock slurry supply with WM, with an option for a 10-year renewal. The contract takes advantage of unused capacity in the plant's three digesters and in the plant's combined heat and power engine (Biocycle 2016). The WRRF aims to optimize digester operations, provide a steady and consistent feedstock supply, and reduce the need for natural gas purchases through increased biogas production. WM has designed and RVSA has built a receiving tank from an existing gravity thickener tank. A State Revolving Fund financed the retrofits that were needed to upgrade the gravity thickener into a receiving tank. WM delivers slurry from its Northern New Jersey CORe® facility recently constructed in Elizabeth, New Jersey. WM will provide 6,000 gallons of EBS® per day to start, and increase the quantity over the course of the agreement. Upgrades such as new covers for digesters are underway. The EBS® product is required to meet specified feedstock standards established under the agreement, which include *de minimus* levels of contamination. WM pays a tipping fee that is inclusive of any potential expenses for increases in biosolids production from the digestate. In addition, RVSA and WM will share in any additional value of energy produced above their baseline conditions in the form of renewable energy credits received.

Greater Lawrence Sanitary District, Boston, MA (See Appendix B)

In response to a Massachusetts diversion mandate in place for commercial establishments generating one ton or more of organic material per week, WM built a CORe® processing facility in Charlestown, MA in 2016. The facility takes in about 50 wet tons/day of residential and commercial food wastes. The company has a five-year contract with the Greater Lawrence Sanitary District (GLSD) to supply EBS® to the WRRF for co-digestion. It is blended with biosolids prior to being put into the digester. Feedstock sources include universities, residential customers, institutions, grocery stores, and food processors in the area.

Bureau of Environmental Services, Portland, OR

In January 2018, the Metro Portland government selected WM to build a CORe® facility to work in tandem with the Portland Bureau of Environmental Services, which operates the city's wastewater treatment plant. In order to guarantee that there will be enough material to feed the CORe® facility, Metro Portland recently adopted a mandate requiring large businesses and institutions to separate out their food scraps. The first phase of the mandate would start in March 2020 and would apply to companies producing more than 1,000 pounds of food scraps weekly.

C.1.2 Grind2Energy/InSinkErator

Grind2Energy is a food scraps grinding product developed by InSinkErator, a division of Emerson Electric Co. The Emerson Electric Company is an American multinational corporation headquartered in Ferguson, Missouri. This Fortune 500 company manufactures products and provides engineering services for a wide range of industrial, commercial, and consumer markets. Emerson has approximately 76,500 employees and 200 manufacturing locations worldwide (Emerson 2017). InSinkErator is a company and brand name known for producing instant hot water dispensers and food waste disposal systems, generally called "garbage disposals" or "garbage disposers." The company was founded in 1927 in Racine, Wisconsin and acquired by Emerson in 1968 (Emerson n.d.). The Grind2Energy product is sold in the Tools and Home Products segment of Commercial and Residential Solutions at Emerson. This segment had 2017 sales of $383 million (Emerson 2017).

C.1.2.1 Grind2Energy's Role in the Field of Co-Digestion Feedstock Supply

Through Grind2Energy's process, food waste is ground on-site using a customized, industrial-strength foodservice grinder of 10 HP and the slurry is then stored on-site in a 3,000 to 4,000-gallon tank. The energy-rich slurry is transported by locally contracted liquid waste haulers to an anaerobic digestion facility where the biogas produced from the slurry is available for renewable energy production. The remaining digestate can become a nutrient-rich fertilizer (if a thermophilic digester is used), or a feedstock to composting or some other form of stabilization (if a mesophilic digester is used).

C.1.2.2 Technologies Used to Create the Co-Digestion Feedstock

As shown in Figure 1, the Grind2Energy system consists of a food waste grinder and a slurry storage tank. Acceptable feedstocks include produce, meats, dairy, breads, grains, fats and oils. Early adopters entered into an agreement with Grind2Energy and paid a monthly fee without upfront capital costs. The monthly fee covered installation of the system, maintenance and monitoring costs, and slurry pump-out and delivery. Fees vary depending on pickup requirements, system specifics, and installation costs. Instead of a lease model, a direct sale business model now allows customers to monitor their own system and coordinate pumping and hauling of slurry to anaerobic digesters.

The produced food waste slurry consists of 10-12% total solids, more than 90% volatile solids, a pH of about 4.0, density of 1 gram/milliliter, chemical oxygen demand of about 150,000 milligrams per liter, a biochemical methane potential of 400-600 liters of methane per kilogram of volatile solids, and low heavy metals.

C.1.2.3 Sites Where Grind2Energy Creates Co-Digestion Feedstock

Grind2Energy has approximately 70 installations at commercial food service establishments, including sporting venues and casinos, but mainly at supermarkets. That includes 17 in the Massachusetts area, 13 in California, 10 in Ohio, and 22 in southeastern Wisconsin. Grind2Energy delivers slurry to nine digesters, both stand-alone and WRRF digesters.

Grind2Energy product is delivered to several WRRFs:

Nine Springs Wastewater Treatment Plant in Madison, Wisconsin

Forest County Potawatomi Casino Digester and the South Shore Water Reclamation Facility receive slurry from multiple systems installed in Sendik's Food Markets in the Milwaukee region

South Shore Water Reclamation Facility in Milwaukee

Downers Grove Wastewater Treatment Plant in Illinois

Derry Township Municipal Authority in Hershey, PA

Joint Water Pollution Control Plant/LACSD, Carson, CA

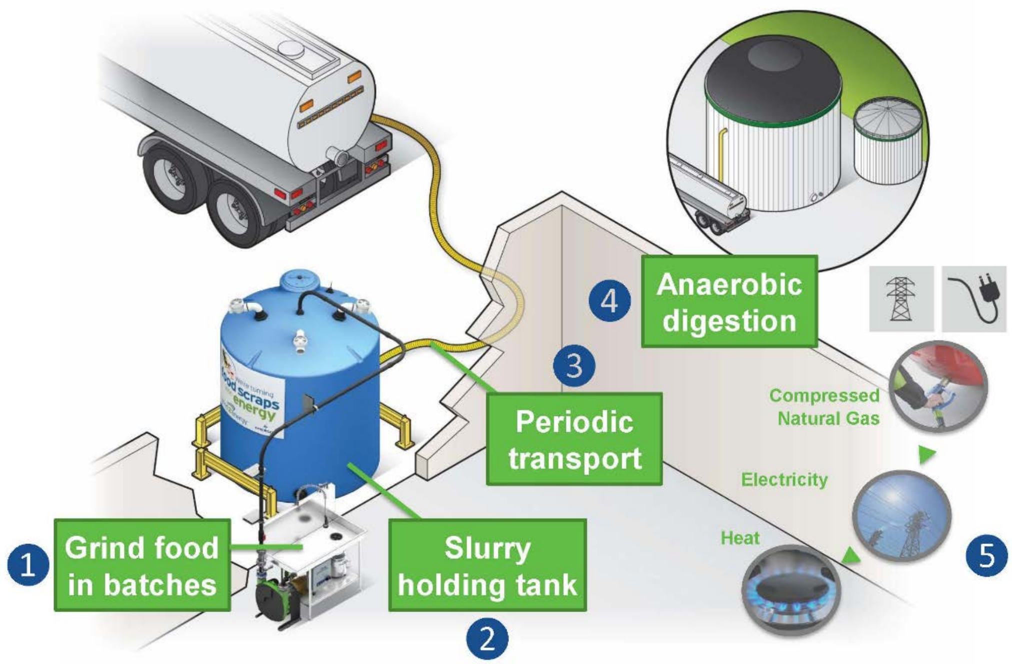

Figure C-1. Grind2Energy Process.
Source: Emerson.

