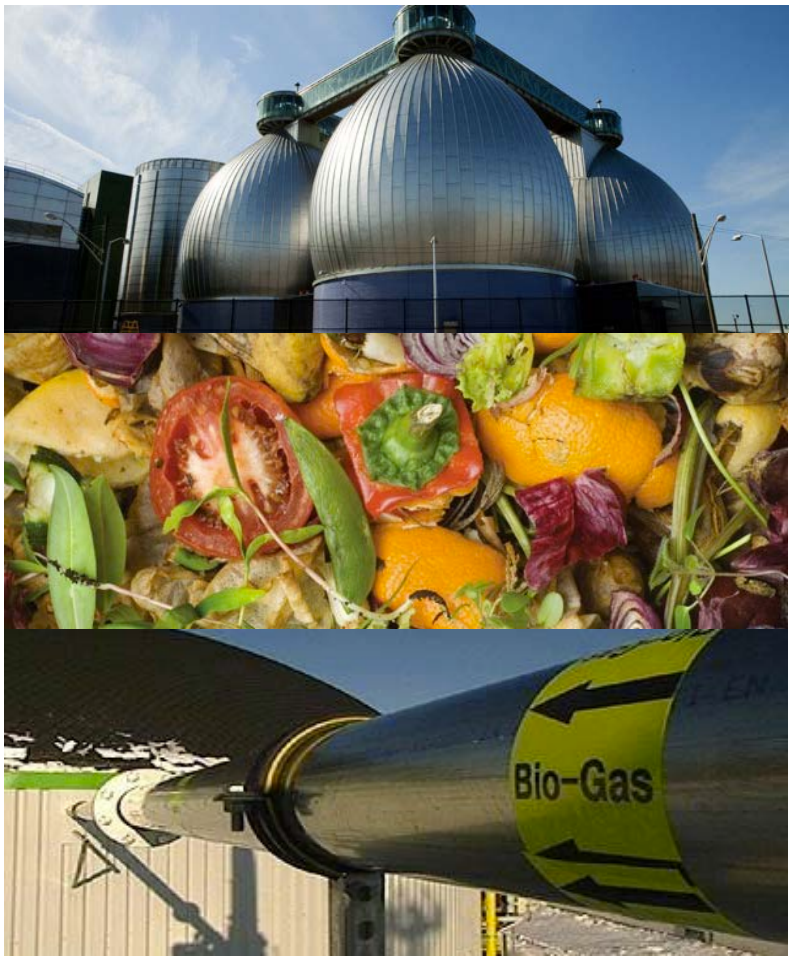

Understanding & Overcoming Barriers to Co-Digestion at Wastewater Treatment Facilities

Kristyn Abhold, Rachel Golden, Lucy McKenzie, & John Romankiewicz

University of California, Berkeley: Goldman School of Public Policy
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Executive Summary

Co-digestion is the process by which food waste materials (including fats, oils, and grease (FOG), food scraps, and food processing wastes) that are rich in energy are added to dairy or wastewater digesters with excess capacity. Through a chemical process called anaerobic digestion, food waste products are broken down to produce biogas, which contains methane, a common energy resource. Converting food waste into energy reduces waste in landfills, provides a source of renewable energy, and reduces greenhouse gas (GHG) emissions. Moreover, wastewater treatment facilities (WWTFs) that adopt co-digestion can save money on electric utility bills and receive additional revenue from tipping fees, selling excess electricity, and other mechanisms. However, despite the environmental and economic benefits of co-digestion, the adoption of this process by WWTFs has been slower and less widespread than hoped for by the EPA Region 9 (hereto referred to as "EPA").

The paper describes (a) the barriers WWTFs face in choosing to invest in co-digestion, and (b) recommendations for how the EPA can help enable the adoption of co-digestion. The paper presents the findings of a survey of 48 WWTFs in the U.S. as well as interviews with wastewater industry experts.

The main barriers to adoption of co-digestion practices at WWTFs fall into six categories: financial, infrastructural, organizational, regulatory, biological, and informational.

- *Financial:* It is often difficult for a WWTF to allocate resources towards endeavors that do not fall within the scope of regulatory compliance driven projects. Furthermore, due to financial uncertainties many facilities struggle to obtain the upfront capital needed to develop a co-digestion program.

- *Infrastructural:* Many WWTFs have physical space constraints, concerns about producing noxious odors, and other infrastructure limits, which can restrict the adoption of co-digestion.

- *Organizational:* Co-digestion is not considered to be part of a WWTFs core business. Lack of staff resources and entrepreneurial will to expand into new business endeavors can keep WWTFs in a business-as-usual framework and prevent adoption of co-digestion practices.

- *Regulatory:* Regulatory uncertainty and risk about the future of wastewater, solid waste, and air quality regulations pose a challenge to WWTFs as they try to evaluate the feasibility of co-digestion.

- *Biological:* The introduction of food waste streams can cause the bacteria needed for anaerobic digestion to react in different and sometimes unexpected ways, creating an operational and environmental risk to WWTFs. The magnitude or severity of these risks is commonly not well understood.

- *Informational:* WWTFs struggle to evaluate the costs and benefits of co-digestion due to the difficulties of obtaining required metrics as well as a lack of a user-friendly financial model. Since processing food waste is not their core business, WWTFs can also lack knowledge about waste supply sources needed to effectively implement co-digestion.

There are several actions EPA can take to encourage and enable more WWTFs to develop co-digestion programs. The EPA can clearly play a significant role in helping WWTFs overcome informational barriers. It is also possible for the EPA to help WWTFs overcome financial and regulatory barriers, but doing so may be resource-intensive or require the EPA to partner with other stakeholder groups. Recommended actions for the EPA are as follows:

- Create opportunities for information sharing and partnership development
    - Facilitate a buddy system that connects WWTFs that don't co-digest with co-digesting facilities and academic institutions
    - Host regional information-sharing and networking events
    - Reach out to targeted WWTFs to increase drive and interest in co-digestion

- Create or improve online resources to overcome informational gaps
    - Provide an overview of financial and funding opportunities
    - Provide model contracts for use with haulers, electrical utilities, and energy consumers.
    - Update EPA's mapping tool that connects WWTFs, producers or organic waste, and haulers
    - Update EPA's Co-EAT cost-benefit analysis tool
    - Create user-friendly regulatory roadmap

- Expand financial incentives and assistance for co-digestion
    - Create access to funding for up-front costs
    - Improve ongoing revenue streams from co-digestion

- Work with regulators to simplify permitting requirements

- Help establish state standards that create incentives or favorable conditions for co-digestion, e.g. landfill waste diversion mandates and renewable portfolio standards

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Acknowledgements

We appreciate the guidance of John Hake at East Bay Municipal Utility District and the following associations who helped spread the word about our online survey:

National Association of Clean Water Agencies, California Association of Sanitation Agencies, Pacific Northwest Clean Water Association, Hawaii Water Environment Association, Energy Trust of Oregon, and the North East Biosolids and Residuals Association.

Definitions and Commonly Used Acronyms

Definitions:

Biogas: In this report, biogas refers to a mixture of gases (primarily methane [CH_4] and carbon dioxide [CO_2] as well as small amounts of other gases) produced by the breakdown of organic matter in the absence of oxygen, a process also known as anaerobic digestion.

Food waste: In this report, food waste refers to organic matter that is food-related that can be used to produced biogas, including food scraps, liquid and solid wastes from food processing facilities, and fats, oils, and grease.

Acronyms:

AD: Anaerobic digester
CO_2: Carbon dioxide
CoEAT: Co-digestion Economic Analysis Tool, created by EPA Region 9
EBMUD: East Bay Municipal Utility District
EPA: Environmental Protection Agency
FOG: Fats, oils, and grease
GHG: Greenhouse gas
kWh: Kilowatt-hour
Region 9: EPA service territory that includes Arizona, California, Hawaii, Nevada, Pacific Islands, and 148 Tribal Nations
WWTF: Wastewater treatment facility
WERF: Water Environment Research Foundation

Introduction

Despite the sustainable infrastructure and zero-waste benefits of co-digestion, the adoption of this technology by wastewater treatment facilities (WWTFs) has been slower and less widespread than hoped for by the Environmental Protection Agency (EPA) Region 9. The objective of this report is to help the EPA understand the barriers that may be preventing WWTFs from developing a co-digestion program, and suggest ways that the Agency can expand its role in promoting the adoption of co-digestion at WWTFs.

Waste-to-Energy

Converting food waste into energy addresses two of the most pressing environmental concerns of urban centers: efficient waste management and renewable energy production. WWTFs have the potential to capture and recover the energy stored in food waste. The following section provides an overview of how this is achieved and the benefits that can accrue.

Anaerobic Digestion and Co-Digestion

Anaerobic digestion is a process in which microorganisms break down biomass[1] material in the absence of oxygen to produce biogas (a blend of methane, carbon dioxide [CO_2], and other gasses), and solid residuals that can be used for animal bedding and fertilizer. Anaerobic digestion is a long-established and commonly used process for WWTFs to treat sewage sludge. However, in the U.S., 83% of the 1,500 WWTFs with anaerobic digesters (ADs) flare (i.e. waste) their biogas.[2] The remaining WWTFs with AD use the biogas for

[1] Biomass is organic matter formed by photosynthetic capture of solar energy and stored as chemical energy, which includes agricultural crops and wastes, animal wastes, forest and mill residues, wood and wood wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes. A current trend to develop and expand renewable energy production in the U.S. has lead to increased exploration of the bioenergy contained in biomass. The solar energy stored in biomass can be released as biogas, a mixture of methane, CO_2, and some trace gases, through anaerobic and/or co-digestion digestion.

[2] Maile Lono-Batura, Yinan Qi and Ned Beecher, "Biogas Production and Potential From U.S. Wastewater Treatment," *BioCycle*, December 2012, Vol. 53, No. 12, p. 46. *http://www.biocycle.net/2012/12/18/biogas-production-and-potential-from-u-s-wastewater-treatment/*

heat and power. Co-digestion is one way to improve the energy yields of anaerobic digestion at WWTFs.

Co-digestion at WWTFs is a process whereby energy-rich organic food waste materials (including fats, oils, and grease [FOG]), slaughterhouse products, food-scraps, and other waste streams) are added to sewage sludge of ADs with excess capacity. An estimated 216 WWTFs located in the U.S. haul in food waste for co-digestion with sewage sludge. This accounts for approximately 17% of WWTFs that process sewage sludge using ADs.[3]

Co-Digestion at WWTFs

The EPA has targeted wastewater treatment facilities as good candidates for increasing co-digestion uptake for a number of reasons. The fact that many WWTFs already have ADs with excess capacity eliminates the up-front costs associated with building digesters. Additionally, WWTFs often already have staff with on-site expertise in operating digesters, and these facilities are located in dense, urban areas where large amounts of food waste are generated and therefore hauling costs are low.[4]

Beyond creating management interest in co-digestion, WWTFs must take several steps in order to start co-digesting. These include:

- Locating food waste and determining how waste will be collected, separated, and treated for use in digesters.
- Choosing the infrastructure technology that best suits the characteristics of the food waste and facility space limitations.
- Identifying how the facility will manage and/or utilize the products of co-digestion (both solids and gasses).
- Conducting analyses of the costs and benefits to generate a convincing business case for the long-term financial feasibility of a co-digestion program.

[3] Yinan Qi, Ned Beecher, and Maggie Finn, "Biogas Production and Use at Water Resource Recovery Facilities in the United States." Water Environment Federation and the National Biosolids Partnership, Phase 1 Data Report, Project 11-WSEC-01, July 2013, *http://www.casaweb.org/documents/8-5-2013_wef-phase1_biogas_data_results.pdf*
[4] U.S. EPA Region 9, "Wastewater Treatment Facilities Taking Food Waste," *http://www.epa.gov/region9/waste/features/foodtoenergy/wastewater.html*

Food waste

Co-digestion works with many types of waste streams including sewage, manure, forestry waste, agricultural waste, and food waste. This report focuses on utilizing food waste from homes, businesses, and food processing companies that would have otherwise ended up in landfills. Food waste can be either pre-consumer (e.g., waste from breweries, dairies, canneries, slaughterhouses, and FOG from restaurants) or post-consumer waste (e.g. table scraps and restaurant leftovers). Certain industrial waste products, such as glycerol (a byproduct of biodiesel production) are sometimes also included in the food waste category. While enhancing biogas production by adding FOG to ADs has become a common industry practice, less widespread is the addition of other types of food waste material.

While WWTFs can purchase trucks, hire drivers, and establish contracts with feedstock sources, it is typically more cost-efficient for WWTFs to establish agreements with existing waste haulers to collect and deliver food wastes. Ideally, WWTFs would like to secure multiyear contracts and receive a consistent amount of feedstock, but food waste generators and/or the haulers may be reluctant to commit to a certain price (per ton or per gallon) as the solid waste disposal market is highly competitive.

WWTFs can charge waste haulers a "tipping fee" for accepting the food waste. A co-digesting WWTF must establish a level of tipping fees that make pre-treating and delivering the waste to the WWTF attractive for food waste generators and/or haulers. This may be achieved by offering a tipping rate lower than the nearby landfill or composting facilities.[5] Competitive tipping fees can provide an incentive for waste haulers to deliver food wastes to WWTFs. The tipping fee a WWTF can charge will depend on local conditions and are typically set a level necessary to cover costs to build and operate a food-based co-digestion program. Nationally, tipping fees range from $30 a ton to $50.[6]

Handling and treatment of food waste is more difficult than treating wastewater at WWTFs, as it requires a larger amount of investment and technological experience. Some food waste is delivered in a solid or semi-solid state and must be preprocessed to reduce the solids content before being loaded into the AD. This treatment process often entails additional capital expenditures for the WWTF.

