Co-Digestion Capacity Analysis
Prepared for the California State Water Resources Control Board under Agreement #17-014-240

CO-DIGESTION CAPACITY IN CALIFORNIA

FINAL | June 2019

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

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Abbreviations

AB	Assembly Bill
AD	anaerobic digestion
ADC	alternative daily cover
ADWF	average dry weather flow
AUIS	all units in service
BEAM	Biosolids Emissions Assessment Model
BioMAT	Bioenergy Market Adjusting Tariff
Board	Board of Commissioners
Btu	British thermal unit
Cal-ARP	California accidental release prevention
CalRecycle	California's Department of Resources Recycling and Recovery
CARB	California Air Resources Board
Carmel	Carmel Area Wastewater District
Carollo	Carollo Engineers, Inc.
CASA	California Association of Sanitation Agencies
CCI	construction cost index
CCR	California Code of Regulations
CCST	California Council on Science and Technology
CEC	California Energy Commission
CERF	compost emission reduction factor
cf	cubic feet
CHP	combined heat and power
CLEEN	California Lending for Energy and Environmental Needs
CMSA	Central Marin Sanitation Agency
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalence
COD	chemical oxygen demand
CORe®	Centralized Organic Recycling
CPI	consumer price index
CPUC	California Public Utilities Commission
CRF	capital recovery factor
CSE	Center for Sustainable Energy
DRU	demographic research unit
EBMUD	East Bay Municipal Utility District
EBS®	Engineered Bioslurry
ECBP	East County Bioenergy Project
EERE	Energy Efficiency & Renewable Energy
EI&C	electrical, instrumentation, and controls
ENR	engineering news record

EPA	United States Environmental Protection Agency
EREF	Environmental Research and Education Foundation
ERS	Economic Research Service
F2E	Food to Energy
FOG	fats, oil, and grease
FTE	full time equivalent
g	grams
GGE	gallon gas equivalent
GHG	greenhouse gas
Goleta	Goleta Sanitary District
gpd	gallons per day
gpm	gallons per minute
H_2S	hydrogen sulfide
Hp	horsepower
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program
IBank	California Infrastructure and Economic Development Bank
IC	internal combustion
ISO	Independent System Operator
JPA	Joint Powers Agreement or Authority
JWPCP	Joint Water Pollution Control Plant
kg	kilogram
kWh	kilowatt hour
LACSD	Sanitation Districts of Los Angeles County
lb	pound
LBNL	Lawrence Berkeley National Lab
lbs	pounds
lbs/p/week	pounds per person per week
LCFS	low carbon fuel standard
LHV	low heating value
LNG	liquefied natural gas
LUOOS	largest unit out of service
MCE	Marin Clean Energy
MDRR	Mount Diablo Resource Recovery
MG	million gallons
mg/L	milligrams per liter
mgd	million gallons per day
MJ	mega joule
mm	millimeter
MMBtu	million British thermal units
MOA	memorandum of agreement
MRF	materials recovery facility
MSS	Marin Sanitary Services
MSW	municipal solid waste

MT	metric ton
MT CO_2e	metric tons of carbon dioxide equivalent emissions
MW	megawatt
MWh	megawatt hour
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
NRDC	National Resource Defense Council
O&M	operations and maintenance
OCSD	Orange County Sanitation District
OREX™	Organics Extrusion Press
OSHA	Occupational Safety and Health Administration
PG&E	Pacific Gas and Electric
ppd	pounds per day
PSM	process safety management
R2	resource recovery
RCNG	renewable compressed natural gas
ReFED	Rethink Food Waste Through Economics and Data
Resolution	Comprehensive Response on Climate Change
RFS	Renewable Fuel Standard
RIN	renewable identification number
RMP	risk management plan
RNG	renewable natural gas
SB	Senate Bill
SBWMA	South Bayside Waste Management Authority
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
scf	standard cubic feet
scfd	standard cubic feet per day
scfm	standard cubic feet per minute
SCG	SoCalGas
SGIP	self-generation incentive program
SJVAPCD	San Joaquin Valley Air Pollution Control District
SOP	standard operating procedures
SRT	solids residence time
SSO	source separated organics
SVCW	Silicon Valley Clean Water
SWRCB	State Water Resources Control Board
TPY	tons per year
TS	total solids
TWAS	thickened waste activated sludge
USDA	United States Department of Agriculture
VFD	variable frequency drive

VOC	volatile organic carbon
VS	volatile solids
VSLR	volatile solids loading rate
WMA	Waste Management Agency
WWTP	wastewater treatment plant

INTRODUCTION

In 2016, Senate Bill 1383 (SB 1383) was adopted requiring the reduction of short-lived climate pollutant emissions, including a 40 percent reduction below 2013 levels in methane emissions statewide by 2030. Because landfills represent 20 percent of the state's methane inventory, a key strategy to achieve methane reduction is to divert organic waste from landfills to prevent the degradation that leads to methane production and release. SB 1383 establishes targets to achieve a 50 percent reduction in the level of statewide disposal of organic waste from the 2014 level by 2020, and a 75 percent reduction by 2025.

In March of 2017, the California State Water Resources Control Board adopted its Comprehensive Response on Climate Change (Resolution) promoting measures taken by the water industry that mitigate greenhouse gas emissions and adapt to the effects of climate change. The Resolution directs the State Water Board staff to support the California Air Resources Board's Short-Lived Climate Pollutant Reduction Strategy, which assesses opportunities to reduce methane emissions from landfills through organic waste diversion. Municipal wastewater treatment plants (WWTPs) are identified as part of the solution by accepting food waste diverted from landfills and co-digesting it with sewage sludge. Through co-digestion of diverted food waste in anaerobic digesters, municipal WWTPs can produce, capture, and make beneficial use of biogas, which is a renewable source of methane.

The State Water Board received a multi-purpose grant from the United States Environmental Protection Agency (EPA) to analyze co-digestion capacity at municipal WWTPs in California. The State Water Board in turn issued a Request for Proposals for the project and awarded it to Carollo Engineers, Inc. (Carollo). Carollo and the State Water Board are leading the Co-Digestion Capacity Analysis to determine the extent to which municipal WWTPs can support the implementation of SB 1383.

The chapters that summarize this Co-Digestion Capacity Analysis include:

- Chapter 1 - Food Waste Disposal Analysis
- Chapter 2 - Analysis of Existing Capacity for Co-Digestion of Food Waste
- Chapter 3 - Investments to Maximize Co-Digestion
- Chapter 4 - Greenhouse Gas Emission Reductions from Co-Digestion of Food Waste
- Chapter 5 - Co-Digestion at Small to Medium Size Wastewater Treatment Plants
- Chapter 6 - Co-Digestion at Large Wastewater Treatment Plants

Chapter 1 describes the results of the food waste disposal analysis, in which we estimate the amount and spatial distribution of food waste in 2025 and 2030. We use the food waste projections from this chapter in all subsequent analyses.

In Chapter 2, we analyze the excess capacity of municipal WWTPs in California to accept and co-digest food waste diverted from landfills, beneficially use the resulting biogas, and process biosolids within existing onsite infrastructure. We base this analysis on a survey developed and distributed to WWTPs for this project. We build on the capacity assessment from this chapter to determine additional infrastructure needs in Chapter 3.

In Chapter 3, we estimate the infrastructure investments needed for WWTPs to fully utilize their existing excess anaerobic digestion capacity to process food waste diverted from landfills. These infrastructure investments include systems to accept food waste slurry, manage the resulting biosolids, and beneficially use the produced biogas. Chapter 3 additionally presents the costs, benefits, and community impacts associated with maximizing co-digestion of food waste at California's WWTPs. We summarize regulatory considerations that impact the feasibility of co-digestion in the state, and present funding opportunities for bioenergy and GHG-reducing projects. This analysis provides a comprehensive assessment of the infrastructure needs and potential impacts of co-digestion at WWTPs across the state. However, it is focused on WWTPs and the upgrades required onsite. We assume that food waste will be collected and pre-processed offsite, and then delivered to WWTPs as a pumpable slurry. To develop a holistic assessment of investment needs, we recommend additionally studying the investments required for this offsite pre-processing.

In Chapter 4 we estimate the GHG emissions reduction potential associated with diverting food waste from landfills to municipal WWTPs for co-digestion. We first derive a co-digestion emissions reduction factor. Using information about the amount of projected divertible and digestible food waste (Chapter 1), the estimated existing capacity for co-digestion (Chapter 2), and potential investments to maximize co-digestion (Chapter 3), we assess the possible GHG emission reductions from co-digestion of food waste.

Chapter 5 presents case studies from four medium sized facilities in California that do or are planning to receive food waste for co-digestion: Central Marin Sanitation Agency, Manteca Wastewater Quality Control Facility, Delta Diablo, and Silicon Valley Clean Water. The factors that impede and facilitate co-digestion at these facilities are unique, however the lessons learned are relevant to facilities of all sizes throughout California.

Chapter 6 describes the co-digestion systems and operations of two large facilities: the East Bay Municipal Utility District's Main Wastewater Treatment Plant, and the Sanitation Districts of Los Angeles County's Joint Water Pollution Control Plant. We describe the digestion system at each facility and highlight how co-digestion of food waste has impacted biogas and biosolids production.

Appendices associated with each chapter provide additional information on analyses, assumptions, and references.

Chapter 1

FOOD WASTE DISPOSAL ANALYSIS

1.1 2016 Baseline Organic Waste Inventory

This project specifically focuses on co-digestion as an avenue for the state to meet its organic waste diversion mandates. Substrates that would be suitable for co-digestion include high-moisture and/or low-fiber organic material. Food waste, properly collected and processed, meets these suitability criteria and is thus a potential feedstock for co-digestion at wastewater treatment plants (WWTPs). The other organic components of Municipal Solid Waste (MSW) such as paper and cardboard or grass and woody material, are not suitable for WWTP anaerobic digesters because of their poor digestibility and are better handled in other ways (e.g., composting). When considering the current MSW disposal stream, we assume food waste is the only component suitable for co-digestion, which is the focus of this study.

California's Department of Resources Recycling and Recovery (CalRecycle) tracks total annual waste disposal in the State of California. In addition, CalRecycle has conducted four waste characterization studies to assess the composition of the disposal stream (Table 1.1), with the most recent done in 2014. For this project, we use the CalRecycle disposal data from 2017 and the 2014 Waste Characterization Study (Cascadia 2015) to estimate the baseline organic waste disposal for 2017. From the 2017 baseline, we estimate the amount and spatial distribution of food waste in 2025 and 2030.

Table 1.1 Composition of California's Organic Waste Stream as a Fraction of Total Disposed Waste

Characterization Study Year$^{(1-4)}$	Food Waste	Paper/ Cardboard	Wood Waste	Other Organics$^{(5)}$	Prunings, Branches & Stumps	Leaves and Grass	Total Organic Fraction
1999	15.7	30.2	4.9	9.1	2.3	7.9	70.1
2004	14.6	21	9.6	9	2.6	4.2	61
2008	15.5	17.3	14.5	9.8	3.3	3.8	64.2
2014	18.1	17.4	11.9	10.7	4.8	3.8	66.7

Notes:
(1) (Cascadia 1999).
(2) (Cascadia 2004).
(3) (Cascadia 2009).
(4) (Cascadia 2015).
(5) Other includes Manures, Textiles, Carpet, and "Remainder/Composite Organic".

Californians disposed of 37.5 million short wet tons of MSW in landfills in 2017, the most recent year for which total disposal data are available (Cascadia 2015; CalRecycle 2018c). Based on the composition of the waste stream in 2014 (Cascadia 2015), we estimated the amount of organic material disposed of in 2017 which was 25 million short wet tons (i.e., 66.7 percent of 37.5 million wet tons), of which 6.8 million short wet tons was food waste (i.e., 18.1 percent of 37.5 million short wet tons). This approach and the results are consistent with other studies that estimated the quantity of food waste disposed of in California (Breunig, Jin et al. 2017) (Williams, Jenkins et al. 2015) (see Appendix 1A).

The 6.8 million short wet tons of the total 2017 food waste is the gross amount of food waste that is potentially available for co-digestion if segregated and recovered from the MSW stream (i.e., "diverted"). However, the amount that is recoverable with suitable quality at feasible costs (i.e., "digestible") is less than this gross quantity, as we discuss in the estimate of food waste projections (Section 1.2).

Total statewide disposal of organic waste trended downward from 26 million short wet tons in 2000 to a low of about 19 million short wet tons at the end of the most recent recession (2008 to 2012).[1] The total organic waste disposed of has increased as overall disposal has increased post-2012 (Figure 1.1). However, the amount of food waste disposed of has remained relatively stable at 5 to 7 million short wet tons per year.

In general, the relatively stable food waste disposal amounts, despite the population growth of 5.6 million from 2000 to 2017, suggests that the statewide per capita food waste disposal has been declining. Further decrease in per capita food disposal is plausible, given the increased awareness of wasted food, source reduction though better ordering on the wholesale level to match use, messaging to consumers, recovery, any future downturns in the economy (which appear to lead to temporary decrease of per capita disposal), etc.

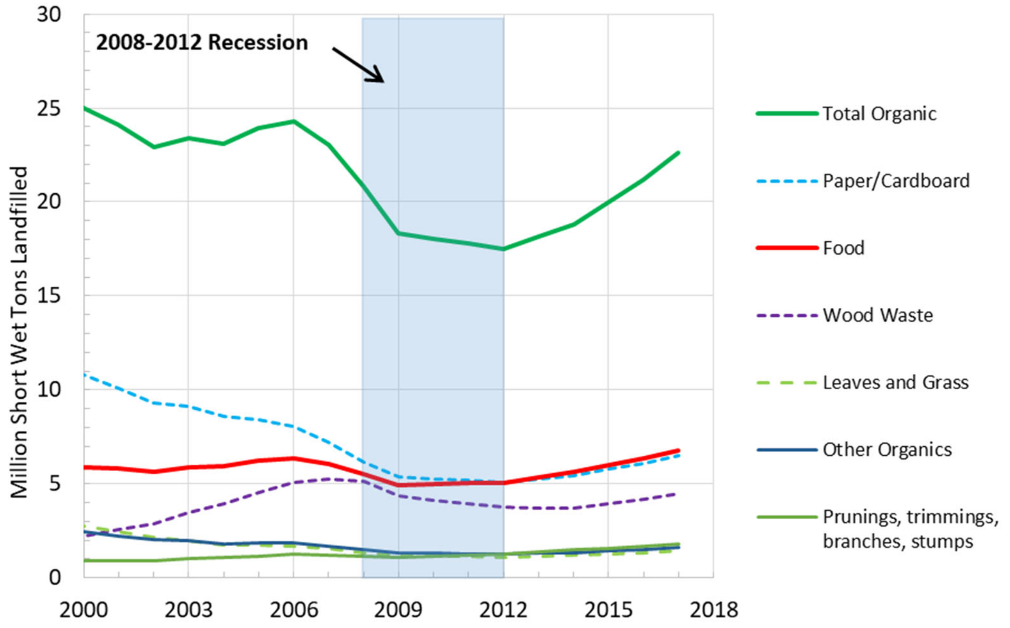

Figure 1.1 Organic Waste Disposal Trends by Component from 2000 to 2017

Note: This figure is based on CalRecycle annual waste disposal totals, and the composition from Waste Characterization Studies. Composition fractions between waste characterization study years were estimated by linear interpolation. Composition for 2015, 2016, and 2017 are based on the 2014 Characterization Study.

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[1] Composition fractions between study years were estimated by linear interpolation.

1.1.1 County-Specific Organic Waste Disposal

For the purposes of its Waste Characterization Study, CalRecycle assigned counties to one of five regions in the state based on demographics, climate, geography, and economic characteristics (Cascadia 2015) (Appendix 1B). Regional MSW disposal amount and population are correlated (Figure 1.2). For example, southern California, with nearly 60 percent of the state's population, disposes of about 60 percent (22 million short wet tons per year) of the state's MSW. The Bay Area and the Central Valley each dispose of about 6.5 million short wet tons annually, followed by the Coastal and Mountain regions with a combined 2.3 million short wet tons per year.

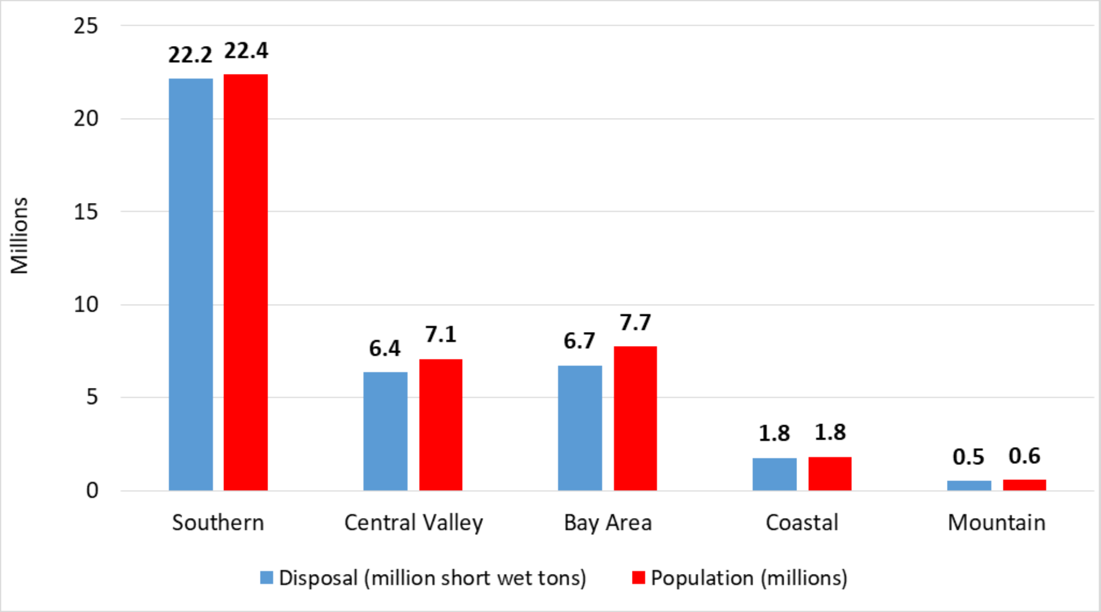

Figure 1.2 Regional MSW Disposal and Population in 2017

<u>Note</u>: Disposal data is from (CalRecycle 2018c). Population data is from (DRU 2017).

The statewide 2017 per capita food waste disposal was estimated to be 6.6 pounds per person per week (A comparison with estimates of per capita food waste across the United States is discussed in Appendix 1C). However, the fraction of food waste in disposed MSW varies slightly by geographical region (Table 1.2) (CalRecycle 2018).

Regional food waste component fractions from 2014 were applied to the 2017 total MSW disposal by county (CalRecycle Disposal Reporting System) to estimate the 2017 amount of the organic waste disposal at the county level (Figure 1.3) (Appendix 1D). We then used estimated county disposal in 2017, and actual 2017 county population (demographic research unit [DRU] 2018) to estimate per capita food disposal factors for each region and county (Table 1.2) (for county estimates see Appendix 1D).

Table 1.2 2017 Estimated Regional Food Waste Disposal

Region	Food Waste Percentage of MSW Disposal	Estimated 2017 Food Waste Disposal (Million Short Wet Tons)	Per Capita Food Waste Disposal	
			(short wet tons/person/ year)	(wet lbs/person/ week)
Southern	17.1	3.8	0.17	6.5
Central Valley	19.6	1.2	0.18	6.8
Bay Area	19.8	1.3	0.17	6.6
Coastal	19.8	0.4	0.19	7.4
Mountain	20.0	0.1	0.18	6.8
Statewide	**18.1**	**6.8**	**0.17**	**6.6**

Note: Regional characterization of California's organic waste stream is based on the most recent data provided for the year 2014 (CalRecycle 2018). Per capita values are based on relative food waste disposal amount determined from CalRecycle 2014 regional composition data (CalRecycle 2018), 2017 disposal data, and population data from the Demographic Research Unit (DRU) at the California Department of Finance (DRU 2018).

1.2 Projecting Food Waste Disposal in 2025 and 2030

As noted earlier, the food waste portion of the organic waste stream can be effectively co-digested with municipal WWTP sludge. Hence, we focus on food waste to project the quantity of material that could be diverted from landfills for co-digestion at municipal WWTPs.

To project the food waste disposal through 2025 and 2030 by county, we assumed that the per capita food waste disposal will remain constant from 2017 through 2030 (Table 1.2). We used population projections by county (DRU 2018) to estimate the future food waste disposal. Assuming no change in the per capita disposal rate from 2017 through 2030 is a conservative assumption (i.e., it potentially over-estimates disposal), given that the overall trend since 1999 has been a slight decline in the statewide per capita food waste disposal (Appendix 1E).

To investigate the potential effect of this declining trend, we did a sensitivity analysis in which per capita disposal gradually decreases to 10 percent below the "constant per capita" scenario in 2025. The "10-percent decrease" scenario accounts for continued decrease in per capita food disposal due to messaging and increased consumer awareness, source reduction, and effects of downturns in the economy, etc.

Figure 1.4 shows the projected statewide food waste disposal for the "constant per capita" disposal scenario, and the "10-percent decrease" in per-capita disposal scenario. The projected regional food waste disposal in 2025 and 2030 for these scenarios is provided in Table 1.3 (county level projections are provided in Appendix 1F).

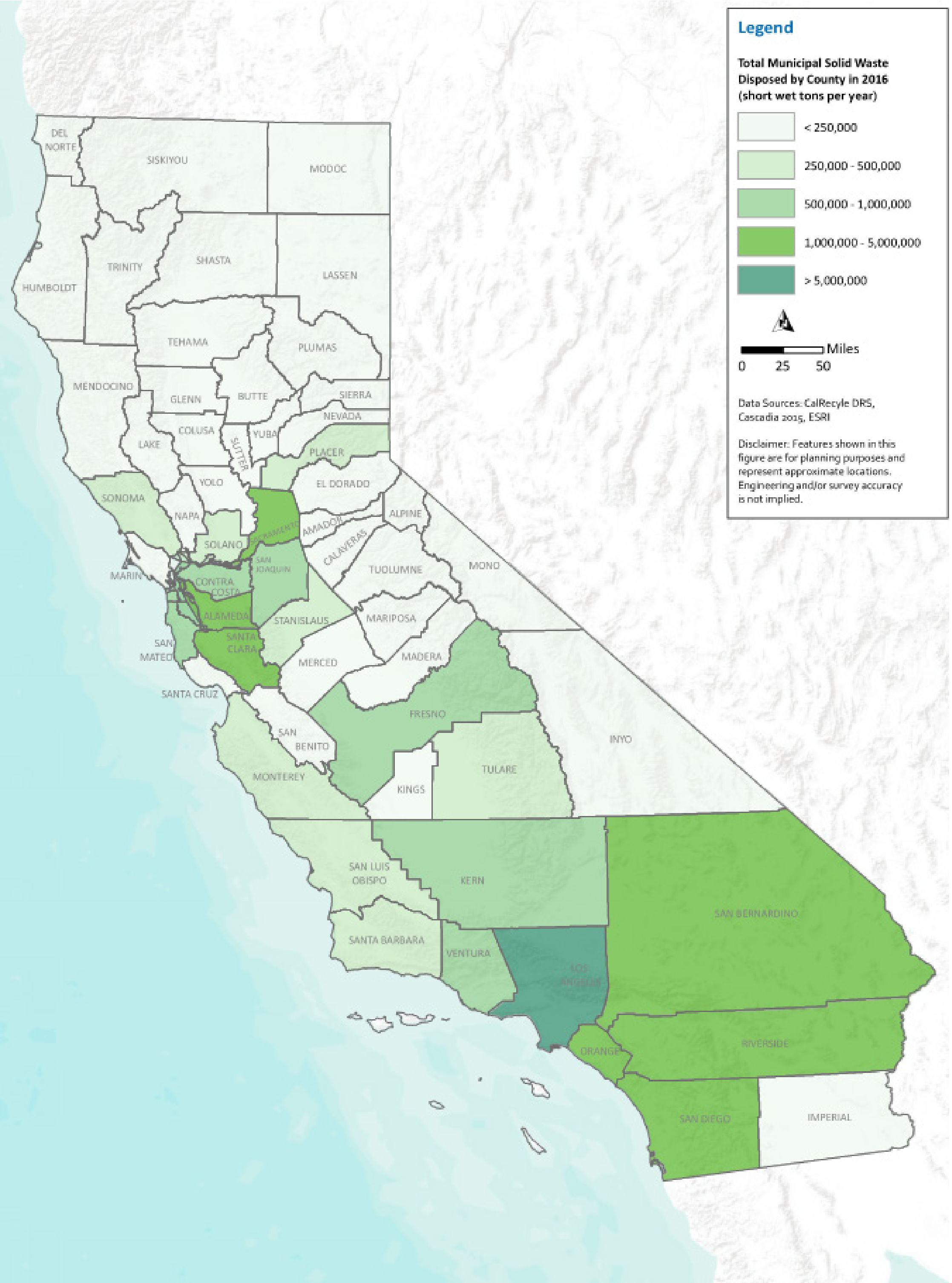

Figure 1.3 County of Origin (short wet tons per year)

Table 1.3 Projected Food Waste by Region (million short wet tons per year)

Region	Constant Per Capita Disposal		10% Decrease in Per Capita Disposal	
	2025	2030	2025	2030
Southern	4.01	4.13	3.61	3.72
Central Valley	1.37	1.45	1.23	1.30
Bay Area	1.44	1.50	1.29	1.35
Coastal	0.37	0.38	0.33	0.34
Mountain	0.11	0.11	0.10	0.10
Total	**7.30**	**7.57**	**6.57**	**6.82**

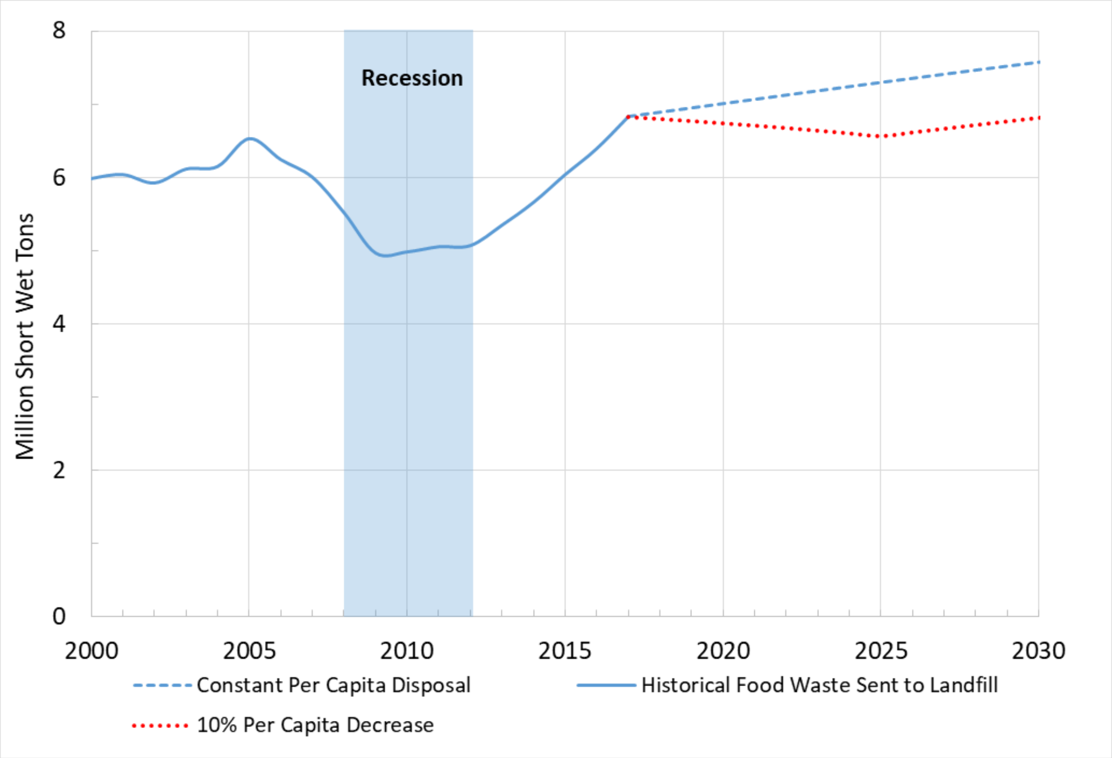

Figure 1.4 Projected Food Waste Disposal without Actions to Divert From Landfills

Note: Two disposal scenarios are modeled with the projected population growth: per capita food waste disposal remains constant at the 2017 level, and per capita disposal gradually decreases to 10 percent below the 2017 level in 2025 and then remains constant.

1.2.1 Senate Bill 1383 Edible Food Rescue Goal

Senate Bill (SB) 1383 targets a 50 percent reduction of statewide disposal of organic waste relative to 2014 levels by 2020 and a 75 percent reduction by 2025 (CalRecycle 2018b). The overall SB 1383 disposal reduction targets may be met by reducing and diverting various organic components at different rates. In addition to the overall organic waste diversion targets, a specific goal for food waste, under SB 1383, is that no less than 20 percent of edible food that is currently disposed of is recovered for human consumption by 2025 (also known as food rescue).

To account for edible food rescue, we considered the portion of the food waste stream that is edible, and the source of the edible and rescuable food. Based on the wide range of edible wasted food amounts reported in the literature, from about 5 to 50 percent of total food waste sent to the landfill (TetraTech 2015) (Rethink Food Waste Through Economics and Data [ReFED] 2016), we assumed 20 percent of the food waste stream is edible. Meeting the food rescue goal, the statewide food rescue would amount to 4 percent of the total disposed food waste (20% x 20% = 4%).

Additionally, we assume that the majority of recoverable edible food waste will come from the commercial sector, specifically the grocery and restaurant/food service entities (ReFED 2016). In 2014, 43 percent of the disposed food waste was from the commercial, and 57 percent was from residential sources (Cascadia 2015). Food waste from the residential sector is assumed to have no rescuable edible portion as the majority of residential waste systems collect food waste in a mixed waste bin or an organics bin.

Assuming that 20 percent of the food waste stream from the commercial sources (and zero percent of the residential food waste stream) is edible, we estimate that the fraction of edible and rescuable food statewide is 1.7 percent of the total disposed food waste (43% x 20% x 20% = 1.7%). These assumptions are simplistic, and are meant to understand the potential magnitude of food rescue under SB 1383. Because it is a small fraction (1.7 percent), and potentially highly variable (TetraTech 2015, ReFED, 2016), we do not account for food rescue when estimating recoverable food waste for codigestion in the following analysis. For specific information, readers are directed to a forthcoming 2018 Waste Characterization Study that CalRecycle is expected to release in 2019.

1.2.2 Practical Food Waste Recovery Factors for Co-Digestion at Municipal WWTPs

To be co-digested at municipal WWTPs, food waste needs to be separated from the mixed waste stream or collected separately at the source (source separation), then processed to remove contaminants (e.g., glass, plastics, grit, other inert material) and made into a pumpable slurry (Bernstad, Malmquist et al. 2013) (Edwards, Othman et al. 2017) (Nghiem, Koch et al. 2017).

To estimate an overall food waste recovery factor for co-digestion, a simple mass balance exercise was done using the projected food waste disposal, a range of participation in source separation, and a range of food waste extraction rates (Figure 1.5). In the mass balance, the food waste sources include both residential, and commercial sectors. Each source type is collected either via source separation (or bagged co-collection)[2] (Lo and Woon 2016) or mixed with other waste as MSW. As practical food waste recovery factors and reported source separation participation rates vary, we conservatively assumed a mid-range from the literature (Oakley 2015) (Freeman and Skumatz 2011) (Scherson 2016). These assumptions yield an overall food waste recovery rate of 50 to 60 percent.

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[2] For example, the "Blue Bag" co-collection model enables residential customers to bag food and kitchen waste in an issued colored bag which is put in the garbage (black) bin and collected with the rest of the trash. The bags are removed at a MRF via optic or manual sorting. After removal from the bags, the food waste has fewer contaminants than MSW, similar to results of source separation methods.