C.1.3 Organic Waste Logistics (OWL)/BioWhale

Organic Waste Logistics (OWL) is a United Kingdom (U.K.) organic management company that sells the BioWhale, a customizable organic waste management system manufactured by Whale Tankers. BioWhales are unit systems located on the site of food waste-producing institutions such as malls and food manufacturing industries. Food waste loaded to the BioWhale is disposed of in a vacuum chute and macerated into a BioSoup, a liquid slurry with solids 8mm in size. The food slurry is then stored under vacuum to reduce odors and pests. OWL monitors the system remotely and collects the slurry using a vacuum tanker truck when the system is full. The slurry is then delivered to one of 150 digesters in the U.K., where it produces renewable gas or electricity and organic fertilizer. Currently all OWL BioWhale clients are located in the U.K. and include a two food manufacturers, shopping centers, a university and a hotel (OWL n.d.). The company is developing a demonstration project in the U.S. as an entry point into the U.S. market.

OWL manages the installation and maintenance of the BioWhale and also provides hauling and coordinates disposal of the slurry. The BioWhale has three different loading options and can be ordered in three sizes: compact (5 tons), standard (13 tons), and large (26 tons). Generally, OWL recommends disposal of food scraps into a pail which can then be loaded into the BioWhale. Alternatively, BioWhale can be constructed to use bin lifters or a remote hopper loaded directly from the kitchen.

For food waste generators producing 100 tons per year of food waste, OWL estimates the BioWhale system will cost $181 per ton per year. Costs decrease with scale: food waste generators producing 500 tons will pay an estimated $60 per ton. In the U.K., these costs are competitive with the expensive advanced composting systems now replacing windrow composting, which is illegal in the U.K. One case study reduced their food waste recycling costs by a third using BioWhale. Moreover, the frequency of truck visits decreased from 300 to 30 per year.

In the U.S., however, BioWhale costs are much higher than the average landfill tipping fee. OWL expects to compete in areas that require organic waste recycling. In regions where space is too limited for composting systems, the small footprint of the BioWhale could be particularly attractive.

OWL customers pay a monthly service fee that is calculated based on the frequency of pickups and the volume of food waste. OWL customers must agree to the multi-year contract for OWL service. Customers are required to provide space for the BioWhale, and an electrical connection. OWL provides the BioWhale with services and repairs for the system, employee training on food waste separation and environmental reports for companies looking to certify their green waste disposal practices (Heller 2019).

C.2 FOG Suppliers

C.2.1 Liquid Environmental Solutions

Liquid Environmental Solutions (LES) is a national company that specializes in the management of liquid non-hazardous waste streams, maintains grease and grit traps for businesses, and also recycles cooking oil from businesses. Recovery of grease/oils from grease traps and oils from industrial sources are core to the company’s strengths, and it also recycles chemical, coolant, equipment, latex, and lint trap waste waters among other substances (LES 2019a).

The company was founded in 2002 in Irving, Texas to acquire U.S. Liquids' Texas commercial wastewater division. From 2008-2017, it expanded into multiple states. LES now has 55 service locations in 28 states. In 2014, LES received a $31.6 million Series C minority growth investment led by ABS Capital Partners, a leading investor in later-stage growth companies (Sormani 2014) In December 2017, LES was acquired by Audax Private Equity (BusinessWire 2017).

Figure C-2. Map of Liquid Environmental Solutions' Processing Facility Locations.
Source: Liquid Environmental Solutions.

All 55 service locations handle grease trap wastes (GTW), 39 handle cooking oils, nine handle oil/water separators and grit traps, and nine handle all industrial wastewaters. Recycling GTW has grown in recent years with the proliferation of municipal sewer ordinances mandating that grease traps be cleaned on a periodic basis (usually monthly).

At five of its full-service locations, LES used tricanter centrifugation to separate out oils, solids and water. The oils are recycled into biodiesel, the solids are diverted to composting or landfilling (depending on the availability of composting outlets) and the water is discharged to a WRRF. Recovered cooking oils are recycled into one of several types of consumer products (animal foods, cosmetics, etc.) LES recovers more than two million gallons of oil annually (Sormani 2014). GTW is hauled to an accepting WRRF. The company does not handle septic tank or portable bathroom wastes.

LES is a fee-for-service business. Fees for liquid wastes recycling are tailored to each customer based on waste type, collection frequency, hauling distances and similar typical waste management economics. LES also imposes surcharges for energy and environmental costs beyond its control, such as surcharges for diesel fuel price spikes and for environmental compliance costs. LES incurs significant costs in municipal manifest costs, wastewater discharge expenses, permitting fees and waste disposal surcharges every year. The Energy/Environmental Charge that is included in a customer's invoice is determined by applying the percentage from the Liquid Environmental Solutions Energy Surcharge Table to the invoice charges (excluding tax). The 9.8% (Commercial) or 6.4% (Industrial) environmental component is then applied to the sum of the invoice charges and the energy surcharge amount, excluding taxes. For example: the environmental component for a bill that totals $100.00 before tax for services and $4.00 for the energy surcharge would see only an additional $10.19 for Commercial or $6.67 for Industrial. (LES 2019b).

C.2.2 Tempe Arizona Grease Cooperative

The Tempe Grease Cooperative (TGC) is an innovative partnership between the City of Tempe and its restaurants to better manage fats, oils and grease (FOG). It is the first program in the world in which a city brokers both pricing and service quality for grease trap and interceptor maintenance on behalf of community restaurants and food service establishments. The Tempe Grease Cooperative is a voluntary program; any food service establishment may choose to join or withdraw at any time, with no fees and no contract.

The sustainability benefits intended from the cooperative model include reducing upsets of the sewer system and also recycling the FOG for energy and nutrient recovery in local digesters. The latter is still under development. In the meantime, the residuals are being land-filled.

The benefits to the members of the coop touted by the city include lower cost and higher service quality from haulers, repair support, and compliance assurance. Through the power of collective contracts established and administered by the city, the TGC provides members with an average discount of 15% on service cost. As the administrative arm of the Cooperative, the city holds contracted pumpers to the highest standard, ensuring top-quality service for TGC members. The city also has full control of the grease disposal from disposal to digestion and can design it to maximize grease recovery and create a convenient FOG management program at the city's WRRF. For example, the city can designate convenient times for grease haulers to deliver waste to the WRRF. Grease traps can be specifically designed to maximize grease waste recovery.

At a citywide level, proper cleaning and maintenance of grease traps and interceptors help prevent backups and odors, ensuring a clean and sustainable city sewer system. As grease traps and interceptors age, repairs become an important factor in ensuring the functionality of grease devices. Upon first service, the city will perform a complimentary assessment of the device. If repairs are needed, the TGC may be able to offer discounted services. By receiving the scheduled service and paying the bill on time, TGC members are assured compliance with all city requirements pertaining to grease traps and interceptors.

The concept is currently in the early stages of discussion in several other U.S. communities, including Fort Wayne, IN, Little Rock, AR, and Roseville, CA.

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APPENDIX D

Tools for Assessing the Business Case

D.1 Introduction

Most tools are for preliminary screening of co-digestion options, prior to hiring a consulting a firm to do a more in-depth feasibility study. Some tools focus on financial implications, others on environmental implications (notably GHG emissions), and others combine the two or add community impacts for a triple bottom line analysis.