Infrastructure Needs

A typical co-digesting facility has six major infrastructure components:

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[5] Kristi Moriatry, "Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana," National Renewable Energy Laboratory, January 2013, *http://www.nrel.gov/docs/fy13osti/57082.pdf*

[6] Renewable Waste Intelligence, "Business Analysis of Anaerobic Digestion in the USA," March 2013, *http://www.renewable-waste.com/pdf/AnaerobicDigestionEbrief.pdf*

- A food waste receiving area where haulers deliver their loads, in either solid or liquid form. This requires the WWTF to have available land to build new infrastructure.
- Equipment to pretreat and remove contaminants from hauled-in waste.
- The digester, where biological degradation occurs.
- Infrastructure to treat the resulting solid by-product
- Infrastructure that cleans the biogas and uses the resulting methane. Typically, methane is combusted to heat steam that then turns a turbine and generator, producing electricity.
- A biofilter, which ensures that offensive odors do not leave the WWTF.[7]

Use of Resulting Biogas and Solids

Adding food waste to WWTF digesters can increase biogas production significantly depending on the feedstock utilized and mixing ratios.[8] If 50% of the food waste generated each year in the U.S. was co-digested, enough electricity would be generated to power over 2.5 million homes for one year.[9] Biogas from co-digestion can be recovered and used to generate electricity for on-site use or sale to the local electric utility. Thermal energy in the form of waste heat, produced during electricity generation, can also be recovered to heat digesters or adjacent buildings. Other uses include heat generation by burning biogas in boilers, upgrading biogas to pipeline quality, and converting biogas to compressed natural gas for a variety of fuel applications, including vehicle fueling.[10]

Costs

Economic analysis must be conducted to generate a capital and operating cost estimate of a co-digestion project. The cost of a co-digestion program can vary significantly depending on the price and availability of land, the range and purity of food waste collected, rate recovery, landfill tipping fees, waste hauling costs, markets for biogas and compost, electricity prices,

[7] Karena Ostrem, "Greening Waste: Anaerobic Digestion for Treating the Organic Fraction of Municipal Solid Wastes," Earth Engineering Center, Columbia University, May 2004, *http://wtert.gr/Pdfs/anaerobic_digestion_Ostrem_Thesis.pdf*
[8] David Parry, "Co-Digestion of Organic Waste Products with Wastewater Solids," Water Environment Research Foundation, IWA Publishing, 2014, *http://www.werf.org/a/k/Search/ResearchProfile.aspx?ReportID=OWSO5R07*
[9] U.S. EPA Region 9, "Turning Food Waste Into Energy at the East Bay Municipal Utility District (EBMUD)," *http://www.epa.gov/region9/waste/features/foodtoenergy/*
[10] U.S. EPA, "Case Study Primer for Participant Discussion: Biodigesters and Biogas," Technology Market Summit, May 14, 2012, *http://www.epa.gov/agstar/documents/biogas_primer.pdf*

training required for operators, government reporting requirements, permitting fees, tax credits, and other conditions.[11]

A digester is a major investment, with an approximate initial cost of up to $600 per annual ton of capacity.[12] Capital costs are high due to the equipment necessary for co-digestion, in particular feedstock preprocessing equipment, storage, digester, energy generator and hydrogen sulfide management. Operating costs are also substantial and depend heavily on individual project considerations. They range between $40 and $150 per ton of waste delivered.[13] The cost-savings and revenue potential of co-digestion vary significantly based on local energy prices, financial incentives or subsidies, and local tipping fees for haulers. While average co-digestion project payback time is five to seven years, some feasibility studies estimate a longer period.[14]

In short, the economic viability of co-digestion depends on the interactions between three basic conditions. First, the cost of tipping at nearby landfills will ideally be sufficiently high to make the cost of a co-digesting WWTF competitive. Second, proximity to electricity and/or solid products markets is key. If biogas and electricity are not used on-site and there is some to be sold, proximity to markets and ease of sale are considerations for those facilities. Finally, the waste streams must be sufficiently clean and have a large organic content to maximize energy production and reduce pre-treatment costs.[15]

Benefits of Co-Digestion

Co-digestion of food wastes provides many potential benefits to WWTFs, their ratepayers, and to society. Co-digestion diverts food waste and FOG from landfills, reduces greenhouse gas (GHG) emissions, produces renewable energy (i.e. biogas), can reduce water pollution, and has the potential to create financial savings or additional revenue streams.

Energy Savings

The services WWTFs provide are very energy-intensive. EPA estimates 3-4% of national electricity consumption,[16] is used to provide drinking water and wastewater services, which costs approximately $4 billion per year. Water and wastewater utilities are typically the

[11] Ostrem, "Greening Waste"
[12] Renewable Waste Intelligence, "Business Analysis of Anaerobic Digestion in the USA"
[13] Id.
[14] Id.
[15] Ostrem, "Greening Waste"
[16] Equivalent to approximately 56 billion kilowatts

largest consumers of energy in municipalities, often accounting for 30-40%of total energy consumed.[17] For WWTFs, energy bills can be nearly 30% of total operation and maintenance costs, usually representing a facility's second or third biggest expense.[18] Any reduction in energy consumption will benefit WWTFs and their ratepayers.

Co-digestion can help to lower WWTFs' electricity bills. For example, East Bay Municipal Utility District (EBMUD) in Oakland, CA has reached net-zero energy by combining co-digestion of food waste with energy efficiency measures. Nationwide, co-digesting systems have the potential to produce up to 18.7 billion kilowatt-hours per year.[19] Furthermore, because biogas is a renewable energy source, it qualifies for renewable energy credits in most states. Another potential advantage for the WWTF is independence from the grid and therefore continued electricity supply during blackouts.

Landfill Diversion

Unprecedented amounts of food are wasted in the U.S. In fact, more food reaches landfills and incinerators than any other single component of municipal solid waste (Figure 1). According to the EPA, in 2012, Americans sent about 35 million tons of food waste to landfills and incinerators – equivalent to half a pound per person per day. Food waste that is diverted from landfills and processed through co-digestion can be reduced by 40% of its original weight and significantly less volume. Therefore diverting food waste from landfills to WWTFs for co-digestion can significantly reduce the amount of landfill volume currently needed.[20]

[17] U.S. EPA, "Sustainable Infrastructure: Water & Energy Efficiency," *http://water.epa.gov/infrastructure/sustain/waterefficiency.cfm*
[18] Keith Carns, "Bringing Energy Efficiency to the Water and Wastewater Industry: How Do We Get There?," Water Environment Federation, January 1, 2005, *http://dx.doi.org/10.2175/193864705783813728*
[19] Thomas D. DiStefano and Lucas G. Belenky, "Life-Cycle Analysis of Energy and Greenhouse Gas Emissions from Anaerobic Biodegration of Municipal Solid Waste," *Journal of Environmental Engineering*, ASCE, November 2009, *http://www.seas.columbia.edu/earth/wtert/sofos/MSW_AD_LCA_DiStefano.pdf*
[20] U.S. EPA, "Reducing Food Waste for Businesses: Food Waste Basics," *http://www.epa.gov/foodrecovery/*

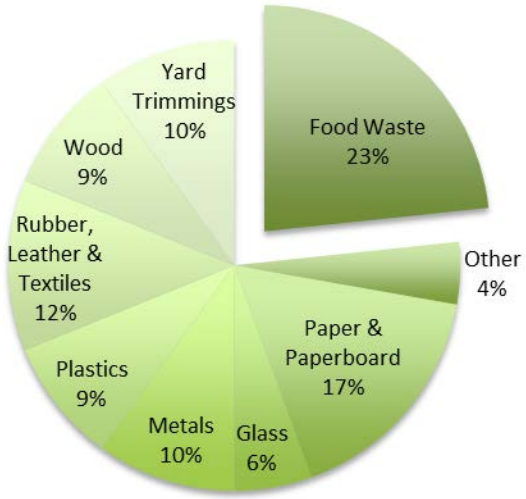

Figure 1: Municipal solid waste going to landfills and incineration,
Source: EPA 2012 Municipal Solid Waste Characterization Report

Disposing of food waste in landfills is an inefficient use of landfill space because the technology exists to capture its embedded energy and to reduce the final size and weight of the disposed waste. Although the "digestion" process occurs naturally in landfills, the process is much slower than using co-digestion and the energy released is not harnessed. The use of co-digestion at WWTFs diverts food waste from landfills, conserves landfill space, and reduces the demand for new landfills.

Co-digestion can also improve the quality of water run-off from landfills. The natural decomposition of waste causes landfill odor and water pollution issues. Landfills emit chlorinated and other volatile organics, such as sulphides, ammonia and mercury. Leachate containing these chemicals that can contaminate nearby water sources, even long after a landfill is closed. This is due to the time lag associated with the decomposition of waste and the associated reactions of various pollutants in the landfill. This is true even in landfills that are currently collecting and treating leachate. Therefore, water quality is further enhanced when the volume of food waste in landfills is shrunk.[21,22]

Greenhouse Gas Reductions

Greenhouse gases, gases the EPA has identified as contributing to global climate change, may be reduced through co-digestion. There are three ways that co-digestion can reduce

[21] Nikita Naik, Ekaterina Tkachenko, and Roy Wung, "The Anaerobic Digestion of Organic Municipal Solid Waste in California," University of California, Berkeley, May 15, 2013, *http://bcgc.berkeley.edu/sites/default/files/Anaerobic-Digestion-report.pdf*
[22] Nickolas Themelis and S. Verma, "The Better Option: Anaerobic Digestion of Organic Waste in MSW." *Waste Management World*, January/February 2004.

GHG emissions: (1) capture methane (2) reduces transportation and (3) displace fossil-fuel power generation.

Co-digestion can reduce GHG emissions by capturing and reusing methane. The main components of biogas – typically 60% methane and CO_2 as the primary other component – are both GHGs. Methane has a greenhouse warming potential 20 times more powerful than CO_2. It is important to control biogas from waste disposal operations in order to reduce the release of GHGs into the environment.

Landfills account for 17.5% of the total methane emissions in the U.S. and are the largest man-made source of methane emissions in the U.S.[23] Municipal solid waste in landfills generates roughly 11.6 teragrams (Tg) of methane, or 66.7 million metric tons of carbon dioxide per year.[24] Co-digestion can reduce GHG emissions through the capture and reuse of methane. Capturing methane emissions that would have otherwise been released into the atmosphere is an activity that is eligible to generate carbon credits. A study conducted by the Water Environment Research Foundation (WERF) found that disposal of food waste at WWTFs with co-digestion had the lowest carbon footprint, whereas disposal of food waste at landfills had the highest carbon footprint.[25]

Furthermore, the transportation of food waste to landfills produces GHGs. Landfills are typically farther away from urban areas than WWTFs. Processing food waste locally at WWTFs that are closer to urban areas reduces truck traffic and associated air emissions. [26]

Lastly, co-digestion can reduce GHG emissions by decreasing demand for electricity generated from fossil fuels. According to the EPA, burning methane is cleaner than burning coal or oil. Compared to the average air emissions from coal-fired power generation, methane produces half the CO_2, less than a third of nitrogen oxides, and only 1% of the sulfur oxides. Nationwide, co-digesting systems are projected to reduce GHG emissions by 7.2 billion tons CO_2 equivalent, over a 50-year period, if biogenic methane replaces natural gas for electricity production.[27]

[23] U.S. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks," April 15, 2014, *http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf*
[24] Id.
[25] Water Environment Research Foundation, "Sustainable Food Waste Evaluation," April 30, 2012, *https://www.werf.org/a/ka/Search/ResearchProfile.aspx?ReportId=OWSO5R07e*
[26] Id.
[27] DiStefano "Life-Cycle Analysis of Energy and Greenhouse Gas Emissions from Anaerobic Biodegration of Municipal Solid Waste"

Survey Methodology

Despite its potential to address pressing environmental concerns and generate revenue, co-digestion is not widespread in the U.S. as compared to other regions like the European Union. In order to identify the barriers to co-digestion in the U.S. and potential actions EPA Region 9 can take to help WWTFs overcome these challenges, the research team conducted an online survey of WWTF staff, interviewed WWTF staff and industry experts, and reviewed existing literature.

The survey was designed with input from EPA Region 9, EBMUD, and the National Association of Clean Water Agencies. The online survey collected basic infrastructure information (such as utilities' service populations and average wastewater flow), practices with respect to anaerobic digestion and co-digestion, and WWTFs' perception of barriers. The survey had specific questions geared towards respondents who are practicing co-digestion, not practicing co-digestion, and in transition to practicing co-digestion. Short answer questions allowed participants to provide additional information on financial, informational, regulatory, and other barriers to co-digestion as well as potential tools and solutions to overcome those barriers. The short answer questions allowed the research team to identify key candidates for further questioning via phone interview. Overall, the survey was designed to take 10-15 minutes to complete.

The online survey was distributed to WWTFs across the U.S., including the networks of the National Association of Clean Water Agencies, California Association of Sanitation Agencies, Pacific Northwest Clean Water Association, Hawaii Water Environment Association, Energy Trust of Oregon, and the North East Biosolids and Residuals Association. When the survey was closed on April 14, 48 facilities had responded, 22 of which are located in Region 9. In order to obtain more detailed information, 12 WWTFs were interviewed (6 located in Region 9). Perspectives and information were also collected from industry experts CDM Smith (an engineering consulting firm) and WERF.

Although this report is focused on barriers and solutions for WWTFs in Region 9 (Arizona, California, Hawaii, and Nevada), WWTFs across the U.S. were interviewed and surveyed. This approach enabled the identification of common trends and issues, and highlighted needs in the industry.

Survey Results

After extensive outreach, a total of 48 survey responses were received. The responses came from 16 states and one U.S. territory (Guam). Twenty respondents are located in Region 9: two in Hawaii and 18 in California. The geographic dispersion of responses is shown in Figure 2.

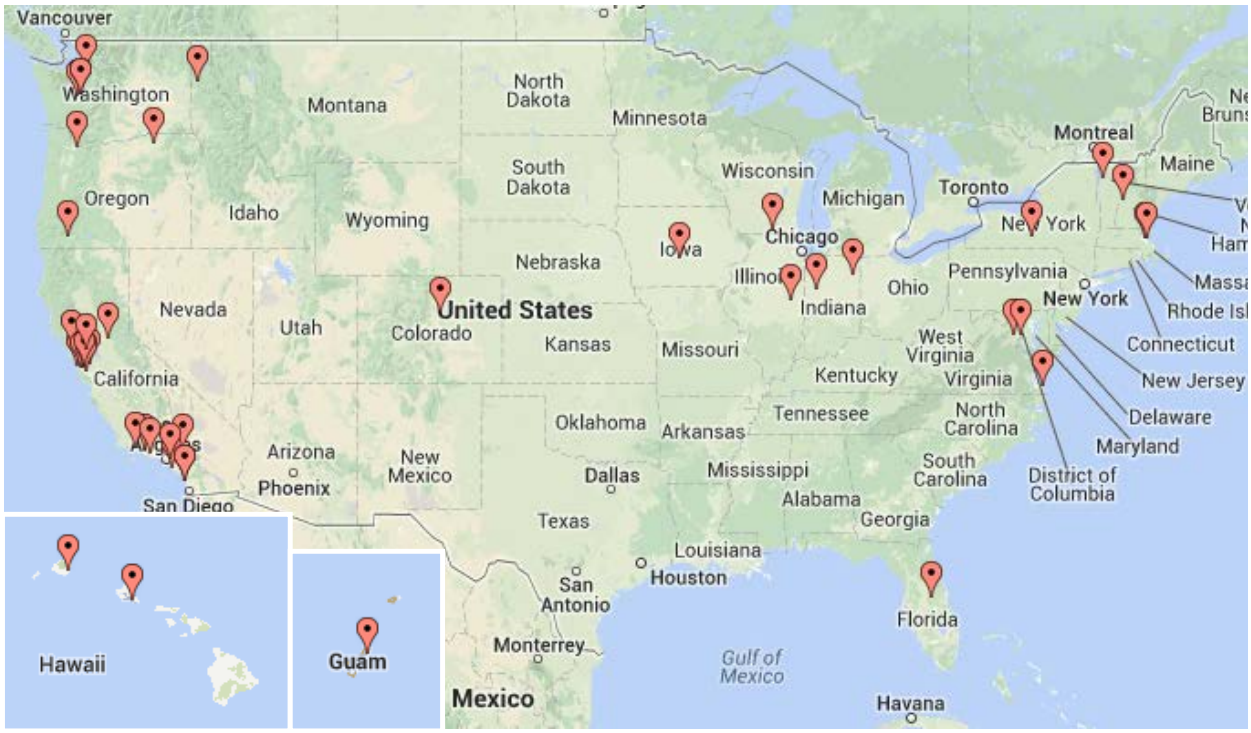

Figure 2: Map of WWTF survey respondents

Of all 48 respondents, only one reported that they were not familiar with the practice of co-digestion. Seventeen respondents (35%) are practicing co-digestion, eight respondents (17%) are currently transitioning to co-digestion, and 23 respondents (48%) are not practicing co-digestion. Of those 23 respondents, 74% still reported that they had considered co-digestion for their facility in the past, though the extent of that consideration was not quantitatively measured.