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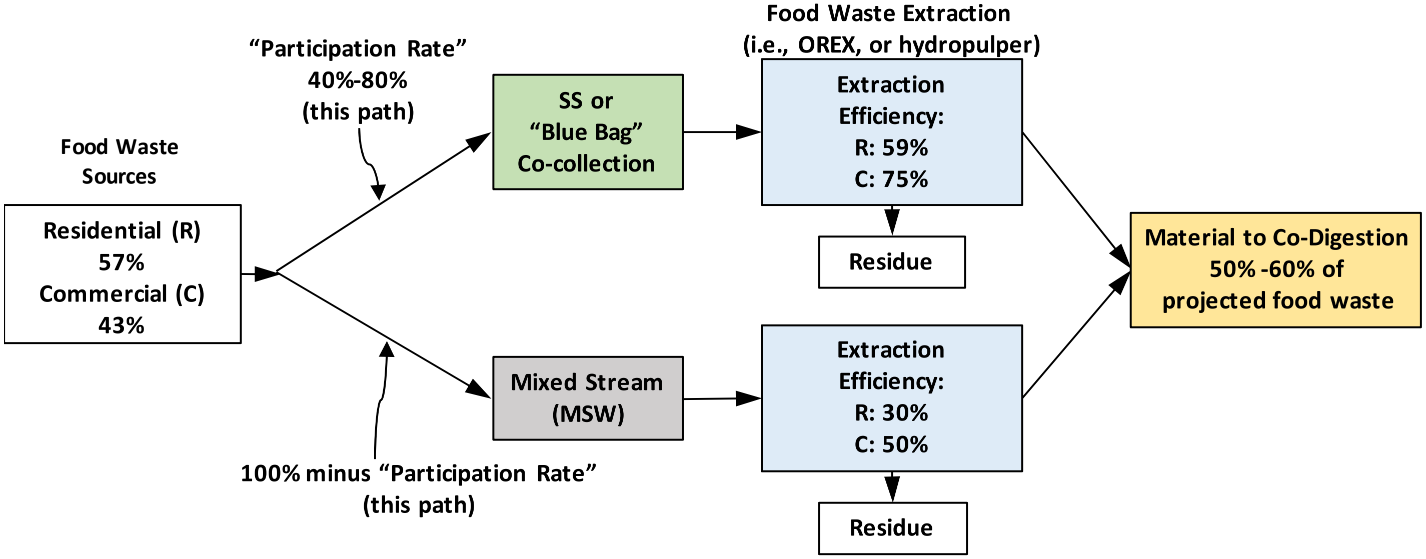

Figure 1.5 Food Waste Recovery Mass Balance Schematic

Note: The participation rate for source separation (or bagged co-collection) is set as 40 to 80 percent in the mass balance. The relative amount of material that is collected in the MSW stream is 100 percent minus the participation rate. This is a conservative range, as food scrap extraction and preparation from commercial source separated waste can reach 90 percent, but participation was reported at less than 50 percent for voluntary programs (Freeman and Skumatz 2011). Similarly, participation using separate food and organic waste bins in Alameda County has fallen to about 50 percent from an initial 70 percent participation rate (Oakley 2015).

Food waste extraction efficiency for source separation material is set at 59 percent for R and 75 percent for C in the mass balance. Extraction efficiency from the MSW stream is 30 percent for R and 50 percent for C (Scherson 2016) (Jank et al. 2017). For extracting food waste from delivered mixed or source separated material, companies specializing in this stated a range of recovery efficiencies from about 30 percent for residential MSW to more than 90 percent for source separated organics from commercial sources (Scherson 2016).

Food rescue is not accounted for in the mass balance because it is highly uncertain and likely small (our estimate is 1.7 percent of total).

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Figure 1.6 shows the amount of landfilled food waste after potential recovery for co-digestion from the constant per capita disposal scenario. Under SB 1383, the allowable disposal of total organics in 2025 is 5.7 million short wet tons [75 percent below the 2014 level] (CalRecycle 2017). As food comprises approximately 30 percent of total organics disposal, these projections suggest that co-digestion at California WWTPs may play a major role in helping the state meet its food waste diversion goals. These projections also underscore the importance of actions to promote and incentivize diversion of food waste, and to improve pre-processing and extraction technologies.

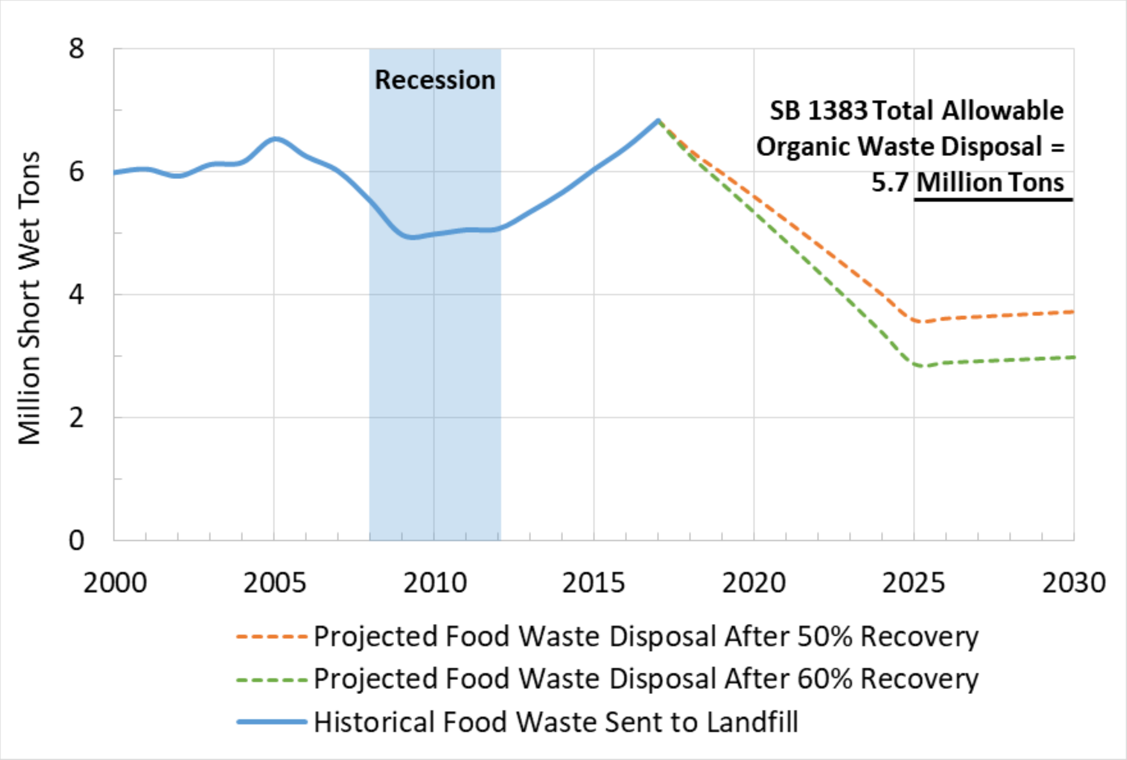

Figure 1.6 Projected Food Waste Remaining after Recovery for Co-digestion at Municipal WWTPs

Note: SB 1383 target for 2025 and beyond is for illustrative purposes, and shows allowable organic waste disposal. The overall SB 1383 disposal reduction targets may be met by reducing and diverting various organic components at different rates.

1.2.3 Summary of Food Waste That Could be Diverted to Municipal WWTPs

We developed a range of projected food waste that could be diverted from landfills and co-digested at WWTPs by taking the difference between the projected food waste and the practical food waste recovery estimates. The range is bound by a high, and a low projection (Figure 1.7):

- High Projection (i.e., largest potential amount of food waste that could be diverted and digested) = [60 Percent Recovery of the "Constant Per Capita" Food Waste Disposal Scenario].
- Low Projection (i.e., lowest potential amount of food waste that could be diverted and digested) = [50 Percent Recovery of the "10 Percent Decreased Per Capita" Food Waste Disposal Scenario].

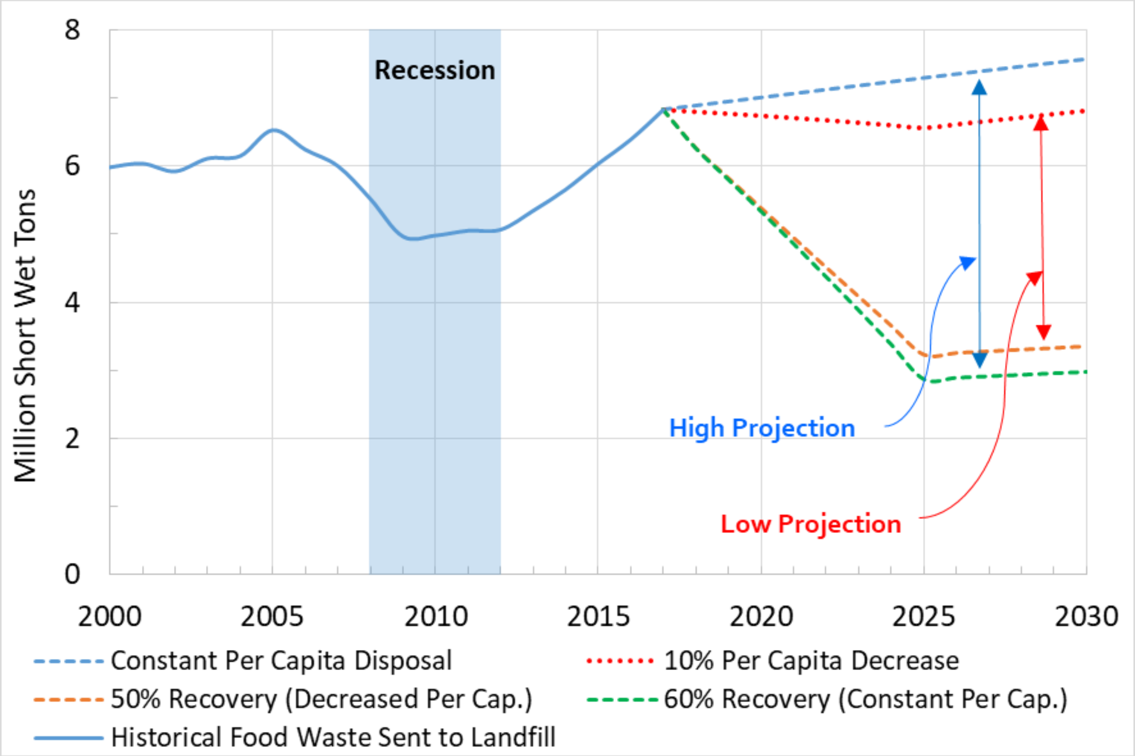

Figure 1.7 Disposal and Recovery Scenarios to Determine the Range of Food Waste Quantities that could be Diverted Statewide to Municipal WWTPs

The projected potential amount of food waste that could be diverted to municipal WWTPs for 2025 ranges from 3.30 to 4.37 million short wet tons, and by 2030 the potentially recoverable food waste ranges from 3.41 to 4.55 million short wet tons (Figure 1.8 & Table 1.4).County level projections are provided in Appendix 1G.

Table 1.4 Potential Range of Recoverable and Digestible Food Waste by Region (million short wet tons per year as diverted from a landfill)

Region	High Projection		Low Projection	
	2025	2030	2025	2030
Southern	2.41	2.48	1.81	1.86
Central Valley	0.82	0.87	0.62	0.65
Bay Area	0.86	0.90	0.65	0.68
Coastal	0.22	0.23	0.17	0.17
Mountain	0.06	0.07	0.05	0.05
Total	**4.37**	**4.55**	**3.30**	**3.41**

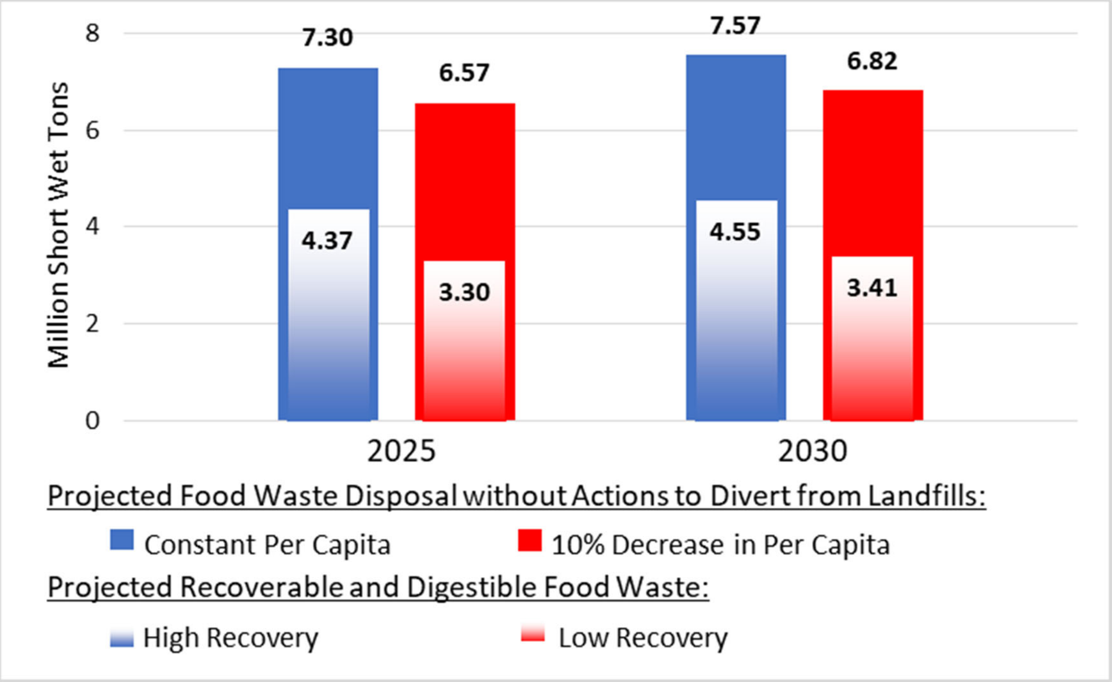

Figure 1.8 High and Low Recovery Projections with Total Food Waste Projections

1.3 Summary of Estimates and Recommendations

We analyzed waste disposal and characterization data for California to determine a baseline inventory of organic waste disposed of at landfills in 2017. We estimated that food waste, the fraction of organic waste suitable for co-digestion at municipal WWTPs, comprised approximately 18 percent of the disposed of MSW stream (6.8 million short wet tons) in 2017 (Section 1.1). Using this food waste baseline, and the 2017 population, we estimated per capita disposal rates for each county and region in the state, and projected two disposal scenarios with population growth in 2025 and 2030 (i.e., the "constant per capita" and "10 percent decrease per capita" scenarios; Section 1.2).

Taking into account high and low food waste recovery factors for co-digestion (i.e., the assumption that between 50 and 60 percent of disposed food waste can be diverted for digestion; Section 1.2.2), we estimated a range of food waste available for co-digestion in 2025 and 2030 ("low" and "high" projected amount of digestible and divertible food waste; Section 1.2.3) (Figure 1.9 & Figure 1.10).

SB 1383 mandates 50 percent organics diversion by 2020, and 75 percent diversion by 2025 (relative to 2014 levels). By 2030, we estimate from 3.41 to 4.55 million short wet tons of food waste would be suitable for digestion at California WWTPs. As food comprises approximately 30 percent of total organics disposal, this suggests that co-digestion at California WWTPs may play a major role in helping the state meet its food waste diversion goals.

To avoid over-estimating available food waste and the role co-digestion at California WWTPs may play in helping the state reach its goals, the "low" projection (3.4 million short wet tons per year diverted food waste in 2030) will be carried into subsequent chapters of this analysis.

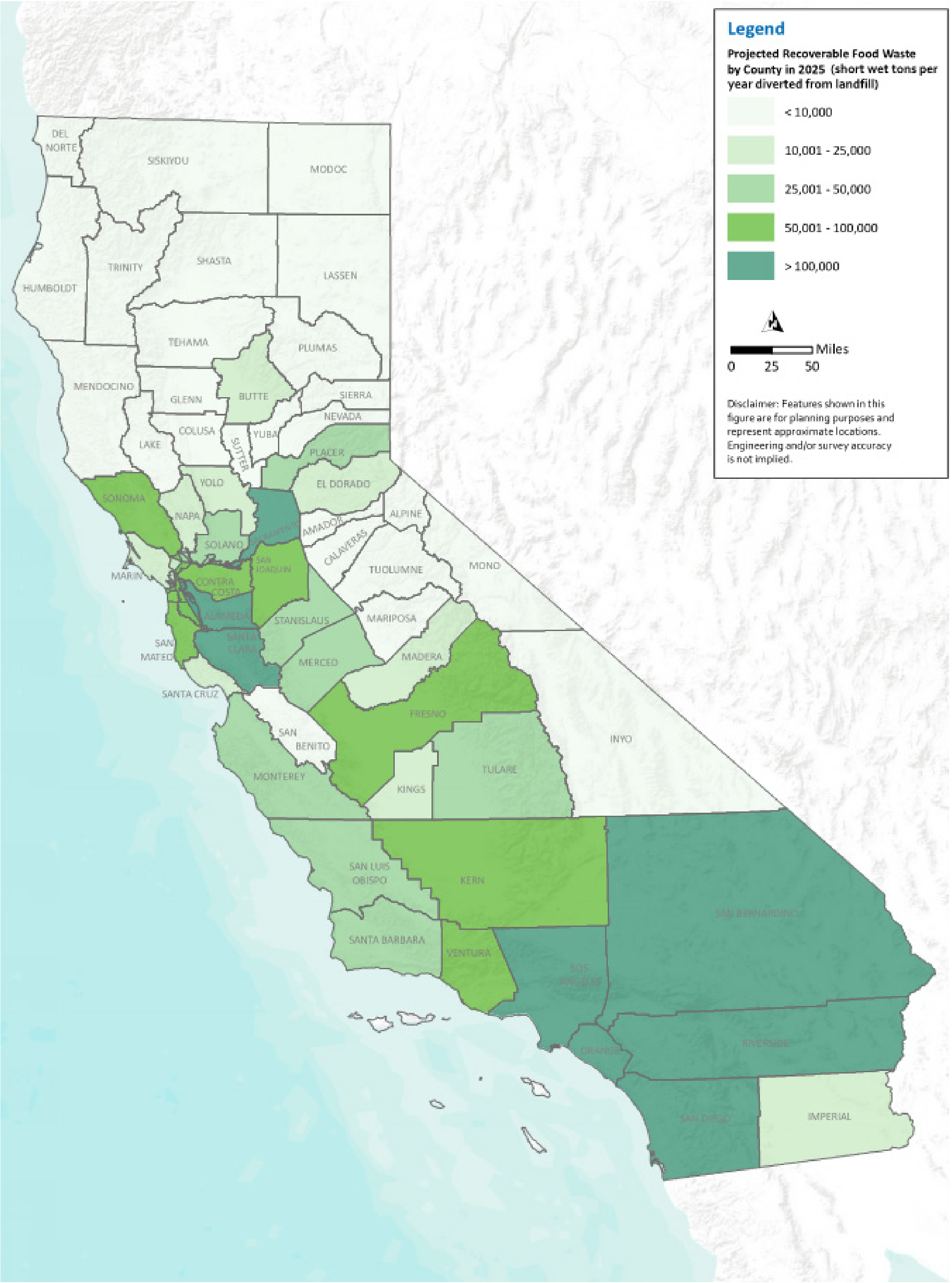

Figure 1.9 Spatial Distribution of Recoverable Food Waste by County (2025, low projection)

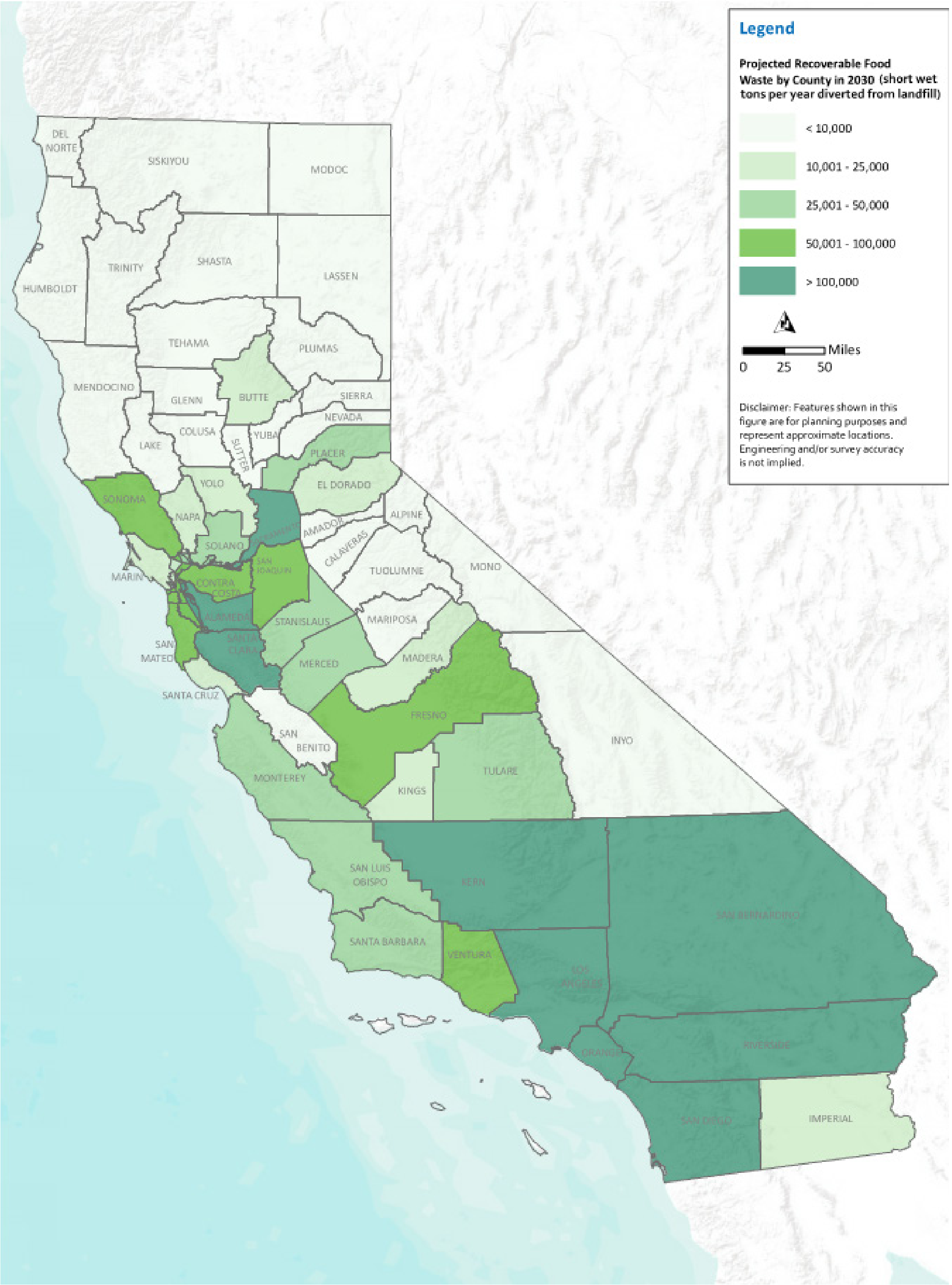

Figure 1.10 Spatial Distribution of Recoverable Food Waste by County (2030, low projection)

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Chapter 2

ANALYSIS OF EXISTING CAPACITY FOR CO-DIGESTION OF FOOD WASTE

2.1 Existing Infrastructure and Excess Capacity

The first step of the assessment was to estimate existing excess capacity of key systems that must be in place in order to accept food waste for co-digestion at a wastewater treatment plant (WWTP) and utilize the products (Figure 2.1):

1. A receiving station (suitable for food waste slurry).
2. Anaerobic digestion.
3. Biosolids dewatering.
4. Biogas conditioning and utilization.
5. Biogas flare (required for safe operations)

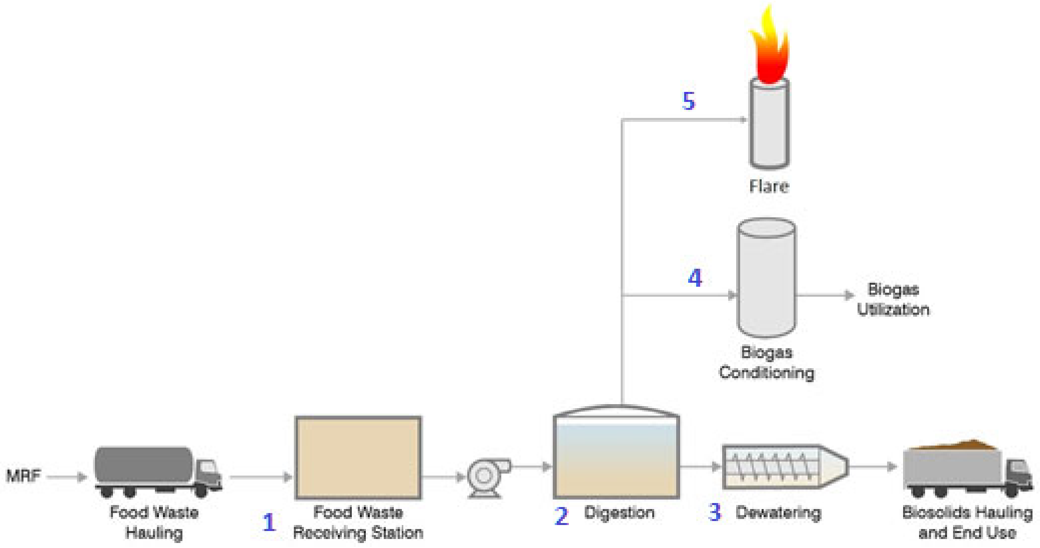


Figure 2.1 Typical Facilities Required for Food Waste Co-Digestion at a WWTP

To accept food waste and make beneficial use of the bioproducts of co-digestion, a single facility needs to have capacity in each of the key systems. For example, if a WWTP has available digester volume to handle additional slurried food waste but is unable to dewater the resulting additional biosolids, the overall processing capacity is limited by the biosolids dewatering. By analyzing the capacities of each of the key systems and identifying the limiting factor, we can more accurately gauge existing excess capacity for food waste co-digestion.

Pre-processing of food waste into a digestible form (removing contaminants and diluting it to a pumpable slurry) is another critical element. Pre-processing food waste typically takes place offsite, at materials recovery facilities (MRFs) that are often incorporated into transfer stations.

According to CalRecycle's Solid Waste Information System database, there are 20 transfer stations that currently accept food waste (CalRecycle 2019). These facilities have the capacity to accept over 1 million tons per day of waste, with reported throughput less than 2 percent of that. However, assessing whether the existing MRFs could accept additional food waste, and whether the facilities possess the infrastructure needed to suitably process the food waste for co-digestion at a WWTP was beyond the scope of this study. This gap could be addressed in subsequent studies.

We report excess capacity of existing infrastructure in wet short tons of food waste per year, as diverted from landfills. We assume typical solids content for food waste diverted from landfills is 30 percent. Most WWTPs could not accept food waste in this form. A MRF would first have to pre-process the waste, removing contaminants and thinning it to produce a pumpable slurry of 15 percent solids. WWTPs can receive the slurried food waste and incorporate it into their digester feed. Because the primary goal of this project is to determine how much food waste can be diverted from landfills, we report excess processing capacity in existing infrastructure in wet tons per year of diverted food waste (i.e., material at 30 percent solids). To convert into the quantity of slurried material as received at a WWTP (i.e., material at 15 percent solids), multiply by two.

To assess the ability of municipal WWTPs to co-digest food waste now (with no modifications) and in the future, the project team conducted a survey in August 2018 (referred to as the 2018 Carollo survey in further text; Appendix 2A). The California Association of Sanitation Agencies (CASA) distributed the survey to 223 permitted municipal WWTPs. The responding sample of 99 facilities broadly represents California's overall wastewater flow, including a mix of facility sizes (Figure 2.2, Appendix 2A).

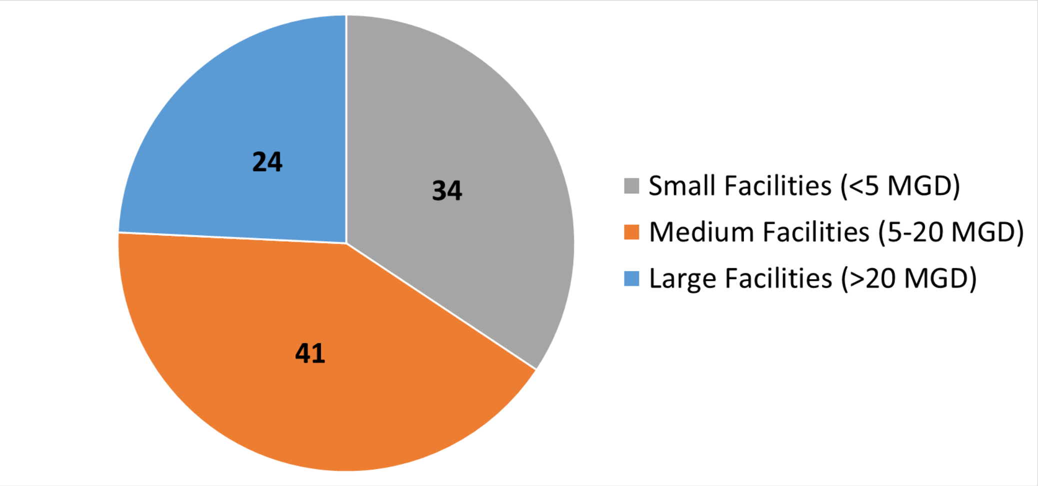


Figure 2.2 Number of Facilities that Responded to the Survey by Permitted Flow Capacity

Of the 99 responding facilities, 59 had an anaerobic digestion process. The capacity analysis focused on facilities with anaerobic digestion. Using the survey results, we determined excess processing capacity within existing systems for each facility. Figure 2.3 shows the inventory (reported presence or absence) of key processes at the 59 facilities with an existing anaerobic digestion system. Seven facilities currently have, or will soon have, <u>all</u> of the key processes necessary for food waste co-digestion. Two of these seven facilities did not report flares, but further research indicated that both do have flares onsite. However, their flare capacities were not reported and could not be included in specific capacity estimates for that process. Fifteen other WWTPs have all but one of the required processes (Figure 2.3).

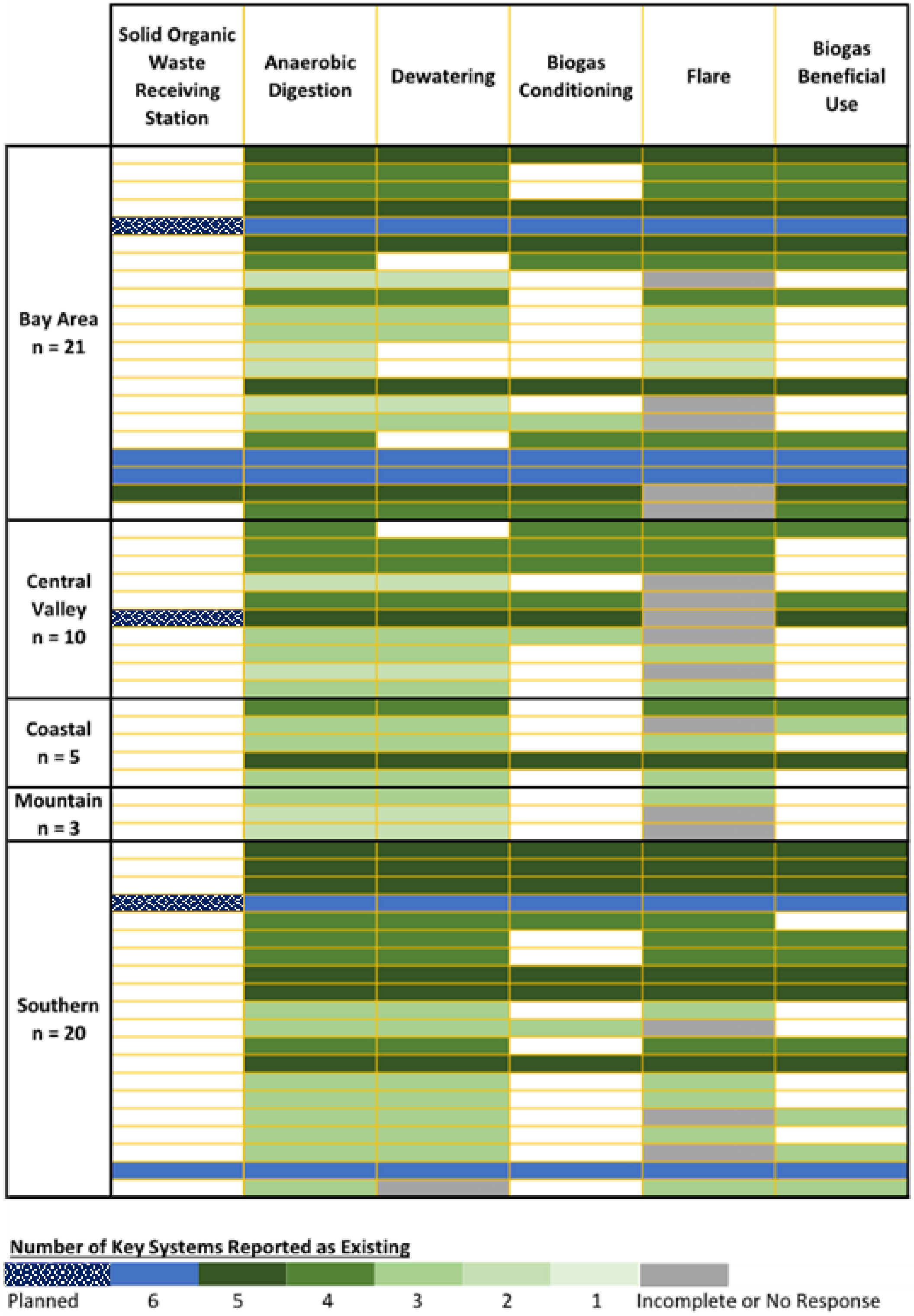
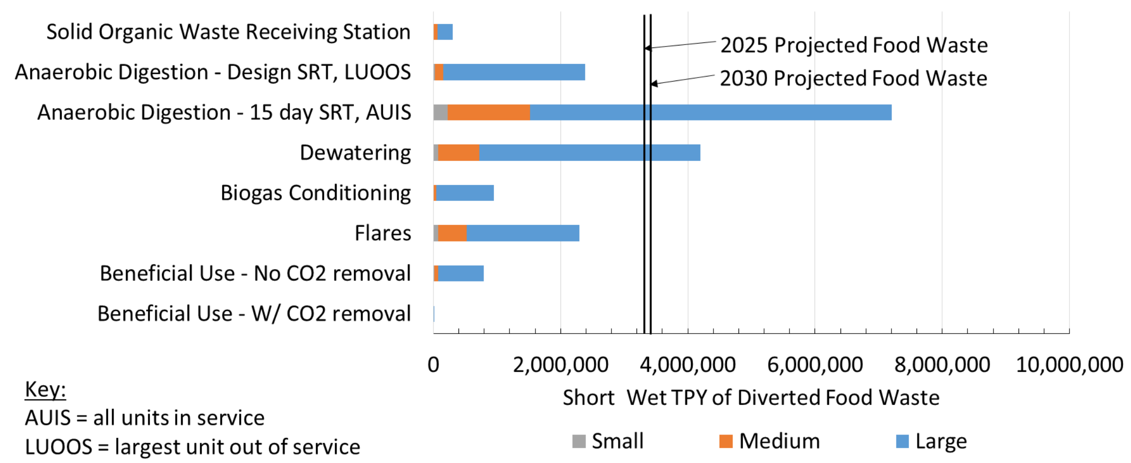


Figure 2.3 Inventory of Key Processes at WWTPs with Anaerobic Digestion by CalRecycle Region

Figure 2.4 shows the estimated existing excess capacity by process and facility size for the 59 California WWTPs that responded to the survey and have anaerobic digestion onsite. The majority of excess capacity is at the large facilities rather than medium or small plants. The anaerobic digesters and dewatering generally have the most excess capacity of all the processes considered. Summed across the state, the processes with the least excess capacity (i.e. those that place the most significant limitations for advancing co-digestion statewide) are the food waste receiving station and biogas beneficial use systems.