D.2 Comparing Co-Digestion Options

D.2.1 Anaerobic Digestion – Project Screening Tool (U.S. EPA and CCA Coalition 2018)

The U.S. Environmental Protection Agency developed the Anaerobic Digestion – Project Screening Tool (AD-PST) to assist stakeholders in assessing the potential feasibility of an anaerobic digestion (AD) project. The tool estimates how much biogas and digestate a proposed AD project could generate and evaluates the end-use options for the resulting biogas and digestate. The tool requires minimal waste-related data inputs (e.g., wet or dry system, waste composition, and AD system temperature) and provides defaults that users can overwrite with more project-specific information.

The tool uses this information to generate the following outputs:

- Annual biogas and digestate production.
- Biogas composition.
- A recommended bioreactor type and design information (such as minimum reactor volume and solids retention time).
- Example applications for each potentially feasible project type (e.g., electricity production, natural gas production, cooking gas potential, and home heating potential).

The tool can be used to evaluate AD opportunities for a variety of feedstocks, including organic municipal solid waste, agricultural residues, and wastewater.

D.2.2 Co-Digestion Economic Analysis Tool (U.S. EPA 2018a)

Co-Digestion Economic Analysis Tool, (CoEAT), which provides a more detailed screening assessment than AD-PST, identifies the various logistical, operational, and equipment considerations within an "economic cost model" resulting in the calculation of the Net Present Value (NPV) of the project. The three objectives of the model are: 1) to calculate a screening economic feasibility assessment for evaluating which organic wastes to accept, including FOG, food scraps and other liquid organic wastes; 2) to compare the relative merits of three uses of biogas including heating, electrical generation and compressed natural gas (CNG); and 3) to provide clear explanations of economic implications given user inputs. CoEAT is designed for decision-makers with technical experience in anaerobic digestion, including municipal managers, engineers, and operators of anaerobic digestion systems.

The Co-EAT model outputs are the capital and O&M costs and projected potential benefits of biogas generation to project cash flows and a calculation of Net Present Value (NPV) for the project. The overarching assumptions are: 15-year project timeline, discount rate and financing rates entered on the user input page, and using the biogas in place of natural gas used elsewhere. Many other scenarios are possible especially with respect to the biogas use including steam generation, cogeneration for electricity, etc.

Because empirical data are not available for a wide variety of food waste co-digestion projects in the U.S., the model uses the best current publicly available data and should be considered a screening tool for initial evaluation.

CoEAT requires the input of data and specific parameters from the facility under evaluation. CoEAT does not require pre-existing WWTP digesters, and will calculate results with no pre-existing digester in place, however the model was intended to help WWTP operators assess the viability of implementing food waste co-digestion with existing anaerobic digesters

D.3 Comparing Co-Digestion with Other Organics Management Options

D.3.1 WARM (U.S. EPA)

U.S. EPA created the Waste Reduction Model (WARM) to help solid waste planners and organizations track and voluntarily report greenhouse gas (GHG) emissions reductions from several different waste management practices. WARM calculates and totals GHG emissions of baseline and alternative waste management practices – source reduction, recycling, anaerobic digestion, combustion, composting and landfilling (U.S. EPA 2018b).

D.3.2 OrganEcs

The OrganEcs is a tool for estimating the economic costs associated with alternative technologies for implementing an organic waste management project, including open-air composting without forced aeration, composting with forced aeration, high-tech wet anaerobic digestion, and high-tech dry anaerobic digestion. It provides planning-level assistance to local governments, waste professionals, policymakers, facility operators, and project developers to help them make financial decisions about their potential organic waste management projects. Specifically, the tool assists users in determining appropriate 1) gate fees (e.g. the per-unit charge for disposing waste at the facility), or 2) product sale price requirements (e.g. for compost, electricity), in order to meet specified investor returns (CCA Coalition 2016).

D.4 Identifying Feedstock Suppliers

D.4.1 U.S. EPA Excess Food Opportunities GIS Database (U.S. EPA 2019a)

The U.S. EPA Excess Food Opportunities Map and GIS Database identifies and displays facility-specific information about potential generators and recipients of excess food in the industrial, commercial and institutional sectors and also provides estimates of excess food by generator type.

The map displays the locations of more than 500,000 potential excess food generators from the following sectors:

- Correctional facilities.
- Educational institutions.
- Food banks.
- Healthcare facilities.
- Hospitality industry.
- Food manufacturing and processing facilities.
- Food wholesalers and distributors.

The map also displays the locations of communities with source separated organics programs, as well as more than 4,000 potential recipients of excess food. These include:

- Anaerobic digestion facilities.
- Composting facilities.
- Food banks.

The mapped establishments and their locations are provided for informational purposes only. The Agency does not guarantee the accuracy or completeness of the information provided as it has not been verified.

D.5 Comparing Energy Options

D.5.1 NYSERDA Microgrid Benefit-Cost Analysis (NYSERDA n.d.)

New York State Energy Research and Development Authority (NYSERDA) developed a Benefit-Cost Analysis (BCA) model to assess the monetary and non-monetary benefits and costs of proposed microgrid systems to assist in project ranking for the NY Prize Community Grid Competition (NY Prize). The BCA model categorizes benefits into energy and environmental categories. Benefits covered include the gains in resiliency in power supply to critical local services from providing a distributed power source.

D.5.2 EPA CHP Emissions Calculator (U.S. EPA 2019b)

EPA's CHP Partnership's Emissions Calculator compares the energy savings and reductions in air emissions of CHP systems relative to grid-supplied power from conventional fossil fuel power plants and to an on-site boiler system. The EPA calculator estimates reduction in the conventional air pollutants NO_X and oxides of sulfur (SO_X) as well as in greenhouse gas emissions. Because this calculator uses regional data from eGRID, the estimate reflects the power generation mix in the project location (U.S. EPA 2019b).

D.5.3 WRF Life Cycle Assessment Manager for Energy Recovery, LCAMER (WRF 2011)

LCAMER (Life Cycle Assessment Manager for Energy Recovery) is a spreadsheet-based tool developed for comparing the benefits and costs of onsite energy recovery alternatives throughout the lifetime of a waste water treatment facility.

D.6 Comparing Biosolids Options using Triple Bottom Line (TBL) Analysis

The Triple Bottom Line Tool for Assessing Biosolids Management Options is designed to evaluate the economic, social and environmental outcomes from six scenarios for biosolids management including AD with pretreatment, AD with co-digestion, incineration and gasification, with the final disposal options of land application or landfill disposal for the first two processing options, and only landfill disposal for the third and fourth processing option (Elenbaas et al. 2014). The spreadsheet is transparent and flexible and allows the user to modify, add, or delete criteria and change weights, calculations, and metrics, resulting in a TBL approach tailored to the needs of the specific user group.

This tool was developed as part of WRF's larger Net-Zero project designed to aid water resource recovery facilities (WRRFs) in moving toward "net-zero" energy use through near-at-hand practices and technologies in the areas of energy conservation, demand reduction, and enhanced production. The team relied on energy and process modeling developed for WRF's Net-Zero report (ENER1C12) to help determine operating costs and some of the environmental criteria (Elenbaas et al. 2014).

D.7 Basic Asset Management Accounting

D.7.1 WRF SIMPLE Tool (WRF n.d.)