Facilities were asked to provide information on the size of their service population as well as the average daily wastewater flow to their facility. The average daily wastewater flow reported was 10 million gallons of wastewater for every 100,000 people served. This can be

seen in Figure 3 and Figure 4, with Figure 4 showing a focused cross-section for where most of our data points fell – up to 70 million gallons per day and 700,000 people served.

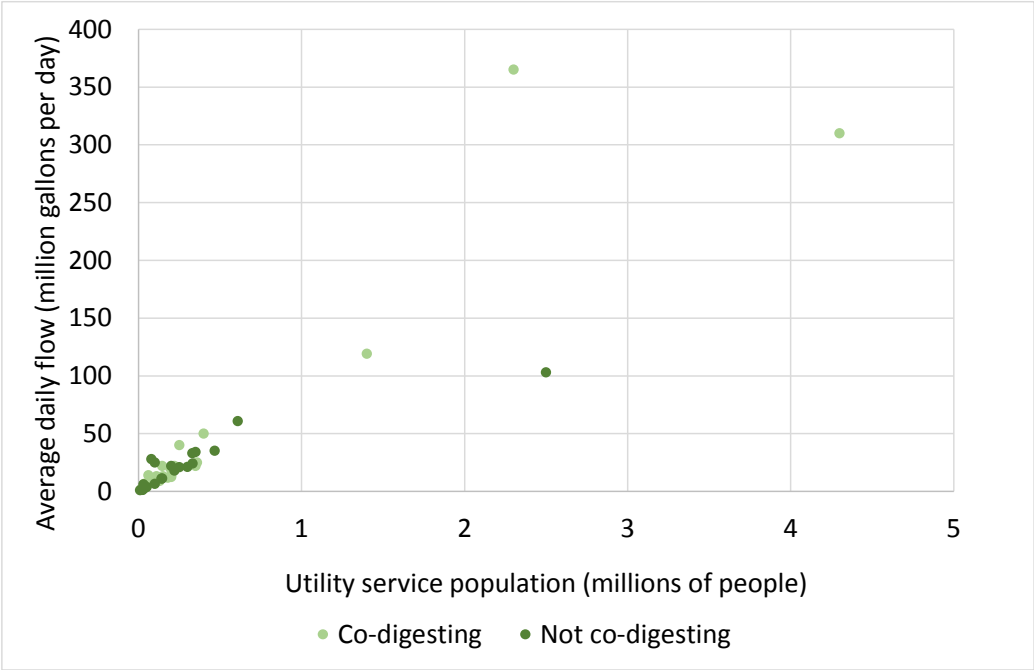

Figure 3: Size of facilities as measured by utility service population and average daily wastewater flow

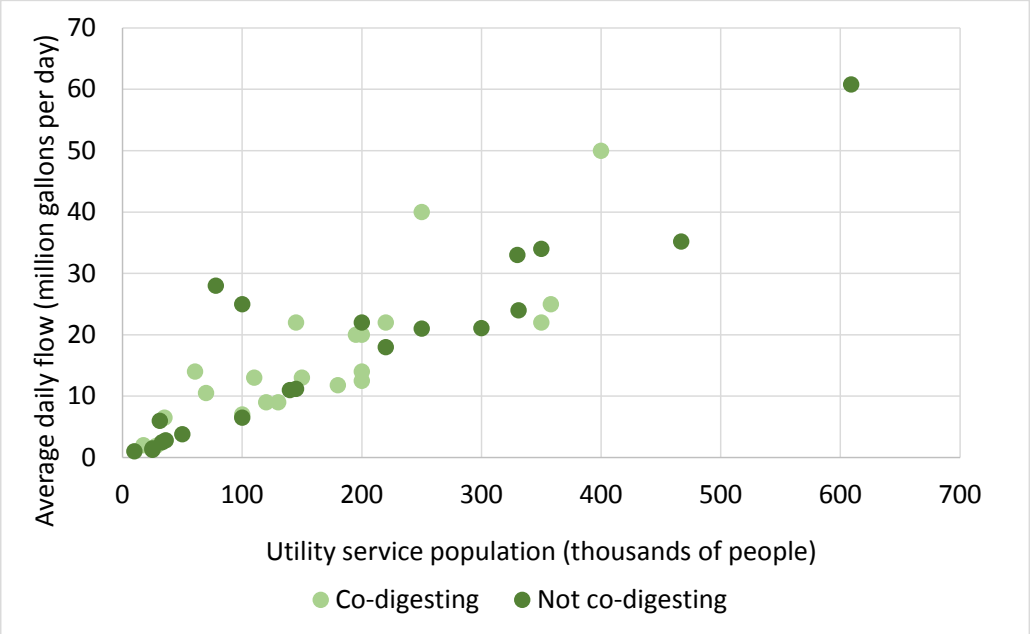

Figure 4: Close-up of Figure 3

There was no statistically significant difference in size between facilities that practice co-digestion and those that do not. The range, median, and average values for daily wastewater flow can be found in Table 1, broken down into three categories: all facilities, facilities practicing co-digestion or in transition to practicing co-digestion, and facilities not co-digesting.

Table 1: Descriptive statistics on average daily wastewater flow from WWTF survey respondents

Daily wastewater flow (million gallons per day)	Min	Max	Median	Average
All facilities	1.0	365.0	19.0	37.3
Co-digesting or in transition	1.9	365.0	14.0	51.6
Not co-digesting	1.0	103.0	21.0	21.7

Ninety percent of respondents reported that they currently use anaerobic digestion in the treatment of sludge on-site. Of that group, 82% of respondents reported having excess digester capacity, and 70% reported a specific value. Excess capacity was reported as a percentage of total digester capacity. Values ranged from 8% to 60%, with a median value of 25% and an average of 29%. Figure 5 shows the breakdown of responses in increments of 10 percentage points. Two-thirds of facilities reported spare capacity between 20% and 39%.

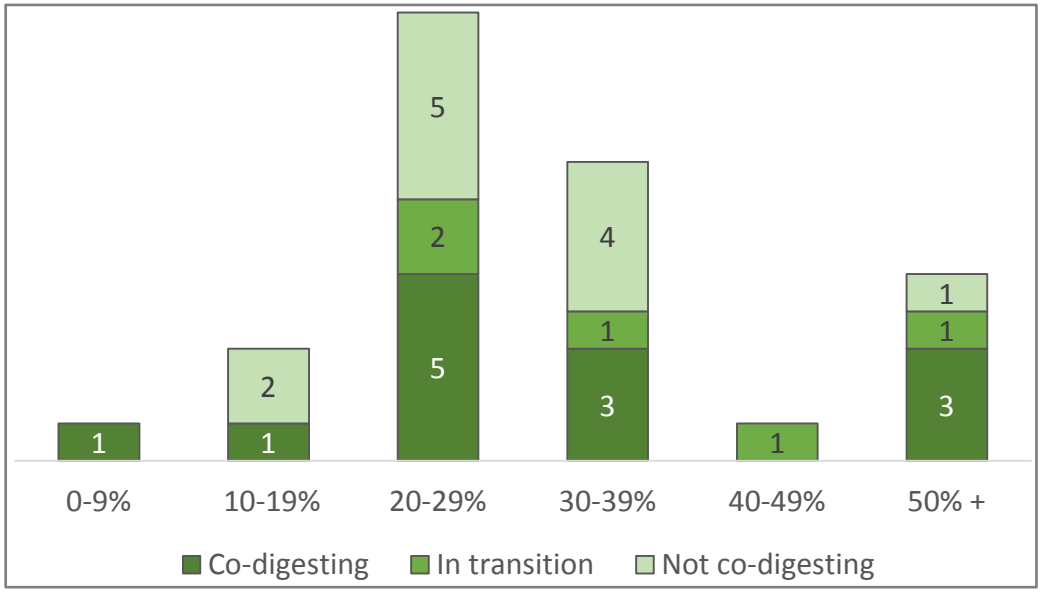

Figure 5: Number of facilities by percentage of spare digester capacity reported

Respondents were also asked questions about their potential motivations for pursuing anaerobic digestion and co-digestion. Seventy-three percent of facilities recognized landfill tipping fees as a potential financial opportunity for their facility to pursue co-digestion,

while 88% of respondents saw energy costs as a driver to either save energy or produce their own energy on-site. For the 25 facilities either practicing or transitioning to co-digestion, Figure 6 shows when the facilities began co-digesting. Though this is a very limited sample, it seems that there has been growth in the practice of co-digestion in the past five years.

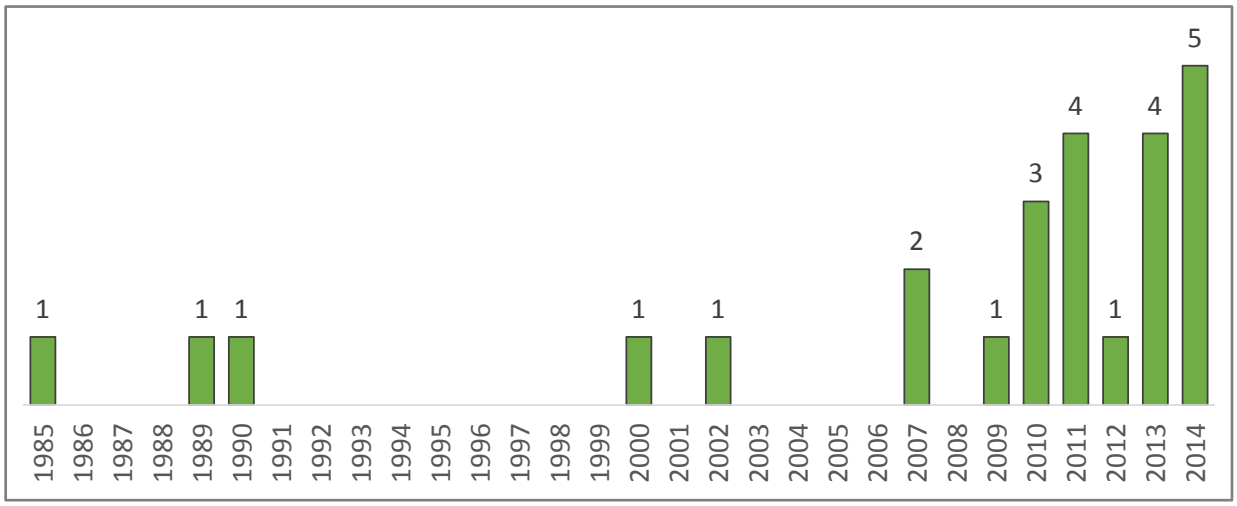

Figure 6: Number of surveyed facilities beginning co-digestion in each year

Electricity prices range widely across the U.S., and this wide range is clearly represented in our survey sample (Table 2), with prices as low as $0.03 per kilowatt hour (kWh) in the Pacific Northwest and as high as $0.42/kWh in Hawaii. Electricity prices were not an indicator for co-digestion as both WWTFs facing high electricity prices but not practicing co-digestion and WWTFs facing low prices but still practicing co-digestion were observed.

Table 2: Descriptive statistics on electricity price from WWTF survey respondents

Electricity prices for WWTF's ($/kWh)	Min	Max	Median	Average
All facilities	0.03	0.42	0.10	0.12
Co-digesting or in transition	0.04	0.38	0.10	0.11
Not co-digesting	0.03	0.42	0.10	0.12

Of the 25 WWTFs either practicing or transitioning to co-digestion, 24 facilities reported the types of waste they procure or plan to procure for their co-digestion needs. The following two tables describe the breakdown of waste in two different ways. Table 3 simply shows how many facilities reported each waste type. Since most facilities use more than one type of waste, the total exceeds 100%. FOG and solid food waste are the most common types of waste procured, so Table 4 shows the amount of facilities using only FOG, only solid food waste, only other types of waste, as well as various combinations of those types of waste,

such that the percentages all total up to 100%. Wastes reported as "other" in the survey included wastes from milk and yogurt processing facilities.

Table 3: Types of waste and number of facilities using those types of waste

Type of waste	Number of facilities using that type of waste	Percentage of facilities using that type of waste
Fats, oils, & grease (FOG)	18	75%
Solid food waste	6	25%
Brewery wastes	5	21%
Glycerin	3	13%
Dairy processing wastes	2	8%
Septic tanks	2	8%
Other	5	21%

Note: Percentages do not add to 100%.

Table 4: Waste combinations and number of facilities using those combinations of waste

Type of waste	Number of facilities using that type of waste	Percentage of facilities using that type of waste
FOG + other	9	38%
FOG only	5	21%
Other only	3	13%
Solid food waste only	3	13%
FOG + solid food waste	2	8%
FOG + solid food waste + other	2	8%

Enabling Factors for Co-digestion

In discussions with managers at successfully co-digesting WWTFs, six major factors and circumstances stood out as enablers of successful co-digestion projects. In general, at least two of these factors were present and in some cases, all six factors were present. The presence of these enabling factors did not mean that the transition to co-digestion was easy, and co-digesting WWTFs noted that they still faced many hurdles. However, interviews suggested that if a facility does not possess some of these factors, its likelihood of pursuing co-digestion will decrease significantly. These six factors are listed below.