Key:
AUIS = all units in service
LUOOS = largest unit out of service

Figure 2.4 Total Existing Excess Capacity of Key Systems at Facilities that Responded to Survey in Short Wet Tons Per Year (TPY) of Diverted Food Waste by Facility Size

Note: Digestion capacity is governed by solids retention time (SRT, also known as the mean cell residence time), number of units (digesters) in service, and organic loading rate. The anaerobic digester capacity estimates include various combinations of operating conditions: All Units in Service (AUIS), Largest Unit Out of Service (LUOOS), design SRT, and 15-day SRT (See Section 2.1.2 and Appendix 2B). Digestion capacities shown in this figure do not account for limits on organic loading.

Table 2.1 summarizes the existing excess capacity to accept food waste at individual WWTPs by process, as determined from the survey results. For example, the table shows that 53 of the surveyed WWTPs with anaerobic digesters also have dewatering; the facility with the greatest excess capacity in its dewatering process could dewater an additional 782,000 wet short tons of diverted and co-digested food waste. Similarly, of the 53 surveyed WWTPs that have dewatering, the facility with the least excess capacity in its dewatering process has no excess capacity. Note, the results for anaerobic digestion capacity in Table 2.1 reflect two "bookend" scenarios of the digester operating parameters, representing the most and least conservative conditions WWTPs may choose to operate under.

The sections below summarize the capacity findings for each of the key processes necessary for co-digestion of food waste.

Table 2.1 Summary of Survey Results for Excess Capacity by Existing Processes at Individual Facilities

Process	Excess Capacity to Accept Food Waste at an Individual WWTP (short wet TPY of Diverted Food Waste)			
	Minimum	Median	Maximum	Count of Surveyed Facilities with Process Listed
Solid Organic Waste Receiving Station	0	37,000	133,000	7
Anaerobic Digestion (Minimum Capacity, Most Conservative Operating Scenario)(1)	0	200	446,000	59
Anaerobic Digestion (Maximum Capacity, Least Conservative Operating Scenario)(2)	0	47,000	1,042,000	59
Dewatering	0	13,000	782,000	53
Biogas Conditioning	0	2,000	379,000	29
Flare	0	12,000	779,000	43
Biogas End Use	0	2,000	309,000	34

Notes:

(1) Operating scenario assumed Largest Unit Out of Service, design SRT, and 0.2 ppd VS/cuft VS loading rate (See Section 2.1.2).

(2) Operating scenario assumed All Units In Service, 15-day SRT, and no limit on VS loading rate (See Section 2.1.2).

2.1.1 Solid Organic Waste Receiving Stations

Among the survey respondents, seven WWTPs either have or are in the process[1] of installing a receiving station suitable for food waste slurry (Figure 2.3). While numerous WWTPs across the state have various organic waste receiving stations, these are designed for liquid wastes like fats/oils/grease (FOG) and food processing/manufacturing wastes. These other receiving stations are not designed to handle thick food waste slurry, and we did not include the capacity of these stations in the co-digestion capacity assessment.

The estimated excess capacity of the solid organic waste receiving stations, statewide, is 306,000 short wet tons of diverted food waste per year (Table 2.2). The excess capacity was estimated as a difference between the design capacity of the facility's organic waste receiving station, and the amount of organic waste slurry the facilities received in 2017. Table 2.2 lists the excess capacity, the design capacity, and the amount of diverted food waste received in 2017. Note that, to estimate excess capacity, we accounted for the capacity used for other types of organic waste the WWTPs received in 2017 (e.g., FOG) but do not show these amounts in the table.

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[1] One of the WWTPs that does have a solid organic waste receiving station onsite is in the planning phase for a new, larger receiving station to take the place of their existing receiving station. Additionally, three of the WWTPs are designing new food waste receiving stations. These planned facilities are included in the existing capacity analysis because the receiving stations are expected to be constructed by 2025.

Table 2.2 Existing Solid Organic Waste Receiving Stations - Excess Capacity at the Seven WWTPs with Existing or Planned Solid Organic Waste Receiving Stations

WWTP	Organic Waste Receiving Station Design Capacity (short dry TPY)	2017 Organic Waste Received (short dry TPY)				Excess Capacity for Food Waste (short dry TPY)(2)(3)	Excess Capacity for Food Waste (short wet TPY as Diverted from a Landfill)(2)(3)
		Food Waste	FOG	Liquid Food & Beverage	Other		
Facility 1	4,600	400	700	0	0	3,500	12,000
Facility 2	65,200	1,100	700	18,400	5,300	39,800	133,000
Facility 3(1)	26,100	3,800	0	0	0	22,300	74,000
Facility 4(1)	15,600	0	900	0	0	14,800	49,000
Facility 5	800	0	1,700	0	0	-	0
Facility 6(1)	200	0	0	0	0	200	1,000
Facility 7(1)	11,000	0	0	0	0	11,000	37,000
TOTAL	**123,500**	**5,300**	**4,000**	**18,400**	**5,300**	**91,600**	**306,000**

Notes:

(1) Planned facility or facility expansion.

(2) The number of days per week each feedstock was delivered and the percent solids of each feedstock was incorporated into the calculation of excess external feedstock capacity.

(3) Rounded values shown.

2.1.2 Anaerobic Digestion Capacity

The estimated existing excess anaerobic digestion capacity of the WWTPs that responded to the survey ranges from 2 million to 7.2 million short wet tons per year (TPY) of food waste diverted from landfills (Figure 2.5)[2], depending on the conditions governing digestion capacity. Digestion capacity is governed by solids retention time (also known as the mean cell residence time), number of units (digesters) in service, and organic loading rate.

To determine excess capacity available for food waste co-digestion, we compared the current Solids Retention Time (SRT), the design SRT, and a 15-day SRT. The 15-day SRT is the minimum required for Class B biosolids pathogen reduction from mesophilic digestion[3]. The design SRT typically ranges from 15 to 30 days (WEF, MOP 8). Facilities sometimes operate at different SRTs from the design SRT based on experience, solids production rates, and facility characteristics.

In addition to digester capacity with All Units In Service, the project team analyzed digester capacity with the Largest Unit Out of Service, a planning strategy used to maintain operational redundancy during digester maintenance. The scenario using the design SRT and the Largest Unit Out of Service is the minimum capacity scenario (most conservative operating scenario). The scenario using a 15-day SRT and All Units In Service is the maximum capacity scenario (Appendix 2B).

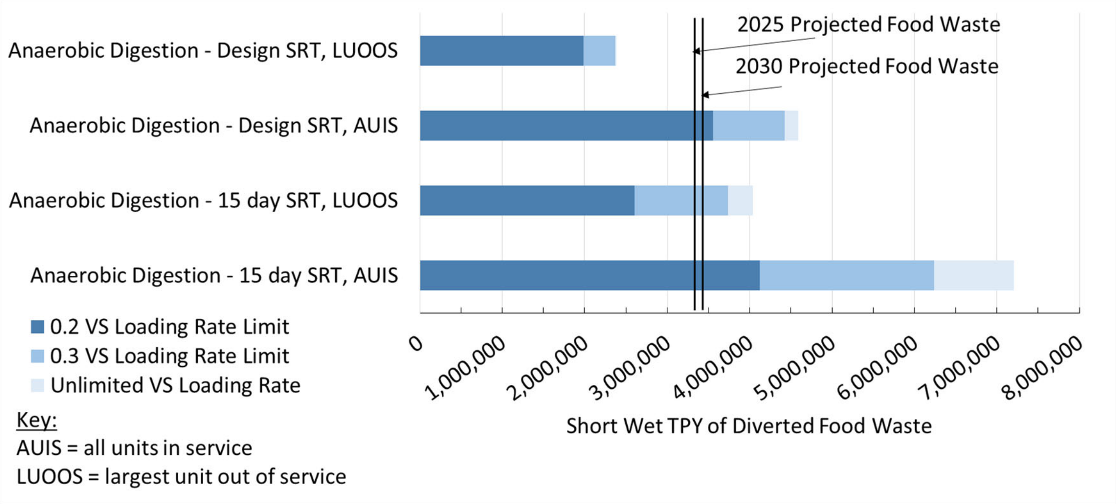

Figure 2.5 Total Existing Excess Digestion Capacity in Short Wet TPY of Diverted Food Waste by Volatile Solids (VS) Loading Rate Limit

<u>Note</u>: The analysis assumes that all mixing, heating, and transfer equipment was adequately sized to handle loads up to the 15-day SRT with All Units In Service.

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[2] This estimated range includes reserved digestion capacity to handle increased municipal solids commensurate with projected population growth by 2030.

[3] Part 503 in Title 40 of the Code of Federal Regulations (EPA 2018).

Finally, for typical digestion capacity analyses, the organic loading rate is assessed in terms of volatile solids (VS) fed to the digester. While some facilities have started assessing loading relative to chemical oxygen demand, most facilities still track the VS loading rate, which is the parameter used in this analysis. Acceptable VS loading rates for municipal sludge digestion under mesophilic temperatures range from 0.1 pounds of VS per day per cubic foot (ppd VS/cf) to 0.2 ppd VS/cf (WEF, MOP 8). To analyze the possibility of stable operations at higher than typical loading rates, we assessed digester capacity for this study for three VS loading rates: 0.2 ppd VS/cf, 0.3 ppd VS/cf, and unlimited (Appendix 2B).

Previous analyses have estimated excess digester capacity. The U.S. Environmental Protection Agency (EPA) cites an estimate of 15 to 30 percent excess capacity for digesters, based on an analysis of 137 wastewater treatment plants (EBMUD 2008),(Shang et al. 2006). CASA estimated California's WWTPs could co-digest 75 percent of the state's food waste stream. To make this estimate, CASA used data from the largest WWTPs in the state (representing 35 percent of the state's wastewater flow) and assumed a 15-day SRT and no limit on VS loading rate. This is similar to the light blue bar in Figure 2.5 representing 15-day SRT, All Units in Service, and unlimited VS loading rate. CASA then extrapolated data for all California WWTPs and also estimated the divertible food waste available in California (Barillo 2016). Our estimates suggest that under many operating scenarios, the anaerobic digesters at California's WWTP have even greater excess capacity than these previous estimates.

2.1.3 Biosolids Dewatering

After solids are digested, the resulting biosolids are typically dewatered before being hauled off-site. Fifty-three, out of 59 survey respondents with anaerobic digestion, have biosolids dewatering onsite. Based on the design capacity and actual use in 2017, 36 of these facilities have excess dewatering capacity to accommodate biosolids from an estimated 4.2 million short wet TPY diverted food waste accepted for co-digestion.

In this analysis we assumed that the volume of liquid effluent from the digesters is equal to the liquid volume fed to the digesters. Further, we did not account for the synergistic effects observed by some co-digesting WWTPs. Such effects could enhance overall solid digestion and minimize biosolids production (Higgins et al. 2017). The digester effluent, or digestate, is fed to the dewatering system and represents the current dewatering feed rate. We assumed that digestate is dewatered from 2 percent solids to 27 percent solids.

Table 2.3 shows the excess capacity of the dewatering systems estimated for the seven WWTPs with existing or planned solid organic waste receiving stations.

Table 2.3 Existing Dewatering - Excess Capacity at the Seven WWTPs with Existing or Planned Solid Organic Waste Receiving Stations

WWTP	Facility Size	Dewatering Facility Design Capacity (gpm)	Currently Used Dewatering Capacity Including Projected Sewage Sludge (gpm)	Associated Excess Capacity for Food Waste(2)		
				gpm(3)	Short Wet TPY as Received at a WWTP (4)	Short Wet TPY as Diverted from a Landfill(4)
Facility 1	Medium	230	50	80	61,000	**31,000**
Facility 2	Large	620	510	120	98,000	**49,000**
Facility 3(1)	Large	4,860	3,500	1,710	1,393,000	**697,000**
Facility 4(1)	Medium	120	60	180	147,000	**73,000**
Facility 5	Large	100	130	100	81,000	**41,000**
Facility 6(1)	Medium	640	40	120	98,000	**49,000**
Facility 7(1)	Large	1,950	750	300	245,000	**122,000**
TOTAL	**NA**	**8,520**	**5,040**	**2,610**	**2,123,000**	**1,062,000**

Notes:
(1) Planned facility or facility expansion.
(2) It was assumed that small facilities run 40 hours per week, medium facilities run 60 hours per week, and large facilities run 144 hours per week. Capacity was also reserved for growth of municipal flows through 2030.
(3) It is assumed that the digestate fed to the dewatering facility is 2-percent solids.
(4) Excess capacity of food waste in short wet TPY is calculated by assuming that 86 percent of TS in the food waste was VS and assuming that the volatile solids reduction was 75-percent.

2.1.4 Biogas Conditioning, Use, and Flare

To assess biogas conditioning and utilization system capacities, we analyzed three system components: 1) the excess capacity in the biogas conditioning system; 2) the excess capacity in the existing on-site beneficial utilization system; and 3) the excess capacity of the flare, required for safe operations and prevention of unrestricted biogas release to atmosphere when biogas utilization systems are out of service or insufficiently sized to handle generated biogas. The limiting capacity of these three components determines the overall existing biogas handling capacity at a WWTP. Based on survey responses, the ability for WWTPs statewide to beneficially use biogas is limited by the existing biogas end use capacity.

Twenty-nine survey respondents have biogas conditioning systems (Figure 2.3); their combined excess biogas conditioning capacity could handle the biogas produced from the co-digestion of 950,000 short wet TPY of diverted food waste. Thirty-four facilities, out of the 59 with anaerobic digestion, reported beneficially using biogas (Figure 2.3). We estimated that the excess biogas end-use capacity could handle the biogas produced from the co-digestion of 800,000 short wet TPY of diverted food waste. Virtually all WWTPs with anaerobic digesters have flares to safely operate and prevent unrestricted biogas release to the atmosphere. We estimated that WWTPs have excess flare capacity to handle the biogas produced from the co-digestion of 2.3 million short wet TPY of diverted food waste.

Increasing organic loading to the digesters is expected to increase the amount of biogas produced (Appendix 2C, Table 2C.3). However, the quantitative increase in biogas is uncertain.

We assume production of an additional 3,968 standard cubic feet (scf) biomethane per wet ton of food waste fed to the digester for co-digestion (Appendix 2C). Biogas yield represents gas yield coming out of the digesters. Biomethane yield represents biogas yield at specified quality. This report assumes that biomethane constitutes 60 percent of biogas produced (Appendix 2C).

Table 2.4 and Appendix 2B detail the capacity for biogas conditioning, utilization, and flaring for the seven WWTPs with all processes necessary for food waste co-digestion.

Table 2.4 Existing Biogas Handling Systems - Excess Capacity at the Seven WWTPs with Existing or Planned Solid Organic Waste Receiving Stations

WWTP	Biogas Production		Biogas Conditioning System			Beneficial Use				Flare	Limiting Capacity		
	Current Average Production (biogas scfm)	Projected Increase Due to Municipal Load by 2030 (biogas scfm)	Total Capacity (biogas scfm)	Capacity w/o CO_2 removal (biogas scfm)(2)	Capacity w/ CO_2 removal (biogas scfm)(2)	Total Capacity (biogas scfm)	Cogeneration Capacity (biogas scfm)	CNG Fueling Station Capacity (biogas scfm)	Pipeline Injection Capacity (biogas scfm)	Total Flare Capacity (biogas scfm)	Limiting Excess Capacity (biogas scfm)(4)	Excess External Feedstock Capacity (short wet TPY as received at a WWTP) (6)	Excess External Feedstock Capacity (short wet TPY as diverted from a Landfill) (6)
Facility 1	200	10	260	260	-	260	260(3)	0	0	320	50	9,000	**4,000**
Facility 2	2,250	110	2,700	2,700	-	3,150	3,150	0	0	3,000	340	55,000	**28,000**
Facility 3(1)	5,810	500	600	-	600	10,700	10,100	0	600	7,200	890(5)	141,000	**71,000**
Facility 4(1)	160	20	270	-	270	260	260	0	0	330	80	13,000	**6,000**
Facility 5	260	30	300	300	-	270	270(3)	0	0	Not Reported	0	0	**0**
Facility 6(1)	100	10	70	-	70	70	0	70	0	Not Reported	0	0	**0**
Facility 7(1)	1,860	140	3,000	3,000	-	4,010	4,010	0	0	2,160	160	26,000	**13,000**
TOTAL	**10,640**	**820**	**7,200**	**6,260**	**940**	**18,720**	**18,050**	**70**	**600**	**13,010**	**1,520**	**244,000**	**122,000**

Notes:

(1) Planned facility or facility expansion.

(2) All reported biogas conditioning systems remove H_2S, moisture, and siloxanes.

(3) Facility 1 and Facility 5 recorded cogeneration capacity in kW. An engine fuel rate of 8,900 BTU/kWh and a biogas low heating value of 600 BTU/cuft were assumed.

(4) Excess capacity was determined by subtracting the sum of the current biogas average production and projected biogas increase due to municipal load by 2030 from the biogas conditioning system, biogas beneficial use, and flare capacities. The minimum of these three values is shown in the table.

(5) Iron salts are added to the sewage sludge prior to digestion to prevent H_2S formation. Thus biogas produced can be beneficially used without further conditioning. So, the biogas conditioning system capacity was assumed not to be limiting.

(6) To calculate the excess external feedstock capacity it was assumed that the limiting biogas facility was running 24 hours per day, 365 days per year. Capacity was also reserved for growth through 2030 in municipal biogas production.

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2.2 Extrapolated Statewide Capacity

The survey responses captured only a portion of California's permitted wastewater flows. To better account for **statewide** capacity for co-digestion, we extrapolated using the survey responses (See Appendix 2A for additional details). We used a flow-based extrapolation for non-discretionary processes such as digestion, dewatering, and flare capacities. Solid organic waste receiving stations, biogas conditioning, and biogas utilization are discretionary. Systems that must be in place for treatment needs are sized for the plant's treatment capacity; discretionary systems are not. Because the capacities of solid organic waste receiving stations, biogas conditioning, and biogas end use capacities may not follow linearly with permitted flow, we did not extrapolate the statewide capacity for these systems.

We extrapolated capacity only for large facilities because we had a high response rate for large facilities, with only 9 known large facilities missing from the 2018 Carollo survey results. The large facilities with anaerobic digestion systems that did not respond to the Carollo survey account for an additional 20 percent of permitted flow statewide. To extrapolate the excess capacity statewide, we added 20 percent to our estimates for excess digestion, dewatering, and flare capacities. Figure 2.6 shows the statewide excess existing capacity by process for the California WWTPs that responded to the survey as well as the extrapolated results for digestion (assuming unlimited VS loading rate), dewatering, and flare capacity at large facilities.

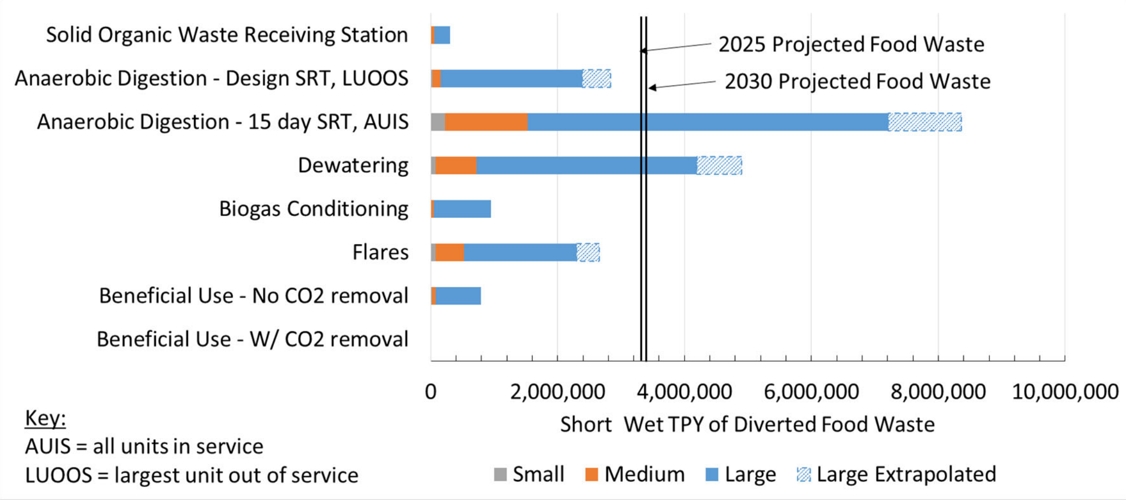
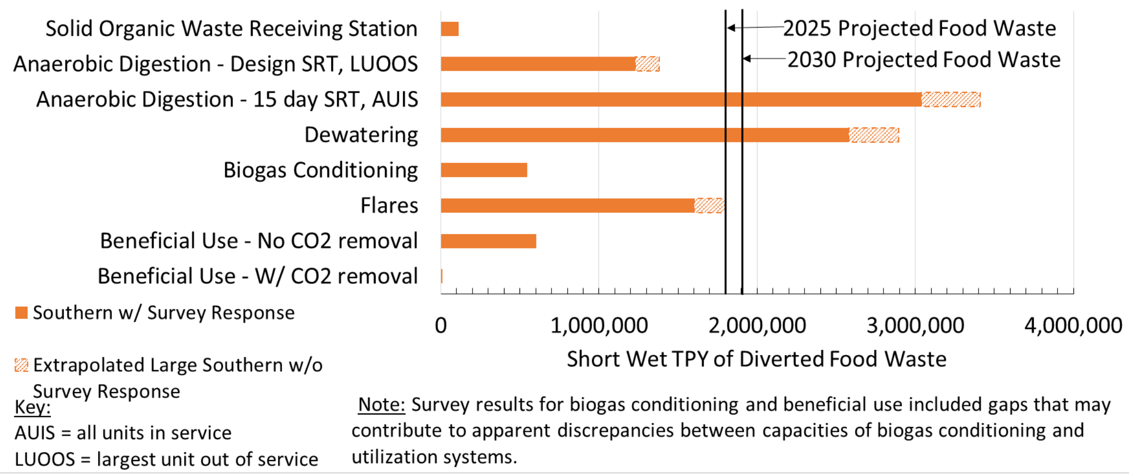


Figure 2.6 Total Existing Excess Capacity per Required Process in Wet Short TPY of Food Waste by Facility Size

Figures 2.7 through 2.11 show the aggregate excess capacity for each of the key processes by region for the facilities that responded to the survey and have anaerobic digestion onsite. These figures also show the projected amount of digestible and divertible food waste in 2025 and 2030 for each region (See Chapter 1).

In general, the Southern, Bay Area, and Central Valley regions have the most excess capacity. The Coastal and Mountain regions had the fewest survey respondents with anaerobic digestion and the least excess capacity at those facilities. Under all the anaerobic digester operating scenarios we considered, the Bay Area appears to have more digester capacity than needed to accept the projected amount of divertible and digestible food waste in 2025 and 2030. For all but the most conservative operating scenario, the Southern and Central Valley regions also appear to have sufficient excess capacity to accept the projected divertible and digestible food waste in those regions.

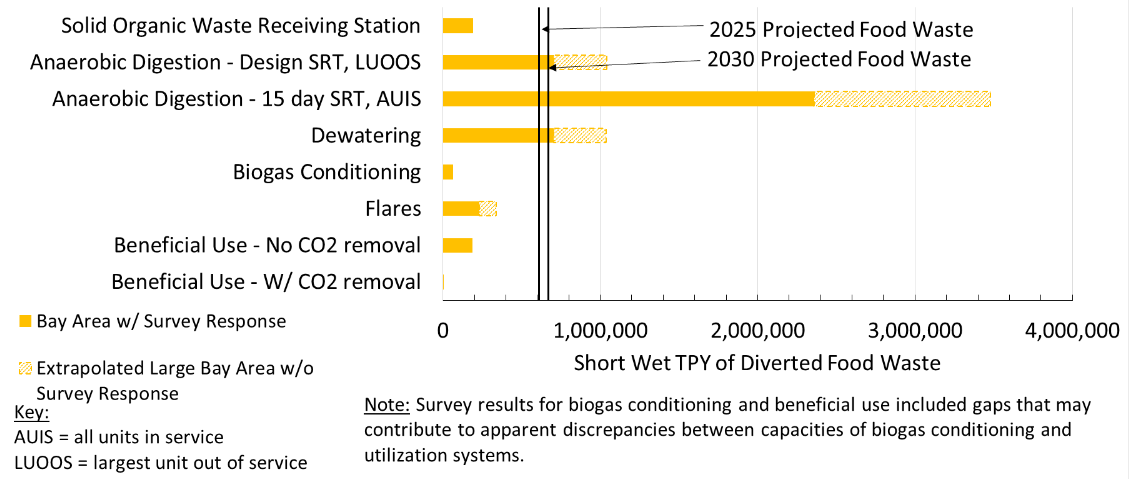
It is important to note that the results shown for the Coastal and Mountain regions only represent the results from the survey data collected, with no extrapolation. Likewise, we did not extrapolate the survey data for medium and small facilities in the Southern, Bay Area, and Central Valley regions. In other words, statewide excess digester capacity may be greater still.



Key:
AUIS = all units in service
LUOOS = largest unit out of service

Note: Survey results for biogas conditioning and beneficial use included gaps that may contribute to apparent discrepancies between capacities of biogas conditioning and utilization systems.

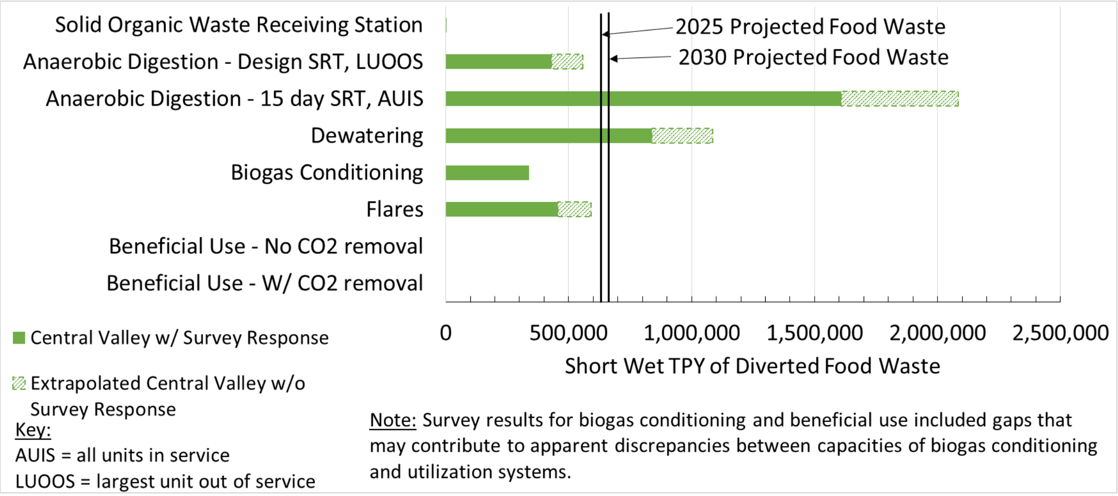
Figure 2.7 Total Existing Excess Capacity per Required Process in Short Wet TPY of Food Waste - Southern Region



Key:
AUIS = all units in service
LUOOS = largest unit out of service

Note: Survey results for biogas conditioning and beneficial use included gaps that may contribute to apparent discrepancies between capacities of biogas conditioning and utilization systems.

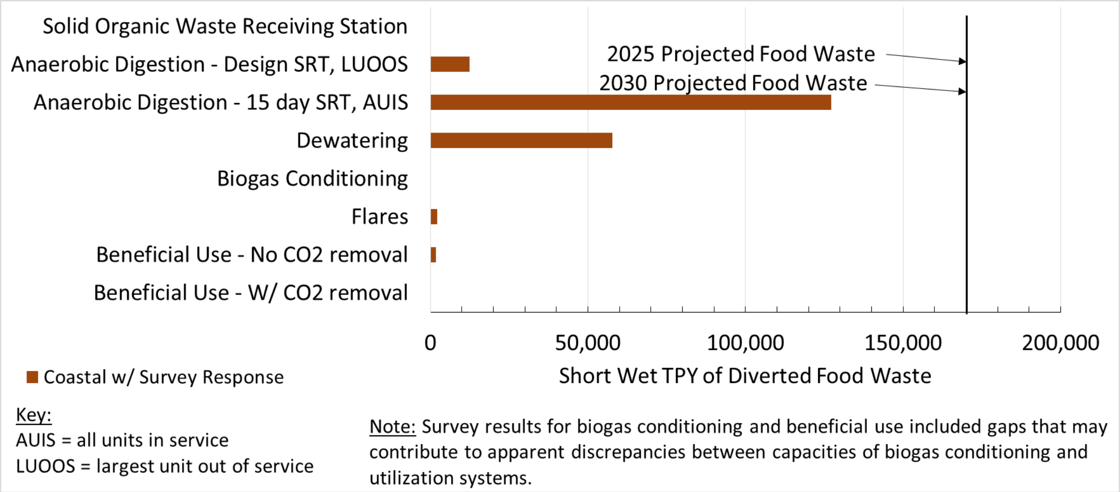
Figure 2.8 Total Existing Excess Capacity per Required Process in Short Wet TPY of Food Waste - Bay Area Region



Key:
AUIS = all units in service
LUOOS = largest unit out of service

Note: Survey results for biogas conditioning and beneficial use included gaps that may contribute to apparent discrepancies between capacities of biogas conditioning and utilization systems.

Figure 2.9 Total Existing Excess Capacity per Required Process in Short Wet TPY of Food Waste - Central Valley Region



Key:
AUIS = all units in service
LUOOS = largest unit out of service

Note: Survey results for biogas conditioning and beneficial use included gaps that may contribute to apparent discrepancies between capacities of biogas conditioning and utilization systems.

Figure 2.10 Total Existing Excess Capacity per Required Process in Short Wet TPY of Food Waste - Coastal Region

Note: Capacity was not extrapolated due to a small sample size.