The tool suite covers the 10 steps of asset management. A subset is relevant here including: Life Cycle Cost Assessment, Business Risk Analysis and Benefit Cost Evaluation. The suite provides tools for evaluating performance of current assets and assessing the benefits of investments to further WRRF goals. A triple bottom line framework is incorporated in the tool.

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APPENDIX E

Investment Decision-Making: Financial and Triple-Bottom Line Criteria and Metrics

E.1 Introduction

The criteria (and their performance thresholds) a utility uses to evaluate its investment decisions will be guided by its charter, as interpreted by the utility board of directors. Generally, the farther away a project is from the core missions of the utility, the greater the stringency of the rate of return requirements. For investments that serve the core mission, generating a positive return on investment (ROI) during the lifetime of the capital may be sufficient. (For investments to comply with regulations, a positive ROI is not required. If multiple options are under consideration, another criterion would be that the selected project is the most cost-effective one to meet the performance goals). For investments less central to the core mission, more stringent financial performance criteria may be applied, such as a ROI greater than X%, or a payback period less than Y years.

Originally, the core mission of wastewater utilities was to treat wastewater. However, the vision of the core mission is expanding in some utilities as they shift their focus from treating wastewater to recovering resources from wastewater, including water, energy, and nutrients/soil amendments.

Utilities may incorporate this shift in focus explicitly into their decision-making by adopting triple bottom line investment criteria, which expand the evaluation to include environmental and social indicators as well as plant financial criteria. Examples of utilities that have adopted a broader set of criteria include the Victor Valley Wastewater Reclamation Authority in Victor Valley, CA and NEW Water in Green Bay, WI. Both WRRFs have applied the Utility of the Future framework to their operations and consider resource recovery a key goal for their respective WRRFs.

E.2 Financial Criteria

The literature identifies several financial criteria that are used to evaluate the financial implications of an investment:

- Net present value (NPV) ($) or return on investment (ROI) ($).
- Equivalent Uniform Annual Net Value (NUV).
- Internal rate of return (IRR).
- Payback period.
- Risk Analysis.
- Scenario Analysis.

Each criterion has its advantages and disadvantages, and may yield different rankings of projects. However, only **Net Present Value (NPV)** provides information about the **total net gains** (revenues minus costs) from the project over its lifetime. **Equivalent Uniform Annual Net Value (NUV)** allows for comparison of average annual returns for options with different longevities. **Return on Investment (ROI)** indicates the percentage return on investment, which can be compared to the cost of capital (interest rate or return on equity) or another threshold value to decide whether to move forward with the project; however, ROI does not provide information on the scale of the total net gains. The internal rate of return (IRR) assumes that project net gains can be reinvested at the same rate of return as the prior investment, which may not be the case.

Payback period only tells you how many years it takes for the cumulative returns to turn positive; it does not provide information about total returns. As a result, a project with a shorter payback period may have lower total returns and a lower ROI than a project that calculates NPV for the lifetime of the equipment.[9] Also, multiple IRRs may be calculated if the cash flow turns negative at some point during the project. Finally, **risk analysis** and **scenario analysis** are two approaches to quantifying the uncertainty associated with a project by taking into account the potential variability in key revenue and cost variables. Whereas risk analysis is based on the development of assumptions about the distributions of various input variables, scenario analysis is based on the development of a range of specific scenarios and associated assumptions about the values of input variables.

E.3 Triple Bottom Line Criteria (Elenbaas et al. 2014)

Triple bottom line (TBL) analysis uses economic, environmental and social criteria to answer the question: "Is this [project or program] a good long-term investment?" TBL analysis breaks down economic, environmental, and social evaluations into criteria and sub criteria that are both qualitative and quantitative. These criteria can then be weighted based on local contexts and applied to feasibility studies. Development of a Triple Bottom Line analysis provides an opportunity to involve a variety of stakeholders, be objective, and use risk analysis by testing the sensitivity of results to varying inputs (i.e. the projected price of electricity) (U.S. EPA 2015; Elenbaas 2014; WRF 2013.). Accounting for the impacts of each criterion over the project life cycle is important for a complete analysis. TBL analyses can be used to compare project alternatives, as well as to decide whether to move forward on a project or not.

The Water Environment Research Foundation (now The Water Research Foundation) and the New York State Energy Research and Development Authority (NYSERDA) have provided the following guidance to WRRFs that are implementing TBL (Elenbaas, et al. 2014).

To select criteria for TBL analysis:

- Identify non-redundant criteria that meet all requirements for sustainability.
- Ensure that the criteria are clearly defined and understood by all stakeholders.
- Develop a ranking system and weight system for the criteria to aid in the decision-making process. (The three sets of criteria – economic, social and environmental – are often weighted equally.)
- Include "upstream" and "downstream" impacts of choices made (i.e. technology choices) which are "directional, concise, complete and clear" (Yoe 2002).

E.3.1 Economic Criteria

All economic impact criteria should, at their most basic, assess project costs and benefits over the lifetime of an investment, and take into account the time value of money by discounting future revenues and costs to the present. Researchers from WRF and NYSERDA (hereafter referred to as WRF researchers) recommend the widely used Net Present Value analysis for economic criteria, supplemented by additional engineering and technical factors. (See Figure 4.1.)

Other economic considerations used by utilities conducting TBL assessments may include the economic impact on stakeholders such as business owners and the tax revenue impact on state and local governments.

Additional recommended engineering and technical criteria include:

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[9] For further discussion of this point, see (Willis, et.al. 2012).

- Simplicity: Complexity adds to risk for failure. Simple technologies are more likely to be accepted by the WRRF workforce.
- Flexibility: The ability to convert or modify technologies is important for meeting the WRRF's future needs.
- State of technology: It is easier to understand costs and performance of well-established technology. This criterion gives an advantage to established technologies and curtails innovation in the water sector (L.A. Stone, 2019). However, WRF researchers note that it is important to balance the disadvantages of new technology (i.e., additional staff training) with the benefits.

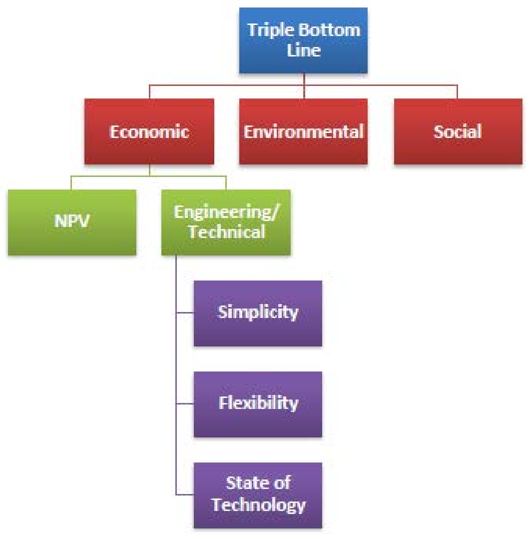

Figure E-1. Economic Sub-Criteria Proposed for TBL.
Source: Elenbaas et al. 2014.

E.3.2 Environmental Criteria

Based on a review of TBL analyses, WRF researchers identify three basic categories of environmental criteria (see Figure E-2).

E.3.2.1 Conservation and Optimization of Resources

This criterion refers to maximizing the recovery of the energy, water, and nutrients in biosolids.