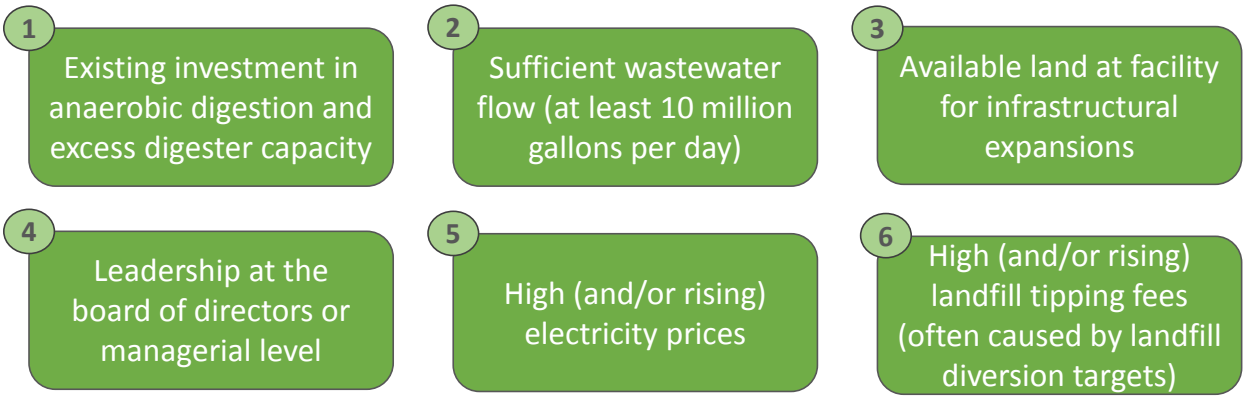

Figure 7: Enabling factors for co-digestion at WWTF's

The first four variables (numbers one to four) are generally endogenous to the facility – that is, they have to do with the facility and its staff itself as opposed to some external factor.

First, the facility has likely already invested in anaerobic digestion. If the facility is to pursue co-digestion, then it should have some spare capacity in its digesters so that it would have room to insert various food-related waste streams for co-digestion.

Second, a frequent enabling factor is the volume of wastewater flow. Larger facilities tend to face a better business case for co-digestion, since a) securing low-cost funding for upfront capital costs is generally easier, b) the increased energy for larger facilities makes potential energy cost reductions more attractive, and c) economies of scale mean that larger facilities receive a higher return on the regulatory and organizational hassle of adding this new line of business. A general rule of thumb suggested by one WWTF was 10 million gallons per day as a minimum volume of wastewater flow for a WWTF to consider co-digestion.

Third, receiving stations, additional roadways and parking, and possibly on-site waste storage will be needed to handle the incoming trucks that bring in the waste streams. Often, facilities have a fixed physical footprint, for instance they may be located in a suburban or urban part of a community, surrounded by other residential or commercial infrastructure and thus have no means to expand. Facilities that co-digest did in fact have space on site to make way for the necessary infrastructural expansions.

Fourth, many co-digesting facilities had either a visionary Board of Commissioners interested in pursuing progressive energy and waste management goals, or management staff capable of overseeing the staffing and operational transitions pursuant to co-digestion.

The last two enabling variables (numbers five and six) can generally be considered exogenous to the facility – that is, they are regional characteristics that may have to do with the price of goods or local policies in place. First, given the energy intensive nature of wastewater treatment, high electricity prices are a driver for both anaerobic digestion and co-digestion, since they are a means to produce large amounts of electricity on-site at costs lower than the local utility's rate. While it is hard to generalize, electricity prices higher than $0.10/kWh seem to be a driver for anaerobic digestion and co-digestion. Additionally, if a facility believes prices will increase over time, then this is also a driver. Second, wherever landfill tipping fees are high, there is an opportunity for WWTF's to accept food-related waste streams and receive a payment for accepting that waste. Generally, these fees will be lower than the local tipping fee in order to make it an attractive option for waste haulers. Often, a regional or municipal goal to divert a certain percentage of food waste from the landfill can lead to high tipping fees.

Barriers to Co-Digestion

With any large infrastructure project, it is a long road from conception, through planning, and to completion. Renewable energy projects like co-digestion are no exception. It is important to identify and understand the barriers to co-digestion in order to provide WWTFs with the right set of tools and knowledge to reap the benefits of co-digestion.

As part of the survey, respondents were asked to score a number of barrier categories (financial, infrastructural, organizational, regulatory, biological, and informational) on a scale from 1 to 5, with 1 indicating that a barrier category has/had no impact on the facility's decision to co-digest, and 5 indicating that the barrier category has/had a very significant impact.[28] Figure 8 shows the average score for each barrier category for the 25 facilities that are already co-digesting or in the process of transitioning to co-digestion alongside the average score for the 23 facilities that are not co-digesting.

[28] Examples of barriers were provided as follows to the survey respondents: financial (e.g. upfront capital costs are too high, energy prices are too low, or other reasons), infrastructural (e.g. do not have the capacity or space for bringing in extra waste streams), organizational (e.g. complex decision making or lack of organizational resources), regulatory (e.g. extra permitting required for expanded operations is burdensome), biological (e.g. risk associated with dealing with wastes or the damages that wastes may cause on infrastructure), and informational (e.g. lack knowledge of co-digestion or its risks, costs, benefits).

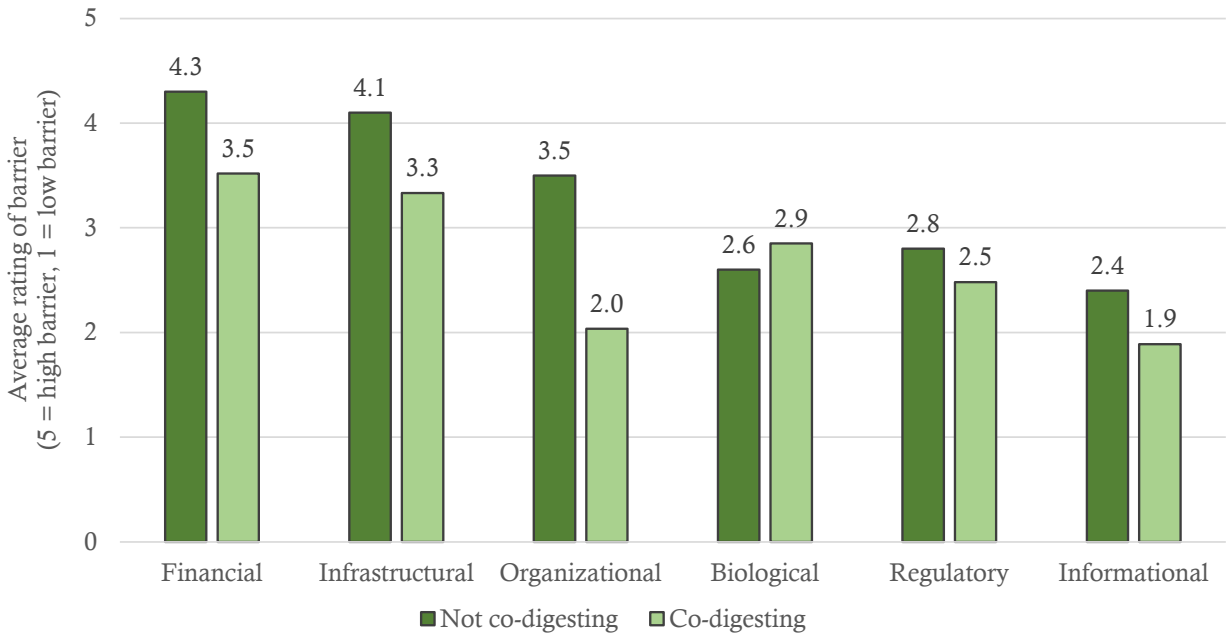

Figure 8: Average ratings of barrier categories

Note that co-digesting facilities may under-report the barriers since they have already been overcome in the past. In fact, the average values were lower for co-digesting facilities than for not co-digesting facilities in all cases except for biological barriers. This may be because biological is more of an operational concern (day to day concerns about whether a specific batch of waste will upset the digestion process) as opposed to a concern faced when initially making the decision to invest in co-digestion. Financial and infrastructural barriers were rated the highest while informational and regulatory barriers were rated the lowest. The largest difference between facilities that do and do not co-digest was for organizational barriers. An additional qualification is that facilities may have different perceptions on what an informational barrier is versus a financial barrier for instance. Some may consider lacking access to information on landfill tipping fees to be a financial barrier while others may consider it to be an informational barrier.

Survey respondents also provided additional written explanations on their experience of barriers in these various categories, which will be described in detail in the following sections.

Summary of Barriers

The primary barriers categories to adoption of co-digestion practices at WWTFs are: financial, infrastructural, organizational, regulatory, biological, and informational. The following provides a brief overview of the barriers identifies within each category. It is important to note that many of the barriers identified in the next section overlap and can encompass more than one of the barrier categories developed. Barriers have been placed in the category that best represents their core underlying issue.

- *Financial:* It is often difficult for a WWTF to allocate resources towards endeavors that do not fall within the scope of regulatory compliance driven projects. Furthermore, due to financial uncertainties many facilities struggle to obtain the upfront capital needed to develop a co-digestion program.

- *Infrastructural:* Many WWTFs have physical space constraints, concerns about producing noxious odors, and other infrastructure limits, which can restrict the adoption of co-digestion.

- *Organizational:* Co-digestion is not considered to be part of a WWTFs core business. Lack of staff resources and entrepreneurial will to expand into new business endeavors can keep WWTFs in a business-as-usual framework and prevent adoption of co-digestion practices.

- *Regulatory:* Regulatory uncertainty and risk about the future of wastewater, solid waste, and air quality regulations pose a challenge to WWTFs as they try to evaluate the feasibility of co-digestion.

- *Biological:* The introduction of food waste streams can cause the bacteria needed for anaerobic digestion to react in different and sometimes unexpected ways, creating an operational and environmental risk to WWTFs. The magnitude or severity of these risks is commonly not well understood.

- *Informational:* WWTFs struggle to evaluate the costs and benefits of co-digestion due to the difficulties of obtaining required metrics as well as a lack of a user-friendly financial model. Since processing food waste is not their core business, WWTFs can also lack knowledge about waste supply sources needed to effectively implement co-digestion.

(1) Financial Barriers

In order to minimize payback time to attract investment, all three revenue streams of an AD project should be maximized. These are: converting biogas into electricity for sale to the grid, charging tipping fees for processing organic waste and selling the digestate as fertilizer.

Survey respondents indicated financial concerns as the most prominent barrier to investing in co-digestion. While financial barriers overlap and play a critical role in the other barrier categories analyzed in this report, the specific barriers listed below represent purely financial hurdles that must be overcome to make co-digestion a viable undertaking by WWTFs.

Interestingly, many survey respondents characterized some barriers as financial barriers, when in fact the primary underlying issue was more closely aligned with another barrier category.

Funding Priorities

For many survey respondents, co-digestion is not a funding priority compared to regulatory compliance driven projects. For some WWTFs this is because there are more important infrastructure upgrades that need to be financed to meet current regulatory obligations and permit requirements. Many WWTFs surveyed reported that they will prioritize investments and activities that help meet their primary mandate of treating wastewater; any energy or cost-saving investments will be secondary priorities. For example, many respondents indicated that any available funding in the near future may need to be directed towards new regulatory requirements such as nutrient removal in effluent first before financing can be allocated to any other activities.

Upfront Cost and Funding Availability

Co-Digestion requires high up-front costs for many WWTFs, especially for utilities that do not already utilize ADs. Co-digestion may require the installation of additional digesters if excess capacity is not available, along with new turbines and pre-treatment equipment.

Co-digestion is a relatively new industry in the wastewater sector. Because it is new and more complex it is often labeled as risky compared to other more traditional wastewater infrastructure projects. This makes banks and lending organizations more reluctant to finance co-digestion projects. Often, trying to make a business case for co-digestion is difficult without secure food waste feedstock contracts to satisfy lenders. Yet food waste collectors are often hesitant to introduce food waste services until WWTFs have built or established a co-digestion program. Because co-digestion requires feedstock to be hauled-in

and competition for hauled wastes exists in the marketplace – this uncertainty of consistent and available feedstock can make securing financing for co-digestion difficult.

Lack of Financial Incentives

A key financial incentive for co-digestion at WWTFs is high energy costs. In areas where the price of energy and natural gas is high, it can often be the largest cost associated with utility operations. The desire to reduce energy-bills often drives WWTFs to generate their own power through co-digestion, anaerobic digestion, and combined heat and power systems. While energy and natural gas prices are high in some parts of the country, they are still relatively cheap in other parts. Many survey respondents indicated that the largest barrier to co-digestion was cheap energy. If the resulting energy cost-saving from co-digestion is low – there is little incentive to invest.

Payback

A key financial concern for survey respondents was whether co-digestion is economically feasible with timely payback or return on investment (ROI). It's difficult to predict with certainty how long it may take to achieve payback due to fluctuating energy prices, tipping fees, and food waste feedstock availability.

In some areas tipping fees are too low and the proceeds may not be substantial enough to cover operational expenses or help with payback. Furthermore, as more WWTFs begin co-digesting competition for high-energy food waste feedstock may result in less energy production – resulting in escalated costs and reduced profits – as WWTFs transition to food-stocks that have lower energy potential and may require greater pre-treatment.

If electricity prices are low or if they fall from present trends, payback could be extended by years because energy cost-savings would be diminished. Furthermore, if a co-digesting WWTF is able to achieve net-zero energy use and has excess energy or gas, it will want to sell excess electricity to an energy provider. Uncertainty over the ability to form third-party partnerships with electric utilities makes estimates of payback difficult to trust.

The greater the uncertainty over future costs, the shorter WWTFs want payback on their investment. While payback estimates may differ for each WWTF, it is often the primary barrier or enabler of co-digestion investment.

(2) Infrastructural Barriers

WWTFs make infrastructure investments with a certain use in mind. They are designed to serve a certain size of population and are designed to handle a set of expected wastewater flows, depending on the concentration and type of nearby residences, business, and industry which expel wastewater to the WWTF. WWTFs are usually designed such that some growth in industry and population is expected as a possibility (however small that probability might be), and therefore buffers of space are often designed into a facility's footprint so that the WWTF can have room to grow if such a need presents itself. WWTFs in urban and suburban areas also have odor control equipment and measures to ensure that any nearby residents do not complain.

Most WWTFs did not have co-digestion in mind when they first designed their facilities. Consequently, infrastructure barriers are very common and come in the form of concern for an increase in odors, physical space limitations on-site, and surrounding infrastructure inadequacies. In our survey responses, infrastructure barriers ranked roughly as a medium-high barrier.