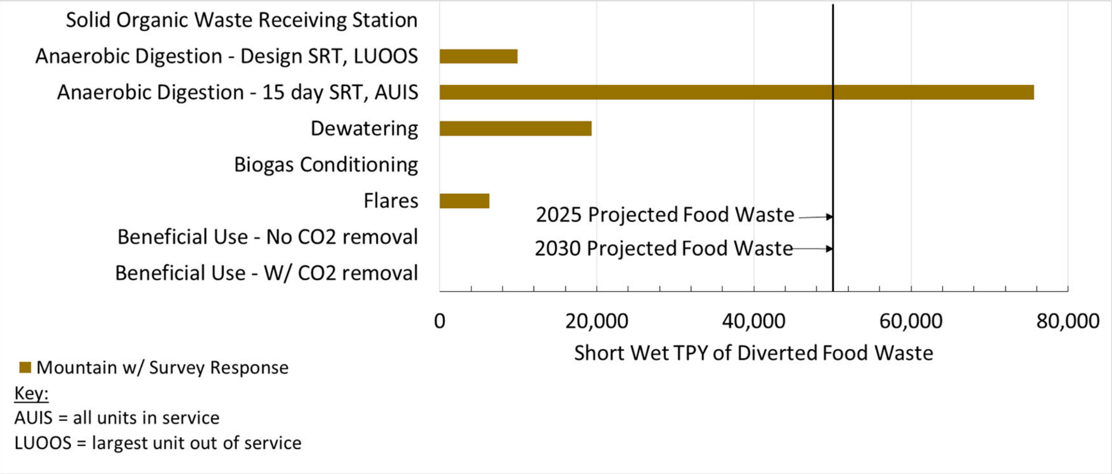


Figure 2.11 Total Existing Excess Capacity per Required Process in Short Wet TPY of Food Waste - Mountain Region

Note: Capacity was not extrapolated due to a small sample size.

2.3 Maximizing Co-digestion Capacity at the Seven Facilities with Existing Infrastructure

The seven facilities (Table 2.2), to our knowledge, are the only facilities in California that will have solid organic waste receiving stations and all of the other processes necessary for food waste co-digestion and the beneficial use of bioproducts by 2025 (Table 2.5). The WWTPs with existing food waste receiving and co-digestion processes are located in areas with high food waste projections (Figure 2.12). This makes them attractive destinations for food waste diverted from landfills.

We estimated these facilities have the excess capacity to handle an additional 118,000 short wet tons of diverted food waste per year. Their co-digestion capacity is limited by the existing capacity of specific processes, particularly the capacity limits of their biogas conditioning and utilization systems. If the capacity of these other key processes were increased to match the excess capacity of the digesters, we estimate these facilities could handle between 846,000 and 2,195,000 short wet TPY of diverted food waste. The actual capacity available would depend on the digestion scenario at which each facility can comfortably operate. The digester capacity scenarios included in Table 2.5 provide “bookends” for potential digestion capacity. These bookends represent scenarios where facilities decide to operate conservatively at a design SRT with redundancy or to maximize co-digestion adhering to the minimum 15-day SRT with all units in service and high VS loading rates.

2.4 Conclusion

The Food Waste Disposal Analysis (Chapter 1) estimated that there will be 3.30 million short wet TPY of recoverable and digestible food waste in 2025 and 3.41 million short wet tons per year in 2030. Without any infrastructure modifications, we estimate seven of California’s WWTPs currently have the excess capacity to handle approximately 118,000 short wet TPY, or 3.5 percent of projected food waste. However, our assessment of existing capacity only accounts for the facilities that responded to the survey, are in place now, or are planned for construction by 2025. There may be more capacity available at existing facilities that did not respond to the survey - and there may be more facilities constructed before 2025 that could accept additional recoverable and digestible food waste.

If just these seven facilities were modified such that the overall system capacity matched the their excess digestion capacity, they would be able to annually handle between 850 thousand and 2.2 million additional short wet tons of food waste diverted from landfills. This represents 25 to 64 percent of the recoverable and digestible food waste in 2030.

We estimated the minimum statewide anaerobic digestion capacity (design SRT, largest unit out of service, and 0.2 VS loading rate limit) for facilities that responded to the 2018 Carollo survey at 2 million short wet tons of diverted food waste. Extrapolated statewide (adding 20 percent), the minimum excess anaerobic digester capacity is sufficient to accommodate 2.4 million short wet tons of diverted food waste. In Chapter 3 - "Investments to Maximize Co-Digestion," we estimate the infrastructure needed to maximize co-digestion statewide.

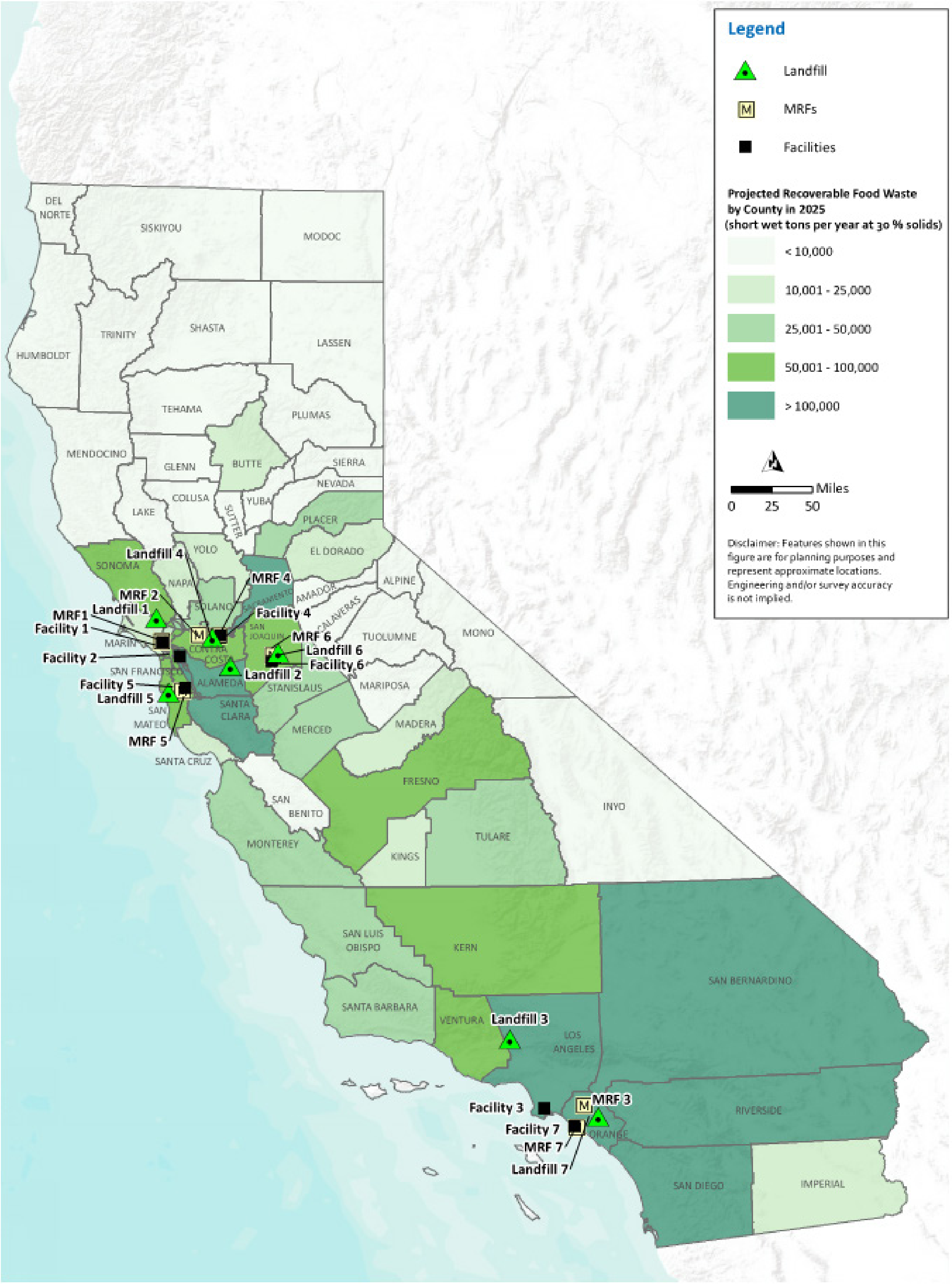


Figure 2.12 Spatial Distribution of Recoverable and Digestible Food Waste by County (2025, low projection)

<u>Note</u>: Also shown, seven WWTPs with all infrastructure needed for co-digestion, currently used MRFs, currently used landfills near the MRFs, and 2025 food waste projections.

Table 2.5 Summary of the Existing Capacity Assessment Results for Facilities with Existing or Planned Food Waste Receiving Stations

WWTP	Estimated Excess Capacity by Process (short Wet TPY as diverted from a Landfill)(2)									Limiting Capacity	
	Solid Organic Waste Receiving Station	Anaerobic Digestion (Design SRT, LUOOS, 0.2 ppd VS/cuft Limit)	Anaerobic Digestion (Design SRT, LUOOS, 0.3 ppd VS/cuft Limit)	Anaerobic Digestion (Design SRT, LUOOS, no VS Loading Rate Limit)	Anaerobic Digestion (15 day SRT, AUIS, 0.2 ppd VS/cuft Limit)	Anaerobic Digestion (15 day SRT, AUIS, 0.3 ppd VS/cuft Limit)	Anaerobic Digestion (15 day SRT, AUIS, no VS Loading Rate Limit)	Dewatering	Biogas Conditioning & Utilization	Excess External Feedstock Capacity (short wet TPY as received at a WWTP)	Excess External Feedstock Capacity (short wet TPY as diverted from a Landfill)
Facility 1	12,000	0	0	0	20,000	39,000	48,000	31,000	4,000	0	**0**
Facility 2	133,000	134,000	303,000	303,000	168,000	356,000	451,000	49,000	28,000	55,000	**28,000**
Facility 3(1)	74,000	446,000	446,000	446,000	632,000	632,000	632,000	697,000	71,000	141,000	**71,000**
Facility 4(1)	49,000	15,000	24,000	24,000	36,000	68,000	98,000	73,000	6,000	13,000	**6,000**
Facility 5	0	150,000	211,000	211,000	242,000	381,000	553,000	41,000	0	0	**0**
Facility 6(1)	1,000	8,000	8,000	8,000	33,000	55,000	73,000	49,000	0	0	**0**
Facility 7(1)	37,000	93,000	93,000	93,000	214,000	340,000	340,000	122,000	13,000	26,000	**13,000**
TOTAL	**306,000**	**846,000**	**1,085,000**	**1,085,000**	**1,345,000**	**1,871,000**	**2,195,000**	**1,062,000**	**122,000**	**235,000**	**118,000**

Notes:

(1) Planned facility or facility expansion.

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Chapter 3

INVESTMENTS TO MAXIMIZE CO-DIGESTION

3.1 Additional Infrastructure Needed to Maximize Co-Digestion

In Chapter 1, we projected the amount of food waste that would be generated in 2025 and 2030 and then estimated how much of it could be diverted from landfills and co-digested at municipal wastewater treatment plants (WWTPs). To avoid overestimating the amount of food waste available for co-digestion and the role California WWTPs may play in achieving the State's waste diversion and greenhouse gas emission reduction goals, we carried forward the lower-range estimate (vertical lines in Figure 3.1).

In Chapter 2 we summarized and extrapolated the results of a 2018 survey to assess the ability of California WWTPs to co-digest food waste (2018 Carollo survey). In estimating excess capacity, we considered various anaerobic digester operating conditions, governed by the solids retention time (SRT), number of units (digesters) in service, and the organic loading rate (Figures 2.5 and 2.6). Under most combinations of operating conditions we considered, the State's WWTPs have adequate excess anaerobic digestion capacity to accommodate all of the estimated divertible and digestible food waste in 2025 and 2030.

In Chapter 3, we evaluate what infrastructure investments would be needed to maximize co-digestion at California's WWTPs. We assumed no new digesters would be built. Rather, we considered what additional capacity would be needed in each of the other key processes (food waste receiving station, biosolids dewatering, biogas conditioning, biogas use, and flares) to fully utilize existing excess anaerobic digestion capacity. We completed the analysis for two "bookend" scenarios of digester capacity:

- The conservative scenario, Scenario 1, assumed all WWTPs operate digesters at design SRT, the largest digester at each WWTP is out of service, and the organic loading rate is restricted to 0.2 pound of volatile solids per cubic feet per day (Figure 2.5). Under this scenario and extrapolated statewide by adding 20 percent, California WWTP could accommodate 2.4 million wet tons of diverted food waste (74 percent and 71 percent of divertible and digestible food waste in 2025 and 2030, respectively).
- The more optimistic scenario, Scenario 2, represents multiple combinations of digester operating conditions in which California's WWTPs have more than enough excess digester capacity to accommodate digestible and divertible food waste. For the purpose of this analysis, we constrained the digestion capacity by the estimated amount of digestible and divertible food waste available in 2030: 3.4 million wet tons (Table 1.4 and Figure 1.8).

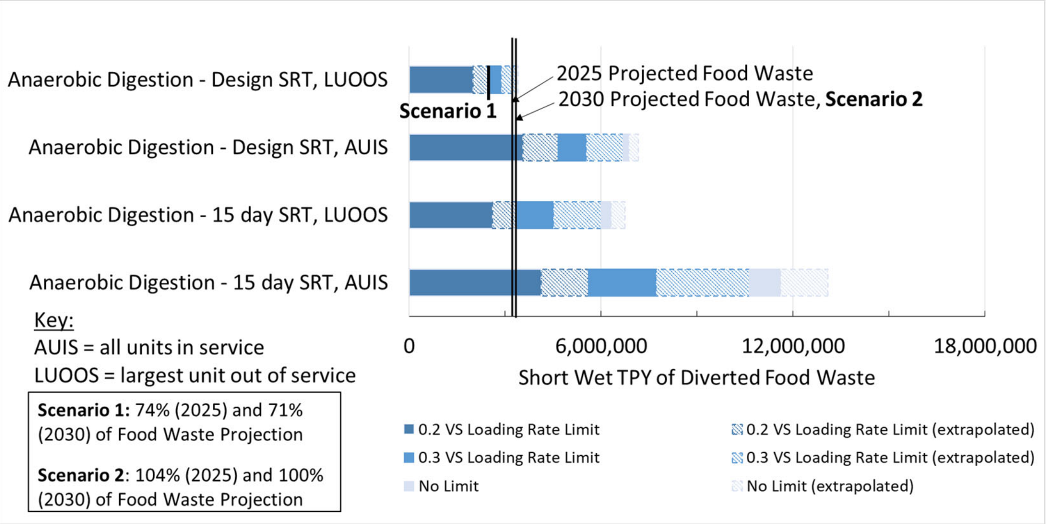


Figure 3.1 Total Existing Excess Digestion Capacity of California WWTPs Under Various Digester Operating Conditions

As discussed in Chapter 2, the anaerobic digestion process generally has the highest existing excess capacity among the key processes required for food waste co-digestion. The excess capacity for each of the key processes varies by facility. To evaluate what infrastructure investments would be needed to maximize co-digestion at California's WWTPs, we calculated the needed process expansions facility-by-facility and then aggregated for a statewide estimate. Aggregating the capacities of such unique systems does not produce a foolproof statewide picture, but it is a decent starting point for estimating statewide costs.

For both the "conservative" (Scenario 1) and the "optimistic" (Scenario 2) scenarios, maximizing co-digestion would require expanding the capacities of all other **(i.e., non-digestion)** processes. Figures 3.2 and 3.3 show the statewide aggregate of <u>existing excess</u> capacities as <u>dark brown</u> bars. The open (unfilled) portion of the dark brown bars represents extrapolated capacity. The <u>tan</u> bars show <u>required additional</u> capacity statewide; they represent the sum of the specifically-sized capacity expansions individual WWTPs would make to fully utilize excess digester capacity. The open portion of the tan bars represents extrapolated excess digester capacity. When aggregated statewide, it appears, for example, that the existing capacities in dewatering and flaring are greater than needed to match the digestion capacity. They only appear so because the required additional capacity reflects the sum of estimated individual facility needs.

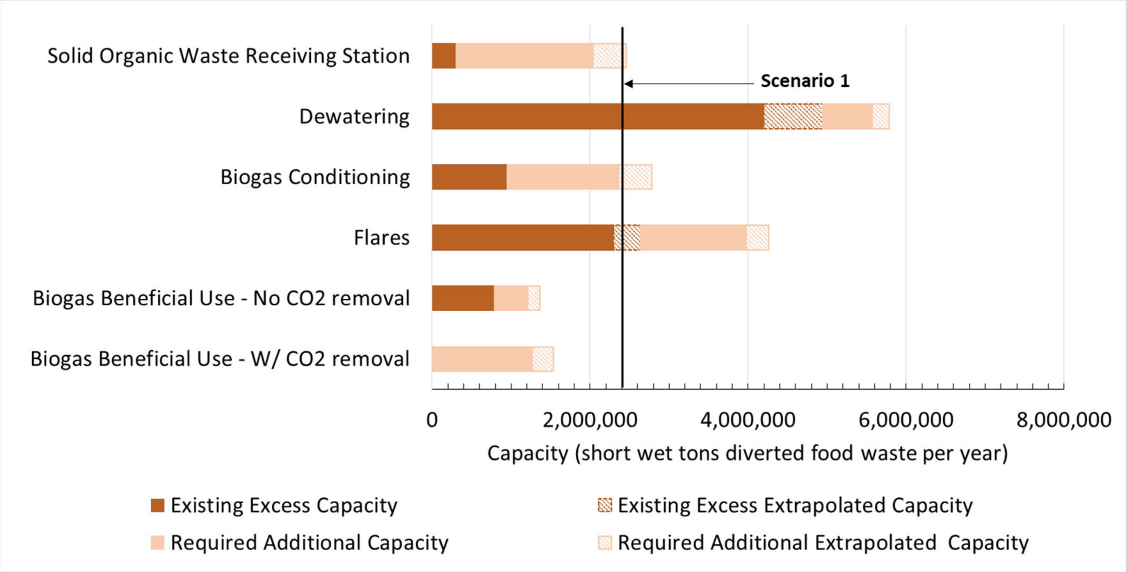


Figure 3.2 Additional Capacity Needed by Process to Match Existing Excess Capacity for Scenario 1

Note: Additional capacity is calculated per facility and then summed across all facilities. The sum of the required additional capacity for non- anaerobic digestion processes may not match the Scenario value shown.

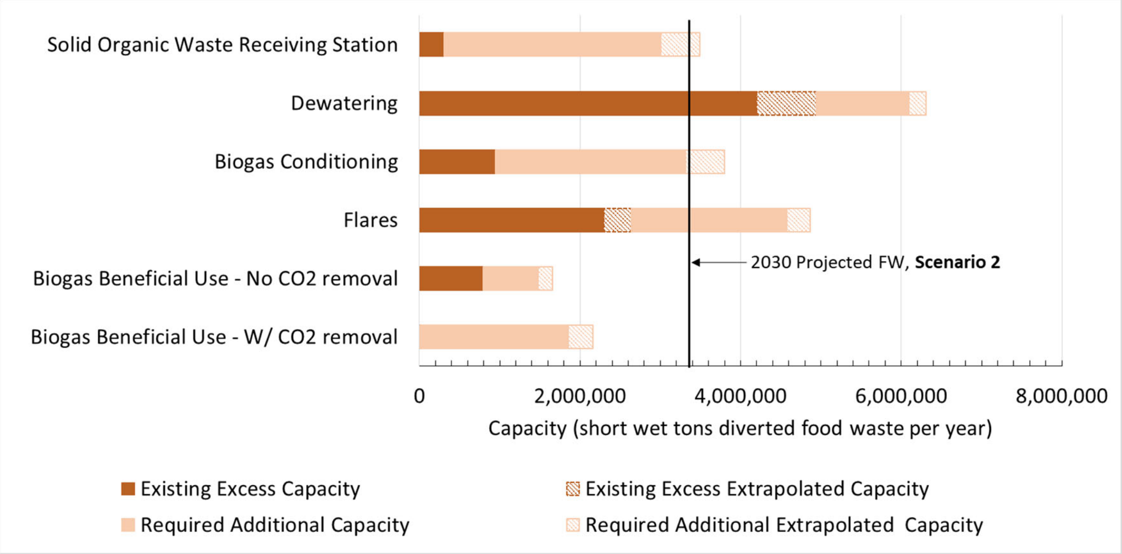


Figure 3.3 Additional Capacity Needed by Process to Match Existing Excess Capacity for Scenario 2

Note: Additional capacity is calculated per facility and then summed across all facilities. The sum of the required additional capacity for non- anaerobic digestion processes may not match the Scenario value shown.

3.2 Economic Impact

3.2.1 Capital Costs

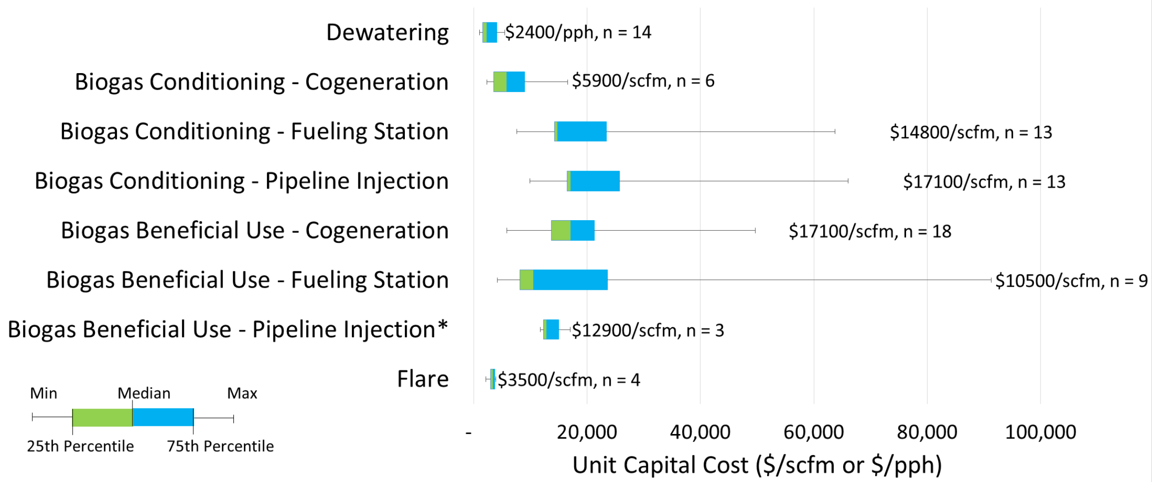
We estimated capital costs for the process expansions required to maximize food waste co-digestion for both the "conservative" (Figure 3.2) and "optimistic" (Figure 3.3) scenarios (Appendix 3A). We used planning level cost estimates corresponding to the Association for the

Advancement of Cost Engineering Class 5 estimate, which can range from -50 percent to + 100 percent of the actual bid cost. The cost estimates reflect full project costs typically incurred in a municipal bid process: costs for structures, civil work, mechanical and electrical equipment, process piping, controls and instrumentation, installation, 30 percent contingency, taxes, insurance and bonds, general contractor overhead and profit, and engineering, legal, and administration fees (Appendix 3B).

For most of the processes, we estimated the costs of capital investments using a unit cost approach. The unit cost approach assumed capital costs scale with flows or loads, a reasonable assumption for a planning-stage, statewide analysis. We used the median unit cost based on vendor quotes, constructed facilities at WWTPs, engineering estimates from multiple consulting firms, and contractor guaranteed maximum prices (Figure 3.4). For some processes, we had limited cost data (pipeline injection systems); for others (fueling stations), costs varied considerably. Note that we assumed that all biogas conditioning and upgrading would take place on-site (Appendix 3C provides additional details and compares the costs associated with biogas conditioning and beneficial uses). Finally, using the unit cost-based approach, we do not account for some economies of scale that might otherwise be considered to compare projects and estimate costs. Costs for specific projects at unique facilities would differ from the median values presented here.

For solid organic waste receiving facilities, we developed costs for three different sized "typical" solid organic waste receiving stations: one for small facilities, one for medium facilities, and one for large facilities. We used this approach rather than unit costs to reflect differences in system automation, redundancy, and operational use of storage tanks at small, medium, and large facilities.

For the required pipeline interconnection costs, we assumed a flat fee of $2 million per interconnection.



* An estimated $2 M interconnection fee must be added to each Pipeline Injection Project in addition to the unit costs shown here.

Figure 3.4 Spread of Unit Cost Data Used to Determine Median Unit Project Costs

<u>Note</u>: Unit costs reflect a full project cost, including equipment and installation, mechanical and electrical equipment, process piping, controls and instrumentation, contingency, taxes, insurance and bonds, general contractor overhead and profit, and engineering, legal, and administration fees.

3.2.2 Operations and Maintenance Costs

For the annual Operations and Maintenance (O&M) costs and revenues, we estimated only incremental additional costs and revenues associated with food waste co-digestion (Appendix 3D). For each of the key processes, we assumed annual maintenance costs (including labor and parts) are equal to two percent of the estimated capital costs (Appendix 3A). While we excluded the annual maintenance required for baseline municipal sewage sludge digestion and processing, we did include the maintenance costs associated with utilizing existing excess capacity in those key processes needed for co-digestion. To do this, we estimated the value of the existing excess capacity using the same approach as for new infrastructure described above (e.g., Figure 3.4), and assumed two percent of that value was the maintenance cost.

We also accounted for increased operating costs associated with food waste co-digestion. We estimated the additional energy needs to heat, pump, and dewater the additional feedstock and determined that these energy demands could be met by using approximately 5 percent of the additional biogas produced. We assumed digester mixing energy would not increase significantly with food waste addition relative to the energy required to mix municipal sludge, so no additional costs for mixing energy were included. In addition to increases in energy costs, we accounted for polymer consumed in dewatering and the cost of hauling additional biosolids generated from food waste co-digestion. Finally, we also estimated the annual cost of operations and administrative labor by assuming one full time equivalent (FTE) for each small and medium facility and two FTEs for large facilities (EDD 2018).

3.2.3 Revenue

Revenue from Tipping Fees

We assumed that WWTPs would charge $20 per wet ton of pre-processed food waste (at 15 percent solids) delivered to their plant. This value is at the low end of the $20 - $65 per wet ton range reported by the Environmental Protection Agency (EPA) (2014). While some WWTPs may be able to negotiate higher tipping fees within that range (e.g., OCSD Biosolids Master Plan [2017]), some may not and could even receive less than $20 per wet ton.

Revenue from Electricity and Natural Gas

Biogas end use is the other major revenue source for co-digesting at WWTPs. The type and value of this potential revenue stream depends on how the biogas is used. These biogas utilization pathways offer differing advantages and disadvantages.

If a WWTP converts biogas to electricity, the facility can generate revenue by using it onsite to offset purchased power or by selling it, either to the power utility or another power user. The main difference between these two electricity end uses is the monetary value assumed for the electricity produced. We assumed an electricity price of $0.08 per kilowatt hour (kWh). This price is in line, on average, with what power utilities currently pay to buy electricity generated at a WWTP. This price is also in line with the effective offset value of using the electricity onsite. When used onsite, WWTPs can offset power purchases and we assumed the same value ($0.08/kwh) for selling or offsetting electricity use onsite. However, this rate does not include demand- and standby charges, which are costs incurred regardless of offsets. These fixed charges must still be paid to the utility.

WWTPs can also use biogas onsite for digester heating or they can convert it to renewable compressed natural gas (CNG). If used to heat digesters, WWTPs may offset the cost of natural gas (for the statewide estimates, we assumed a price of $0.88 gasoline gallon equivalent [GGE] [US EIA 2019]). If a WWTP converts biogas to renewable CNG, the facility may either use it onsite as vehicle fuel or inject it into the natural gas pipeline. The sale price of renewable CNG varies depending on its use. If a WWTP uses it onsite as vehicle fuel, the facility would offset the costs associated with fueling CNG vehicles (for the statewide estimates, we assumed price of $2.4/GGE). If a WTTP injects it into the pipeline, the facility would sell the renewable CNG wholesale to a natural gas provider (for the statewide estimates, we assumed price of $0.93/GGE).

Revenue from Credits

Low Carbon Fuel Standard (LCFS) credit and Renewable Identification Number (RIN) credit can augment the revenue generated when WWTPs convert biogas to renewable CNG. In the past, the U.S. EPA considered the biogas generated from food waste a Cellulosic Biofuel (D3 bucket). However, biogas generated from food waste now only qualifies as an Advanced Biofuel (D5 bucket). D5 RIN credits are less valuable than D3. For this analysis, we assumed an LCFS credit value of $169 per metric ton of carbon dioxide equivalent (MT CO_2e) and a RIN credit value of $0.47/RIN (the assumed D5 value). These credits reflect recent values, but as shown in Figures 3.5 and 3.6, the LCFS and RIN credits have varied over time. We further assumed WWTPs would receive the full credit amount associated with producing renewable fuel from biogas. This requires agreements with CNG off takers to determine and define credit ownership. The proportional distribution of credit and the specific credit values themselves can differ based on such agreements and market conditions. Hence, the value of these credits reflect an uncertain source of revenue for WWTPs.

The Self-Generation Incentive Program (SGIP) provides incentives for technologies to meet all or a portion of the electric energy needs of a facility onsite (SGIP 2017). The SGIP credit is limited to a maximum power production of 3 MW per facility and an annual funding cap every year. Because our analysis indicated that WWTPs would not exceed the 3 MW limit, we included the SGIP credit ($0.60/W, excluding biogas adder) up to the 2019 annual cap for all facilities using biogas to produce power. This value represents expected changes in the program in 2020. In conformance with additional program constraints, we also assumed that no facility would generate more than 125 percent of the electricity used onsite.

Source: NESTE

Figure 3.5 Historical Value of LCFS Credits (NESTE 2019)

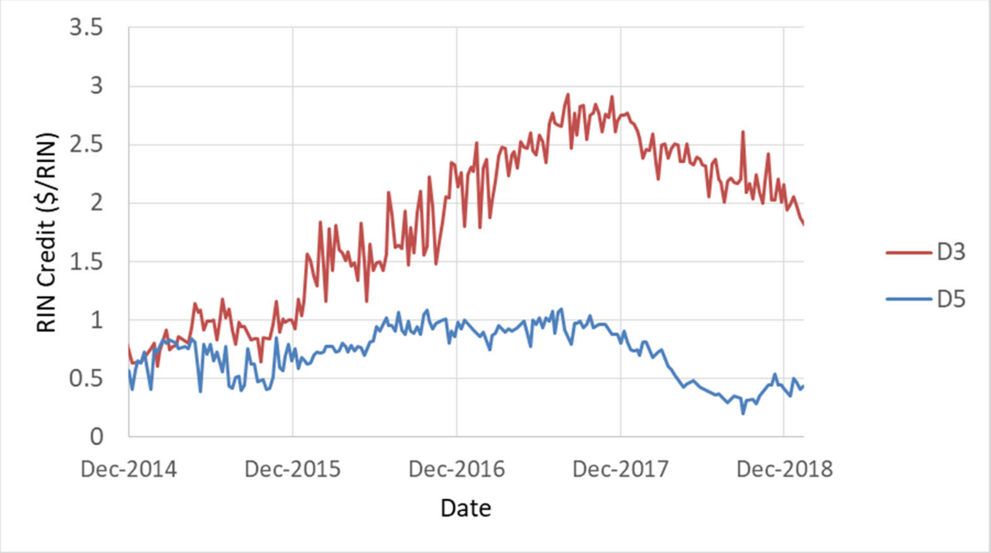


Figure 3.6 Historical Value of RIN Credits (EPA 2019)

3.3 Economic Analysis for an Illustrative WWTP

Table 3.1 shows the economic impact of co-digestion on an illustrative facility: a medium size WWTP with enough excess anaerobic digester capacity to annually accommodate 45,000 wet tons of food waste diverted from landfills. We assume the 45,000 wet tons of food waste would be diverted from a landfill at 30 percent solids, pre-processed and slurried to 15 percent total solids offsite, and then delivered to the WWTP.

We calculated costs as described in Sections 3.2.1 and 3.2.2. We also assumed the following:

- The illustrative facility only has excess capacity in its anaerobic digestion process and so must invest in expanding the capacities of all other key process in order to co-digest the food waste.
- The facility would produce an additional 4,800 dry tons per year of digestate. Dewatering would cost $63/dry ton digestate for additional polymer. Biosolids hauling and tipping fees would cost $189/dry ton digestate[1].
- The facility would produce approximately 565 standard cubic feet per minute (scfm) of additional biogas (179 million scf of biomethane each year)[2], a portion of which would first be used to meet on-site energy demands associated with co-digesting the food waste.
- After meeting the incremental increase in energy needs to heat, pump, and dewater the additional feedstock (approximately 5 percent of the biogas), the remaining additional biogas would be used to generate renewable CNG for onsite vehicle fueling.