- The "fixed carbon" sub criterion addresses the quantity of greenhouse gases (GHG) emitted or avoided as a result of the biosolid management program and how much energy is recovered through the management program. Energy recovery criteria often complement economic criteria; for example, increased energy efficiency or renewable energy production will generate cost savings as well as avoided carbon emissions.
- The water conservation sub-criterion addresses the amount of water saved through the biosolids management process. For example, biosolids with high water holding capacity can help to reduce the amount of water needed to irrigate farmlands in biosolid management programs that use land application.
- The nutrients sub criterion addresses the amount of nutrients such as phosphorous and nitrogen recovered.

E.3.2.2 Net Impacts on Environmental Media (Soil, Water, Air)

- The management of biosolids can improve or negatively impact soil, water and air depending on management methodology.
- Potential impacts to land/soil include the improvements to soil fertility.
- Impacts to water quality should address downstream impacts in nearby water bodies and the surrounding watershed from potential over-application of biosolids.
- Impacts to air should address, for example, the increase in NO_x and VOC emissions due to treatment technologies such as combustion and composting. Pollutants assessed should include:
    - NO_X.
    - SO_2.
    - Particulate matter.

E.3.2.3 Compliance with Biosolid/Effluent Quality Requirements

WRRF projects should ensure consistent compliance with current regulations, but should also be sufficiently flexible and forward-looking to enable compliance with future regulations. Other environmental criteria that have been used by WRRFs in TBL analyses include environmental toxicity, environmental and human health burden, solids minimization and the risk for remediation. Some of these criteria may be nested within the criteria mentioned above.

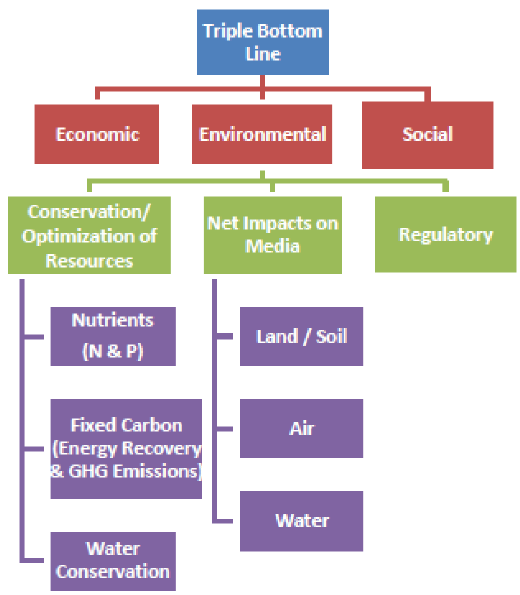

Figure E-2. Environmental Criteria and Sub-Criteria for This TBL.
Source: Elenbaas et al., 2014.

E.3.3 Social Criteria

WRF researchers identified three main criteria that are important in assessing the social impact of WRRF projects:

- **Nuisance issues** will be based on the local context and can include issues with:
    - Odors.
    - Dust.
    - Visual appearances.
    - Noise.
    - Truck traffic.
- **Workplace conditions** criteria should address whether a certain piece of technology makes the WRRF workplace uncomfortable. Unsafe work environments should automatically exclude a project alternative from consideration.
- **Public engagement** criteria should address the level of interaction with the public as well as public acceptance of the project. Improving community relationships can also be considered under public engagement. Some WRRFs note that providing a community service by accepting food wastes from local industries can improve relations with and attract industry to surrounding communities (U.S. EPA 2012).

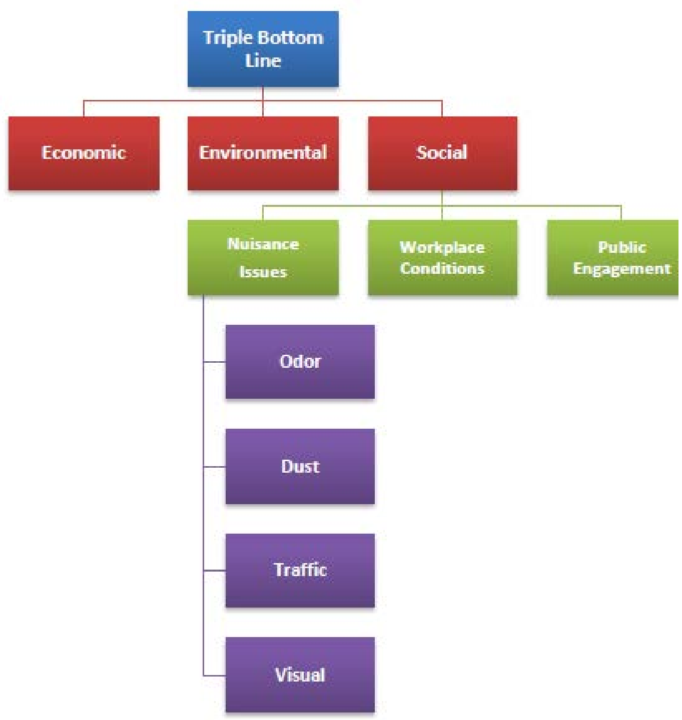

Figure E-3. Social Criteria and Sub-Criteria for This TBL.
Source: Elenbaas et al., 2014.

After data are collected for indicator variables for the various criteria, they are normalized, ranked and then weighted according to a set of weights developed in the TBL process. WRF researchers note that a variety of different criteria and varying levels of detail can be used in TBL analyses.

E.4 Risk Management and Resiliency Assessment

Analysis of financial, regulatory and political risks is important information to include and should be imbedded in the analyses conducted for each project. As described above, risk analysis for financial risks is the most developed.

Monte Carlo simulation is a computerized mathematical technique that allows people to account for risk in quantitative analysis and decision-making.[10] Monte Carlo simulation furnishes the decision-maker with a range of possible outcomes and the probabilities they will occur for any choice of action. It shows the extreme possibilities – the outcomes of going for broke and for the most conservative decision – along with all possible consequences of middle-of-the-road decisions. Alternatively, scenario analysis generates a range of outcome predictions based a range of project scenarios.

It may be possible to translate regulatory risks into time delays and cost uncertainties that can be quantified in the financial analysis. Alternatively, political and regulatory risks may be more suited to a prior qualitative analysis.

Resiliency assessment is also useful, for example of the potential for distributed production at WRRFs to increase energy resiliency for the WRRF and for users of the local grid. In some cases, co-digestion may increase biogas sufficiently so that the utility can supply power locally and distribute it via the micro-grid, thereby reducing dependency on the larger electrical grid and reducing the impacts of power outages affecting critical local services, including water, wastewater treatment, emergency medical, police, and fire services. However, in the past, biogas-fired combined heat and power (CHP) systems at WRRFs have not been considered to be a credible means of providing resiliency through backup power sources because of limitations in their ability to start up without access to other power sources. If these obstacles can be overcome with an integrated CHP/backup power design, then co-digestion-related CHP systems may be able to reduce risks to power supply for the WRRF and other community services, which also should be taken into account in the risk assessment.

E.5 Examples of WRRF Energy and Co-Digestion Investment Decision Making

Utilities have adopted a range of decision criteria for co-digestion and energy projects. Further, a 2017 NYSERDA/WRF study has documented that the scope of factors included in investment feasibility studies for CHP investments varies widely, relative to the NYSERDA guidelines for investment analysis.

New York City Department of Environmental Protection **(NYCDEP) (Mikael Amar, interview with authors, October 25, 2017):** In New York City, innovation in renewable energy and energy efficiency projects is a citywide goal. Financial considerations are less important than demonstrating innovative practices. As long as the project can pay for itself over its lifetime, it is considered economically viable.

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[10] Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values – a probability distribution – for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values.