Increase in Odors

Inherently, co-digestion is the use of wastes that were normally intended to end up in a landfill, which are typically placed further away from populations due to concerns for odor. Bringing in odoriferous wastes to WWTFs often located in close proximity to urban and suburban populations raises large concerns with those populations and thus with water utility boards.

Odors were highlighted in at least seven short answer responses on barriers to co-digestion. Many of the facilities we surveyed are located in close proximity to residential, commercial (motels, markets), and recreational areas. Even if additional measures could be introduced to control odors of incoming waste streams, public perception of the potential for odors would still be a barrier to overcome. There is a large fear among facility managers of upsetting the neighbors. Yet, additional odor control measures can be cost-prohibitive for water utilities, especially for wastes that are trucked in as opposed to piped in, and may have to be stored on-site for a number of days at a time as the wastes are fed into the digesters.

On-site & Surrounding Infrastructure Limitations

Co-digestion expands the scope of a WWTF's operations. A WWTF needs space to be able to bring in, process, and potentially store food waste streams on-site. Facility managers are concerned about having the physical space to accommodate such expansions as well as the impact these processes will have on existing operations. There are additional concerns about

local civil infrastructure, for instance if the roadways near the facility can handle additional truck traffic or if there are gas pipelines nearby if the WWTF ends up producing excess gas it wants to export for profit (as opposed to electricity export).

Infrastructure limitations were highlighted in at least seven short answer survey responses directly. One respondent said, "Our facility layout is such that FOG or food waste acceptance would necessitate allowing haulers into the very heart of our facility; operations is not too keen on that." Many respondents highlighted the lack of space for receiving facilities and for potential traffic routes for the trucks to drive in and drop off waste. Other respondents worried that they wanted to save any extra space they had for future infrastructure needed for nutrient removal if NPDES requirements expand in the future. One respondent noted that though their project had started as a small-scale co-digestion pilot, operations quickly grew as co-digestion proved to be good for profits, but then capacity and space quickly became an issue. In some cases, WWTFs may be directly next to a residential community, and there is fundamentally no room to expand beyond its existing footprint even if they had they fiscal resources to do it.

Interestingly, while issues with physical capacity can often be a barrier, there are situations where extra infrastructural capacity becomes available, acting as an enabling factor to co-digestion. For instance, a number of WWTFs started to look into co-digestion when industrial and residential populations left their district. West Oakland suffered from a lot of industry and residents moving away, but EBMUD then had extra wastewater capacity with which it could begin to explore co-digestion. One survey respondent commented that when a large brewery moved to another city, it left half of the normal wastewater treatment load idle, potentially presenting the room to do co-digestion if other enabling factors were present.

(3) Organizational Barriers

Beyond the more technical barriers to co-digestion, the human barriers that develop and are inherent in organizational structures can inhibit invest in new technologies and endeavors such as co-digestion. Organizational barriers had the largest discrepancy between barrier rankings by co-digesting WWTFs and non co-digesting WWTFs. Interestingly and perhaps not surprisingly, WWTFs that are co-digesting ranked organizational barriers at a lower barrier level than non co-digesting WWTFs. This may indicate that organizational barriers may be the most difficult barrier for non co-digesting WWTFs to overcome. Below are the most common reported organizational barriers WWTFs face to investing in co-digestion.

Lack of Leadership Support

Often the primary barrier to any new endeavor is a lack of support and political will of key decision makers at WWTFs. For some survey respondents their governing Board of Directors lacked sufficient information about the benefits of co-digestion, others were hesitant to change facility operations to accommodate food waste haulers because it can viewed as a risk to their core responsibility of treating wastewater. Others are concerned about public support with regard to odor and traffic concerns. While technically these are informational barriers, WWTF staff are tasked with convincing their Board and eventually the public that investing in co-digestion is an economically and environmentally beneficial decision. WWTF directors need to have leadership and communication skills to secure buy-in from their Boards and staff.

Insufficient Staff Resources

Some survey respondents indicated their WWTF staff is not capable or willing to handle additional operations and maintenance commitments associated with co-digestion. WWTFs may need to train staff to manage and maintain a co-digestion program. Respondents indicated that training may not be enough to handle the new operational requirements of co-digestion and that new staff would need to be hired, ultimately adding to the financial burden of co-digestion.

(4) Biological Barriers

The principal mandate of WWTFs is to treat incoming wastewater and discharge it in compliance with effluent standards. Bacteria are an important part of the wastewater treatment and anaerobic digestion processes. The introduction of various food-related waste streams can make the bacteria react in different and sometimes unexpected ways, which brings operational and environmental risk to the WWTF. Biological concerns along these lines are a barrier to adoption of co-digestion practices, though many WWTF have used a small co-digestion pilot to see how its bacteria will react and how its facility will continue to perform under its fundamental treatment mandate.

Main concerns about the incoming waste include the following:

Volatile Solids

Volatile solids destruction efficiency is regulated by the EPA under EPA 40 CFR. Bringing in food waste that increases the amount of volatile solids in the digester is a concern for many WWTF's, since it is unclear if the digester will be able to handle them and break them

down efficiently enough. If the digester's bacteria cannot handle them, there may either be a rapid rise in sludge content or foaming, either of which a problem that WWTF managers want to is avoid. One survey respondent had the additional concern that since his WWTF uses ultra-violet disinfection (as opposed to chlorine-based disinfection), that more electricity would be needed to run the UV lamps if there was an increase in volatile solids.

Nutrient Content

Generally, waste streams come in the categories of proteins, carbohydrates, and fats, which all have varying levels of carbon, nitrogen, and phosphorus. A low carbon to nitrogen ratio is generally bad for digester performance. Nitrogen and phosphorus are both important to the digestion process, but can be toxins at very high concentration levels. One survey respondent voiced concern that co-digestion had the potential to release phosphorus back into the waste stream, and given discharge limits, extra phosphorus removal would be difficult and expensive.

Acidity

The anaerobic digestion produces many intermediate acid products before the end product of methane. However, if there is too much acid (a problem that often occurs with FOG waste), then this may inhibit the methanogenesis process (production of methane). Monitoring the relative acidity or alkalinity of the waste is important to maintain process control in the digester.

Cleanliness

Some waste is described as not being "clean", which means they may have foreign or hazardous materials present in addition to the liquid and solid digestible wastes. Throwaway cutlery and chopsticks are a common example that need to be screened by a separate machine before they can be put into the digester. If these bulky wastes get into digester, it can cause erosion and clogs in pumps and other equipment, which will lead to increased operation and maintenance costs.

More quantitative information on potential waste streams is needed to address these concerns before WWTF's can begin using those wastes. This type of waste characterization was the subject of a recent study by WERF, whereby they did detailed laboratory and on-site testing to determine how digesters reacted to different types of waste streams.[29]

In general, it is better to slowly feed waste streams into the digester rather than "batch feed" which could upset the digester. It has been recommended by WERF and many co-digesting

[29] Water Environment Research Foundation, "Co-Digestion of Organic Waste Products with Wastewater Solids"

WWTF managers to increase feed frequency and decrease the feed volume per cycle to optimize digester efficiency and decrease risk of upset. Unfortunately, since many WWTF's are limited by human resources, personnel cannot be on-site all the time to perform and monitor this continuous feeding, so this organizational constraint is important to keep in mind.

(5) Regulatory Barriers

Co-digestion is a relatively new process in the U.S.; therefore, much uncertainty exists over current and future regulatory requirements and issues that may arise as more WWTFs begin adopting the practice. WWTFs may be subject to new regulatory requirements. WWTFs must determine how to balance meeting current regulatory requirements for treating wastewater and new requirements that are associated with co-digestion.

Compared to the other barrier categories regulatory barriers were ranked rather low. Many survey respondents indicated that the barriers they listed under this category were "manageable" but upon further discussion in follow-up interviews, they emphasized challenges of regulatory uncertainty. Regulatory uncertainty and risk about the future of wastewater and solid waste regulations was the most common barrier reported by survey respondents.

Wastewater Regulatory Obligations

WWTFs have a legal obligation to meet wastewater treatment requirements stipulated in the Clean Water Act. This is their mandate and primary focus. Some respondents noted that currently regulatory requirements are a higher priority than any benefits they may receive from investing in co-digestion. An added complication of co-digestion is that the resulting biosolid product may not meet current regulatory standards due to nutrient loading from the addition of food waste.

Solid Waste

The lack of regulatory support from State solid waste agencies to ban or divert organic waste from landfills creates little incentives for WWTFs to adopt co-digestion. Survey respondents indicated that a lack of regulatory incentives, resources, and guidance from State environmental agencies on how WWTFs can comply with solid-waste regulations and develop relationships with solid-waste agencies has been a barrier to co-digestion.

Clean Air Regulations and Permitting

Difficulties with obtaining air pollution permits and navigating air-related regulatory requirements were common barriers cited by survey respondents. Some noted that the cost of compliance was high while others indicated that unfamiliarity and lack of a "regulatory roadmap" for air permitting and regulations was a barrier. Additionally, air pollution requirements may require infrastructure upgrades and costly retrofits adding to eventual costs and payback concerns.

Renewable Energy

Some survey respondents indicated that the federal government and many State environmental agencies place a low priority on making biogas a viable renewable energy alternative. If considered at all, biogas production, especially by co-digestion at WWTFs, is often ranked as a low priority. This coincides with survey respondent's claims that there are inconsistent governmental policies supporting renewable energy development by co-digestion, indicating that regulatory agencies are undecided on their support of biogas generation by co-digestion.

Furthermore, many survey respondents indicated they have experienced significant difficulties working with energy providers such as energy and gas utilities. Some survey respondents have had a difficult time establishing connections to the energy grid due to their underdeveloped relationship with their local electric utility. Often electric utilities have stronger negotiating power due to regulations or existing electric utility policies. For example, some WWTFs cannot connect to the grid because existing rules will only allow them to use energy on-site. This creates a disincentive for WWTFs to become net-producers of energy. In some cases, biogas is not considered a renewable energy source, this can cause the price for energy generated by biogas to be less than what an electric utility pays for energy generated by wind or solar power.

Regulatory Uncertainty & Risk

Many survey respondents indicated that regulatory uncertainty pertaining to future Clean Water Act regulations as a barrier to investing in co-digestion. In particular many respondents believe regulations for nutrient removal are on the horizon. Many utilities are waiting for a clear indication of what direction this regulation may go before deciding to invest in any additional infrastructure upgrades. Furthermore, co-digestion may impact a WWTF's nutrient discharge, which may then impact permit compliance.

Potential nutrient management reduction requirements may impact digesters utilizing co-digestion, as these digesters add to nutrients on-site. Removing nutrients from sewerage sludge can increase operations and maintenance costs. Given the costs and under-developed

markets for nutrient byproducts, these technologies are not widely used. Therefore, nutrient recovery regulations will result in high-cost infrastructure investments that can prevent a co-digesting program from forming and it can even, as one survey respondent expressed, "kill a current co-digestion program."

Unclear and overlapping regulations that may pertain to co-digestion and uncertainty over who oversees enforcement adds to the risk of investing in co-digestion. In California for example, CalRecycle and the CA State Water Board are debating who has jurisdiction of solid waste and permitting responsibilities at WWTFs. Additionally, zoning issues may arise if receipt food wastes and additional secondary feedstock's may challenge a particular WWTF's status (e.g. industrial vs. agricultural).

(6) Informational Barriers

While almost all of the WWTFs we surveyed are familiar with the practice of co-digestion, most have not had in-depth exposure to co-digestion. There are many uncertainties with an investment in co-digestion, and case studies of successful co-digesting WWTFs have been helpful to date in spreading information on best practices in co-digestion. In the end, each WWTF is different, however, and co-digestion requires a detailed look at the feasibility of project with respect to financing and waste supply. Survey respondents most commonly highlighted information barriers with respect to financial knowledge and waste supply knowledge.

Financial Knowledge

Many facilities we surveyed mentioned the need to better understand both the costs and benefits of co-digestion, both in general terms as well as with some information specific to their location. The most common example of desired information was local tipping fees. Facilities want to know how high tipping fees would need to be to break even on a co-digestion investment or simply how high of a tipping fee they would receive from haulers bringing in food-related waste streams.

Facilities are generally very familiar with the rates they spend on electricity for their facility as it accounts for a high portion of their operating costs. About 75% of survey respondents have cited energy prices as a driver to save energy or produce energy on-site. But facility operators' knowledge about the investment costs of upgrading their facilities to accommodate co-digestion procedures is lacking. The range of costs could be highly variant as well as each WWTF has different infrastructure needs.

Waste Supply Knowledge

Lack of information on the availability of waste streams was frequently mentioned in our surveys and interviews. Over 10 survey respondents made direct mention of an information barrier with respect to waste supply. Some respondents described needing more knowledge on the type of waste streams available in their local region, and were concerned that lack of such knowledge would inhibit their abilities to evaluate the economic benefits of co-digestion. Other respondents said they had trouble getting the word out to their communities that they could accept food-related waste streams. Facilities in rural areas expressed worry about not having enough useful waste streams within a reasonable distance of their WWTF. A facility in Hawaii cited that the food waste collection system was not well understood. One enterprising WWTF used their own regional surveying method to collect information on the types and quantities of waste available. Finally, some facilities mentioned that they thought their affiliated municipality should implement a FOG collection program to help in bringing in more regular streams of waste.

Competition for food waste may become an issue as more WWTFs turn to co-digestion, especially in urban areas with a high concentration of WWTFs and high tipping fees. WWTFs want to remain aware of other nearby facilities that are practicing co-digestion.

Evaluating Potential Solutions

There are several roles that EPA Region 9 can take to drive adoption of co-digestion. In weighing its options, there are a number of factors the Agency should consider. Namely, the EPA should undertake solutions that are expected to be:

1. *Cost-effective.* Low-cost options to help WWTFs should be taken up first, and those that are more expensive and time-intensive to implement should be expected to have a high payoff in terms of their effectiveness in breaking down a barrier to co-digestion.

2. *Effective in overcoming the barrier that they target.* The EPA should focus their resources on strategies that are expected to allow multiple facilities to overcome a given barrier.

3. *Effective in meeting the EPA's strategic goals for co-digestion.* EPA Region 9 provided four strategic goals for co-digestion:

    a. Taking action on climate change by harnessing a local source of renewable energy, decreasing emissions associated with hauling municipal solid waste,

sequestering carbon with the application of the nutrient-rich byproducts onto farmland, and diverting organics from landfills – the third largest source of methane emissions in the United States.

b. Protecting and improving the quality of America's waters. Co-digestion is believed to affect this outcome primarily by offering WWTFs electricity cost savings and thereby making additional funds available for investment in water treatment facilities.

c. Advancing sustainable development by producing local renewable energy, managing organic waste locally, creating valuable byproducts, and generating revenue, for example through energy savings and/or sales.

d. Preventing pollution by drawing less energy from non-renewable sources, by improving soil properties for optimum plant growth and thereby decreasing the need for pesticide and synthetic fertilizers.