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[1] Assuming the facility produces dewatered cake at 27 percent solids, biosolids production would be 17,900 wet tons/year and cost $51/wet ton biosolids for hauling and tipping.

[2] Biomethane calculation assumes 297,600,000 standard cubic feet (scf) of biogas per year, converted to biomethane, BTU, MJ, and GGE assuming the conversions outlined in Appendix 3A, Table 3A.1.

The normalized unit value is $80 per wet ton diverted food waste. However, the economic impact on an actual facility would vary based on the capacity of existing systems, facility size, and biogas end-uses. Additionally, this report assumes biogas upgrading would take place at each WWTP instead of at a centralized system.

Figure 3.7 summarizes the estimated costs and revenues for the illustrative facility, assuming different biogas end-uses. As shown in this figure, renewable CNG for transportation via an onsite fueling station appears to be the most cost effective due to the associated revenue streams. However, the costs presented do not include the costs associated with converting a vehicle fleet to CNG. Such a cost may add considerable capital expense to a biogas-to-vehicle fuel project.

Table 3.1 Illustrative Facility (45,000 Short Wet Tons of Diverted Food Waste): 100 Percent Renewable CNG for Onsite Vehicle Fueling Station

Component	Median Capital Cost	Average Annual O&M Cost	Average Annual Revenue
Solid Organic Waste Receiving Station	($3,660,000)	($70,000)	
Dewatering	($2,650,000)	($50,000)	
Biogas Conditioning | Cogeneration	($164,000)	($3,000)	
Biogas Conditioning | Vehicle Fuel	($7,70,000)	($160,000)	
Flares	($1,980,000)	($40,000)	
Biogas Beneficial Use | Cogeneration	($480,00)	($10,000)	
Biogas Beneficial Use | Vehicle Fuel(1)	($5,650,000)	($113,000)	
Overall Labor		($113,000)	
Additional Polymer		($300,000)	
Biosolids Hauling and Tipping		($900,000)	
Food Waste Tipping			$1,800,000
Renewable CNG Produced			$3,200,000
SGIP Credit	$77,000		
LCFS Credits (CNG020)			$1,340,000
RINs			$930,000
Total (Cost) or Revenue	**($22,370,000)**	**($1,775,000)**	**$7,300,000**
Normalized (Cost) or Revenue(2)(3)		**$3,600,000**	
(Cost) or Revenue per Wet Short Ton of Food Waste at 15% Solids		$40	
(Cost) or Revenue per Wet Short Ton of Food Waste at 30% Solids		$80	

Notes:

(1) The costs for new vehicles, new trucks, or vehicle fleet fuel conversion are not included in the costs shown.

(2) A Capital Recovery Factor (CRF) of 0.086 is assumed. This CRF is calculated using a borrowing cost of 3.32 percent (CA State Treasurer 2018) and a project lifetime of 15 years. See Appendix 3E for a description of how the CRF was calculated and a 'normalized' cost was determined.

(3) To compare to other studies, we also calculated a 12-year net present value of $14,400,000. We assumed an O&M cost and revenue inflation rate of 3 percent per year and a discount rate of 1.8 percent per year. The normalized costs and revenues used in this report do not assume an inflation or discount rate for ongoing costs and revenues because these values will fluctuate over time as the price of power / polymer / labor / etc. change. Such a nuanced analysis was beyond this project's scope.

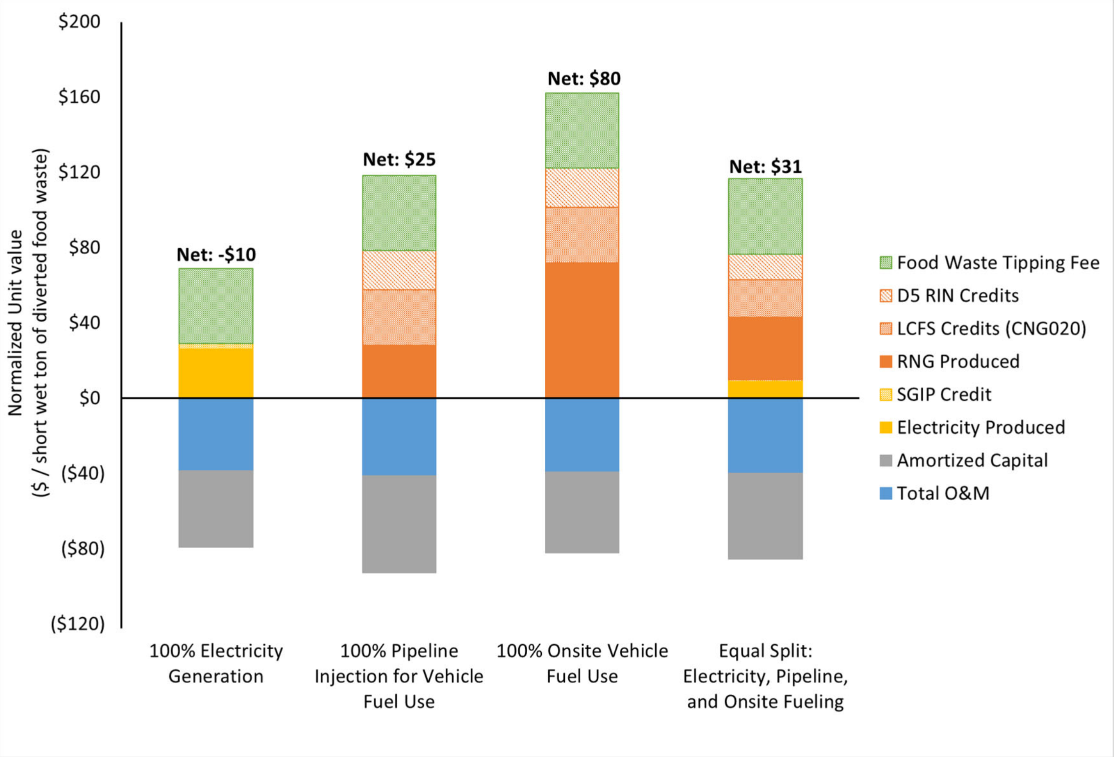

Figure 3.7 Normalized (Costs) and Revenues per Short Wet Ton of Diverted Food Waste by Biogas End-Use for an Illustrative Facility Handling 45,000 Short Wet Tons of Diverted Food Waste Per Year

Finally, we examined how the normalized unit value per wet ton of diverted food waste fluctuates depending on the facility size and biogas end use (Figure 3.8). Assuming the illustrative facility only has existing excess capacity in its anaerobic digester, dedicating the additional biogas to onsite electricity use appears revenue negative - for a range of facility sizes. For a facility that also has capacity in other key-processes, co-digesting food waste and dedicating the additional biogas to electricity may appear more cost-effective. This analysis also assumes $0.08/kWh as the value for electricity. Higher unit values for power would also make electricity generation more favorable.

While the use of renewable CNG for vehicle fuel may be the most beneficial biogas use relative to the State's LCFS goals and available credits, the feasibility of this option requires proximity to a large demand base and vehicle fleets that can use CNG. The use of renewable CNG for pipeline injection also requires proximity to a sufficiently sized utility gas pipeline and overcoming current barriers like high interconnect fees and gas quality standards. Based on these conditions and constraints, electricity production has historically been the most viable biogas utilization option for most facilities (EPA 2018). Chapter 5 and Chapter 6 discuss non-economic factors that both impede and facilitate various biogas end uses in further detail.

Today, most WWTPs dedicate biogas to combined heat and power (CHP) systems for on-site use (EPA 2018).

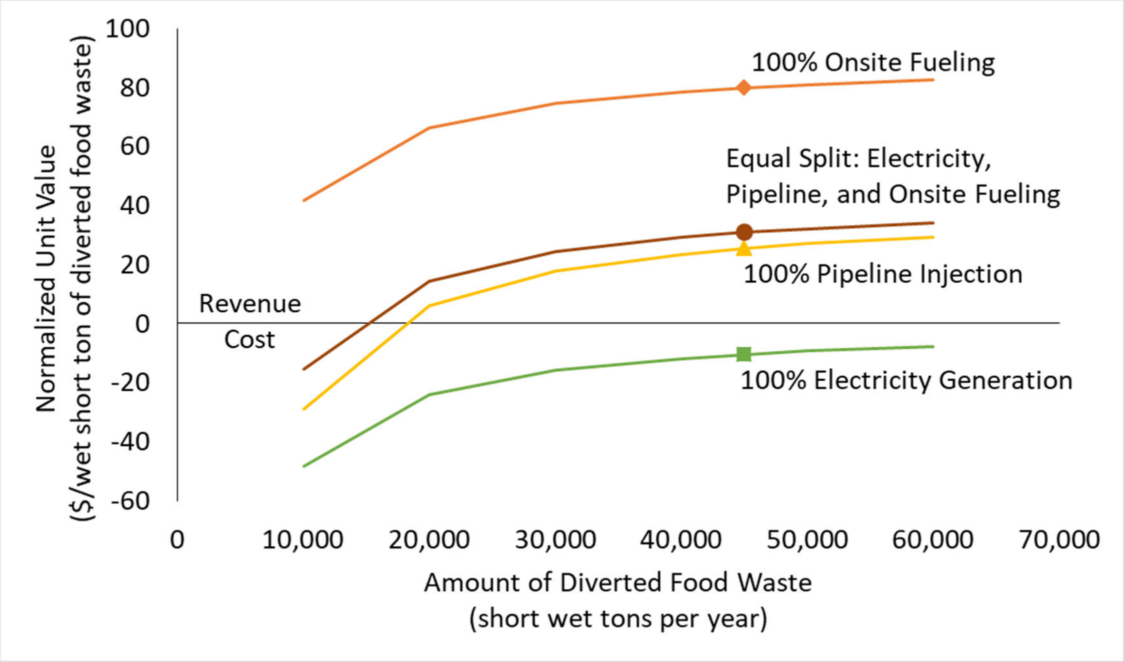

Figure 3.8 Normalized (Costs) or Revenues per Short Wet Ton of Diverted Food Waste by Biogas End Use for Various Facility Sizes

Note: Symbols indicate the normalized unit value for the illustrative facility handling 45,000 wet tons of diverted food waste per year, with biogas end-uses shown in Figure 3.7.

3.4 Statewide Investment Estimates

We estimated the overall statewide costs for expanding key WWTP processes to fully utilize the existing excess anaerobic digestion capacity for the two "bookend" scenarios. We based these overall costs on the aggregate additional infrastructure needed to maximize co-digestion statewide (Figures 3.2 and 3.3), infrastructure investments based on unit costs (Figure 3.4), and O&M cost and revenues discussed above.

We assumed that, once WWTPs used some of the produced biogas to meet the incremental increase in onsite electricity and heating demands associated with co-digestion, the remaining biogas would be split equally among three end-uses:

- Generate electricity (earning $0.08/kWh used onsite or sold back to the grid).
- Generate renewable CNG for onsite vehicle fuel (earning $2.4/GGE).
- Generate renewable CNG for pipeline injection (earning $0.93/GGE).

In completing the analysis, we did not apportion unique biogas utilization strategies facility-by-facility. Rather, we broadly assumed that some facilities would choose one biogas utilization pathway or another, and cumulatively, this would result in a statewide allocation equivalent to the proportioning described above.[3] Hence, the analysis assumes each facility will include

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[3] Currently, the majority of WWTPs dedicate biogas to cogeneration, producing heat and power to meet onsite needs. However, based on the State's goals to reduce carbon intensive vehicle fuels and limit stationary source emissions in nonattainment areas, our analysis assumes the highest value for biogas would be to dedicate it to renewable CNG for vehicle fueling. Hence, even though the today's WWTPs do not dedicate the majority biogas to producing CNG, we assumed they would by 2030.

baseline cogeneration (for producing the electricity required to process the additional food waste) and one of the three other utilization pathways for the remaining biogas.

The overall statewide estimates (Tables 3.2 and 3.3) do not reflect any attempt to optimize co-digestion of food waste across the State such that those facilities with the most excess capacity in multiple key processes accommodate the most food waste. Rather, these costs reflect a distribution of food waste in proportion only to excess digestion capacity. The scale of this study makes it difficult to optimize to this level of detail; however, it is possible that optimizing the allocation of food waste across California WWTPs, could decrease statewide capital costs (Appendix 3F).

Our results indicate maximizing co-digestion in California would be a net positive investment. For Scenario 1, we calculated the costs of co-digesting 2.4 million wet tons of food waste diverted from landfills. We found expected revenues would exceed capital and O&M costs for a normalized value of $98,000,000, or $41 per wet short ton of diverted food waste. For Scenario 2, we calculated the costs of co-digesting 3.4 million wet tons. We found expected revenues would exceed capital and O&M costs for a normalized value of $132,000,000, or $39 per wet short ton of diverted food waste.

These are statewide estimates, calculated by aggregating the unique investments individual WWTPs may make to expand key processes and fully utilize their existing excess anaerobic digestion capacity. For any given WWTP, regional and facility-specific conditions will influence costs. Revenue, too, will vary as tipping fees, electricity and fuel prices, and renewable fuel credits fluctuate. The value of these revenue streams strongly affects the viability of co-digestion projects. For instance, the food waste tipping fee accounts for 35 percent of the annual project revenue in the statewide cost estimate. While some WWTPs may be able to negotiate higher tipping fees, some may not and could even receive less than the $20 per ton of slurried food waste assumed in this analysis.

Figure 3.9 shows the range of normalized values as power and CNG prices vary. To develop this two-dimensional sensitivity analysis, we made the same assumptions as we did with Scenarios 1 and 2: once WWTPs use some of the produced biogas to meet the increased onsite electricity and heating demands associated with co-digestion, they would proportion the remainder equally among electricity generation, renewable CNG for onsite vehicle fueling, and renewable CNG for pipeline injection.

Table 3.2 Scenario 1 - Statewide Summary of Estimated Costs and Revenues for Co-Digestion of 2.4 Million Short Wet Tons Diverted from Landfills: Equal Split of Biogas Beneficial Uses among Electricity Generation, Renewable CNG for Onsite Vehicle Fueling, and Renewable CNG for Pipeline Injection

Component	Median Capital Cost(1)	Average Annual O&M Cost	Average Annual Revenue
Solid Organic Waste Receiving Station	($192,000,000)	($3,900,000)	
Dewatering	($50,000,000)	($2,840,000)	
Biogas Conditioning | Cogeneration	($47,000,000)	($1,310,000)	
Biogas Conditioning | Vehicle Fuel	($240,000,000)	($6,140,000)	
Flares	($71,000,000)	($2,120,000)	
Biogas Beneficial Use | Cogeneration	($124,000,000)	($3,800,000)	
Biogas Beneficial Use | Vehicle Fuel(1)	($264,000,000)	($5,300,000)	
Overall Labor		($7,120,000)	
Additional Polymer		($16,430,000)	
Biosolids Hauling and Tipping		($48,590,000)	
Food Waste Tipping			$96,490,000
Electricity Produced			$20,810,000
Renewable CNG Produced			$79,760,000
SGIP Credit	$20,000,000		
LCFS Credits (CNG020)			$47,870,000
RINs			$33,330,000
Total (Cost) or Revenue	($968,000,000)	($97,550,000)	$278,260,000
Normalized (Cost) or Revenue(2)(3)		$98,000,000	
(Cost) or Revenue per Wet Short Ton of Food Waste at 15% Solids		$20	
(Cost) or Revenue per Wet Short Ton of Food Waste at 30% Solids		$41	

Notes:

(1) The costs for new vehicles, new trucks, or vehicle fleet fuel conversion are not included in the costs shown.

(2) A CRF of 0.086 is assumed. This CRF is calculated using a borrowing cost of 3.32 percent (CA State Treasurer 2018) and a project lifetime of 15 years. See Appendix 3E for a description of how the CRF was calculated and a 'normalized' cost was determined.

(3) To compare to other studies, we also calculated a 12-year net present value of $1,045,000,000. We assumed an O&M cost and revenue inflation rate of 3 percent per year and a discount rate of 1.8 percent per year. The normalized costs and revenues used in this report do not assume an inflation or discount rate for ongoing costs and revenues because these values will fluctuate over time as the price of power / polymer / labor / etc. change. Such a nuanced analysis was beyond this project's scope.

Table 3.3 Scenario 2 - Statewide Summary of Estimated Costs and Revenues for Co-Digestion of 3.4 Million Short Wet Tons Diverted from Landfills: Equal split of Biogas Beneficial Uses among Electricity Generation, Renewable CNG for Onsite Vehicle Fueling, and Renewable CNG for Pipeline Injection

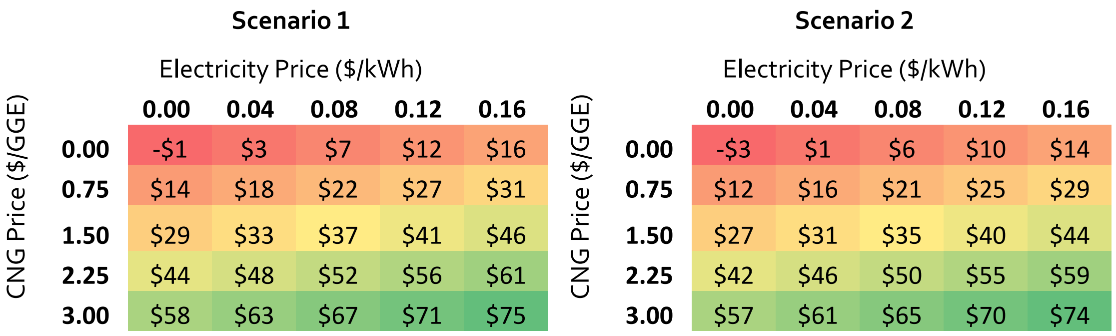
Component	Median Capital Cost(1)	Average Annual O&M Cost	Average Annual Revenue
Solid Organic Waste Receiving Station	($270,000,000)	($5,670,000)	
Dewatering	($80,000,000)	($4,010,000)	
Biogas Conditioning | Cogeneration	($71,000,000)	($1,850,000)	
Biogas Conditioning | Vehicle Fuel	($380,000,000)	($8,670,000)	
Flares	($98,000,000)	($3,000,000)	
Biogas Beneficial Use | Cogeneration	($187,000,000)	($5,370,000)	
Biogas Beneficial Use | Vehicle Fuel(1)	($378,000,000)	($7,580,000)	
Overall Labor		($10,170,000)	
Additional Polymer		($23,210,000)	
Biosolids Hauling and Tipping		($68,660,000)	
Food Waste Tipping			$136,350,000
Electricity Produced			$29,410,000
Renewable CNG Produced			$112,700,000
SGIP Credit	$28,000,000		
LCFS Credits (CNG020)			$67,650,000
RINs			$47,100,000
Total (Cost) or Revenue	($1,436,000,000)	($138,190,000)	$393,210,000
Normalized (Cost) or Revenue(2)(3)	$132,000,000		
(Cost) or Revenue per Wet Short Ton of Food Waste at 15% Solids	$19		
(Cost) or Revenue per Wet Short Ton of Food Waste at 30% Solids	$39		

Notes:

(1) The costs for new vehicles, new trucks, or vehicle fleet fuel conversion are not included in the costs shown.

(2) A CRF of 0.086 is assumed. This CRF is calculated using a borrowing cost of 3.32 percent (CA State Treasurer 2018) and a project lifetime of 15 years. See Appendix 3E for a description of how the CRF was calculated and a 'normalized' cost was determined.

(3) To compare to other studies, we also calculated a 12-year net present value of $1,405,000,000. We assumed an O&M cost and revenue inflation rate of 3 percent per year and a discount rate of 1.8 percent per year. The normalized costs and revenues used in this report do not assume an inflation or discount rate for ongoing costs and revenues because these values will fluctuate over time as the price of power / polymer / labor / etc. change. Such a nuanced analysis was beyond this project's scope.



Scenario 1

CNG Price ($/GGE)	Electricity Price ($/kWh) 0.00	0.04	0.08	0.12	0.16
0.00	-$1	$3	$7	$12	$16
0.75	$14	$18	$22	$27	$31
1.50	$29	$33	$37	$41	$46
2.25	$44	$48	$52	$56	$61
3.00	$58	$63	$67	$71	$75

Scenario 2

CNG Price ($/GGE)	Electricity Price ($/kWh) 0.00	0.04	0.08	0.12	0.16
0.00	-$3	$1	$6	$10	$14
0.75	$12	$16	$21	$25	$29
1.50	$27	$31	$35	$40	$44
2.25	$42	$46	$50	$55	$59
3.00	$57	$61	$65	$70	$74

Figure 3.9 Normalized Value ($/wet ton diverted) for Scenario 1 and Scenario 2 as Electricity and CNG Prices Vary

3.4.1 Comparison to Recent Cost Estimates

The CalRecycle's *Standardized Regulatory Impact Assessment* for the *Proposed Regulation for Short-Lived Climate Pollutants: Organic Waste Methane Emissions* considered the expected cumulative costs and revenues associated with implementing Senate Bill (SB) 1383 (CalRecycle, 2018). CalRecycle analyzed the economic impact of a scenario in which a combination of new compost and anaerobic digestion facilities would handle the food waste diverted from landfills. CalRecycle estimated a 12-year Net Present Value (NPV) of $528 Million for 60 compost facilities and $3,177 Million for 26 new stand-alone anaerobic digestion facilities. The 26 new stand-alone anaerobic digestion facilities would accept 2.6 million wet tons per year of diverted food waste[4].

The NPV values for compost are likely lower than those for co-digestion (Tables 3.2 and 3.3) because co-digestion provides benefits that compost does not, i.e., renewable energy and low-carbon fuel use. On the other hand, the estimated NPV values for stand-alone digesters appear higher than those for co-digestion. It is important to emphasize that our analysis provides a more comprehensive picture of the expected capital costs than previous estimates that focused on individual components of the overall system.

The California Energy Commission (CEC)'s *Renewable Energy Resource, Technology, and Economic Assessments: Appendix H* presents levelized cost of energy for biogas distributed power generation that range from $51/MWh to $76/MWh for wastewater facilities (CEC, 2017b). The CEC analysis was not specifically for co-digestion and only accounted for the capital and O&M costs associated with biogas distributed power generation. Only accounting for the total capital and O&M costs, we estimate Scenario 1 would cost $59/MWh and Scenario 2 would cost $58/MWh. These values fall within the range of those estimated in the CEC report.

3.5 Community Impacts

In addition to supporting the State's organic waste diversion goals and greenhouse gas emission reduction targets, co-digestion of diverted food waste at WWTPs could have impacts on surrounding communities. The impacts - which include job creation, truck trips, noise, and odors - are described in the sections that follow.

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[4] Each facility would have a throughput of 100,000 wet tons per year (CalRecycle 2018).

3.5.1 Job Creation

To develop a conservative cost analysis, we assumed that additional labor would be necessary at the scale required for statewide implementation. We assumed that, at small and medium facilities, one additional FTE would be required; at large facilities, two additional FTEs. Using these assumptions, Table 3.4 summarizes the potential additional jobs created by region and for each scenario.

However, based on the survey and follow up communications with facilities currently co-digesting food waste, it is not guaranteed that co-digestion will create additional jobs. Only one large facility (of the seven WWTPs with existing or planned solid organic waste receiving stations in California) added 2 FTEs. The remaining six facilities did not provide a response. While three large facilities reported dedicating staff to biosolids and biogas handling systems, the facilities did not specify how many or whether these dedicated staff came onboard to manage new duties associated with co-digestion specifically.

In follow up conversations with several of these agencies, they indicated that additional jobs could be created in the future as their programs expand. Or, they could instead reallocate existing resources. For many of these facilities, it is too early to determine the additional workload and staffing needs associated with food waste co-digestion. Given this inconsistency and the small sample size, we cannot gauge job creation attributable to food waste co-digestion at WWTPs[5] with confidence.

Table 3.4 Estimated Job Creation by Region and by Scenario

Region	Jobs Created Under Scenario 1	Jobs Created Under Scenario 2
Bay Area	16	28
Central Valley	20	23
Coastal	2	5
Mountain	2	3
Southern	23	31
Total	**63**	**90**

3.5.2 Truck Trips, Noise, and Odors

The number and distance of truck trips would change as food waste is diverted from landfills to WWTPs. Food waste would travel from material recovery facilities (MRFs) to WWTPs rather than to landfills. This would increase the number of trucks traveling to WWTPs. Because food waste co-digestion produces more biosolids, the number of trucks traveling from WWTPs to biosolids end uses would also increase. We did not analyze potential changes in transport between sources (residences, institutions, commercial locations) and the MRFs.

We assumed that each truck trip can transport 4,000 gallons of slurried food waste to WWTPs. For Scenario 1, this equates to an additional 289,000 truckloads per year, or around 790 additional truckloads per day. We also assumed that each truck trip could transport 20 tons of biosolids from WWTP to end users. For Scenario 1, this equates to an additional 48,000 truckloads per year, or around 130 additional truckloads per day. The combined truck trips to and

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[5] Estimating job creation at Material Recovery Facilities (MRFs) may be more reasonably estimated. We did not include MRFs in this analysis.

from the WWTPs for Scenario 1 would result in an additional 337,000 truckloads per year. Similarly for Scenario 2, food waste co-digestion would result in an additional 477,000 truckloads per year.

As the number of truck trips increase to and from WWTPs, the associated truck traffic noise would increase. For instance, a diesel truck traveling at 50 miles per hour typically generates a maximum instantaneous noise level of around 85 dBA at a distance of 50 feet. This is around 10 dBA louder than the noise generated during the day in an urban area, which is around 75 dBA (California Department of Transportation 2013). However, this truck traffic is periodic. According to the California Department of Transportation, the maximum allowable noise exposure over 15 minutes is 115 dBA (2013). The expected truck traffic noise is less than this threshold.

Food waste trucks are enclosed and should not cause additional odors during transport, but odors may escape during offloading at the WWTP. Additional onsite odor control may be necessary at WWTPs to mitigate the risk of odor releases during offloading. We accounted for additional odor control in the capital and O&M cost estimates conducted for this study.

3.6 Regulatory Considerations

Maximizing co-digestion statewide will require complying with increasingly stringent regulations governing water quality, air quality, and solids management. Rather than incorporate potential compliance costs into the overall costs estimates, we identify a few potential regulatory obstacles and acknowledge overcoming them may increase the cost of co-digestion projects.

3.6.1 Water Quality

Co-digestion of diverted food waste increases nutrient loads in the digesters and the resulting biosolids. Upon dewatering biosolids, the liquid residue, centrate, which contains a high concentration of nutrients (e.g., nitrogen), is typically routed back to the headworks of a wastewater treatment plant. Co-digestion can increase the nutrient concentration in the centrate, which, could, in turn, increase the nutrient concentration of discharged effluent. There are varying requirements, or limits, for effluent nutrient concentrations depending on where the effluent is discharged or reused.

The State Water Resources Control Board and the Regional Water Quality Control Boards govern regulations related to effluent quality. At this time, those agencies are developing regulations that will limit nutrient loading in effluent discharged to the San Francisco Bay. While there are treatment processes capable of removing nutrients from wastewater to meet the limits, these approaches can be costly. Generally, the stricter the effluent limit, the more costly and energy intensive achieving it will be. If the wastewater sector begins implementing co-digestion projects more broadly, the cost of implementing nutrient removal processes should also be considered.

3.6.2 Air Quality

Air emission requirements can present barriers to beneficially using biogas. The regulatory bodies that govern regulations related to air emissions and biogas conditioning and utilization (on or offsite) are the US EPA (Clean Air Act), Occupational Safety and Health Administration (OSHA), California Air Resources Board (CARB), California Public Utilities Commission (CPUC), and local air districts.

SCAQMD Rule 1110.2

The South Coast Air Quality Management District (SCAQMD) Rule 1110.2 was first adopted in 1990, and significantly amended in 2008 and again in 2015. These changes, which other local air districts have followed, resulted in restrictive limits on nitrogen oxides (NO_x) emissions from engines. The air districts aim to achieve an 80 percent reduction of NO_x by 2023 in areas that are in non-attainment for ozone. Engine NO_x limits dropped from 36 ppmvd to 11 ppmvd. To meet this limit while continuing to generate power via biogas combustion requires costly air pollution control equipment or an alternative to onsite combustion. Currently, these requirements impact WWTPs in the South Coast and San Joaquin air basins, but may soon have more widespread impact, as additional air districts are considering more stringent NO_x limits for engines.

SCAQMD Rule 1118.1

The SCAQMD adopted Rule 1118.1 on January 4, 2019. This rule restricts NO_x, volatile organic compounds (VOCs), and carbon monoxide (CO) emissions from non-refinery flares; it focuses on maximizing emission reductions, minimizing routine flaring, and encouraging beneficial use of gases that would otherwise be flared. This rule may impede co-digestion at WWTPs because of increased nitrogen loading (See Section 3.6.1). Depending on digester operations, the additional nitrogen load may increase free ammonia in the biogas, which, when combusted in a flare, converts to NO_x. The subsequent flare emissions may not comply with 1118.1's very restrictive limits for NO_x (0.025 pounds per million British thermal units [lbs/MMBtu] for major sources and 0.06 lbs per MMBtu for minor sources). The Rule contains resolution language to evaluate best available control technologies if NO_x emissions exceed thresholds, which could be very costly and diminish the economic feasibility of co-digestion projects.

This rule also contains language requiring research be done by SCAQMD in 2019 to examine the potential impact of SB 1383 (i.e., diverted food waste co-digestion) on WWTPs. The goal of this research is to determine if the NO_x limit needs to be modified to reduce barriers to the implementation of SB 1383.

CPUC Standards for Biomethane Pipeline Injection

In addition to the high cost of interconnecting into a natural gas pipeline in California, the CPUC biomethane standard (i.e., a required heat content of 990 Btu/scf) for pipeline injection has been difficult to achieve in a cost-effective manner. These barriers have disincentivized projects that aim to increase production of biogas for sale to local utilities. In 2018, the California Council on Science and Technology (CCST) released a comprehensive review of the technology and issues concerning injecting renewable natural gas (RNG) into the natural gas pipeline. The study covers the different sources of biomethane, difficulties meeting pipeline specifications, and concerns that might arise with RNG deployment scenarios (CCST 2018).

As a result of CCST's work, the CPUC opened proceedings in the fall of 2018 to adjust the required heat content for biomethane pipeline injection to 970 Btu/scf, which is attainable via current biogas conditioning technology. It is anticipated that this proceeding will conclude by 2020, providing an alternative use of biogas in the event that meeting emissions limits for stationary sources becomes too costly to satisfy.

Cal-ARP Risk Management Plans and OSHA Process Safety Management Procedures

In the Clean Air Act Amendments of 1990, Congress required OSHA to adopt the Process Safety Management (PSM) and required EPA to issue the Risk Management Plan Rule (RMP). These regulations were developed to prevent the release of an extremely hazardous or flammable substance such as the toxic gas release that occurred in Bhopal, India in 1984. PSM and RMP were written to complement each other in accomplishing these Congressional goals; they act in parallel and have many similarities but also some key differences. Both regulations regulate the owner or operator of a stationary source with more than a threshold quantity of a regulated substance in a process. The threshold quantities differ slightly between PSM and RMP as do the requirements and exceptions.

In the State of California, the "Risk Management Plan Program" is the California Accidental Release Prevention Program, or CalARP. CalARP is the Federal Risk Management Plan Program with additional state requirements, including an additional list of regulated substances and thresholds (CCR, Title 19, Section 2770.5).

While Federal OSHA does not have direct jurisdiction over employees of state and local governments, twenty-five States, including California, administer their own occupational safety and health programs under plans approved by OSHA. These States are required to adopt and enforce occupational safety and health standards which are at least as effective as those promulgated by OSHA and must extend their coverage to public sector employees (OSHA Act of 1970, Section 18). As a result, in California, POTWs must also comply with the PSM standard if they exceed the threshold quantity of a regulated substance.

For both regulations, a stationary source can be a building, structure, or piece of equipment; and the process is where the substance is stored, used, manufactured, or handled. Under OHSA, flammable gas is a regulated substance with a threshold quantity of 10,000 lbs. If a facility exceeds the threshold quantity of flammable gas, it must comply with the PSM standard for the covered process.

In parallel, per the California Code of Regulations (CCR) Title 19 Division 2, Chapter 4.5 (Cal-ARP Program), methane is a regulated substance with a threshold quantity of 10,000 lbs. If a facility exceeds the threshold quantity of the regulated substance, the facility must prepare a RMP and implement the risk management program. There are three program levels of RMPs, the most stringent being Program Level 3, which has similar requirements as the OSHA PSM standard (CCR, Title 8, Section 5189). Additionally, there is a guidance document by the EPA specifically developed for WWTPs. It explains that the threshold applies to the total weight of the digester gas mixture, not only the fraction of methane within that mixture, and also provides guidance on how to determine whether a facility has 10,000 lbs of digester gas mixture onsite at any one time (EPA 2013).