Green Bay, WI (Pat Wescott, interview with authors, October 25, 2017): NEW Water in Green Bay, WI uses TBL to measure its operational success. Its 2016 strategic plan focuses on three criteria to guide WRRF operations: "people", "environmental leadership" and "economic vitality." For example, NEW Water's Resource Recovery and Electrical Energy Project fulfills the sub criteria to "recover resources and extract inherent value" under the "Environmental Leadership" objective (New Water 2016).

Milwaukee Metropolitan Sewerage District, WI (Kevin Jankowski, interview with authors, October 25, 2017): Milwaukee has established a goal of 100% renewable energy sources by 2035. As a result, part of the WRRF mission is to reduce energy use and increase renewable energy production. Their 2035 strategic vision highlights the use of a sustainability bottom line "that considers balanced Economic, Environmental, Operational, and Social Values." For the Milwaukee Metropolitan Sewerage District, a positive return on investment of up to 20 years or the lifetime of the equipment can be acceptable for resource recovery projects, including co-digestion.

NY State Feasibility Studies

NYSERDA has recommended a set of triple bottom line principles for evaluating energy projects at wastewater utilities to evaluate energy programs for the NY Prize, "a statewide endeavor to modernize New York State's electric grid." However, a recent study of a selection of feasibility studies for WRRF anaerobic digester CHP projects indicates that non-monetary benefits often were not included, or incorrectly estimated, or estimated but not used in decision-making process (O'Brien and Andrews 2017).

The most common criterion mentioned by the utilities is that projects should provide a positive cash flow or at least break even on a life-cycle basis so they do not put pressure on rates; however, a number of WRRFs cite more conservative "go" thresholds. Of the four feasibility studies for projects that did not move forward, three required a payback period of 12-15 years, which is more stringent than a breakeven threshold, and assumed no grant funding. Utilities expressed concerns as to whether the feasibility studies were adequately capturing ancillary capital costs and O&M costs, and in the case of co-digestion, the uncertainty of the long-term availability of organic feedstocks. The findings were consistent with other studies that have indicated WRRFs prefer to have partial grant funding or more attractive financial metrics to serve as a buffer against project risk (Willis 2012; Willis 2015).

Only four out of the six feasibility studies used non-monetary benefits in their project assessments. Non-monetary benefits included avoided peak demand, avoided distribution losses, monetized SO_X and NO_X emissions credits, estimated GHG emissions credits, and marginal emissions rate basis. None of the studies used more than three categories of non-monetary benefits. TBL analyses appear to be highly variable across the subset of WRRFs that conduct them and include non-monetary benefits to different degrees.

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APPENDIX F

Federal and State Programs Providing Grants and Loans

F.1 Introduction

Appendix F complements Section 3.7 of the report (Financing and Funding Options). Each year, $30 to $40 billion in wastewater projects are financed. While most projects rely on municipal bonds and State Revolving Loan Funds as financing instruments, there are many grants, low interest loans, and programs at the federal, state, and local level that can provide funding for projects at WRRFs (Curley 2017). Appendix F provides a list of potential funding sources that WRRFs can use.

F.2 Federal Grants and Loans

F.2.1 USDA Rural Development Water Environmental Program (WEP)

WEP is a “needs-based” program that provides assistance to communities that cannot obtain funding from commercial lenders. The program provided over $1.7 billion in assistance to 945 projects in 2016.

There are three criteria that determine a community’s “need:”

- The state’s percentage of the national rural population.
- The state’s percentage of the national rural population with incomes below the poverty level.
- The state’s percentage of national nonmetropolitan employment.

The fund provides assistance to rural communities in three ways:

- By setting interest rates at Normal, Intermediate and Poverty rates. As of 2014, municipal bond interest rates were at 3.2%. The “Normal” rate under the WEP was 3.125%, the “Intermediate” rate is 2.5% and the “Poverty” rate was 1.825%.
- By setting longer term loans. The WEP can set 40-year loans if the lifetime of a project is at least 40 years.
- By providing grants to subsidize projects in areas where rate increases are inevitable. The WEP will analyze how a wastewater project will influence ratepayers in a district. If the rates are much higher than a neighboring district’s rates or if the district’s rates increase significantly due to the project, the WEP will use grants to subsidize wastewater projects. In 2013 and 2014 about 70% of funds were handed out as loans and 30% as grants (Ramseur 2017).

The USDA defines a publicly owned works as being in a rural area if it serves fewer than 10,000 people (USDA n.d.). In 2017, Congress appropriated $571 million for water and waste disposal projects. However, the proposed FY 2018 budget does not provide any funding for this program.

F.2.2 The National Bank for Cooperatives: Loans (NCB n.d.)

The National Bank for Cooperatives has provided $1.5 billion in loans as financial assistance to water and wastewater systems. The Bank provides pre-development loans, interim or bridge loans and long-term loans for capital projects.

F.2.3 National Rural Water Loan Fund: Loans (NRWA 2014)

National Rural Water Loan Fund was founded by the National Rural Water Association with a grant from the USDA. Loans are limited to the lesser of 75% of the project cost or $100,000. However, approval for loans is quick and loans for disaster recovery are available with up to 90 days of no interest.

F.2.4 2014 Water Infrastructure Finance and Innovation Act (WIFIA): Loans (Ramseur 2017)

Modeled after the 1998 Transportation Infrastructure Finance and Innovation Act (TIFIA), WIFIA allows the EPA to provide credit assistance for water and wastewater projects costing $20 million or more. In rural areas projects must cost $5 million or more. WIFIA loans have terms up to 35 years; however, loans may not contribute to more than 49% of project funds and total federal funds may not exceed 80% (certain Native American tribes are exempt from this cap). The EPA issued $2.3 billion in loans for 12 projects in 2017, the first year of the program's implementation.

F.2.5 The U.S. Department of Housing and Urban Development: Grants

The Department of Housing and Urban Development administers the Community Development Block Grant. Water and waste disposal projects account for 10% of grant projects in recent years.

F.2.6 The U.S. Department of Commerce: Grants

The Department of Commerce provides grants for the construction of public facilities in areas lagging in economic growth. These projects include water and sewer projects.

F.2.7 U.S. Environmental Protection Agency Nonpoint Pollution Source Grants (Clean Water Act Section 319[h]): Grants (U.S. EPA 2017a)

These grants provide technical assistance, education, training, demonstration projects as well as funding. States receive grant money each year and designate which utilities received funds. Congress appropriated $167.9 million for this program in 2017. The program is listed specifically for small and rural wastewater treatment plants.

F.2.8 U.S. Environmental Protection Agency Water Pollution Control Grants Program (Clean Water Act Section 106): Grants (U.S. EPA 2016)

States, interstate agencies, and tribal governments are all eligible to receive Section 106 funds. Funds from the grant can be used to achieve permit compliance and manage permits, implement enforcement actions, and manage water quality. Congress appropriated $226 million to fund Section 106 grants in 2017.

F.2.9 The U.S. Department of Energy (DOE)

F.2.9.1 Energy Efficiency Block Grants: Grants (Vedachalam and Geddes 2017)

These grants from the DOE can be used for community-wide energy efficiency and conservation projects, as well as renewable energy installations on government buildings. The availability of this funding is not stable.

F.2.9.2 DOE Better Plants

The Better Plants program promotes energy efficiency across U.S. industry. The program has specifically focused on wastewater utilities since 2014. Better Plants offers trainings that are relevant to wastewater utilities and energy efficiency.