To the extent that a solution to a co-digestion furthers all of these goals, it may be preferred by the EPA.

4. *Likely to be implemented by WWTFs.* Ease of implementation by WWTFs will be key to the success of any solution. The EPA should take care to ensure that uptake of any proposed solution is not hindered by the same barriers that are already preventing WWTFs from investing in co-digestion.

5. *Able to be enacted by the EPA.* According to staff at EPA Region 9, the Agency has historically affected outcomes by a) enforcing regulation, b) providing funds to get projects off the ground, and c) developing and disseminating knowledge. This factor may prove the most restrictive for the EPA, as many of the solutions needed to break down co-digestion barriers are likely to be outside the direct control of the Agency.

Recommendations for the EPA

Survey responses indicate there is a growing awareness and a gradual uptake of co-digestion practices. Before offering potential solutions to accelerate WWTF's use of co-digestion, it is useful to consider the "business as usual case"—i.e., what would happen should no new

EPA action be pursued. Under this scenario, it is likely that co-digestion will occur mostly among WWTFs that possess the enabling factors discussed on page 14. As shown in Figure 8, WWTFs that have already decided to co-digest report facing significantly lower barriers than those not yet co-digesting in almost every barrier category. This suggests that many of those facilities holding full information, a clear business case, and limited other obstacles to co-digestion have already begun co-digesting. Co-digestion is not a new technology, but results from the survey and interviews suggest that uptake has increased significantly over the last seven years as a result of increased access to information, knowledge of success stories, capital-funding options and other policies. Thus, though it is impossible to know the exact level and pace of co-digestion uptake absent any EPA action, it seems reasonable to assume that any work the Agency can do to break down the barriers reported by survey respondents should help speed the move to towards co-digestion's full potential.

Interviews with WWTFs revealed a number of actions the EPA can take to help WWTFs overcome barriers to co-digestion. Further information about the rules governing specific actions by the EPA and the EPA's on-going prioritization of their aims for co-digestion is required to fully measure potential solutions against the criteria outlined in the previous section. However, these criteria have been used to segment recommendations for the EPA into three broad categories:

- *Low-hanging fruit:* These are recommendations that are likely to be clear winners along all lines, i.e. they are relatively low-cost to implement, likely to help WWTFs, and fit within the EPA's current role. These solutions are discussed first and may represent a good place for the EPA to begin its efforts.

- *Resource intensive:* There are additional recommended actions the EPA could pursue that would be more challenging. These recommendations may be more difficult to carry out as they require more staff time, greater financial resources, and/or stretch the historic role of the agency.

- *Multi-stakeholder:* Lastly, there are actions that may be necessary to create a more favorable environment in the long-term for co-digestion uptake. These recommendations are likely to require participation and action beyond the EPA's mandate, and entail collaboration with willing WWTFs and other stakeholders. These recommendations may require more time to achieve and could be subject to significant political and regulatory opposition.

Table 5 summarizes the recommendations to the EPA to help WWTFs overcome key barriers.

Table 5: Matrix of co-digestion barriers and suggested solutions

Low-hanging fruit Resource-intensive Multi-stakeholder		Barriers to Co-Digestion											
		FINANCIAL				INFORMATIONAL		BIOLOGICAL	INFRASTRUCTURAL		ORGANIZATIONAL		REGULATORY
Overall Goal	Specific Recommendations	Funding Priorities at Facility	Funding Upfront Costs	Ongoing Revenue or Cost Benefits to Operations	Long Payback Periods	Knowledge of Costs, Benefits & Available Financial Resources	Waste Supply Knowledge	Volatile Solids, Nutrients, & Other Concerns	Odors	On-site Space Limitations	Leadership Support	Staff Resources Needed	Regulatory Risk and Uncertainty
Create opportunities for information sharing and partnership development	Create Buddy Systems					X	X	X					
	Host Regional Information Sharing and Networking Events					X	X	X				X	X
	Targeted outreach to WWTFs to increase consideration of co-digestion					X	X				X	X	
Create and update online resources	Finance and funding online info					X							
	Model contracts						X					X	
	Mapping Tool						X	X				X	
	Co-EAT					X						X	
	Regulatory pathways/road map											X	X
Expand financial incentives and assistance for co-digestion	Upfront investment costs	X	X		X								
	Ongoing revenue streams	X		X	X								
Streamline regulatory process	Simplify permitting requirements											X	X
	Increase regulatory incentives			X	X								X

Low-Hanging Fruit Recommendations

1. Create opportunities for information sharing and partnership development

Though only one out of 48 survey respondents indicated that they were not familiar with the co-digestion process, a number of facilities indicated that they face a lack of push, drive or mandate from stakeholders or management towards co-digestion, or that they don't have all the information they need to begin co-digesting. Thus, while there does not seem to be much need for the EPA to create initial awareness of co-digestion, the Agency could play a large role in connecting stakeholders and making available the information that facilities need to overcome their individual barriers to co-digestion.

Create Buddy Systems

The EPA Region 9 can create and facilitate a "buddy" system that pairs up successful or experienced co-digesting WWTFs with other facilities that are considering or interested in the technology. Many of the WWTFs that were interviewed emphasized the value in speaking with co-digesting WWTFs. Connecting facilities could help WWTFs that are considering co-digestion to understand the short and long-term costs and benefits of investing in the process. Experienced WWTFs will also be able to shed light on the permitting and regulatory requirements, and provide advice to facilities on how to overcome these challenges. Lastly, experienced WWTFs can help to alleviate fears of damage to existing infrastructure.

The WWTFs interviewed were explicit that they benefited from talking to WWTFs who have experience with co-digestion and also responded enthusiastically that they would be willing to provide advice and guidance to other facilities who are considering the transition. Interviews revealed that there is a sense of pride, entrepreneurship and leadership among successful co-digesting WWTFs and a willingness to help others make the transition. One caveat discovered during interviews was that facilities would be less willing to speak to others that are likely to compete for nearby waste products. It is therefore important that the buddy system be sensitive to geography: the EPA should connect facilities that have characteristics in common (i.e. similar property-size constraints, electric utilities, and/or financial conditions) but are not in the same geographic location.

The extent to which the EPA actually connects these "buddies" depends on what information the Agency is allowed to share, what information individual WWTFs are willing to make public, and staff resources available for this program. The program could involve providing names of facilities, providing contact information, or building on current

survey results to create a list of willing WWTFs and their specific barriers of expertise. Ideally, the EPA could even expand program into a "peer exchange," whereby the EPA facilitates site visits and meetings amongst WWTFs that are facing and have overcome the same barriers to co-digestion

It could also be valuable to buddy WWTFs that are facing significant barriers to understanding costs and benefits of co-digestion with research institutions and students who have or could potentially work on financial modeling. A few respondents indicated that students and faculty at colleges, specifically the University of Massachusetts at Amherst and Cornell University, had provided valuable help with financial modeling that had allowed them to overcome informational barriers and undertake co-digestion. To the extent that the EPA can connect these colleges (and others that have student project programs) with WWTFs, facilities may be able to find low-cost help with complicated financial models.

Host Regional Information Sharing and Networking Events

EPA Region 9 can organize and host information-sharing events that bring together WWTFs and sectors with which they don't necessarily have close ties and would need to work with to undertake co-digestion. Examples include regulatory bodies, waste management companies, haulers, engineering firms, and others. In doing so, WWTFs that are not co-digesting can close informational gaps and be able to more realistically evaluate the costs, benefits, and next steps for co-digestion. Survey respondents at WWTFs reported that strong relationships are key to overcoming barriers. One respondent believed that relationships "based on trust" with local haulers was critical to the success of their co-digestion program. It was suggested that the effects of contaminated FOG on their co-digestion equipment was of major concern for their facility, and that this barrier was overcome by getting to know the haulers and communicating with them that trust in their waste product is integral to their business dealings.

Similarly, one respondent credited strategic relationships with their local regulators as the key to success for his facility's program. "Some of my peers seem to think their regulators are from a different planet," he said, "but once we're able to explain to them what we're trying to do, they are usually on board." Respondents suggested that most of the conferences today are geared towards facilities that are already co-digesting, and it would be prudent for the EPA to broaden the agenda and focus on WWTFs that are not yet co-digesting. The EPA could work with industry groups to organize or finance such events and market to potential participants. The challenge here for the EPA is to research and reach out to WWTFs that are good candidates for a co-digestion program and to encourage their staff participation in these events.

Another information-sharing role for the EPA relates to public-private partnerships for co-digestion. The EPA's role in this solution would be to provide networking opportunities and facilitate information sharing amongst potential private-sector partners and WWTFs. It is understood that the EPA could face issues in implementing this recommendation due to limits on its ability to favor particular companies. But any informational role that could be played by the Agency could have significant payoffs. In interviews, a number of respondents suggested that such partnerships could be an effective, forward-thinking response to the upfront capital barrier faced by many public facilities. Since private investors are not using public funds and therefore likely face less risk-averse decision makers, they may be in a good position to take on or lessen any financial risk involved with co-digestion in return for expected profits.

This solution does create some complex contracting requirements and organizational issues, but a number of WWTFs have already used it successfully to get co-digestion off the ground. For example, Encina Wastewater Authority currently uses co-digestion to produce nearly 80% of its 2.2MW annual electricity needs through a partnership with hauler Liquid Environmental Solutions that split the cost of building a receiving station for hauled-in waste. Under this arrangement, the hauler provided an agreed-upon percentage of the upfront capital cost for the receiving station. Other benefits received by Encina included reliable tipping fee revenues and known quality and quantity of waste. In return, Encina is able to provide exclusivity and predictability for the waste hauler.[30]

Another successful public-private partnership has been undertaken by Central Marin Sanitation Agency (CMSA). When interviewed, the General Manager at CMSA reported having an overall positive experience setting up a public-private partnership. CMSA and Pacific Gas & Electric co-funded a report released in 2009 on the feasibility of methane capture in the Central Marin area. The study, completed by Kennedy/Jenks Consultants, fostered important relationships and began important conversations between interested stakeholders and led to the implementation of a successful co-digestion program that generates 75 percent of the facility's energy needs. The program features a further partnership between CMSA and Marin Sanitary Service, a private hauler that brings food waste from 35 Marin restaurants. The hauler took on the task and risk involved in locating sufficient, quality waste for the program.[31]

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[30] PRWeb, "Encina Wastewater Authority Announces Joint Venture to Produce Renewable Energy Through Recycling Waste Cooking Oil," January, 17, 2014, *http://www.prweb.com/releases/2014/01/prweb11497996.htm*

[31] Central Marin Sanitation Agency and Marin Sanitary Service, Inc., "Agreement Between the Central Marin Sanitation Agency and Marin Sanitary Service, Inc. for Commercial Food waste Processing and Disposal Services," May 2013, *http://www.cmsa.us/assets/documents/administrative/ADM%20Contracts%20MSS%20F2E%20Final%2005%202013%20Full%20Signed.pdf* (additional detail provided in interview)

Some private partners have been willing to take on an even greater share of payback risk in return for profits. An example is Anergia, Inc. This Ontario, Canada-based company has made a number of investments in co-digestion infrastructure. In 2012, Anergia invested in a 2.8MW biogas-powered fuel cell at the Inland Empire Utility Agency (IEUA) wastewater facility. Anergia owns and operates the fuel cell and sells the generated power (about 60 percent of the facility's needs) to IEUA under a 20-year power purchasing agreement[32] Another co-digesting WWTF interviewed is looking into the use of their produced biogas for transportation rather than electricity, and is considering a partnership with the manufacturer of the technological equipment needed to do so. Such a partnership would benefit the manufacturer by drawing attention and interest to their new technology.

Of course, public-private partnerships are not always easy to set up. They often require connections, negotiations and contracts that are beyond the usual operations of wastewater facilities, and therefore can be subject to the same barriers of organizational drive and informational gaps previously mentioned. For example, Victor Valley Wastewater Reclamation Authority (VVWRA) reported significant difficulties in locating solid waste haulers that were reliable and willing to contribute sufficiently to any co-digestion partnership. Nonetheless, VVWRA has recently initiated a co-digestion project with Anergia using an Innovative Technology Grant from the California Energy Commission that the facility believes will generate 90 – 100 percent of its energy needs by 2015. The EPA could play a role in spreading public-private partnership success stories and in connecting known and interested partners like Anergia and Liquid Environmental Solutions with prospective co-digesters.

Targeted outreach to WWTFs to increase consideration of co-digestion

The EPA could use the enabling factors resulting from our survey and discussed on page 14 to narrow in on facilities that it believes are prime targets for co-digestion but which have not yet begun the process. Our survey suggests that nearly all facilities (98%) are aware of co-digestion, so the purpose of such outreach would not be to introduce the concept. Instead, materials provided could include success stories, links to online resources, and offers of "buddy-ing" with co-digesting facilities designed to create a clear, easy-to-visualize path forward for WWTFs. Interviews with WWTFs indicated that the organizational barrier related to a lack of "drive" amongst WWTF management could be most effectively overcome with a top-down Board mandate. It therefore may be useful for the EPA to

[32] "California gets 2.8 MW biogas fuel cell," Biomass Magazine, November 20, 2012, *http://biomassmagazine.com/articles/8342/california-gets-2-8-mw-biogas-fuel-cell*

provide materials to staff that can be used to convince the Boards of Commissioners that oversee facilities of co-digestion's ratepayer benefits. Interviews suggest that these materials should frame co-digestion as a means to energy independence and a form of insurance against rising energy prices.

2. Create online resources of finance opportunities and provide model contracts

Financing and funding opportunities

The EPA Region 9 can create a new section of their co-digestion website to provide a comprehensive overview of available funding opportunities. This financial tool will help WWTFs overcome informational barriers and financial gaps. Many WWTFs surveyed indicated that they have not found a comprehensive online resource of financing options or opportunities. The online resource should:

- summarize available opportunities;
- list eligibility requirements; and
- provide links to the finance mechanism.

Below is a list of finance opportunities utilized by WWTFs that were surveyed, interviewed, or researched online. See Appendix C for further details of these programs.

- Landfill diversion program incentives
- Renewable Energy Credits
- USDA Advanced Biofuel Payment Program
- Self-Generation Incentive Program
- Carbon credits
- Bioenergy feed-in tariffs
- Clean Water State Revolving Fund (SRF) loan
- Demonstration project grants from state energy commissions, Department of Energy, and Environmental Protection Agency

- Renewable Fuel Infrastructure grants

The EPA should include these finance programs on the website and update it annually. It is also important for the EPA to actively promote their online resources through to ensure WWTFs are aware of the resources and tools available to them. Although this may take staff time and resources, if the website is up-to-date, comprehensive, and broadcasted widely, it will play an important role in closing information gaps.