If a facility exceeds the methane/flammable gas threshold with its onsite biogas production process AND uses all of it onsite, they are exempt from both the PSM standard and the Cal-ARP program. However, if all or even a small portion of that biogas is used offsite, then that facility must comply with both regulations.

Implementing a RMP and PSM program proved too onerous for one Bay Area utility. Currently this utility sells surplus electric power from onsite cogeneration to a wholesale customer. Onsite cogeneration is exempt from PSM and RMP regulations. But the value of renewable electricity has declined in California, making co-digestion projects that use cogeneration less financially attractive. To find greater value in biogas produced from co-digestion, the facility had been planning to interconnect to the local utility pipeline grid and deliver renewable natural gas for use as a transportation fuel. Faced with PSM and RMP requirements and their associated costs, this facility abandoned the project, forfeiting a proposed grant award from the California Energy Commission as well as the potential LCFS and RFS credits. Because of the relatively low value of renewable electricity, generating a renewable transportation fuel from biogas was a critical factor in its plans to expand co-digestion and the utility is now uncertain if accepting additional food waste will be financially viable.

3.6.3 Solids Management

The US EPA, the State Water Resources Control Board, and CalRecycle govern regulations related to biosolids treatment and use. County jurisdictions across the state also play a role in that some have limited the land application of Class B biosolids. While co-digestion may increase biosolids production at a WWTP, it does not affect a facility's ability to meet regulatory requirements related to biosolids quality. Inasmuch, the state and local requirements pertaining to biosolids use are what may increase co-digestion O&M costs beyond the estimates presented in Section 3.2.2.

The ordinances banning the land application of Class B biosolids have already compelled many WWTPs to haul solids great distances (even out of state[6]) or to landfills. Alternative biosolids treatments, ranging from composting to heat drying to gasification, could help WWTPs navigate use restrictions; such treatments are, however, more expensive.

Currently, state law incentivizes using biosolids as alternative daily cover (ADC) at landfills. Jurisdictions sending biosolids to a landfill as ADC may count that as a *diversion* credit, helping them to reach AB 939 diversion goal mandates. However, the SB 1383 rulemaking may make ADC a less attractive option for organic waste management. For the purposes of the SB 1383 regulation, using organic waste (including biosolids) as landfill cover will constitute *disposal* of organic waste.

On the other hand, the new regulation establishes procurement targets for the recovery of organic waste products. The targets would require jurisdictions to procure a certain amount of these products (e.g., compost and renewable fuel) on an annual basis. Renewable fuel produced by WWTPs would be considered an eligible organic waste product if the WWTP co-digests with diverted organic waste and recovers at least 75 percent of the biosolids it produces (i.e., no more than 25 percent of biosolids could be landfilled, either as ADC or disposal). Biosolids composted at a permitted compost facility would also be considered an eligible organic waste product.

To what extent SB 1383 incentivizes the land application of biosolids, prompts more expensive treatments, or both is uncertain. For some WWTPs, being unable to estimate the costs of increased biosolids production with some certainty may make co-digestion appear too risky of an investment.

3.7 Summary of Findings

In Chapter 1, we estimated there will be 3.41 million short wet tons per year of divertible and digestible food waste in 2030. In Chapter 2, we analyzed survey results to understand whether

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[6] About 70 percent of California's biosolids were land applied in 2018, 21 percent of which were land applied in Arizona.

and to what extent California WWTPs have excess capacity in anaerobic digesters and other key system processes to accommodate that food waste.

In Chapter 3, we considered what additional infrastructure would be needed to maximize co-digestion potential in California - and at what cost. We found that, if the capacity of key processes were expanded to match the excess capacity of anaerobic digesters, California WWTPs could accept from **71 percent** (Scenario 1) to **100 percent** (Scenario 2) of divertible and digestible food waste.

Our results indicate maximizing co-digestion in California would be a net positive investment. For Scenario 1, we estimated the costs of co-digesting 2.4 million wet tons of food waste diverted from landfills. We found expected revenues would exceed capital and O&M costs for a normalized value of $41 per wet short ton of diverted food waste. For Scenario 2, we estimated the costs of co-digesting 3.4 million wet tons. We found expected revenues would exceed capital and O&M costs for a normalized value of $39 per wet short ton of diverted food waste.

While these estimates are more comprehensive than those provided in previous analyses, true statewide benefits could be lower for numerous reasons. For example, the revenue associated with co-digested food waste may fall. Tipping fees could drop, as could the value of renewable electricity, LCFS- and RIN credits. New regulatory pressures may also drive up costs.

Grants and loans could help WWTPs shoulder heavy costs. Appendix 3G lists some of the grant and loan programs that could support co-digestion projects. Multiple parties (MSW facilities, WWTPs, 3rd parties, etc.) could come together to finance a co-digestion project, advancing an effort that might otherwise be too burdensome for a WWTP. Especially with financial assistance, statewide benefits could be higher.

Our capital unit costs are sometimes higher than those assumed in past analyses, in part because our costs encompass those typically incurred for publicly bid municipal projects. If statewide costs were lower, statewide benefits could be higher.

Whether higher or lower than presented here, statewide benefits would accrue based on the decisions of individual WWTPs. The amount of co-digested food waste, biogas and biosolids management strategies, and project economics will vary depending on site-specific conditions. While co-digestion may pencil out for one facility, it may not for another.

In addition to analyzing costs, Chapter 3 also considered some of the non-economic impacts of food waste co-digestion at WWTPs. In Chapter 4 we analyze the greenhouse gas emission reduction potential associated with diverting food waste from landfills to WWTPs for co-digestion. Finally, in Chapters 5 and 6, we discuss the barriers and opportunities for food waste co-digestion at specific facilities across the state.

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Chapter 4

GREENHOUSE GAS EMISSIONS REDUCTIONS FROM CO-DIGESTION OF FOOD WASTE

4.1 Co-Digestion Emission Reduction Factor

The analysis to derive a co-digestion emission reduction factor follows the methodology established in the California Air Resources Board's (CARB's) Draft Method for Estimating greenhouse gas (GHG) Emission Reductions from Diversion of Organic Waste from Landfills to Compost Facilities (CARB 2017a; referenced herein as the CERF Report). We modified factors where information specific to co-digestion was available and cite the CERF Report for any factors that remain unchanged.

The co-digestion emission reduction factor (Co-DigERF) is the sum of emission reductions and GHG emissions associated with co-digestion, expressed in metric tons of carbon dioxide equivalents (MT CO2e) per wet ton of food waste diverted from landfill:

$$\text{Co-DigERF} = \underbrace{(\text{ALF} + \text{BioG} + \text{BioS})}_{\text{Emission Reductions}} - \underbrace{(T_E + P_E)}_{\text{Emissions}}$$

Where,

Co-DigERF = Co-digestion emission reduction factor (MTCO$_2$e/short wet ton of diverted food waste)

ALF = Emission reduction associated with the Avoidance of Landfill methane emissions (MTCO$_2$e/short wet ton of diverted food waste)

BioG = Emission reduction associated with biogas used to generate electricity or renewable natural gas (RNG) vehicle fuel (MTCO$_2$e/short wet ton of diverted food waste)

BioS = Emission reduction associated with biosolids land application (soil erosion decrease, decreased fertilizer use, and decreased herbicide use) (MTCO$_2$e/short wet ton of diverted food waste)

T_E = Transportation emissions (MTCO$_2$e/short wet ton of diverted food waste)

P_E = Process emissions (MTCO$_2$e/short wet ton of diverted food waste)

Note about food waste to biosolids conversion:

We calculated that one wet ton of diverted and digestible (co-digested) food waste generates 0.394 wet tons biosolids (dewatered to 27 percent solids), or 0.1065 dry tons biosolids (rounded to 0.107 below).

We assumed that diverted wet food waste is 30 percent solids (which is within the range of literature values). We further assume that volatile solids comprise 86 percent of food waste solids. Assuming co-digestion destroys 75 percent of volatile solids, co-digesting one ton of wet food waste would generate 0.107 dry tons of extra biosolids (0.3 * (1 - 0.86 * 0.75)). The weight of wet biosolids dewatered to 27 percent solids is 0.394 tons (i.e., 0.107/0.27). For additional details and assumptions see Appendix 2C Tables 2C.1 and 2C.2.

4.1.1 Emissions

The main emissions sources associated with co-digestion of diverted food waste include those from transporting diverted food waste, pre-processing food waste, heating the digesters in proportion to the additional food waste, and dewatering the resulting biosolids.

4.1.1.1 Transportation Emissions

Transportation emissions (T_E) associated with co-digestion of diverted food waste occur during 1) the transport of the diverted food waste to a materials recovery facility (MRF) to be separated and slurried and 2) the transport of food waste slurry to a municipal wastewater treatment plant (WWTP) for co-digestion. We consider this the "inbound" transportation distance. Transporting the resulting biosolids to end-users also results in emissions. We consider this the "outbound" distance.

We estimated representative inbound transportation distances based on the geo-spatial analysis of MRF and municipal WWTP locations in each of CalRecycle's five Waste Regions: Southern, Bay Area, Central Valley, Coastal, and Mountain (Table 4.1). Using a waste-by-region weighted average, we estimated the statewide average distance traveled for a ton of pre-processed food waste slurry (diluted to 15 percent solids) is 11.6 miles. To convert the distance traveled per short wet ton food waste slurried into distance traveled per short wet ton of food waste diverted, we used a conversion factor of two (each one ton of diverted food waste is pre-processed and diluted into two tons of food waste slurry).

We estimated outbound transportation distances, i.e., hauling biosolids from municipal WWTPs to end-users, using the information collected in the 2018 Carollo survey (Chapter 2). Using a waste-by-region weighted average for outbound travel distance, we estimated the statewide average outbound distance traveled per short wet ton of biosolids (dewatered to 27 percent solids) is 116.2 miles. To convert the distance traveled per short wet ton of biosolids into distance traveled per short wet ton of diverted food waste, we used a conversion factor of 0.394.

Using the total distance for the collection and processing of food waste and delivery of biosolids, and the emission factor of 101 g CO_2e/ton-mile (CERF Report), the resulting average transportation emissions for co-digestion are **0.008 $MTCO_2$e/short wet ton of diverted food waste**.

Table 4.1 Diverted Food Waste Transportation (Inbound) and Biosolids Delivery (Outbound) Distances and Transportation Emission Factor

	Waste Region					Weighted Average Distance (miles/ short wet ton material)	Conversion Factor	Total Distance (miles/short wet ton diverted food waste)
	Southern	Bay Area	Central Valley	Coastal	Mountain			
% of Statewide Food Waste	60	16	17	5	2			
Food Waste(1) to MRF (miles)	13	6	12	7	24	11.6	1	11.6
Food Waste Slurry(2) to WWTP (miles)	13	6	12	7	24	11.6	2	23.2
Biosolids(3) to End-Users (miles)	157	52	33	125	93	116.2	0.394	45.8
Total Distance (miles/short wet ton diverted food waste)								80.6
Transportation Emissions (T_E) - MTCO$_2$e/short wet ton diverted food waste								**0.008**

Notes:
(1) Diverted food waste at 30 percent solids.
(2) Slurried food waste at 15% solids.
(3) Biosolids at 27% solids.

The average transportation emissions for composting were estimated at 0.008 MTCO$_2$e per short wet ton of diverted food waste, and found to be functionally equivalent to landfilling with regards to transportation emissions (CERF Report). As the transportation distances and emissions of 0.008 MTCO$_2$e per short wet ton for co-digestion of food waste are similar to those for composting, we consider them to also be functionally equivalent to landfilling for the purposes of estimating the emission factors. Therefore, the transportation emissions term for co-digestion is set to zero for the emissions calculations.

4.1.1.2 Process Emissions

Co-digestion process emissions (P_E) are from the energy required to 1) pre-process (separate, slurry, and dilute) food waste before anaerobic digestion, 2) operate and heat the digesters, and 3) dewater the resulting biosolids.

Based on literature, pre-processing one wet ton of food waste takes an average of 30 kilowatt-hours (kWh) of electricity (Jin et al., 2015, Edwards et al., 2017, and Pérez-Camacho et al., 2018). California's average grid electricity emissions factor for 2010 to 2016 is 0.000228 MTCO$_2$e per kWh (CARB 2018a).

We assumed that the energy to operate and heat the digesters from ambient to mesophilic temperature (i.e., from about 70 to 95 degrees F) is provided by combusting biogas. Raising the temperature of one pound of water by 1°F takes one British thermal units (Btu), and there are 2 tons of slurry per ton of diverted food waste. Assuming an 80 percent boiler efficiency results in a required energy input of 0.125 million British thermal units (MMBtu) per wet ton of food waste as diverted from landfill. The biogas combustion emissions factor is 52.338 kg per MMBtu and is based on default emission factors from Tables C-1 and C-2 to Subpart C of 40 CFR 98.33. While the CO_2 emissions from the combustion of biogas are biogenic, we have included them in the emissions factor for completeness.

Finally, we estimated the energy required to dewater the biosolids after co-digestion. Energy input required for common dewatering equipment used in WWTPs, belt filter presses and centrifuges, is typically 10 - 45 kWh per dry ton (Huber, Hospido et al. 2005), and 30-92 kWh per dry ton (Brown et al. 2010, vendor quotes[1]), respectively. For this analysis, we assumed a mid-range energy consumption of 50 kWh per dry ton biosolids. To convert energy consumption from dry tons of biosolids into wet tons of diverted food waste, we used a conversion factor of 0.107, or 5.35 kWh additional energy input per short wet ton of diverted food waste.

To calculate the process emissions associated with dewatering biosolids, we additionally considered the emissions associated with polymer production and delivery. WWTPs report using 19 pounds (lbs) of active polymer per dry ton of biosolids (WEF 2012, and experience from California WWTPs), or 2.03 lbs of polymer for each short wet ton of diverted food waste. Assuming that the energy intensity for polymer production is 17,000 Btu per lb polymer (Owen 1982), supplied by the combustion of distillate fuel oil, we estimated a polymer production emission factor of 1.26 kg CO_2e per lb. We estimated the polymer delivery emissions factor is 0.152 kg CO_2e per lb polymer[2].

Table 4.2 summarizes the process emissions sources that sum to the total P_E factor for diverted food waste co-digested at municipal WWTPs. We estimated the Total Process Emissions Factor is **0.017 $MTCO_2e$ per short wet ton of diverted food waste**.

Table 4.2 Process Emissions for Co-Digestion per Short Wet Ton of Diverted Food Waste

Process Emissions Sources	Additional Energy Input	Emission Factor	Emission Factor ($MTCO_2e$/short wet ton diverted food waste)
Pre-Processing (Slurry)	30 kWh	0.228 kilogram (kg) CO_2e/kWh	0.0068
Digester (Slurry) Heating	0.125 MMBtu	52.338 kg CO_2e/MMBtu	0.0065
Dewatering	5.35 kWh	0.228 kg CO_2e/kWh	0.0012
Polymer Production	2.03 lbs	1.26 kg CO_2e/lb	0.0026
Polymer Delivery	2.03 lbs	0. 152 kg CO_2e/lb	0.00031
		Total Process Emissions Factor (P_E)	**0.017**

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[1] Vendor quotes from Andritz, Centrisys, Alfa Laval.

[2] We conservatively assumed the polymer production energy is from the combustion of fuel oil distillate (rather than, for instance natural gas) and, using default fuel oil combustion emission factors from Tables C-1 and C-2 to Subpart C of 40 CFR 98.33, the estimated polymer production emission factor is 1.26 kg CO_2e/lb.
Polymer transport distance is estimated assuming 3,000 miles (since polymer is manufactured in the southeast U.S.) and the transport emission factor of 101 g CO_2e per ton-mile (CERF Report), resulting in 0.152 kg CO_2e per pound.

Estimates of landfill related process emissions range from 0.007 to 0.018 $MTCO_2e$ per ton (CERF Report). Because process emissions from co-digestion fall within the same range as landfilling process emissions, we set the process emissions term to zero for the co-digestion related process emissions.

4.1.2 Emission Reductions

The GHG emissions reductions associated with co-digestion include the avoided emissions that would otherwise occur if the food waste had been disposed of in a landfill, and the benefits accrued by using the resulting products of the co-digestion process: biosolids and biogas.

4.1.2.1 Net Avoided Emissions from Landfills

For the avoided emissions from landfilling, we used **0.388 $MTCO_2e$ per short wet ton of diverted food waste** (CERF Report), which is conservatively based on decay rate representing dry conditions found in Southern California landfills.

4.1.2.2 Biosolids Use

Land applying biosolids has similar benefits to applying compost (Mcivor et al., 2016, Wang et al., 2008), such as reducing soil erosion, reducing synthetic fertilizer use, and reducing herbicide use. With respect to decreased soil erosion, we assume the same benefit as estimated in the CERF Report (0.14 $MTCO_2e$/ ton land-applied material) and assume negligible benefit associated with reduced herbicide use.

To estimate the benefits related to reduced synthetic fertilizer use, we used the reduction factor developed for and used in the Biosolids Emissions Assessment Model (BEAM)[3]. BEAM estimates the avoided GHG emissions to be 0.056 MT CO_2e per wet ton land-applied biosolids (Brown et al., 2010). Since this emission reduction is small and the co-benefits related to reduced synthetic fertilizer use are uncertain at this time, we conservatively set this term to zero. However, there is ongoing research demonstrating the usefulness of biosolids in replacing conventional sources of nutrients and organic matter (Broderick 2017, Sullivan et al 2015). Accounting for reduced synthetic fertilizer use would have resulted in greater emission reductions and would require further research.

The overall estimated benefit associated with land application of biosolids is 0.140 $MTCO_2e$ per wet ton land-applied biosolids, or **0.055 $MTCO_2e$ per short wet ton diverted food waste.** While this analysis evaluates the benefits from a GHG perspective, more benefits may result from land application of biosolids (such as carbon sequestration, increased crop yield, increased soil permeability, water retention, and organic content). More research is needed to quantify additional GHG benefits resulting from biosolids land application.

4.1.2.3 Biogas Use

Through co-digestion of diverted food waste in anaerobic digesters, municipal WWTPs can produce, capture, and make beneficial use of biogas, which is a renewable source of methane. This additional biogas produced via co-digestion of the diverted food waste can be used either for heat and power, and/or low-carbon transportation fuel, displacing other sources of energy.

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[3] BEAM was developed by Sylvis Environmental for the Canadian Council of Ministers of the Environment to allow municipalities to estimate GHG emissions and benefits from biosolids management. The tool was developed using data from peer reviewed literature and municipalities (Sylvis Environmental, 2009).

To estimate the net GHG emission reduction benefit of biogas use for onsite energy production, and for transportation fuel we used emission factors from the quantification methodology for the waste diversion program (CARB 2016).

We assumed the digestate would be composted and averaged the emission factors developed for co-digestion at small-medium and medium-large WWTPs (Ahuja et al. 2014, & CARB 2015). The resulting average emission factor for converting biogas to renewable electricity is 0.21 $MTCO_2e$ per short wet ton of diverted food waste.

The resulting average emission factor associated with converting the biogas to renewable compressed natural gas (RNG, a low carbon transportation fuel) is 0.26 $MTCO_2e$ per short wet ton of diverted food waste.

The emission reductions associated with biogas utilization ranges from **0.21 to 0.26 $MTCO_2e$ per short wet ton of diverted food waste,** depending on whether the additional biogas is used to generate electricity or to generate RNG vehicle fuel.

4.1.2.4 Summary of Co-Digestion Emission Reduction Benefits

The co-digestion emissions reduction benefits and factors described in this section are summarized in Table 4.3. The net emissions reduction factor is presented as a range from 0.65 to 0.70 $MTCO_2e$ per short wet ton of diverted food waste, depending on whether the biogas is used for electricity generation or vehicle fuel, respectively.

Table 4.3 Breakdown of Co-Digestion Emissions Reduction Factors per Wet Ton of Diverted Food Waste

Emissions Reduction Type	Emission Reduction Factor (MTCO2e/wet ton food waste as diverted from landfill)
Avoided Landfill Emissions (ALF)	0.388
Biosolids Use (BioS)	0.055
Biogas Use (BioG)	0.21-0.26
Net Emissions Reduction Factor	**0.65-0.70**

4.2 GHG Emission Reduction Potential

The overall co-digestion emissions reduction factor (Co-DigERF) is **0.65 – 0.70 $MTCO_2e$ per short wet ton of diverted food waste.** The Co-DigERF is sensitive to the biogas generation rate (the range of typical biomethane potential of food waste is provided in Appendix 2C, Table 2C.3). While it is most sensitive to biogas end-use relative to other factors considered, a ±50 percent change in biogas end-use results in only a ±15 percent change in the Co-DigERF value.

The avoided landfill emissions (ALF) factor is the largest single component for both co-digestion and composting emission reductions (Figure4.1). The beneficial use of biogas from co-digestion as transportation fuel is the next largest emission reduction benefit from co-digestion. The emission reductions associated with land-applying biosolids are estimated to be smaller than those for composting, primarily because of the conservative assumptions we used to estimate the impact of decreased fertilizer use. However, the process emissions associated with co-digestion are lower than those associated with composting. Therefore, co-digestion appears to have a greater GHG reduction potential than composting.

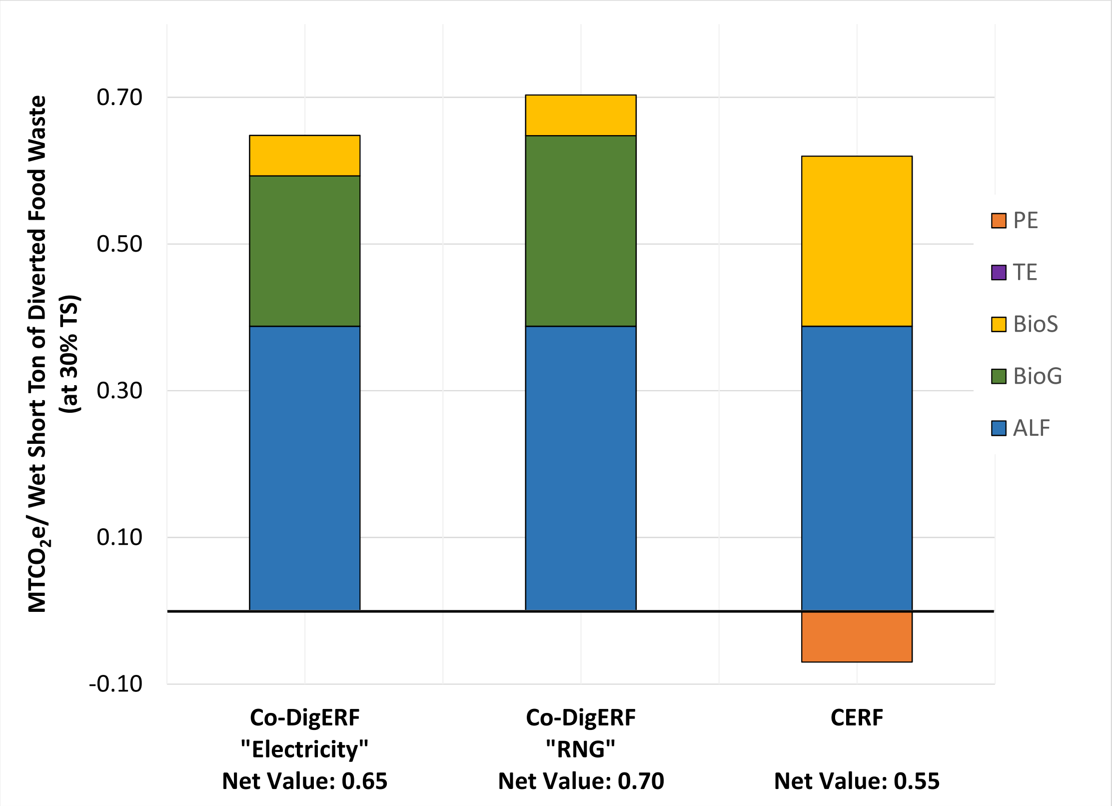

Figure 4.1 Comparison of Emission Reduction Factors for Co-digestion (Co-DigERF) and Composting (CERF)

<u>Note</u>: Co-DigERF includes two end-uses of the biogas derived as a by-product of co-digestion: biogas used for onsite electricity generation, and biogas upgraded to transportation fuel.

Using the derived Co-DigERF, and the low-end divertible and digestible food waste projection (Chapter 1), we estimated the GHG emission reduction potential associated with diverting food waste from landfills to WWTPs for co-digestion. We based the estimates on the existing capacity for co-digestion (Chapter 2) and on the possible capacity if future investments are made to maximize co-digestion of diverted food waste (Chapter 3).

The GHG reduction potential when relying on existing capacity for co-digestion (Chapter 2) represents the scenario in which only the excess capacity of existing infrastructure at municipal WWTPs is used to co-digest diverted food waste. This means that all key system processes (the receiving station, the digesters, the anaerobic digesters, the dewatering equipment, and biogas management and utilization systems) are already in place and have capacity. We estimated this existing excess capacity at 118,000 short wet tons of diverted food waste per year. Depending on the biogas end-use, the emissions reduction can range from 76,300 to 82,800 MTCO$_2$e per year (Table 4.4).

If investments are made to expand, modify, or newly implement components[4] of key system processes to maximize the use existing digester capacity (Chapter 3), the estimated GHG emissions reduction potential ranges from 1,564,000 to 2,397,000 MT CO$_2$e (Table 4.4). The

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[4] For example, pre-processing facility, dewatering facility, and/or the biogas utilization system and/or modify the digesters.

range encompasses two “bookend” capacity scenarios, the conservative - a digester operated at its design solids retention time, with the largest unit out of service and at 0.2 lb volatile solids per standard cubic feet per day (VS/scfd) loading rate - and the optimistic, capped at the amount of projected divertible and digestible food waste in 2030.

For comparison, landfills account for approximately 8,560,000 MT CO2e emissions as methane in 2016, which is about 22 percent of statewide methane emissions (CARB 2018b). By diverting up to 3,400,000 short wet tons of food waste from landfills to municipal WWTPs for co-digestion, the wastewater sector can provide an estimated emissions reduction of up to 2,397,000 MT CO2e.

Table 4.4 Summary of GHG Emissions Reduction Potential Associated with Co-Digesting Diverted Food Waste under the “Existing” and “Investments to Maximize Co-Digestion” Scenarios

		“Existing” Capacity to Accept Food Waste	“Investments to Maximize Co-Digestion”	
			Scenario 1: Conservative Anaerobic Digestion Capacity (Design SRT, LUOOS, and 0.2 lb VS/cf-day VSLR)	Scenario 2: Combinations of Digester Operating Conditions to Accommodate 2030 Projected Digestible and Divertible Food Waste
Excess Capacity (Wet Short Tons of Diverted Food Waste per Year)		118,000	2,400,000	3,400,000
Net Emission Reductions Potential (MT CO_2e)	Electricity Production	76,300	1,564,000	2,210,000
	RNG Vehicle Fuel Production	82,800	1,696,000	2,397,000

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Chapter 5

CO-DIGESTION AT SMALL TO MEDIUM SIZE WASTEWATER TREATMENT PLANTS

5.1 Case Studies

Small- and medium- sized wastewater treatment plants (WWTPs) (a design average dry weather flow (ADWF) of less than 5 million gallons per day (mgd) and a design ADWF between 5 and 20 mgd, respectively), make up approximately 85 percent of the total number of facilities in California (Carollo 2018a) (SWRCB 2017) (EPA 2012). Large facilities have greater capacity to receive a large fraction of available and divertible food waste (Chapter 3). However, small and medium facilities may be able to reach more areas within the state and could, therefore, play an important role in achieving local food waste diversion and greenhouse gas emissions reduction goals.

Barriers such as operating with a smaller workforce and under a smaller operating budget can hamper a facility's ability to dedicate the time and resources needed to learn about, plan, and implement co-digestion projects. However, as demonstrated through these case studies, co-digestion at small to medium-sized facilities can be advantageous too. For example, closer relationships within the community can result in more effective educational campaigns, better source separation of organic waste and, subsequently, a higher quality feedstock delivered to the WWTP.

Table 5.1 lists the facilities featured in the case studies.

Table 5.1 Case Study Facility Summary

Case Study Facility	Region	Co-digestion Status	Design Average Dry Weather Flow
Central Marin Sanitation Agency	Bay Area	In Operation	10 mgd
Manteca Wastewater Quality Control Facility	Central Valley	Construction	9.9 mgd
Delta Diablo	Bay Area	FOG, Planning food waste	19.5 mgd
Silicon Valley Clean Water	Bay Area	Completed Pilot, Planning full scale	29 mgd

Two smaller facilities may soon pursue small-scale co-digestion pilots: The Goleta Sanitary District (Goleta) and the Carmel Area Wastewater District (Carmel). Goleta is planning a partnership with University of California Santa Barbara to accept food waste at its 9.6 mgd ADWF plant. Carmel is considering entering a Grind2Energy program that would deliver ground slurry from food-related commercial establishments to its 3 mgd ADWF treatment plant. These projects are in the early stages of planning, and we do not describe their efforts any further.

5.1.1 Central Marin Sanitation Agency

Central Marin Sanitation Agency (CMSA) is located in San Rafael, Marin County, California. It is a medium-sized facility with a design ADWF of 10 mgd. In 2017, it received and treated approximately 8.3 mgd (Carollo 2018a). CMSA services about 110,000 people and the San Quentin State Prison. It is in a Joint Exercise of Power Agreement (JPA) with four satellite collection agencies.

CMSA, in a public-private partnership with Marin Sanitary Services (MSS), developed the Food to Energy (F2E) program concept in 2009. The plant has been receiving Fats, Oils, and Grease (FOG) since November 2013 and pre-consumer source separated commercial food waste since January 2014. CMSA accepts FOG five days per week and food waste six days per week. In 2017, CMSA received approximately 15,000 gallons of FOG per day and approximately 6-8 wet tons of slurried food waste per day (at 18 percent total solids). In 2017, CMSA produced approximately 282,000 cubic feet of biogas per day from the co-digestion of municipal solids and external feedstock; they combusted the biogas in a cogeneration engine to produce electricity to power their plant and hot water to heat their digesters. CMSA is currently working on facility modifications to export excess power to the grid (Carollo 2018a).

The metrics that the plant monitors are presented in Table 5.2 (CMSA 2019). See also Appendix 5A.

Table 5.2 Organic Waste Program Metrics

Parameter	Value
Types of Organic Wastes Accepted (2018)	FOG, Food Waste Slurry, Soy-Whey, Brewery Waste
Number of Participants in F2E Program (2018)	209 Food Service Establishments
Quantity of FOG Delivered (2017)	15,000 gpd/5 days per week
Quantity of Food Waste Slurry Delivered (2017)	6-8 wet tons/day at 18% TS
Concentration of Blended FOG/Food Waste Slurry Fed to Digesters (2018)	7.2% TS; 93.7% VS
Percent of Total Digester Volatile Solids Loading (2018)	Primary Sludge: 41% by VS Mass TWAS: 36% by VS Mass FOG/Food Waste Slurry: 23% by VS Mass
Digester Hydraulic Retention Time (2018)	45.8 Days
Digester Volatile Solids Reduction (2018)	72%
Volatile Acid: Total Alkalinity Ratio (2018)	0.015
2018 Methane Content of Biogas	64%
2018 Cogeneration Engine Uptime	>90%
2018 Percent of Agency Power Produced by Cogeneration Engine	95%

5.1.1.1 Facility Modifications

CMSA made several modifications to their facility to be able to receive and handle food waste. They installed an Organic Waste Receiving Facility with a polishing paddle finisher and a canister-based odor control system. This process flow diagram is shown in Figure 5.1. The design criteria for the various pieces of equipment that were installed are listed in Table 5.3.

The original rock trap, shown in Figure 5.1, was too small. It was replaced with a Heavy Object Trap and a hot water system. Delivered FOG is sent through this unit before being discharged into the below-grade storage tank. The food waste slurry delivery is also off-loaded from trucks into the below-grade storage tank. When offloading is complete and the level in the slurry tank is above a minimum set point, the FOG/food waste Mixing Pumps mix the FOG/food waste blend for about an hour. The thinner FOG stream blends with the thicker food waste slurry and reduces the blended solids concentration to a pumpable level. Once the mixing cycle has timed out, the paddle finisher loop is initiated, and the FOG/food waste blend is pumped through a paddle finisher before being discharged into the Screened Food Waste Sump. Once the level in this sump rises to an adjustable set point, the FOG/Food Waste feed pumps are initiated, and the FOG/Food waste blend is pumped into the digesters in a dedicated pipeline.