DOE also provides Technical Account Management (TAM) support through the Better Plants initiative by helping partner plants benchmark their energy use, create an energy action plan, and create plans for reporting energy efficiency progress (U.S. DOE 2015).

Better Plant participants are given priority access to DOE's other technical assistance programs which are described below (U.S. DOE 2015 and U.S. DOE n.d. b).

F.2.9.3 DOE SWIFt Accelerator

Beginning in 2016, the Sustainable Wastewater Infrastructure of the Future (SWIFt) Accelerator has worked with state and local agencies to promote sustainable wastewater infrastructure. Over the course of the program's three-year duration it has partnered with over 70 wastewater facilities to adopt best practices in energy, data management, resources recovery, and financing for energy efficiency. The program provides technical assistance and tools to assist wastewater partners in reducing their energy use and implementing resource recovery initiatives (U.S. DOE 2017).

F.2.9.4 Combined Heat and Power and Technical Assistance Partnerships (CHP TAP)

DOE's Combined Heat and Power Technical Assistance Partnerships (CHP TAP) provides end user engagement, market opportunity analysis, stakeholder engagement, and technical services for CHP adoption. Regional advisors assist industries across the United States (U.S. DOE n.d.c). As part of technical assistance, the CHP TAP program provides screening and preliminary analysis of CHP options, a full feasibility analysis, a third-party review of engineering analysis and a review of bids and procurement specifications for product procurement (U.S. DOE 2015).

F.2.9.5 DOE Industrial Assessment Center

The Industrial Assessment Center partners with universities to provide free energy and water use assessments for wastewater and water utilities. To qualify for a free assessment, wastewater utilities must be located within a certain distance of participating universities, have annual utility bills between $250,000 and $2.5 million, and must process more than 2 mgd (U.S. DOE 2015).

F.2.9.6 Funding Opportunity Announcements from EERE

DOE's Energy Efficiency and Renewable Energy Program will occasionally post funding opportunities for AD such as the FY19 Bioenergy Technologies Office Multi-Topic Funding Opportunity Announcement which provides funding for research and development on "Rethinking Anaerobic Digestion" (U.S. DOE n.d.).

F.2.9.7 Energy Savings Performance Contract (ESPC) Toolkit

F.2.10 American Recovery and Reinvestment Act (ARRA): Grants

While no longer in effect, the American Recovery and Reinvestment Act of 2009 helped to jumpstart several wastewater treatment energy projects. Projects beginning construction or operation in 2011 were eligible to receive 30% off qualifying costs in the form of grants as opposed to tax credits.

F.2.11 Region-Specific Programs: Grants

The Department for Health and Human Services provides grants for environmental health and sanitation in tribal communities.

The U.S.-Mexico Border Water Infrastructure Program provides grants for drinking water and wastewater treatment for communities 62 miles (100 km) to the North and 62 miles (100 km) to the South of the U.S.-Mexico Border. The program has been in effect since 2004 and is dedicated to improving the environmental health of the region (U.S. EPA 2017b).

Alaska Native Tribal Health Consortium Grant provides wastewater treatment plant design and construction.

The Appalachian Regional Commission provides grants that both improve environmental health and stimulate economic development in the Appalachian region. The program is a federal-state partnership. Grants are awarded to state and local agencies, governmental offices, local governing boards and non-profit organizations (ARC n.d.).

F.3 State Grants and Loans: Examples

F.3.1 Water and Wastewater Program Examples

F.3.1.1 State Rural Water Associations: Loans

Kansas, Minnesota, Pennsylvania, and Kentucky have Rural Water Associations. These associations provide a variety of instruments including loans and bonds to finance projects.

F.3.1.2 TX: State Water Implementation Funds for Texas (SWIFT): Loans

The SWIFT program provides low-interest loans for water management strategy projects in Texas.

F.3.1.3 OH, VA, ME: State funding pools for loans

States such as Ohio, Virginia, and Maine run pools that provide state appropriations and state bonds to utilities who apply to the pool. These mechanisms can be useful as they do not require voter approval (unlike some municipal bonds).

F.3.2 Energy Program Examples

F.3.2.1 The California Energy Commission (CEC): Grants (CEC n.d.)

The California Energy Commission is California's energy policy and planning agency. Their core missions include improving energy efficiency, developing renewable energy, and investing in energy innovation. The CEC provided grants to East Bay Municipal Utility District (EBMUD) to help start co-digestion. The CEC also provides funding for renewable fuels through their Alternative and Renewable Fuel and Vehicle Technology Program.

F.3.2.2 California Self-Generation Incentive Program (SGIP) (CA Public Utilities Commission n.d.)

California's Self-Generation Incentive Program provides rebates for public utilities pursuing onsite energy generation. Several WRRFs in California including the Hayward Water Pollution Control Facility, Victor Valley Water Reclamation Facility and the Hill Canyon WRRF have taken advantage of the SGIP to facilitate co-digestion and energy upgrades.

F.3.2.3 New York State Energy Research and Development Authority (NYSERDA)

NYSERDA promotes the development of renewable energy and energy efficiency. Approximately $4 million was available in 2016 through the Anaerobic Digester Gas to Electricity Program (NYSERDA n.d). NYSERDA and the Water, Environment and Research Foundation (now WRF) have partnered to improve digester gas use for wastewater treatment plants by co-funding research into biogas, energy efficiency and recovery and co-digestion. NYSERDA also provided $480,000 in funding to the Ithaca Area Wastewater Treatment Facility for energy upgrades.

F.3.2.4 Wisconsin's Focus on Energy (Focus on Energy 2018)

Wisconsin's Focus on Energy program aims to improve energy efficiency in Wisconsin with long term financial benefits. The program has provided support as well as grant funding to WRRFs in Sheboygan, Stevens Point, and Janesville, Wisconsin.

F.3.2.5 The Massachusetts Department of Energy and Massachusetts Clean Energy Partnership

The Massachusetts DOE and Clean Energy Partnership are providing $6 million in grants to fund the new co-digestion facility at the Greater Lawrence Sanitary District WRRF.

F.3.2.6 The Massachusetts Clean Energy Center (CEC) (MASS CEC n.d.)

The Massachusetts CEC has funded several co-digestion feasibility studies through their Commonwealth Organics to Energy program.

F.3.2.7 California Energy Conservation Assistance Act: Loans (CEC n.d.)

The Act provides 0% and 1% loans for energy efficiency projects.

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APPENDIX G

WRF Research Projects on Co-Digestion

Characterization and Contamination Testing of Source Separated Organic Feedstocks and Slurries for Co-Digestion at Resource Recovery Facilities [4915]
Carollo Engineers
The objectives of the project are to identify, evaluate, and develop techniques for characterizing source separated organic (SSO) feedstocks and slurries for co-digestion at resource recovery facilities and testing them for contamination; to link characteristics to product quality; and support development of minimum feedstock quality standards for various product goals and standardization of sampling protocols for rapid monitoring of feedstocks.
Ongoing.

Co-Digestion Experience in Central Europe and Case Study Analysis [ENER9C13a]
Carollo Engineers
This project examines co-digestion programs, drivers, operational practices, and side effects at water resource recovery facilities in Central Europe and provides comparison to programs in the United States.
Published in 2019.

Business Case Analysis of Food Waste Co-digestion at Water Resource Recovery Facilities [ENER19C17]
Environmental Law Institute
The project goal is to develop alternative sustainable business cases for wastewater resource recovery facilities to co-digest food waste, including fats, oil, and grease (FOG), food manufacturing residuals, and source separated organics. The research team will use the “innovation ecosystem” framework to manage risks as clean water utilities deal with increasingly valuable resources.
Published – this report.