Model contracts

The EPA should provide model contracts or templates that WWTFs have established with haulers, electrical utilities, and energy (electricity or transport fuel) consumers. The EPA can use existing contracts (and block out confidential information and names of facilities) so WWTFs new to co-digestion do not need to start from scratch. Staff from a WWTF who was interviewed for this paper reported that reviewing existing contracts of a leading WWTF was extremely valuable and helped the facility to navigate what had felt like uncharted waters. Providing model contracts would be really valuable and will help WWTFs. Some of these contracts are already publically available,[33] but sharing them more widely may not be feasible for the EPA due to legal liability issues. Similarly, once WWTFs know that the EPA is sharing contracts online, they may be less willing to share these contracts so broadly.

Resource-Intensive Recommendations

The following are more resource-intensive actions EPA Region 9 may consider. These recommendations may be more difficult than the "low hanging fruit" recommendations above to carry out as they require more staff time or greater financial resources.

The EPA should update and expand existing online resources. The EPA offers several useful tools online, but they are not wildly used or known about. The following online resources could help WWTFs overcome informational barriers. However, to be effective they would need to be updated annually, expanded to include more metrics, and widely marketed to the WWTF community.

[33] At least one model contract is already available online, see Central Marin Sanitation Agency and Marin Sanitary Service, Inc., "Agreement…" *http://www.cmsa.us/assets/documents/administrative/ADM%20Contracts%20MSS%20F2E%20Final%2005%202013%20Full%20Signed.pdf*

EPA Mapping Tool

The EPA created a very informative mapping tool to connect organic waste producers (e.g. grease rendering facilities or food processing facilities) and potential users (e.g. WWTF's) for the purpose of biogas production through co-digestion. The tool would be of greater help to WWTFs if it included more types of haulers (i.e. not just FOG haulers, but also haulers of food scraps, slaughterhouse waste, spent grains from breweries, etc.) and specified the quantity of waste available or hauling capacity.

If WWTFs are willing to share sufficient information, the tool should also describe the effect of the type of waste on digesters and provide information on which WWTFs have used this type of waste before. This would help WWTFs overcome biological and information barriers. This level of detail would make the tool very useful to WWTF staff in researching the feasibility of co-digestion. The tool should be updated annually and promoted more broadly throughout the waste and wastewater industry. This would require a modest level of EPA staff time and could be a subset of work assigned to a summer intern. This tool fits within EPA's current information-sharing role and could be an effective bridge for WWTFs, organic waste producers, and haulers.

EPA CoEAT

One option available to the EPA to assist WWTFs overcome their lack of understanding of financial costs is updating and marketing EPA Region 9's Co-digestion Economic Analysis Tool (CoEAT) financial modeling tool.[34] However, it is not totally clear that this would be a good use of EPA resources. It does seem that WWTFs in EPA Region 9 have heard of the tool - 7 of the 10 Region 9 survey respondents indicated being aware of the tool. It is even the case that a number of facilities outside Region 9 had come across the CoEAT tool - of 47 national survey respondents, 21 had heard of CoEAT. However, only 2 respondents (one from California and one from New York) had actually used the tool. Interviews with the 2 facilities that *had* used the CoEAT tool revealed that both used the tool only to check modeling that they had developed independently and to cross-check inputs to make sure that they had not missed any major costs or benefits. These respondents described the lack of customizability and the lack of trust in something created by a third party not familiar with any given plant's circumstances as reasons they believed that CoEAT would only ever be used by facilities as a corroborating tool.

[34] U.S. EPA Region 9, "Organics: Co-Digestion Economic Analysis Tool (CoEAT)," *http://www.epa.gov/region9/organics/coeat/*

A final piece of feedback on CoEAT offered by a WWTF that did use the tool was that his facility was looking to compare the financial impacts of co-digestion with other options at their disposal to achieve energy independence. In his opinion, this further limited the tool's usefulness, since its result represented only one piece of the financial puzzle the facility was trying to solve. He believed that other facilities were likely to face the same issue in choosing to use CoEAT.

Given the state-specific regulatory issues and capital funding options mentioned in the barriers section above, it would be extremely difficult and likely not cost-effective for the EPA to make the CoEAT tool sufficiently customizable for WWTFs to find it reliable as a stand-alone input to financial decisions. The facilities using CoEAT did, however, state that the tool offered significant value in its role as a cross-checking mechanism, leading to important edits to WWTFs' own modeling and providing important corroboration for facilities' modeling when putting together presentations to stakeholders and decision-makers.

Given these reactions to CoEAT and the difficulties in customizing the tool, the EPA's scarce resources may be better spent elsewhere. If the EPA does wish to continue making the tool available, it may want to seek specific feedback on CoEAT and update the tool for known changes in data since its creation. However, knowing that it will likely be used as a secondary check on the magnitude of costs and benefits, it may be wise to simply list additional factors that should be considered by WWTFs rather than aiming to make the tool fully customizable. Should the EPA continue to offer the CoEAT tool, the Agency should certainly promote its benefits more through industry groups, biogas events and outreach to WWTFs. As things stands it appears the tool is not being used.

Another alternative to updating its own financial analysis tool would be to direct WWTFs to a financial analysis tool recently developed by WERF. That tool is available online and free to subscribers (or $175 for non-subscribers). This may be an effective way to provide WWTFs with the value of a cross-check of their numbers without using significant EPA resources.

Regulatory Roadmap

The EPA offers important regulatory information and requirements online that are geared to WWTFs in particular states.[35] However, there is a disconnect because WWTFs that do not co-digest still struggle to understand the regulatory pathway to begin co-digestions.

[35] U.S. EPA "AgSTAR: Permitting Practices for Co-digestion Anaerobic Digester Systems," *http://www.epa.gov/agstar/tools/permitting.html*

With some modifications, this tool could help WWTFs overcome information and staff knowledge gaps.

The EPA should keep updated an online overview on the regulatory pathway for WWTFs in Region 9. This flow-chart would show the required federal and state permits a WWTF would need to get when developing a co-digestion program. This will help WWTFs overcome regulatory information gaps and provide greater clarity about the permitting process and requirements.

As long as the Regulatory Roadmap tool is comprehensive, up-to-date, and broadcasted widely, it may be an effective method in helping WWTFs feel greater familiarity about the regulatory pathway. It does not, however, help to overcome the "regulatory risk" barrier, as it cannot guarantee permits if certain conditions are met; it can only provide an overall framework. This recommendation falls within the EPA purview, as it is educational and information-sharing nature.

Multi-Stakeholder Recommendations

As discussed above, financial and regulatory barriers pose a significant challenge to WWTFs considering co-digestion. Many of the financial and regulatory barriers cannot be solved by the EPA alone, and require a broader industry and stakeholder-based effort. Below is an outline of important steps that, if carried out successfully, may significantly improve the success and uptake of co-digestion. These recommendations are, however, more difficult in nature to execute: they require strong sector support, stretch the historical role of the EPA, and may face political challenges.

1. Expand financial incentives and assistance for co-digestion

Upfront Capital Costs

Many of the financial opportunities listed on in Appendix C were critical to helping WWTFs overcome financial barriers. More of these financial incentives are needed to help WWTFs make the transition and afford the upfront capital costs. The EPA can work with co-digestion stakeholders to advocate for additional financial incentives or the expansion of eligibility requirements of existing programs. Although this may be a tenuous position for the EPA, it is clear that attention needs to be put on protecting existing grant programs and expanding the eligibility of others.

There are currently several federal and state grants, including the Renewable Fuel Infrastructure Grants, EPA Clean Water State Revolving Fund, Green Infrastructure Grants, and others. EPA can work with regulators and funding agencies to expand the criteria of the grants to include co-digestion facilities. To the extent possible, EPA and stakeholders can advocate for more funding for co-digestion related grants. Lastly, there is a need for start-up grants to help WWTFs cover the upfront capital costs. Creating a designated EPA fund for short-term co-digestion grants would provide an important stepping stone needed by many facilities.

This solution will not be achieved overnight and may face opposition by managers of the existing loans and grants. Efforts to broaden the eligibility of existing finance opportunities or create new grant programs is a resource-intensive activity that stretches the EPA's historic role. However, a success here could be a game-changer for many WWTFs and enable many more facilities to invest in co-digestion.

Ongoing Revenue Streams

There are several streams of funding that make co-digestion feasible for WWTFs. These include renewable energy credits, carbon credits, tipping fees, payment for biofuels, and others sources of ongoing revenue that help to make the investment in co-digestion profitable in the longer-term. These funding sources also help to tip the scale in favor of transition to co-digestion when WWTFs carry out cost-benefit analysis in the earlier decision-making period. Similar to our previous recommendation, the EPA Region 9 can work with WWTFs to reach out to funding and regulatory agencies that are responsible for designing the framework of these financial mechanisms (i.e. federal EPA, state energy commissions, etc.) to broaden eligibility to include co-digesting facilities. EPA can also work with regulators and stakeholders to determine if there are other potential revenue sources that could be tapped-into by WWTFs. This will be a challenging endeavor. EPA and WWTFs will need to reach out to decision-makers beyond their regular purview. It may also take a significant amount of staff time and resources.

2. Work with regulators to simplify permitting requirements

The EPA can have a significant role in helping WWTFs overcome the regulatory barriers discussed above, particularly those related to regulatory uncertainty. WWTFs in many states face conflicting or duplicative regulatory requirements for co-digestion. Streamlining regulations and creating a clear division of agency responsibility and jurisdiction is necessary for WWTFs to feel greater clarity about the regulatory and permitting process. EPA has the potential to facilitate this process by collaborating with key regulatory agencies to improve regulations and reduce overlap.

It's also important to note that EPA may wish to consider the concerns WWTF have with regard to nutrient management programs and/or the development of new standards. Any regulatory mechanism developed by EPA for nutrient management should create incentives to recover nutrients from digestate by increasing the value of those nutrients as byproducts.

3. Help establish state standards that create incentives or favorable conditions for co-digestion

There are several types of state mandates that can create incentives or a favorable environment for co-digestion. For example, landfill diversion mandates – bans or limitations on disposing of organic waste in landfills – can have favorable repercussions for WWTFs. Landfill diversion mandates result in increases in the amount of organic waste that needs to be processed, repurposed, or reduced, as opposed to dumped. This provides both a large and reliable source of organic waste and a revenue stream from higher tipping fees. In addition, states may create complementary policies to help landfill diversion mandates succeed. For example, states may offer rebates, tax incentives, or low-cost loans for landfill diversion demonstration and deployment projects. The EPA and WWTFs can reach out to states that do not have strong landfill diversion mandates, educate policymakers on the benefits and model policies, and advocate for better waste standards. There is likely to be an appetite for this in states with limited landfill capacity (i.e. smaller and denser states) or an environmentally-inclined voter-base.

Renewable Energy Portfolio Standards (RPS) can also help make co-digestion feasible for WWTFs. When a state enacts a RPS, there is often a flexible compliance mechanism called a Renewable Energy Credit (REC), which creates revenue for renewable energy producers. WWTFs that co-digest can sell electricity from biogas, as well as produce and sell RECs. This creates a revenue stream that provides timely payback or return on investment. In states such as California where there is an RPS in place, the EPA and WWTFs can work with state regulatory bodies to ensure that WWTFs that co-digest are considered "renewable energy resources" and qualify under the RPS for RECs. EPA and WWTFs can also join broader advocacy efforts for other states to adopt an RPS. A campaign to establish an RPS is a highly political endeavor, often met by opposition groups. It is advisable for the EPA and WWTFs to *support* and *join* such an effort, but impractical for them to attempt to spearhead it.

Barriers & Enablers EPA Cannot Address

There are a number of barriers that are not likely to benefit from action from the EPA, and these are briefly discussed here. These barriers are likely to persist even in the 'best case' scenario where the EPA focuses all possible resources on co-digestion efforts.

Electricity Prices

Discussions with survey respondents suggested that for those facilities not yet co-digesting, high energy costs could be a major driver for management and Board of Director interest in co-digestion in the future. With the exception of those facilities facing a number of the enabling factors mentioned above, WWTFs will likely require increased energy costs to make the financial modeling favor co-digestion. As mentioned above, the EPA can target their outreach to facilities with high energy costs and can communicate to facilities the energy independence benefits to co-digestion. However, the Agency is not in a position to significantly, directly affect society's energy costs. Making energy more expensive would involve major changes to rate-making at state utility commissions along with significant political battles. Given that high energy costs appear to be a significant piece of the financial puzzle needed to create interest among non-co-digesting WWTFs, this will likely continue to be a major barrier until markets and regulators make energy more expensive.

Land & Odor Constraints

One of the major infrastructural barriers voiced by survey respondents was a lack of available land to build solid waste receiving stations. Respondents also had concerns about the excess odors created by receiving waste haulers. These barriers were especially significant for WWTFs in dense urban areas, and are particularly hard hurdles to overcome. Beyond connecting WWTFs with "buddy" facilities that may have come up with creative solutions to these issues, the EPA can not do much to lessen their severity.

Adequacy of Future Food Waste Supplies

As mentioned above, the EPA can break down informational barriers by helping WWTFs connect with available waste streams. However, as more facilities begin co-digesting, there will be increased competition for the waste streams that are most easily used in the co-digestion process, such as FOG, brewery waste, and slaughterhouse materials. Some of this competition may even come from other renewable energy and waste programs, such as composting programs. Though the EPA could have some impact on this barrier by prioritizing co-digestion in future regulatory and funding decisions, presumably at some point enough facilities will co-digest that there will be insufficient FOG and other easy digester fodder to go around. This is not necessarily a bad thing, as further competition for waste may force increased investments by WWTFs so that they can digest other, tougher types of waste, thereby increasing total landfill diversion. Our discussions with WWTFs indicated that at some facilities, extra funds were already being put into infrastructural improvements to allow breakdown of tougher solid wastes. However, this extra needed investment may make the financial case tougher for facilities that feel a lot of competition for easy waste streams. In order to keep the financial costs from outweighing the benefits, therefore, it will be extra important for the EPA and other agencies to make co-digestion more financially attractive in the ways outlined above.

Conclusions

There are a number of environmental benefits to co-digestion that should cause the EPA's continued interest in promoting the practice at wastewater treatment facilities. However, a national survey and interviews with WWTF managers suggest that facilities still face significant barriers to adoption of the practice. These barriers are diverse, and the issues faced by a particular WWTF depends on its location, size, infrastructural limits, and a number of financial factors. This diversity makes it difficult to discern any 'biggest' or 'most common' individual barrier. However, survey results suggest that broadly speaking, financial and infrastructural issues seem to be having the most impact on WWTFs' decision to co-digest, and that organizational barriers may be particularly hard for WWTFs to overcome. The diversity of barriers also suggests that there is no "silver bullet" solution for the EPA to implement.