In addition to constructing the Organic Waste Receiving Facility, CMSA also made digester improvements. The digester improvements were due to be completed regardless of the Organic Waste Receiving Facility. CMSA replaced the original compressed gas mixing systems in their two existing digesters with external pump mixing systems and added dual-membrane covers on their digesters to provide biogas storage. In addition, CMSA replaced existing iron sponge scrubbers within their biogas treatment system with an iron impregnated clay scrubbing system for hydrogen sulfide (H2S) removal upstream of the cogeneration unit. The biogas treatment system also includes compression, moisture removal, and siloxane removal.

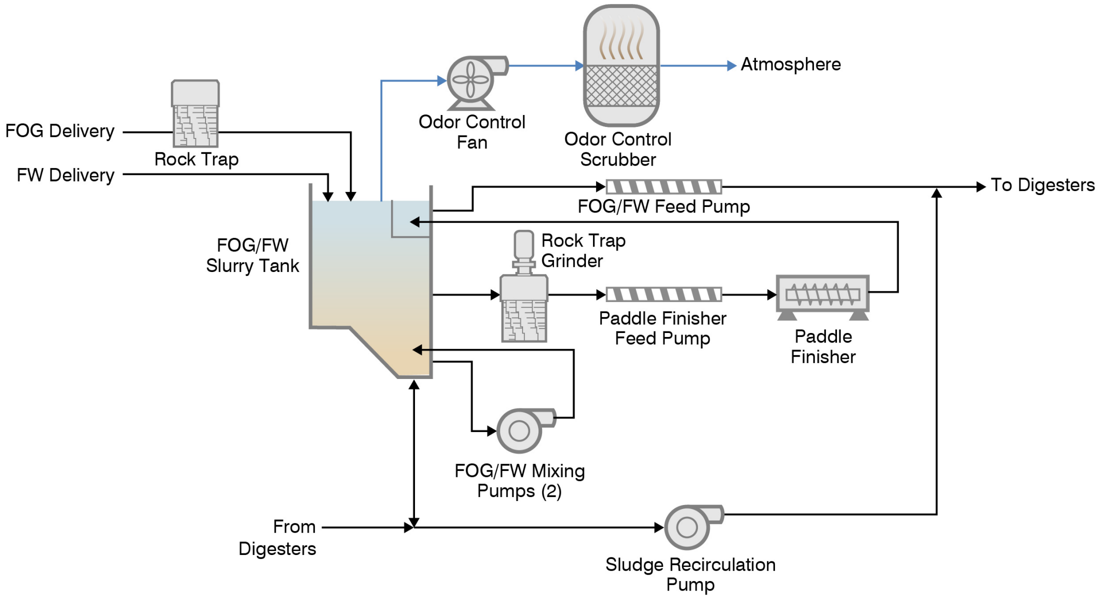

Figure 5.1 CMSA Food Waste and FOG Receiving and Polishing Process Flow Diagram

Table 5.3 CMSA Facility Modifications and Design Criteria(1)

Item	Number	Type	Capacity	Motor
Storage Tank	1		30,000 gallons	
FOG/Food Waste Feed Pump	1	Hose Pump	60 gpm	10 hp, VFD
FOG/Food Waste Mixing Pumps	2	Chopper	1,700 gpm	25 hp, VFD
Sludge Recirculation Pump	1	Chopper	300 gpm	15 hp, VFD
Rock Trap Grinder	1			3 hp
Paddle Finisher	1			40 hp
Paddle Finisher Feed Pump	1	Hose	60 gpm	10 hp, VFD
Odor Control		Carbon Adsorption		
Odor Control Fans	1	Centrifugal	600 gpm	5 hp
Motor Control Center			Feeder Capacity: 300 A Bus Capacity: 600 A	

Notes:
(1) 2017 Facilities Master Plan (Carollo 2018b).

5.1.1.2 Factors Facilitating Co-Digestion

State Regulations

The goals of Assembly Bill (AB) 32 in 2006 aligned with CMSA's interest in innovation and utilizing excess digestion capacity. AB 32 required the state of California to reduce greenhouse gas (GHG) emissions to 1990 levels by 2020. Following adoption of this bill, the California Energy Commission (CEC) and Pacific Gas and Electric (PG&E) made funding available for studies and projects to reduce GHG emissions. The City of San Rafael received a $25,000 grant in 2008 from PG&E to explore co-digestion and beneficial use of the additional biogas produced from food waste.

Preliminary Assessments

The first step in the planning process for CMSA was a Methane Capture Feasibility Study (Kennedy/Jenks Consultants 2008). This was a joint study between CMSA, the City of San Rafael, and MSS, and included:

- Reviews of the experience of other facilities who had undertaken similar projects.
- A study of the quantity and types of waste collected by MSS.
- Conceptual design of the food waste separation and receiving facilities.
- Evaluation of digester performance and digester improvements.
- Preliminary project costs.
- A review of project incentives, loans, and permitting.

This study concluded that receiving and co-digesting food waste was feasible and that it would be an economical way to reduce GHGs.

To garner support for the potential co-digestion project, CMSA conducted outreach events to convey the study results to the service area communities. Once the local town and city councils officially indicated support of the potential project, CMSA asked for approval from its Board of Commissioners (Board). These outreach events, the support of local government entities, and Board approvals were critical to the implementation of the F2E project.

Following the Methane Capture Feasibility Study, a Food Waste Facility Predesign Report (Kennedy/Jenks Consultants 2010) and a PG&E Interconnection Agreement Study (Michael D. Brown Consulting Engineers 2016) were completed.

Supportive Partnerships

The success of the F2E program depended not only on support from the CMSA Board and local government entities, but also on the partnership with MSS. MSS helped fund the initial study and made infrastructure improvements to sort and process the waste into a food waste slurry that could be trucked to the treatment plant. They conducted significant community outreach, including the production of videos and trainings on how to source separate waste. These outreach efforts resulted in a relatively clean feedstock for CMSA. The feedstock agreement is included as Appendix 5B.

The proximity between CMSA and MSS also made co-digestion feasible. The MSS processing center is less than 1 mile from the CMSA plant, which makes transporting the material very cost-effective. Furthermore, CMSA and MSS share visions for sustainability and environmental stewardship. MSS sought to reuse or recycle all suitable material and strive for a 100 percent diversion rate. This vision, paired with the proximity of the treatment plant and shared interest in organics diversion, led to the partnership between CMSA and MSS.

Initially, MSS pursued the co-digestion project to be good environmental stewards and reduce GHG emissions in an economically viable manner. They now reportedly save about $30-40/ton on tipping fees and have significantly reduced truck miles traveled compared to previous disposal practices at the local landfill.

CMSA also has an interconnection agreement with PG&E and a power purchase agreement with Marin Clean Energy (MCE). MCE is a community choice aggregation program that provides renewable power to Marin County and surrounding communities. The MCE power purchase agreement allows CMSA to sell excess power to the grid when they are producing more than they require and allows them to purchase power back from the grid when needed. While MCE is the power purchaser, PG&E owns the grid infrastructure and so CMSA had to enter into an interconnect agreement with PG&E to export power using their infrastructure. After a review of the interconnect agreement, PG&E required CMSA to upgrade their relays to protect the grid infrastructure from surges. They also performed other electrical system upgrades to allow their cogeneration engine to load share with the diesel engine when islanding in the event of a grid power outage.

Financing

Co-digestion at CMSA has been a positive investment. Revenue and offsets exceed operating costs. CMSA's Organic Waste Receiving Facility cost $1.9 million to build. The project was funded with bond proceed investment earnings from a 2006 issuance. The cost for MSS's equipment was $530,000, and their annual operating costs are $315,000 for collection, processing, disposal, and outreach (MSS & CMSA 2018).

The maintenance costs for CMSA were estimated to be $20,000 per year during the feasibility study, but this estimate was found to be low. CMSA is currently spending $40,000 annually for maintenance-related consumables.

A breakdown of CMSA's 2018 operations and maintenance (O&M) costs and revenues is shown in Tables 5.4 and 5.5, respectively. Based on the costs and revenues associated with the F2E program and the current power agreement, CMSA reports more revenue (or savings) than costs. They expect to save even more on power once they receive a CEC renewable power certification, expand the organics program to receive more feedstocks, and begin exporting power.

Table 5.4 CMSA 2018 Organic Waste Program Expenses(1)

	2018 Cost(2)
Maintenance Costs	$89,000
Operations Labor Costs	$90,000
Administration Costs	$26,600
Supplies and Other Costs	$10,000
Total Costs	**$215,600**

Notes:
(1) CMSA December 2018 Monthly Organic Waste Program and Digester Report.
(2) Values are rounded.

Table 5.5 CMSA 2018 Organic Waste Program Revenues(1)

	2018 Revenue(2)
FOG Revenue	$89,500
Food Waste Revenue	$55,700
Estimated Biogas Energy Value(3)	$167,200
Total Revenue	**$312,400**

Notes:
(1) CMSA December 2018 Monthly Organic Waste Program and Digester Report.
(2) Values are rounded.
(3) Estimated based on avoided natural gas procurement costs when the cogeneration engine is in operation using biogas.

5.1.1.3 Factors Impeding Co-Digestion

CMSA did not encounter any insurmountable barriers to implementation, but they discovered a barrier with state requirements on power forecasting. They are currently in the design phase of a new cogeneration engine project that would allow them to expand their F2E program. California Independent System Operator (California ISO) maintains grid infrastructure reliability and requires power generators with a nameplate capacity of 1 megawatt (MW) or greater to register with them. California ISO also requires all registered power generators to forecast their power a day in advance. Wastewater facility loads and flows are dynamic; likewise, food waste and FOG deliveries may change at any time. This causes substantial variability in digester gas production that is difficult to predict. CMSA did not want to be burdened with forecasting their power production or faced with a fine if they produced more or less than forecasted. Because of this California ISO forecasting requirement, CMSA has opted to purchase a cogeneration engine that will produce a maximum output of 1 MW. This will allow CMSA to export the maximum amount of power without being subject to California ISO requirements.

Regardless of WWTP size, selling electricity back to the grid poses some challenges. First, the financial viability of this utilization pathway depends on the price electric utilities or other power purchasers are willing to pay for the WWTP's electricity. Second, WWTPs must install specific electrical design features (e.g., PG&E required CMSA to upgrade their relays to protect the grid infrastructure from surges). Third, WWTPs must abide by hard production caps imposed by the three major California power utilities. These caps limit the quantity of power that could be returned to the grid from WWTPs. This limits the size of generation equipment and the associated amount of power WWTPs can produce and return to the grid. The California Public Utilities Commission (CPUC) is working with electric utilities to increase the caps.

CMSA currently purchases power from MCE. MCE has a tiered system for power generators, with earlier adopters able to lock in higher rates. CMSA is an early adopter and they have been able to lock in 10.5 cents/kilowatt hour (kWh) up to a contracted limit of 1.3 million kWh/year (MCE 2018). If CMSA wants to expand their food waste receiving program and maximize electricity production from the resulting biogas, they will receive a lower rate from MCE for any power produced over the contracted limit.

5.1.1.4 Lessons Learned

CMSA has operated their food waste facility for more than five years and has gained insight into numerous O&M challenges. This section summarizes their typical O&M activities and discusses some lessons learned.

Feedstock Quality

One of the most important goals for CMSA's F2E program was to obtain high quality and consistent feedstock. CMSA's partnership with MSS is essential to this. With MSS's public outreach campaign, training of commercial establishment staff, and refresher training, their feedstock is relatively clean compared to the food waste slurries co-digested at other WWTPs. Furthermore, MSS hand-sorts waste at their facilities, monitors each delivery of material for contamination, and has agreements with their organic waste producers regarding contamination. Even though the food waste slurry delivered is relatively clean, CMSA installed a paddle finisher to polish the slurry and remove unwanted organic materials such as melon rinds, fruit skins and other remaining fibrous material. The slurry as delivered, along with the contaminants removed from the slurry with the paddle finisher, are shown in Figures 5.2 and 5.3, respectively.

Figure 5.2 CMSA Food Waste Slurry as Delivered

Figure 5.3 CMSA Contaminants Removed by Paddle Finisher

If CMSA received a contaminated load, they would notify MSS and reject the load. This has not happened since the program began. CMSA has opted not to include specifications in their agreement with MSS regarding pH, COD, or other food waste characteristics because they have decided not to sample and analyze the material immediately upon delivery. In the future, if they start accepting other types of high strength wastes, they may begin a sampling program.

Typical O&M Activities

Staff perform daily O&M tasks using the following schedule:

- FOG and food waste deliveries start at 5:30 am and are completed by noon.
- During the day, they fill and mix the slurry tank.
- In the afternoon, they feed the slurry to the digesters and empty the slurry tank.
- In the evening, they clean the Organic Waste Receiving Facility.
- They are ready to receive new material by midnight or 1 am.

The O&M, program management and analysis activities were added to existing staff responsibilities. CMSA hired no additional staff members.

CMSA's typical maintenance schedule is shown in Table 5.6. The plant currently budgets $40,000 per year for maintenance-related purchases.

Table 5.6 CMSA Routine Maintenance Activities

Frequency	Maintenance Activity
Daily	• Hose down equipment and receiving station • Rinse out pumps and piping • Clean out heavy object trap
Weekly (or every other day)	• Clean out pomace bins (MSS picks this up for composting) • Inspect and clean out rock trap grinder • Inspect equipment area
Monthly	• Check clearance on pumps and paddle finisher • Inspect bearing seals on pumps
Every two months (on average)	• Replace hoses in hose pumps
Quarterly	• Clean receiving tank • Inspect coating on receiving tank
Every six months or yearly	• Replace pump impellers if corroded
Annually	• Replace pump impeller and housing
Every 2 years	• Siloxane media change-out • Replace odor scrubber media • Replace biogas conditioning adsorption scrubber media

Spare Parts

An important lesson CMSA learned is that it is critical to keep spare parts onsite or negotiate deals with equipment manufacturers so the manufacturers keep critical spare parts locally and are ready to ship them overnight when needed. This was particularly important for their mixing pumps which originally came from overseas and had a very long lead time. In order to ensure they have the critical spare parts needed, CMSA performed a risk analysis. This risk analysis, included as Appendix 5C, helped them determine the consequences of equipment going out of service; other options they may have when a piece of equipment is out of service; the estimated lead time needed to replace the equipment; and parts they need to keep onsite.

Other Lessons Learned

CMSA learned that having the following made co-digestion successful at their facility:

- *Organic waste coordinator*: They needed someone with a versatile skill set, who could perform administrative duties and communicate well with both field staff and operators. CMSA relied on an existing staff person well versed in lab sampling and analysis, billing, and operations and maintenance.
- *Receiving tank lid*: They improved worker safety by adding a lever and chain to the lid; with this addition, staff did not have to bend down to open the tank hatch cover.
- *Receiving tank coating*: The original polyurethane tank coating failed soon after installation, likely due to improper surface preparation. CMSA has since recoated the tank with an epoxy resin, which has lasted longer than the original coating system.
- *Paddle finisher chute*: To better direct material into the bin, CMSA extended the chute with a simple rubber section down into the receiving bin; this improved worker safety and reduced cleaning efforts.
- *Ladder cleats*: To stabilize the ladder that is lowered onto the slippery receiving tank floor, CMSA added cleats; this improved worker safety.
- *Odor scrubber*: The odor scrubber would draw grease into it from the foul air, necessitating frequent media replacement. To mitigate this, they installed an inexpensive filter upstream of the higher cost media, reducing the media replacement frequency. They also flush the media with hot water to remove the grease that builds up.
- *H_2S removal*: CMSA no longer uses an iron sponge to remove H_2S from the digester gas because they found the media to be dangerous and sometimes spontaneously combust. They were required to keep the spent media onsite for a week until it was no longer combustible, creating a risk for them. They have replaced this system with an iron impregnated clay (Sulfatreat). This replacement happened as part of the broader digester rehabilitation project, i.e., not as a part of the co-digestion program.
- *Dewatering*: They initially found the co-digested sludge harder to dewater in the centrifuges. To continue achieving at least 25 percent solids in the dewatered cake, CMSA needed to increase the polymer dose.
- *Biogas production*: Because CMSA sometimes produces more biogas than they can use, they developed several strategies to avoid flaring. First, they modified upstream solids processes. Second, they modified boiler use. Third, they can store 374,000 cubic feet in the double-membrane digester covers. Fourth, if they have exhausted the previous three options, they stop pumping food waste to the digesters. This immediately reduces biogas production. With the addition of variable frequency drives, staff is also testing the impacts of varying mixing intensities, operating the digester mixing pumps at different speeds.
- *Preparing the digesters*: CMSA has not experienced issues with instability even though they have experimented with a variety of feedstocks and loading rates. To prevent instability, they load at higher rates with sludge before adding the organic waste.

5.1.2 Manteca Wastewater Quality Control Facility

Located in San Joaquin County in California's Central Valley, the City of Manteca's Wastewater Quality Control Facility is a medium-sized facility with a design capacity of 9.87 mgd, and a reported flow of 6.7 mgd in 2017. The facility services a population of approximately 80,500.

5.1.2.1 Facility Modifications

The Waste to Fuel Program comprises five interrelated projects to allow Manteca to accept and co-digest food waste and FOG, generate additional biogas, and utilize the biogas in new boilers to produce heat for use onsite (including heating the digesters to offset purchased heating). Biogas may also be conditioned and compressed for use as a transportation fuel by the City fleet. The approach being considered would first provide Renewable Natural Gas (RNG) to meet the needs of the City's fleet; any remaining would be sold.

There are five projects underway for accepting food waste and FOG. The required facility modifications and components are summarized below (Manteca 2018):

<u>Project 1: Digester and Digester Control Building Improvements Project</u>

- Two new 65-foot diameter digesters with steel floating covers.
- New sludge control system for feeding digesters.
- New high efficiency digester mixing system with draft tube mixers.
- New low-nitrous oxides (NO_x) boilers and hot water heating system.
- New biogas H_2S removal system.
- New biogas flare.
- Rehabilitation of the two existing digesters including dome, lining, recirculation, and biogas piping and pumping replacements.
- New chemical facility and piping for ferric chloride for digester struvite and H_2S control.

<u>Project 2: Food Waste Receiving</u>

- Concrete parking area for truck unloading.
- Pumping and piping equipment to transfer food waste.

<u>Project 3: FOG Receiving</u>

- One above-ground 10,000-gallon stainless steel tank for FOG storage.
- Associated mixing, heating, and pumping equipment.
- Rock screen and crane.
- High pressure cleaning equipment.

<u>Project 4: Compressed Biogas Fueling Facilities</u>

- New biogas conditioning system to remove carbon dioxide (CO_2) and siloxanes from the biogas (BioCNG™).
- Two new boilers to produce digester heat from conditioned biogas.
- A custom-built low British thermal unit (Btu) boiler used to produce waste heat from the BioCNG™ waste gas stream.
- New renewable compressed natural gas (RCNG) compression and high-pressure storage system.
- Intermediate pressure storage tanks.

- New RCNG and compressed natural gas (CNG) fast filling station to allow quick filling of vehicles.
- New timed fill facility to allow overnight parking and filling of RCNG into the city fleet, including a new parking field.
- New vehicle wash facility to allow garbage fleet washing.

Project 5: Food Waste Separation Project

- Food waste separation device such as a turbo separator.
- Two food waste transportation tankers that will double as food waste storage tanks.

Upon completion of the final project, the facility should be able to accept 3,400 wet tons of food waste slurry annually. As the second and third projects are implemented, the plant hopes to accept increasing amounts of food waste slurry for co-digestion.

5.1.2.2 Factors Facilitating Co-digestion

State and Local Regulations

One significant driver for co-digestion is the state's organic diversion goals, prompted by three different bills. AB 341 sets a goal of 75 percent solid waste diversion by 2020; AB 1826 requires organic waste diversion from certain residential and commercial entities by 2020; and Senate Bill (SB) 1383 requires 75 percent diversion of organic waste from landfills by 2025. For the purposes of the SB 1383 regulation, Manteca's current practice of using Class B biosolids as alternative daily cover (ADC) at the Forward Landfill will be considered disposal. Because Manteca operates its digesters at capacity, they decided to evaluate 1) needed digestion capacity into the future and 2) the potential to co-digest diverted food waste and FOG, as this would help Manteca achieve a higher organics diversion rate and produce a beneficially usable product for land application. As a result, Manteca decided to build two additional digesters.

Several state and local regulations pertaining to air quality necessitated a major overhaul of Manteca's biogas utilization infrastructure, including upgrading their boilers and flare and installing a new biogas conditioning system. These required changes also influenced Manteca's decision to co-digest with high strength organic wastes. The boilers were manufactured in 1986 and had exceeded their useful lives. Furthermore, they could not meet the San Joaquin Valley Air Pollution Control District (SJVAPCD) emissions regulations (Manteca & Waste Management 2015) (Manteca 2018). Additionally, potential changes in flare regulations[1] and concerns about the plant's flare capacity prompted the City to also replace its flare infrastructure. Lastly, to protect utilization equipment and meet SJVAPCD regulations, Manteca decided to install a new biogas conditioning system capable of removing H_2S and other contaminants.

The California Air Resources Board (CARB) also recently adopted a regulation requiring that any diesel truck engine older than 2010 be replaced by engines meeting EPA's 2010 emission limits by 2023 (SJVAPCD 2016). The City of Manteca had four such trucks that needed replacement. To avoid risks associated with diesel price volatility and to leverage their proximity to a CNG fueling station in Stockton, the City opted to purchase CNG trucks to replace the old diesel engine trucks.

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[1] For a more detailed discussion about SCAQMD's 1118.1, see the Regulatory Considerations Section in Chapter 3.

In summary, these state and local regulations played a part in Manteca's decisions to accept food waste and FOG for co-digestion, improve their digestion system, and utilize biogas. Accepting external feedstocks will increase biogas production, which they plan to compress and use in the newly purchased CNG trucks. Manteca expects this approach to provide a long-term solution that meets local and state regulatory targets for organics diversion and low-carbon fuels while also shielding them from diesel price volatility in the future.

Supportive Partnerships

The City of Manteca owns the wastewater facility and the solid waste management fleet. San Joaquin County owns and operates the Lovelace Materials Recovery Facility and Transfer Station. The City of Manteca sends its biosolids to the privately-owned Forward Landfill. With the adoption of AB 1826 in 2014, San Joaquin County began an outreach campaign to teach restaurants and schools how to source-separate organic waste so that it could be collected and composted. AB 1826 and AB 341 compelled the City and the County to work together. They entered into a partnership whereby the food waste would first be processed by a turbo separator at the County's Lovelace Transfer Facility and then received at the City's Wastewater Facility, where it would be injected into their digesters.

Planning

In 2016, Manteca commissioned two planning reports with the purpose of developing conceptual projects that could benefit both the solid waste and wastewater sectors. During the planning phase, Manteca and its consultant identified for consideration the development of a co-digestion facility that would convert the City's wastewater sludge and food waste into biogas and RCNG fuel. The planning reports are:

- Biosolids and Biogas Utilization Plan (Herwit Engineering 2016a).
- Solid Waste Master Plan (Herwit Engineering, 2016b).

Financing

The total project cost (to implement all five projects) is approximately $28.8 million (Manteca 2018):

- $19.8 million for the Digester and Digester Control Building Improvements Project.
- $6.1 million for the Compressed Biogas Fueling Facilities Project.
- $1.1 million for the turbo separator at the Lovelace Facility.
- $545,000 for the Food Waste Receiving Facility Project.
- $1.3 million for the FOG Receiving Facility Project.

Because the City of Manteca had budget available at the time of the project, the project was funded primarily by City funds. The City had bonds earmarked for the WWTP expansion with a provision for green energy alternatives, and also received a $3 million grant from the CEC for the digester gas processing facility, and a $1.89 million grant from SJVAPCD for the fuel dispensing facility. Their cost recovery calculations also relied on a continuous credit from Renewable Identification Number (RIN)s from the United States Environmental Protection Agency's (EPA) Renewable Fuel Standard Program and the Low Carbon Fuel Standard.

5.1.2.3 Factors Impeding Co-digestion

Manteca has faced several barriers that have delayed food waste co-digestion.

Inadequate funding

The City of Manteca's solid waste department has not obtained funding for the turbo separator that will be installed at the Lovelace Transfer Facility. Without this critical part of the food waste processing system, Manteca has not been able to receive the food waste slurry for co-digestion at the WWTP.

Also, the change in the value of RIN credits has decreased Manteca's revenue potential. In the past, biogas generated from food waste qualified as Cellulosic Biofuel and was eligible for D3 RIN credits (highest value RIN). However, biogas generated from co-digestion with food waste now only qualifies as an Advanced Biofuel, which is eligible for a D5 RIN credit. While the value of all RIN credit types has varied over time, D5 RIN credits over the past year have been worth about one fourth the value of D3 RIN credits. This change from D3 to D5 RIN credits significantly impacts Manteca's plans to recover costs.

Regulatory Hurdles

San Joaquin County and surrounding counties have banned or restricted the land application of biosolids. These local bans may require hauling biosolids to more distant locations for land application and beneficial reuse.

To receive any "anaerobically digestible material," California wastewater treatment facilities are required by the State Water Resources Control Board to develop and implement standard operating procedures (SOP) to address material handling, spill prevention and response, and avoidance of treatment process upsets, amongst other things. They are also required to maintain records of each load received for three years. At this time, Manteca considers these requirements onerous and plant staff have not yet developed the SOP.

The City is also concerned that the additional nitrogen loading from the food waste will create a higher concentration of ammonia in the dewatering centrate, which is routed back to the plant's liquid treatment train. Manteca's secondary process is a Modified Ludzack-Ettinger, which fully nitrifies and denitrifies the stream to produce a Title 22 compliant effluent that is land applied in the spring and summer. They also have National Pollutant Discharge Elimination System (NPDES) nitrogen limits when discharging to the San Joaquin River in the winter. The additional ammonia load in the recycle stream may exceed the secondary treatment capacity for nitrogen load and subsequently result in increased effluent nitrogen concentrations. As a result, Manteca has planned to install a tank to collect the centrate and return it to the headworks at a metered rate to avoid exceeding nitrogen limits.

5.1.3 Delta Diablo

Delta Diablo is a California special district that provides wastewater services to the City of Antioch, the City of Pittsburg, and the unincorporated community of Bay Point, encompassing 54 square miles and serving over 214,000 residents. The Delta Diablo wastewater treatment plant is located in Antioch, Contra Costa County. It is a medium-sized facility with a design ADWF of 19.5 mgd (ESA 2018). In 2017, it received and treated approximately 12.8 mgd (Carollo 2018a).

Delta Diablo currently anaerobically digests primary and thickened waste activated sludge and receives 10,000 gallons per day (gpd) of FOG for co-digestion. The WWTP has an average electrical demand of 0.9 MW, 0.1 MW of which is supplied by PG&E and 0.8 MW by a cogeneration engine (ESA 2018).

Delta Diablo partnered with Mt. Diablo Resource Recovery (MDRR), the local solid waste hauler, to develop the East County Bioenergy Project (ECBP) in 2016. This project, currently in the planning phase, would allow the production and receipt of up to 285 wet tons/day of a food waste slurry (at 12 percent solids). Delivery of the slurry to the WWTP would occur 5 days/week throughout the year. The acceptance of organics is anticipated to increase the WWTP's electrical production to 2.5 MW and provide 9.4 million Btu (MMBtu)/hr of heat for heating needs (Delta Diablo 2018).

5.1.3.1 Facility Modifications

The facility modifications anticipated (per a 30 percent design plan) are listed below (Delta Diablo 2018):

- Food waste receiving facility (two 110,000-gallon storage tanks, mixers, pumps, odor control).
- Additional ferric chloride feed pumps and piping.
- New high solids digester mixers.
- Recuperative thickening system, including thickener and pumps, to be operated when a digester is out of service.
- New digester gas piping.
- Upgraded digester gas storage and compressors.
- Expanded/renewed biogas conditioning system consisting of H_2S, moisture, and siloxane removal.
- Two new combined heat and power (CHP) units (engines).
- A new flare.
- Sidestream ammonia removal system with an acid scrubber.

5.1.3.2 Factors Facilitating Co-Digestion

State and Local Regulations

The SB 1383 and AB 1826 organic waste diversion goals motivated MDRR. Increasing onsite renewable energy generation and utilizing existing infrastructure capacity to stabilize rates motivated the WWTP. Providing sustainable solutions for shared customers appealed to both the WWTP and MDRR. These shared goals motivated both entities to pursue co-digestion.

Supportive Partnerships

The ECBP is a public-private partnership between Delta Diablo and MDRR. Both parties are working together to develop the project and have gathered information from other agencies and projects to inform the layout and structure of the ECBP. As currently envisioned, MDRR will operate a pre-processing and polishing line to produce a cleaned organics slurry extracted from municipal solid waste. The slurry will then be trucked to Delta Diablo for co-digestion in existing digesters. Preliminary planning and design work have been done with the assistance of a technology partner, Anaergia Technologies, LLC. Both Delta Diablo and MDRR have also hired owner's advisors and specialty legal assistance to help with project development.

Planning

In 2016, Delta Diablo and MDRR entered into a Memorandum of Agreement (MOA) with the purpose of developing conceptual projects that could enhance the use of existing resources from both partners (i.e., biosolids, green waste, food waste). During the planning phase, they identified for consideration the development of a co-digestion facility that would convert the District's wastewater sludge and MDRR's food waste into biogas and renewable energy. The

MOA included a 50/50 cost-share arrangement with both parties obligated to contribute funds to support planning activities. A number of planning reports were produced under the MOA planning efforts. Among the planning reports are:

- Food Waste Receiving Facilities Assessment (Carollo 2016).
- Biogas Utilization Options and Evaluation (Anaergia 2017a).
- Delta Diablo East County Bioenergy Project Organics Co-Digestion Initial Study/Mitigated Negative Declaration (ESA 2018).
- East County Bioenergy Project Draft 30 Percent Design Development – Alternatives Evaluation (Anaergia 2017b).

Future Revenue

The total cost estimate for the capital improvements required for Delta Diablo's WWTP is approximately $30-34 million; for MDRR, $14-17 million. Additionally, Delta Diablo is in the process of developing a rigorous financial model to analyze the success of the overall project and understand the impacts to rates and cash flow. The model considers capital costs as well as operating costs and revenues; it uses Monte Carlo simulations on over 50 different parameters (i.e., staffing levels, tipping fees, power revenue, escalation factors, interest rates, chemical costs, etc.) so that sensitivity and probability analyses can be performed. The model also considers which and/or what percentage of capital and operating costs would be recovered from project revenue (e.g., tipping fees) and which would provide benefits to customers (i.e., by helping to stabilize rates).

Under the current model, about half of the costs would be recovered from the tipping fee and the other half from electricity sales through the Bioenergy Market Adjusting Tariff (BioMAT) program. The BioMAT program is a result of SB 1122, which directs investor owned utilities such as PG&E to offer feed-in tariff power purchase agreements for eligible bioenergy projects. PG&E allocates 30.5 MW to biogas from wastewater treatment, municipal organic waste diversion, food waste processing and co-digestion at a fixed price of $127.72/megawatt hour (MWh) (PG&E 2018). Delta Diablo is also exploring other end uses of the biogas including pipeline injection and use as vehicle fuel. The potential revenues and risks associated with the various options will be evaluated and feasible options will be incorporated into the financial model. To better define the final project scope, Delta Diablo is also evaluating different project timing and phasing options.

5.1.3.3 Factors Impeding Co-Digestion

Delta Diablo has faced three major barriers to date: financial, risk, and third-party requirements.

Inadequate Funding

Because of the large capital costs associated with the ECBP, financing is the most significant challenge for the project. Delta Diablo and MDRR are actively pursuing grants and low-interest loans to help offset financial risks and keep tipping fees in a manageable range. They're exploring several grants and loans opportunities, including the California Department of Resources Recycling and Recovery's (CalRecycle's) Organics Grant Program, the Clean Water State Revolving Fund, Bay Area Air Quality Management District's Climate Tech Financing, California Infrastructure and Economic Development Bank (IBank) California Lending for Energy and Environmental Needs Center (CLEEN), California Alternative Energy Financing Authority's Sales Tax Exclusion, and several from the California Energy Commission. As discussed in the

Financing section above, Delta Diablo is also considering the varying revenue streams associated with different biogas utilization pathways.

Risk

Delta Diablo is investing a significant effort into mitigating risk. Delta Diablo is working with its owner's advisor and legal team to develop a comprehensive risk register that includes technology, regulatory, legal, construction, start-up, operational, and financial risks. Each risk is being scored according to impact and probability of occurrence, and assigned to the appropriate partner (Delta Diablo, MDRR or the design builder). They are also identifying mitigation measures to incorporate into the feedstock and/or design-build agreements.