Manure Resource Recovery Co-Digestion from Fats, Oils, and Grease [STAR_N3R14a]
University of Washington
The purpose of this research was to understand the effect of the FOG feeding conditions on the microbial population and the ability to maximize the FOG processing rate during manure co-digestion. The project team specifically investigated the effect of anaerobic co-digester feeding pattern on: 1) Ability to increase a manure digester methane production rate; 2) LCFA bioconversion kinetics; 3) LCFA co-digester stability and performance; 4) Composition of syntrophic LCFA-degrading consortia; and 5) Threshold inhibitory specific LCFA concentrations throughout long-term FOG co-digestion. A secondary objective on evaluating the potential of improving digester performance by the addition of trace elements (nickel, cobalt, and molybedenum) was investigated.
Published in 2017.

Assessing the Benefits and Costs of Anaerobic Digester CHP Projects in New York State [ENER7C13e]
Brown and Caldwell
This project presents the results of one-on-one interviews with wastewater utility staff to document factors that drive biogas energy projects forward and those that hold them back. While some utilities reported that the biggest hurdle to implementing cost-saving, renewable energy is a perception of “inadequate payback,” many others faced local obstacles related to lack of outside funding, pressing demands for limited capital, and utilities’ own decision-making processes. The report documents the

unique, local nature of biogas project decisions, and notes opportunities to increase consistency and accuracy in financial decision making. It suggests approaches for increasing the value of biogas and for maximizing cost savings through pursuit of favorable agreements with electric power providers**.**
Published in 2017.

Lessons Learned: Developing Solutions to Operational Side Effects Associated with Co-Digestion of High Strength Organic Wastes [ENER8R13]
Hazen and Sawyer
This study presents research collected from over 40 facilities that have implemented or have considered implementing co-digestion. The research team conducted a systematic evaluation of feedstocks available for use in co-digestion and co-fermentation processes by surveying high strength organic wastes (HSWs). The team assessed and quantified operational implications of co-digestion with HSWs, including receiving, pretreatment, digestion, and post-digestion treatment and handling practices. The findings support an accessible framework of operational solutions to challenges encountered during the co-digestion of HSWs and best management practices.
Published in 2017.

Co-Digestion of Organic Waste Addressing Operational Side Effects [ENER9C13]
Carollo Engineers, Inc.
This study evaluated operational side effects associated with co-digestion of high strength waste (HSW) and wastewater solids (thickened primary sludge and thickened waste activated sludge) at water resource recovery facilities (WRRFs). The two goals of this study were to evaluate co-digestion facility design, performance data, and operation and maintenance issues at five WRRFs and to evaluate the impacts of co-digestion of HSW on methane production, sludge production, and nitrogen and phosphorus concentrations in recycle streams. Recommendations for better process control during co-digestion are included.
Published in 2017.

Understanding Impacts of Co-Digestion: Digester Chemistry, Gas Production, Dewaterability, Solids Production, Cake Quality, and Economics [ENER12C13]
Kennedy/Jenks and Bucknell University
The long-term objective of this study is to increase the number of utilities performing co-digestion by providing tools that enable utilities to better understand the implications of co-digestion and to reduce the roadblocks and uncertainty associated with co-digestion. To achieve this, the project team developed a fundamental analytical approach to understand and predict the broad array of Impacts of co-digestion.
Published in 2017.

Renewable Energy Production from DOD Installation Solid Wastes by Anaerobic Digestion [ENER14R14]
CDM Smith
The purpose of this demonstration was to validate anaerobic digestion of U.S. Department of Defense wastes including pre- and post-consumer food waste, waste cooking oil, and grease trap waste as a viable means of disposal and renewable energy generation. The project demonstrated the ability to digest these wastes in a controlled and predictable manner to maximize the generation of biogas, a methane-rich, high-energy byproduct. The project also studied biogas treatment to remove the non-methane portion of the gas including H2S (and carbon dioxide) with the goal to produce treated product gas equivalent in quality to natural gas and suitable for end-use applications and reduce mass of waste disposed by at least 60%.
Published in 2016.

Pathways to Energy Neutrality [ENER7C13c]
Brown and Caldwell
Features the case study of the Victor Valley Regional Water Reclamation Facility, California. This facility was California's first plant to receive preprocessed food waste and the study describes the plant modifications undertaken to accommodate HSW receiving and co-digestion. Through its co-digestion program, the facility has received added revenue streams and has significantly reduced its consumption of purchased energy in recent years.
Published in 2015.

Advancing Anaerobic Digestion of Wastewater Solids and Food Waste for Energy and Resource Recovery: Science and Solutions – A Framework for the Practice of Co-Digestion (ENER20W17/4793)
WRF under National Science Foundation grant number CBET-1632734
Summarizes the outcome and discussion from a workshop integrating research findings with successful practice to lay the groundwork for a framework to advance the practice of co-digestion. The report includes a research roadmap to maximize planned research investments from the wastewater and food waste management industries, as well as Federal agencies. Provides an overview of recent research findings on co-digestion of organic wastes with wastewater solids.
Published in 2018.

Demonstrated Energy Neutrality Leadership: A Study of Five Champions of Change [ENER1C12b]
Black and Veatch
Showcases different case studies of WRRF in the U.S. embarking on the objective of energy neutrality and the role that co-digestion has played for some of them to achieve this objective. While co-digestion was recognized as the best near-term solution to achieve significant energy production on-site at facilities with anaerobic digestion and cogeneration, several challenges were identified, including costs for HSW storage, solids dewaterability, resulting biosolids quality impacts, stability of the digestion process, and food waste availability.
Published in 2015.

Co-Digestion of Organic Waste Products with Wastewater Solids: Final Report with Economic Model [OWSO5R07]
CH2M
This project furthers the understanding of co-digestion of organic waste with wastewater solids, quantifies the benefits of co-digestion, and provides answers to key questions to help overcome barriers associated with greater implementation of co-digestion programs at municipal WRRFs. The practice of adding waste organic feedstock directly to anaerobic digesters is becoming an attractive way for utilities to generate revenue from tipping fees while boosting biogas production. However, the practice is only used by about 20% of WRRFs with AD due to the uncertainty on how to proceed without causing digester upset. Through lab, pilot-scale, and a study of a full-scale facility, this research addresses some of these operational issues. Includes an Excel-based Economic Model that utilities can use to determine an appropriate tipping fee for handling this waste in the digesters – often the source of additional revenue which makes these energy recovery project viable.
Published in 2014.

Wastewater Treatment Anaerobic Digestion Foaming Prevention and Control Methods: Full-Scale Studies and Literature Review/Survey [INFR1SG10]
Pagilla and Subramanian
Even though not specifically focused on co-digestion systems developed a detailed methodology that WRRFs can follow to manage anaerobic digester foaming. The recommendations of this study are also generally relevant and applicable to digester operation under addition of co-substrates.
Published in 2014.

Barriers to Biogas Use for Renewable Energy [OWSO11C10]
Brown and Caldwell
Not all wastewater treatment plants with anaerobic digestion beneficially use their biogas beyond process heating. Knowing this, there must be actual or perceived barriers to broader use of biogas to produce combined heat and power (CHP). This study documented these barriers so that actions can be taken to reduce or remove the barriers that promote energy recovery using proven technology – anaerobic digestion with combined heat and power generation. Includes case studies and biogas factsheet and other materials.
Published in 2012.

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