However, as discussed, there are several ways that the EPA can help. The options available to the EPA that can be considered 'low-hanging fruit' generally involve information-sharing, hosting networking events, and putting in contact facilities that are facing similar issues. If the Agency is willing to devote further resources to this issue, it would be wise to update its online mapping tool, provide updated and connected online tools, and undertake targeted outreach to promising co-digestion candidates.

There are limits, though, to what the EPA can do. Ultimately, in order for co-digestion to reach its full potential in the U.S., it needs to become a higher priority for state and federal regulators. Co-digestion needs to be recognized as an important clean energy and waste-diversion strategy, and supported with financing and streamlined regulations. For this to occur, there needs to be a multi-stakeholder effort. It may take time to improve the financial and regulatory landscape, but doing so will be key to producing the increases in co-digestion the EPA would like to see.

One issue that is not investigated in this report, but which may have significant implications for the EPA's co-digestion efforts, is the internal prioritization of landfill diversion and renewable energy outcomes at the Agency. Co-digestion is a just one piece of the landfill diversion and energy generation puzzle, and the EPA must weigh its effectiveness and costs against other renewable energy generation programs as well as other options such as energy efficiency and composting. Choosing between these technologies in assigning resources will depend on the specific aims and priorities of EPA Region 9, and discussions with the Agency suggested a lack of internal consensus on these. This lack of consensus may not affect the EPA's decisions in taking up the 'low-hanging fruit' recommendations in this report, but may need to be resolved as the Agency moves toward the more complicated, resource-intensive solutions that will no doubt lead to competition for limited resources amongst the many programs at the EPA.

Appendix A: Survey

Wastewater Treatment Facility Co-Digestion Survey

Hi! We are a team of graduate students of the Goldman School of Public Policy at UC Berkeley. Thank you from the bottom of our grad-school hearts for taking ten minutes to fill out our survey! The information gathered will be used to develop tools to help wastewater facilities decide whether to invest in anaerobic co-digestion. Your input is extremely valuable and appreciated.

1. Please share with us your contact information. We will not publish or distribute this information.

- Name
- Position
- Organization
- ZIP Code
- Email address
- Phone number

2. Please tell us about your wastewater treatment facility. What is your facility's utility service population?

3. What is the average daily flow at your facility?

4. Does your facility use anaerobic digestion?

- Yes
- No

5. What is the average detention time (number of days) of your facility's anaerobic digesters?

6. Do you believe your facility has surplus digester capacity for co-digestion of other organic wastes?

- Yes
- No

7. If so, what percentage of your existing digester capacity might be available for other organic wastes?

8. Do you see co-digestion as a financial opportunity for your facility via revenue that could be generated from tipping fees (from the disposal of trucked-in organic waste)?

- Yes
- No

9. Is the cost of energy a driver for your facility to save energy or produce on-site energy?

- Yes
- No

10. What price per kilowatt-hour does your facility pay for electricity ($/kWh)?

The following questions are about co-digestion, or the practice of adding energy-rich organic waste materials (e.g. Fats, Oils, and Grease (FOG) and/or food waste) to wastewater digesters with excess capacity.

11. Are you familiar with co-digestion at wastewater treatment facilities?

- Yes
- No

12. Does your facility currently practice co-digestion?

- Yes
- No
- In transition to co-digestion

Not Co-digesting: Answer to #12 = "No"

13. If your facility does not practice co-digestion, has your facility ever considered co-digestion?

- Yes
- No

14. Are you familiar with EPA Region 9's Co-Digestion Economic Analysis Tool (CoEAT) tool?

- No, I haven't heard of it.
- Yes, I've heard of it but never used it.
- Yes, I've used it before.

15. If you have used the CoEAT tool, how do you think the tool could be improved?

16. Based on your knowledge and experience, please arrange the following barriers to co-digestion by level of concern (the top should be your highest concern, and the bottom should be your lowest concern)

- Financial (e.g. upfront capital costs are too high, energy prices are too low, or other reasons)
- Informational (e.g. lack knowledge of co-digestion or its risks, costs, benefits)
- Biological/chemical (e.g. risk associated with dealing with wastes or the damages that wastes may cause on infrastructure)
- Infrastructural (e.g. do not have the capacity or space for bringing in extra waste streams)

- Organizational (e.g. complex decision making or lack of organizational resources)
- Regulatory (e.g. extra permitting required for expanded operations is burdensome)

17. Based on your knowledge and experience, please weight the following potential barriers from 1 to 5, with: 1 indicating a barrier that has no impact on your facility's decision to co-digest, and 5 being a barrier that has a very significant impact on your facility's decision to co-digest.

- Financial
- Informational
- Chemical/biological
- Infrastructural
- Organizational
- Regulatory

18. Please explain the financial barriers that your facility faces for investment in co-digestion. What policies or resources would help your facility overcome these barriers?

19. Please explain the informational barriers that your facility faces for investment in co-digestion. What policies or resources would help your facility overcome these barriers?

20. Please explain the regulatory or permitting barriers that your facility faces for investment in co-digestion. What policies or resources would help your facility overcome these barriers?

21. Please describe any other barriers for co-digestion that your facility faces (e.g. infrastructural, biological, organizational, etc). What resources or policies would help your facility overcome these barriers?

Co-digesting: Answered "Yes" or "in transition" to #12

22. If your facility does practice co-digestion, in what year did your facility start co-digesting (e.g. 2003)?

23. How much hauled-in waste (e.g. FOG, food processing waste, glycerin, etc.) do you co-digest per day, on average? Please specify units (e.g. gallons or tons).

24. What types of waste streams do you use for co-digestion? Check all that apply.

- Fats, oils, and grease (FOG)
- Slaughterhouse/rendering wastes
- Dairy waste
- Food and drink (non-alcoholic) processing wastes
- Solid food waste
- Brewery/winery waste
- Glycerin
- Septic tanks/portable toilet waste
- Other Please enter an 'other' value for this selection.

25. Are you familiar with EPA Region 9's Co-Digestion Economic Analysis Tool (CoEAT) tool?

- No, I haven't heard of it.
- Yes, I've heard of it but never used it.
- Yes, I've used it before

26. If you have used the CoEAT tool, how do you think the tool could be improved?

27. Based on your experience, please arrange the following barriers to co-digestion (the top should be your biggest barrier, and the bottom should be your lowest barrier)

- Financial (e.g. upfront capital costs are too high, energy prices are too low, or other reasons)
- Informational (e.g. lack knowledge of co-digestion or its risks, costs, benefits)
- Biological/chemical (e.g. risk associated with dealing with wastes or the damages that wastes may cause on infrastructure)
- Infrastructural (e.g. do not have the capacity or space for bringing in extra waste streams)

- Organizational (e.g. complex decision making or lack of organizational resources)
- Regulatory/permitting (e.g. extra permitting required for expanded operations is burdensome)

28. Based on your knowledge and experience, please weight the following potential barriers from 1 to 5, with: 1 indicating a barrier that has no impact on your facility's decision to co-digest, and 5 being a barrier that has a very significant impact on your facility's decision to co-digest

- Financial
- Informational
- Chemical/biological
- Infrastructural
- Organizational
- Regulatory

29. Please explain the financial barriers your facility faced for investment in co-digestion, and state how or if your facility overcame them.

30. Please explain the informational barriers your facility faced for investment in co-digestion, and state how or if your facility overcame them.

31. Please explain the regulatory or permitting barriers your facility faced for investment in co-digestion, and state how or if your facility overcame them.

32. Please describe any other barriers for co-digestion that your facility faces (e.g. infrastructural, biological, organizational, etc), or list policies and informational resources that would help a facility invest in co-digestion.

Appendix B: Interviews

WWTF Staff			
Name	**Title**	**WWTF Location**	**Status of co-digestion**
Rob Lowe	Laboratory Supervisor	Pierce County, WA	No
Brian Owsenek	Deputy Director	Centreville, VA	No
Dave Livingston	Plant Manager	Union City, CA	No
Kevin Maclean	Water Director	Hanover, NH	No
Santos Marquez	Laboratory Supervisor	Thousand Oaks, CA	Yes
Joe Zakovec	Superintendent	Janesville, WI	Yes
Jason Dow	General Manager	Central Marin, CA	Yes
Jose Lozano	Laboratory Director	Ithaca, NY	Yes
John Hake	Process Engineer	Oakland, CA	Yes
Matthew Krupp	Zero Waste Administrator and Project Manager	Palo Alto, CA	In transition
Logan Olds	General Manager	Victor Valley, Hesperia, CA	In transition
Kevin Hardy	General Manager	Encina, CA	In transition
Dan Thompson	Division Manager	Tacoma, WA	In transition

Non-WWTF Employees			
Name	**Title**	**Organization**	**Organization type**
Lauren Fillmore	Senior Program Director	Water Environment Research Foundation	Industry Non-Profit
David Parry	Senior Vice President	CDM Smith	Engineering Consulting Firm

Appendix C: Financial Opportunities

This is a list of standout funding streams used by or available to WWTFs to finance co-digestion. It is *not* a comprehensive list of all of the opportunities in Region 9.

Landfill Diversion Program Incentives

Many states are establishing standards and financial incentives to divert waste from landfills.

Eg: CalRecycle has $30 million in 2014/2015 for grants and loans to promote infrastructure development at facilities in CA that achieve GHG reductions by diverting more materials from landfills and producing beneficial products. This includes financial incentives for capital investments in composting/anaerobic digestions infrastructure and recycling manufacturing facilities.

Eligibility: Government entities: cities, counties, regional or local sanitation agencies, waste agencies & joint power authorities.

Learn More: http://www.calrecycle.ca.gov/Climate/GrantsLoans/

Renewable Energy Credits

States with Renewable Portfolio Standards often add flexibility into the policy by allowing for tradable Renewable Energy Credits (RECs), which creates revenue for renewable energy producers. WWTFs can sell one REC for every 1 MWh of electricity placed they place on the grid.

Eligibility: Varies by state: producers of renewable energy may include biogas, biomass, wind, solar, solar thermal, small hydro and others.

Learn More: *http://www.epa.gov/greenpower/gpmarket/rec.htm*

USDA Advanced Biofuel Payment Program

Funding is available on a quarterly basis for producers to support and expand production of advanced biofuels refined from sources other than corn kernel starch.

For 2014, the USDA will make nearly $60 million in payments to 195 producers of advanced biofuel.

Eligibility: Producers of biofuels derived from waste material, including crop residue, other vegetative waste material, animal waste, food waste, and yard waste.

Learn More: *http://www.rurdev.usda.gov/SupportDocuments/RBS-AdvanceBiofuelPayments3-14.pdf*

Self-Generation Incentive Program

This California program provides rebates and financial incentives to support existing, new, and emerging distributed energy resources on the customer/facility side of the utility meter.

Eligibility: Qualifying technologies include wind turbines, waste heat to power technologies, pressure reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells, and advanced energy storage systems

Learn More: *http://www.cpuc.ca.gov/NR/rdonlyres/D138BD29-2B31-4082-B963-2943114F5B68/0/2014_SGIPHandbook_V1.pdf*

Carbon Credits

Projects that digest eligible feedstocks and combust biogas can earn carbon credits for avoided methane emissions. The regulatory entity overseeing this market in California is the California Air Resources Board (ARB). One project type is avoidance of methane emissions from installation of ADs at dairy and swine farms. Projects of these types anywhere in the United States qualify for the California market. There are also other markets for this outside of California.

Facilities can receive roughly 0.5 carbon credits/metric ton of eligible waste.

Eligibility: Eligible feedstocks include: Dairy or swine manure, Post-consumer food waste, Industrial waste previously managed in an anaerobic lagoon

Learn More: *http://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm*

Bioenergy Feed-in Tariffs

The California Public Utilities Commission (CPUC) is now in the process of developing a feed-in-tariff for 250MW of bioenergy projects.

The California feed-in tariff allows eligible customer-generators to enter into 10-, 15- or 20-year standard contracts with their utilities to sell the electricity produced by small renewable energy systems (up to 3 MW). Based on the results of that Renewable Auction Mechanism the CPUC anticipates the starting price will be $89.23 per megawatt-hour (MWh).

Eligibility: Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Geothermal Electric, Municipal Solid Waste, Anaerobic Digestion, Small Hydroelectric, Tidal Energy, Wave Energy, Ocean Thermal, Biodiesel, Fuel Cells using Renewable Fuels

Learn More: *http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/SB_1122_Bioenergy_Feed-in_Tariff.htm*

Clean Water State Revolving Fund (SRF)

This program provides funding for projects across the country to meet the goals of the Clean Water Act by improving water quality, achieving and maintaining compliance with environmental laws, protecting aquatic wildlife, protecting and restoring drinking water sources, and preserving the nation's waters for recreational use. Low interest loans (~1.7%) are available to fund up to 100 percent of project costs and provide flexible repayment terms up to 20 years.

Eligibility: Many types of water quality projects are eligible, including all types of nonpoint source, watershed protection or restoration, and estuary management projects, as well as more traditional municipal wastewater treatment projects.

Learn More: *http://water.epa.gov/grants_funding/cwsrf/basics.cfm*

Demonstration project grants from state energy commissions, DOE, or EPA

The California Energy Commission, Department of Energy, and Environmental Protection Agency often solicit RD&D grants for early development of promising new energy technology concepts, such as California Energy Commission's Innovative Technology Grant.

Eligibility: New technologies that reduce pollution and/or save energy

Renewable Fuel Infrastructure grants

The California Energy Commission has an annual program budget of approximately $100 million to support projects that develop and improve alternative and renewable low-carbon fuels; produce alternative and renewable low-carbon fuels in California; decrease, on a full fuel cycle basis, the overall impact and carbon footprint of alternative and renewable fuels and increase sustainability; and similar projects. The fund supports projects with grants, loans, loan guarantees, revolving loans, and other appropriate measures.

Eligibility: Eligible recipients include: public agencies, private businesses, public-private partnerships, vehicle and technology consortia, workforce training partnerships and collaboratives, fleet owners, consumers, recreational boaters, and academic institutions.

Learn More: *http://www.energy.ca.gov/altfuels/*

Renewable Fuel Standard (RFS)

Under the Renewable Fuel Standard (RFS), biogas from landfills, sewage waste treatment plants, or manure digesters that is converted to CNG and then used as a transportation fuel qualifies for RINs.

Eligibility: Renewable fuels are those derived from renewable, non-petroleum sources such as crops, animal waste, or municipal solid waste

Learn More: *http://www.eia.gov/todayinenergy/detail.cfm?id=11511*

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