Third Party Coordination

A third challenge in implementing the ECBP has been to coordinate with third parties. From navigating the regulatory requirements of the local air district and CalRecycle to establishing interconnection- and power purchase agreements with PG&E, there are a multitude of factors that affect the scope, timing and financial viability of the project.

5.1.4 Silicon Valley Clean Water

Located in Redwood City in San Mateo County, the Silicon Valley Clean Water (SVCW) WWTP is considered a large facility with a design ADWF of 29 mgd. In 2017, it received and treated approximately 17 mgd (Carollo 2018a). SVCW services about 220,000 people and is a JPA with four member agencies.

SVCW operated a food waste co-digestion pilot from December 2018 through March 2019. Due to numerous challenges faced in the implementation of its pilot project, SVCW could only operate the pilot facility for three months. During this time, they accepted three to six wet tons per day of a food waste slurry produced by a new technology, the organics extrusion press (OREX®).

SVCW is currently awaiting the final results of the pilot project. Based on preliminary positive results, they intend to scale to full size.

5.1.4.1 Facility Modifications

To conduct the pilot project, the facility made the following modifications:

- Repurposed one of the two sub grade FOG receiving tanks to receive food waste.
- Routed plant process water to food waste receiving area for dilution.
- Installed a mixer in the dilution tank.
- Added a feed pump for diluted food waste.
- Added a paddle finisher to remove physical contaminants from food waste.
- Installed a storage tank for the "clean" food waste slurry.
- Utilized one of the two existing pumps to pump the "clean" food waste slurry to the digester.

SVCW did not need to modify their digesters in order to co-digest food waste during the pilot project. Due to contamination, they added a polishing step (paddle finisher) for the food waste to reduce operational issues. If implemented at full scale, they will need a polished feedstock, either from an organics polishing system offsite, or a paddle finisher onsite.

5.1.4.2 Factors Facilitating Co-digestion

Planning

SVCW has been interested in co-digestion since their 2009 energy master plan recommended this approach. In pursuing co-digestion, their primary goals were to increase energy efficiency of the existing system and to explore new opportunities to increase energy generation and reduce power costs.

SVCW also completed its energy recovery master plan in 2009, which laid the groundwork for food waste co-digestion. SVCW opted to conduct a pilot project to understand the operational issues and prove the feasibility before embarking on full-scale organic co-digestion. Planning for the pilot project entailed brainstorming with a consultant, visiting Recology San Francisco to understand the feedstock characteristics, and designing the pilot facility.

Supportive Partnerships

SVCW executed an MOU with the South Bayside Waste Management Authority (SBWMA) in 2014. In addition to the San Francisco Facility, Recology operates a facility at SBWMA. The purpose of this MOU was to "collaborate on the planning and evaluation of options available for a project that would be mutually beneficial to each agency in reaching California's landfill and energy goals" (SVCW 2017). SBWMA, SVCW, and Recology have been working together to relocate an organics extrusion press (OREX®), which preprocesses "black bin" municipal solid waste, extracting the organic material.

The organics extrusion press was originally obtained by Recology San Francisco through a grant from CalRecycle. This grant also included installation of an organics polishing system that would further screen and process the organic waste from the press into a less contaminated organic slurry. San Francisco has such an effective organics source separation process that the fraction of organic waste in the "black bin" is low. Inasmuch, the OREX® did not obtain high organics yields. Recology decided not to operate it at the San Francisco Facility and opted instead to move OREX® to SBWMA's San Carlos Facility.

Financing

The organics extrusion press was purchased for installation at the Recology San Francisco transfer station using a portion of the $3,000,000 CalRecycle Organics Grant awarded in Fiscal Year 2014-2015. The grant also included funding for an organics polishing system for the Recology East Bay Organics processing facility, but that system has not yet been installed. Recology is working with SBWMA and CalRecycle to transfer the organics extrusion press from the San Francisco facility to SBWMA and to redirect remaining grant money to allow the installation of the organics polishing system at the San Carlos Facility.

SVCW participated in this grant as a major contractor (provided the site and in-kind services) to Kennedy/Jenks Consultants, and was awarded a total of $600,000 grant funding for this pilot study. This funding was part of a $1.5 million grant from California Energy Commission to demonstrate a new technology to effectively pre-process food waste and to develop a new strategy to lower the mass of dewatered cake, which would improve the economic viability of co-digestion and biogas energy production at WWTPs.

5.1.4.3 Factors Impeding Co-Digestion

Regulatory Hurdles

SVCW faced several barriers to implementation. The most time-consuming issue was an air permitting issue, which took almost two years to resolve. However, the delay was not directly due to the food waste project. The local air quality management district initially proposed stringent conditions on biogas production, flaring, and H_2S limits. These limits would be difficult to achieve at wastewater treatment plants, which face daily fluctuations in flows, loads, and subsequent treatment processes. The agency and the air district discussed these issues, reached a compromise, and the air district eventually granted a permit to construct.

The other major regulatory barrier that SVCW faces with full-scale implementation of co-digestion is potentially the need for a municipal solid waste permit in order to receive organic waste extruded from "black bin" discards. SVCW could be excluded from the solid waste permit requirement if CalRecycle approves the black bin material received by SVCW as an additional type of "anaerobically digestible material" (14 CCR Section 17896.6).

Contamination

The pilot project at SVCW operated for approximately three months. The facility co-digested with organic waste brought in from Recology San Francisco. The organic waste received by SVCW was approximately 30 percent solids which was diluted to approximately 5 percent solids with plant process water. The waste had about 15 to 20 percent contamination that was removed by the Paddle Finisher and discharged into contaminant bins. This process took approximately thirty minutes and required staff to replace contaminant bins one to two times per day. For their full-scale co-digestion project, SVCW anticipates a cleaner feedstock because the organics polishing system should be installed by that time.

5.1.4.4 Lessons Learned

SVCW learned a number of lessons from their pilot project.

Ensuring High Quality Feedstock

One of the first lessons learned from the pilot project was the importance of securing high quality feedstock in advance of implementation. To ensure reliable operation and optimize results, WWTPs must have a consistent and high-quality feedstock. Early feedstock agreements can be challenging for Waste Management Agencies (WMAs) to commit to in advance of project implementation. However, to meet statewide mandates and secure locations for organic waste diversion, WMAs may become more willing to enter into feedstock agreements at early project stages.

New Equipment to Handle Contaminants

SVCW's pilot facility used a paddle finisher to remove large contaminants from the food waste slurry as it was fed to the digesters. SVCW staff discovered in the early operation of the facility that the type of screen selected for the paddle finisher was not suitable. Once SVCW staff installed the correct type of screen, the performance improved significantly.

Due to a significantly higher than expected percentage of contamination in the incoming organic feedstock, extra garbage bins were needed to discard the screened and manually removed contaminants.

Accommodating Delivery Vehicles

SVCW also learned they needed more space to accommodate food waste trucks. The trucks that deliver food waste can be of different sizes. So, it is important to design a receiving facility that can accommodate various truck sizes.

Increased Biogas Production

Preliminary results showed more biogas production and easier dewatering. The full results will be available with the final report on the pilot study, expected after May 2019.

5.2 Conclusions

5.2.1 Factors Facilitating Co-Digestion

The case studies illustrated that there are common factors that facilitate co-digestion projects at WWTPs.

5.2.1.1 State Law and Regulations

Legislation mandating waste reduction and diversion, and legislation requiring greenhouse gas emission reductions motivated WWTPs (and partner agencies) to pursue co-digestion. Specific catalysts include:

- AB 341 sets a goal of 75 percent solid waste reduction, recycling, or composting by 2020.
- AB 1826 requires organic waste diversion from certain residential and commercial entities to recycling centers.
- SB 1383 sets a statewide organics diversion target of 75 percent by 2025, and could impact facilities' use of landfills as a biosolids disposal option.
- AB 32 requires the state of California to reduce GHG emissions to 1990 levels by 2020.
- SB 32 requires the state of California to reduce GHG emissions to 40 percent below 1990 levels by 2030.

5.2.1.2 Supportive Partnerships

In all the case studies, developing a partnership with a Waste Management Agency was critical for success. The WMAs are ultimately responsible for meeting the SB 1383 targets and will need a destination for their organic waste. Options include educating food waste diversion program participants about proper source-separation and installing equipment to extract the organic matter from the black bin. In most cases, it is likely that this pre-processing will occur offsite at an existing transfer station, either owned or operated by the Waste Management Agency. If black bin waste is used, the transfer stations will require new equipment to extrude the organic fraction of the solid waste stream.

Establishing a feedstock agreement with the Waste Management Agencies can help ensure the WWTPs receive a clean and reliable slurry to protect equipment and maintain consistent operations. These agreements can specify waste quality and/or quantity parameters, describe how deliveries not meeting the specifications will be managed, and establish a tipping fee.

There are several WWTPs that have partnered with WMAs to advance co-digestion projects. These examples include:

- *Central Marin Sanitation Agency in partnership with Marin Sanitary Service.*
- *Silicon Valley Clean Water in partnership with Recology.*

- *Sanitation Districts of Los Angeles County – Joint Water Pollution Control Plant in partnership with Waste Management* (See Chapter 6).

Another important partnership is that with a utility provider. Biogas can be put to multiple end-uses: heat, power, gas converted to vehicle fuel, or gas injected into the pipeline. Cogeneration provides a relatively stable benefit and is applicable in most facilities. In three of the four case studies, the facilities pursued or are seriously considering cogeneration. If a facility determines cogeneration is the right option for them, offsetting energy costs will save the facility money and exporting power can generate revenue. Some important aspects to consider when negotiating agreements to export power include:

- Net metering or sale and purchase costs.
- Limits on cogeneration equipment capacity.
- Additional infrastructure build out.
- Power forecasting and timing requirements.
- Duration of the agreement.
- Local air quality regulations.

Finally, Board member and community support are also critical. Such support helps with local buy-in, financing, and program sustainability. Board support is especially critical to move projects forward and mitigate risk. Education and outreach about source separation can increase the quality of the feedstock and reduce maintenance costs at the facility.

5.2.1.3 Planning

In all the case studies, planning efforts were very important. Each facility has unique needs, especially regarding biogas utilization, energy management goals, and viable avenues for biosolids end use. Feasibility studies can identify local market conditions for organics management, biogas and biosolids use, capacity limitations within the treatment plant, and the costs and payback periods for necessary investments. In some cases, the feasibility studies were joint efforts between the Waste Management Agency and the WWTP and they considered the various requirements of the different entities for project success. Feasibility studies should also consider the availability food waste and the associated contamination, as well as what grant and loans could be used to support different aspects of the project.

Some the featured facilities evaluated the feasibility of co-digestion as part of the master planning process. The City of Manteca, for example, evaluated co-digestion when considering how to address treatment plant capacity limitations and then integrated co-digestion into a capital improvement project to produce higher quality biosolids. Master planning and capital investments for upgrades of existing or installing new components can be viewed as an opportunity to consider resource recovery.

5.2.1.4 Financing

In two of the four case studies, the WWTP had secured financing and saw these projects as a good long-term investment. In the other two case studies, lack of funding is a barrier that has not yet been overcome. Having financial support via grants or low interest loans makes these projects more viable. It is also important for these grants or low interest loans to eliminate restrictions that could limit what a facility does with its biogas. For instance, if a loan requires a 20-year power purchase agreement, but power utilities only provide 10-year agreements, the facility may opt not to export power.

As noted earlier and described in Chapter 3, revenue sources can make co-digestion projects economical, provided they're reliable and cover increased O&M costs. The lack of certainty surrounding tipping fees and the revenue from power sales or biogas production create untenable risk for many agencies. If costs exceed revenue, co-digestion will not be feasible.

5.2.2 Factors Impeding Co-Digestion

5.2.2.1 Insufficient Planning

Based on these case studies, one significant barrier to success is the limited nature of planning studies. Studies that do not encompass all aspects of the projects, consider impacts on ancillary treatment systems, and engage all the entities involved may delay projects. Robust planning and preliminary design efforts are necessary and should evaluate the following: impacts to the treatment plant, treatment plant capacity to handle the additional loads and potential side-stream treatment options, robust equipment evaluation, air quality permit requirements, and other requirements imposed by various regulatory agencies.

5.2.2.2 Regulatory Hurdles

The agencies featured in these case studies are concerned about increased nitrogen loading. The additional nitrogen load from protein-rich food waste ends up in the dewatering centrate, which is recycled back to the liquid treatment train. Some facilities have stringent nitrogen limits for plant effluent. These facilities already have secondary treatment processes that nitrify and denitrify plant influent. Additional nitrogen loads from the centrate could exceed the treatment capacity of the secondary treatment system.

Additional nitrogen loading may require increased aeration in the secondary treatment process. Increased aeration may require larger blowers that consume more energy. If a facility has stringent nitrogen limits and cannot accommodate higher nitrogen loads in the existing mainstream treatment process, co-digestion may require the installation of side stream nitrogen removal processes. This would add additional cost to the project.

Other regulatory obstacles, such as stringent emissions limits on stationary engines and a municipal solid waste permit to receive extruded "black bin" organics, can also present a substantial barrier to implementation.

5.2.2.3 Inadequate Funding

Without financial assistance from grants or low-interest loans, facilities would have to rely exclusively on their ratepayers to cover the high capital costs needed for full-scale implementation of co-digestion projects. However, WWTPs cannot typically justify high-risk ventures that come at significant cost to their ratepayers. They are often unable to take on risk associated with a new technology or burdensome requirements for contract lengths, energy production guarantees, or similar contract terms. Furthermore, many communities cannot or will not agree to rate increases for upgrades perceived as unrelated to a WWTP's core business.

Additional grant programs for newer technologies or processes would help mitigate the risk for these facilities and accelerate technology advancement, such as was the case for Manteca's CNG fueling station.

Public/private partnerships could also be a potential financing option, but the contract terms for such agreements would have to meet the needs and constraints of both parties.

5.2.2.4 Feedstock Contamination

Even if food waste has been source separated (i.e., is a relatively clean feedstock), WWTPs may need to perform an additional polishing step (e.g., paddle finisher) prior to feeding the pre-processed material to a digester. The polishing step also helps protect downstream equipment (i.e., the pumps, valves, and piping) and digester operations.

Operations and maintenance costs are incurred in many ways, but the quality of feedstock significantly impacts O&M labor and equipment costs. Hence, another barrier to success is finding a clean and reliable feedstock at a tipping fee that can help recover costs over the long term.

5.2.2.5 Competition with Composting

Counties are required to divert organics from landfills. They can accomplish that by diverting organics to WWTPs for co-digestion or by diverting organics to composting operations. Many already divert organics to composting operations. Waste Management Agencies that already have an agreement in place with a composting operation may pay less in tipping fees and do minimal pre-processing compared to what might be required at a WWTP. A WWTP may be able to navigate this potential barrier by developing a partnership with the local Waste Management Agency and agreeing to a feedstock agreement with stable tipping fees for the duration of project payback period. Tipping fees at compost facilities are generally shorter term. Longer-term agreements with WWTPs that include set tipping fees may reduce risk to WMAs.

5.3 Screening Questions for Co-Digestion

Based on the case studies and analyses in other chapters, we developed a process that agencies can use to determine whether co-digestion of food waste makes sense at their plants. While there is no one answer for all facilities, this process guides users through a step-by-step approach. The screening questions in the flow chart cover key items to evaluate in the early stages of consideration (Appendix 5D). The screening questions are intended to help facilities avoid some of the barriers to success described in previous sections. Following the screening process may help facilities consider, pursue and implement co-digestion.

5.4 References

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Chapter 6

CO-DIGESTION AT LARGE WASTEWATER TREATMENT PLANTS

6.1 East Bay Municipal Utility District

The East Bay Municipal Utility District's (EBMUD) Main wastewater treatment plant (WWTP) serves approximately 650,000 residents from seven cities and sanitation districts located in the East Bay near San Francisco and Oakland. The Main WWTP's permitted average dry weather flow (ADWF) capacity is 120 million gallons per day (mgd), which is significantly higher than observed flows. The WWTP was originally designed to handle high organic loads from canneries that have since left the area, leaving EBMUD with excess solids treatment capacity for its Resource Recovery program.

A key portion of that excess capacity is provided by eleven digesters, each of which has 1.8 million gallons (MG) of capacity. With all units in service, the digesters would provide a total digestion volume of 19.8 MG (Carollo 2018). Under normal conditions, two of the digesters are out of service to maintain a regular schedule of digester cleaning. While the plant has a design solids retention time (SRT) of 16 days, the actual SRT in 2017 averaged 22 days. EBMUD operates its digesters in the thermophilic temperature regime (Water Environment Federation 2018), heating digesters via spiral heat exchangers. Eight have both draft tubes and pumps for mixing and three are fitted only with pump mixing. The digesters are continuously fed in parallel to reduce digester gas production variability and operational issues such as foaming. One digester is fitted with a double membrane cover for low pressure digester gas storage. The digester gas piping connects all the digesters to this gas storage system.

EBMUD beneficially uses biogas as much as possible. The plant has three 2.1 MW engines and one 4.5-megawatt (MW) gas turbine that utilize biogas to produce power and heat. EBMUD dewaters biosolids with centrifuges that have a total hydraulic capacity of 620 gallons per minute (gpm). The plant uses emulsion polymer for dewatering and produces dewatered cake at an average dryness of 25 percent. The dewatered cake is trucked offsite for various end uses.

6.1.1 Resource Recovery Program

Since 2002, the EBMUD Resource Recovery (R2) program has sought ways to increase biogas production through the co-digestion of additional feedstocks such as fats, oils, and grease (FOG) and other high-strength wastes. In the early 2000s, the agency constructed relatively low-cost systems ($1M in 2002): one to receive lower-strength liquid wastes like septage near the headworks and another, smaller system to receive FOG. EBMUD intended the FOG receiving station to be temporary - and included a macerator, rotary lobe pump, above-grade hoses, a Baker storage tank, two feed pumps, and only a single truck offloading connection.

In 2004, the agency constructed a $7M solids and liquids receiving facility to accept higher-solids material such as food waste. This receiving facility included a sub-grade pit into which high solids material could be delivered, a paddle finisher, positive displacement transfer pumps and associated piping, odor control, and provisions to allow dilution of the high-solids material into a pumpable slurry. The facility began accepting small amounts of source separated food waste in 2005 as part of a pilot test. By 2017, EBMUD was receiving deliveries five days per week, averaging about 4.3 dry tons per day (or 8,700 dry pounds per day) (Carollo 2018).

While intended to be temporary, the original FOG receiving system remained in service for a decade. The "temporary" system allowed the plant to receive substantial quantities of FOG, reaching approximately 22 million gallons in 2010. However, this system limited the volume that could be accepted and required considerable operator attention. In addition, the digesters would occasionally experience foaming issues, the result of individual loads going directly into a digester.

EBMUD installed the permanent receiving facility in 2014 at a cost of $13M. The new receiving facility includes several truck loadout stations, where liquid high-strength wastes could be discharged to below-grade sumps, heated and mixed, pumped to two new blend tanks to be mixed with sludge and other feedstocks, and then finally fed to the digesters in a relatively consistent stream. To increase the amount of high-strength waste it could receive, alleviate operational issues, increase redundancy, and reduce digester foaming, EBMUD combines the plant's municipal solids with organic feedstocks in blend tanks upstream of the digesters and then feeds that blend to the digesters. This blended feed reduces the variability in individual feedstock characteristics and buffers the digestion process from feedstocks that could cause process instability. With the installation of the receiving station and use of its blend tanks, EBMUD now feeds the digesters a more consistent load, preventing foaming issues (EBMUD 2019).

The facility currently receives 100 - 150 trucks per day filled with external feedstocks, only a small portion of which is municipal food waste. Approximately one third of the external organic waste is high-strength[1], including dairy, cheese, beer, wine, and soda processing wastes, FOG, rendering wastes, blood, and others (Table 6.1). To facilitate the monitoring and processing of all deliveries and to avoid an increase in staffing needs, EBMUD developed a software package to control security access, track delivery data, and automate billing. This allows receiving of high strength liquid waste 24 hours per day, 7 days per week.

Table 6.1 Summary of Reported Organic Feedstocks Received by EBMUD in 2017(1)

Feedstock Type	Flow (gpd)(2)	Load (dry short TPY)(3)	No. Days per Week Received	% solids
Fats, Oils, and Grease	34,000	700	7	~1
Liquid Food and Beverage Waste	176,000	18,400	7	1-8
Source Separated Commercial, Institutional, or Residential Organic Waste	13,000 (slurried)	1,100	5	Received: 30 Slurried: 8
Blood	23,000	5,300	7	15

Notes:
(1) (Carollo 2018).
(2) gpd – gallons per day.
(3) TPY – tons per year.

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[1] EBMUD defines high-strength waste as waste with a chemical oxygen demand (COD) concentration greater than 20,000 milligrams per liter (mg/L).

Permitted high strength liquid waste haulers do not require EBMUD staff assistance to deliver feedstock, nor to cross EBMUD's fenceline to deliver the feedstock. In contrast, solid food waste deliveries require plant staff to be present, and hence, those deliveries only occur Monday through Friday during business hours. The food waste accepted at the EBMUD Main WWTP is a high-solids product that comprises the organic portion of the municipal solid waste stream. It is received as a 30-percent solids material, which is subsequently diluted to produce a pumpable slurry at approximately 8 percent solids.

Testing the digestibility of food waste in various forms (Table 6.2), EMBUD found that liquefied or slurried food waste is the easiest to handle.

Table 6.2 Summary of Solid and Liquid Food Waste Types Received at EBMUD to Date(1)

Form of Food Waste	Approach to Contamination Control	Full-Scale Experience	Contamination	
			Light <2 mm(2)	Heavy (grit)
Solid Food Waste				
SSO(3) – Grind to >2 inches	-Customer Education. -Load Rejection (at pickup). -Magnetic Field (after grinding).	-Difficult to process. -Metals/Cutlery issue. -Not cost effective.	4.6%	4.6%
MSW(4)	Screen Press	-Limited Experience. -Requires Polishing.	7.0%	5.0%
SSO(3) Pre-processed	Hammermill Separator	None.	0.7%	7.6%
Liquid Food Waste				
SSO(3) Processed	Screw Press – 1/8" Shaker Screen	Easy to Process.	0%	1.5%(5)
Grind to liquid	Sorted via "weak" grinder	Limited experience, but easy to process to date.	-	-

Notes:
(1) (EBMUD 2019).
(2) mm - millimeter diameter.
(3) SSO - source separated organics.
(4) MSW - municipal solid waste.
(5) Mostly eggshells.

6.1.2 Effluent Impacts

EBMUD has observed an increase in the effluent nitrogen concentration with the addition of organic waste. An attempt to quantify the amount of nitrogen and phosphorus in the organic waste has been challenging as the analyses required for the samples of the hauled-in waste are often incompatible with the standard wastewater analytical methods used by the Agency's and other commercial laboratories. While EBMUD does not currently have nutrient effluent limits, it may in the near future. EBMUD anticipates the facility would not meet nutrient limits even if co-digestion ceased, and it will need a new nitrogen removal process regardless of the R2 program (EBMUD 2019).

With co-digestion, EBMUD staff have also observed a significant increase in salinity between plant influent and secondary effluent. However, because the facility discharges to a saline water body (i.e., the San Francisco Bay), its permitted discharge salinity limit is high and effluent concentrations are well below it (EBMUD 2019). Nevertheless, salinity remains a concern to EBMUD because high salinity can limit the use of recycled water for cooling towers and other salt-sensitive applications.

6.1.3 Biogas Benefits and Challenges

EBMUD has seen a significant increase in biogas production as a result of co-digestion. The facility became energy neutral in 2012 and is now energy positive (EBMUD 2019). Because EBMUD combines multiple external feedstocks with municipal sludge, and feeds the blend to the digesters, data from this facility illustrate the impacts of the combined feed rather than impacts from only municipal food waste.

The left panel in Figure 6.1 shows the amount of biogas EBMUD produced prior to co-digesting organic waste (i.e., the full calendar year of 2001) and the relative increase in production of biogas after (specifically, years 2013 to 2017). According to our analysis, EBMUD's biogas production has increased, on average, by 140 percent. As noted earlier, we cannot distinguish how much of the increased biogas production is attributable to the food waste alone. That said, the benefit of co-digestion is clear: the biogas derived from EBMUD's R2 program reduces power costs by approximately $2M per year and generates approximately $1M per year in revenue from exported electricity (EBMUD 2016).

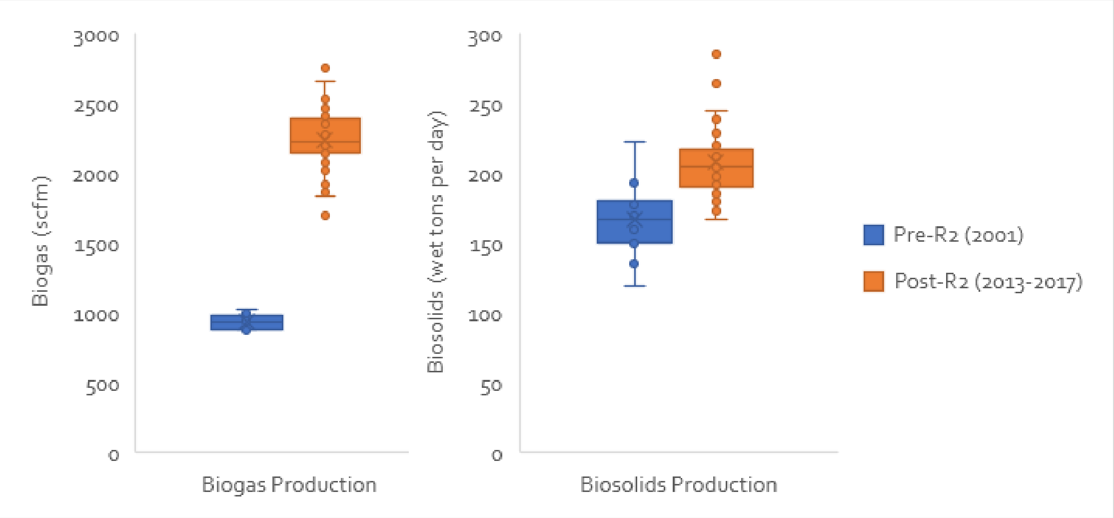

Figure 6.1 EBMUD Biogas Production Before and After Implementation of the R2 Program

Biogas production is highly variable. Production ramps up during the week when feedstock deliveries are more frequent, especially since EBMUD does not require feedstock deliveries to be scheduled, and then drops on the weekends as deliveries decline. This variability poses challenges to biogas management. The equipment is unable to ramp up or down quickly, making it difficult for operations staff to run the system optimally. EBMUD has explored a variety of techniques to optimize biogas production and utilization, including:

- *Continuously feeding digesters the feedstock and sludge blend*. While continuous feed addressed some issues, gas production variability remains an issue.
- *Storing organic (liquid/food) waste onsite*. This option may be problematic as food waste is readily degradable and may produce methane in the storage tank, potentially creating

dangerous conditions both in and around the storage tank; it may also pose odor control issues.

- *Storing biogas onsite*. EBMUD determined the safety risks associated with storing **high**-pressure gas and the high capital cost of infrastructure needed to store a large volume of **low**-pressure gas made this technique unfeasible. Instead, the facility installed a low-pressure digester gas storage membrane cover on one of the plant's digesters. This has provided a buffer within the system.
- *Selling biogas derived power to the grid*. Based on its agreements to date, EMBUD has found that the value of wholesale electricity is decreasing. The agency estimates revenue in the near-term future will be too low to cover the operating costs for the biogas utilization system.
- *Injecting renewable natural gas into the pipeline*. EBMUD has abandoned this option, as the agency discovered it would be subject to additional Occupational Safety and Health Association (OSHA) regulations. EBMUD estimated that the additional engineering activities required to comply would be too costly for this project to be feasible. For more information related to the OSHA regulations, see the "Regulatory Considerations" section in Chapter 3.
- *Incentivizing hauler delivery on weekends rather than weekdays*. EBMUD is considering ways to make delivering feedstock on weekends more attractive to haulers, with the end goal of reducing the variability in biogas production during the week.

6.1.4 Biosolids Benefits and Challenges

Since implementing co-digestion, EBMUD has observed an increase in biosolids production by approximately 25 percent on a wet weight basis (right panel in Figure 6.1). Additionally, the production of biosolids per total solids (TS) fed to the digesters decreased by 7 percent, from an average of 0.32 pounds of dewatered biosolids per pound TS fed to the digester (pound [lb] biosolids/lb TS fed) to 0.30 lb biosolids/lb TS fed. This reduction in biosolids production could be related to the synergistic effects of co-digestion and is a topic being researched within the co-digestion field (Higgins et al. 2017).

The increase in annual biosolids production results in an additional 19,500 wet tons per year, on average. Using an average end use (or disposal unit) cost provided by EBMUD, this results in an additional cost of approximately $1M annually[2]. While co-digestion has increased the cost of biosolids end-use and disposal, that cost is still well below the electricity cost savings and revenue (of approximately $3M) (EBMUD 2019).

In 2017, approximately 92 percent of the biosolids were used beneficially, either as Class B land application via a third party, processed as a fertilizer via a third party, or as Alternative Daily Cover (ADC) at the landfill (Table 6.3).

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[2] This cost does not account for the benefits of biosolids land application, such as carbon sequestration, offsetting synthetic fertilizer demand, increasing the organic content of soils, offsetting irrigation demand by increasing soil moisture holding capacity, increasing nutrient use efficiency, or increasing crop yield.

Table 6.3 Summary of EBMUD's 2017 Reported Biosolids End Uses and Disposal in 2017[(1)]

End Use or Disposal	Biosolids (total wet tons)	Percent of Total
Land Application (Class B) via a Third Party	41,453	49
Processed as Fertilizer via a Third Party	7,708	9
Landfill as ADC	28,405	34
Landfill Disposal	6,820	8

Notes:
(1) (Carollo, 2017).

While the food waste received accounts for less than 5 percent of the total external feedstock accepted at the plant, food waste and FOG represent the most operationally intensive streams with considerable maintenance needs. One reason for this has been the presence of grit, glass, and other hard debris in the food waste and FOG.

To reduce the maintenance associated with the food waste, EBMUD is planning to conduct a pilot study in the summer of 2019 that will test grit removal from a 6 percent solids slurry. Reducing the grit load associated with the food waste would allow EBMUD to receive more source separated organics (SSO) from pre-processed food waste sources (EBMUD 2019).

6.2 Sanitation Districts of Los Angeles County

Located in Carson, the Sanitation Districts of Los Angeles County (LACSD) Joint Water Pollution Control Plant (JWPCP) serves approximately 3.5 million residents in Los Angeles County. The permitted ADWF capacity is 400 mgd, which is significantly higher than observed flows. To manage the solids it receives, the JWPCP operates 24 anaerobic digesters, each having a capacity of 3.7 MG. If all digesters were in service, they would provide a total digestion volume of 88 MG (Carollo 2018). All digesters are operated in the mesophilic temperature regime, mixed via gas injection, and heated via direct steam injection. Under typical operating conditions, two digesters are out of service for cleaning and to ensure all digesters are cleaned on a regular schedule. The plant has a design SRT of 20 days; in 2017, actual SRT averaged 18 days.

The biogas generated at JWPCP is beneficially used via five internal combustion engines, five boilers, and three gas turbines to produce either power or heat (offsetting purchased electricity and heat). The plant produces Class B biosolids, which are dewatered with centrifuges (aided by polymer) to produce a 28 percent biosolids cake (2017 average) that is trucked offsite for various beneficial uses.

6.2.1 Food Waste Project

In 2011, LACSD completed a feasibility study on co-digesting food waste with solids. While uncertain about the economics of such projects, LACSD nonetheless concluded that co-digestion with food waste was technically feasible, allowed under current regulations, and could serve as an immediate option to assist the County and haulers with diversion mandates under Assembly Bill (AB) 341, AB 1826, and Senate Bill (SB) 1383.

In 2012, LACSD performed a bench scale test to quantify the biogas production potential of co-digesting LACSD solids with Waste Management's Engineered Bioslurry (EBS®). The bench scale test found co-digestion with food waste increased biogas production. In the process of bench scale testing, LACSD developed food waste specifications to avoid or minimize negative impacts (e.g., those caused by contaminants such as utensils, cans, and packaging) on the digester operations.

As a next step in 2013, LACSD entered into public/private partnership with Waste Management to perform a co-digestion demonstration project at JWPCP. As part of the agreement, Waste Management collected the source separated food waste from restaurants, food processing plants, cafeterias, and grocery stores, and brought it to its Centralized Organic Recycling (CORe®) system to pre-process the feedstocks and produce the EBS®. The JWPCP received up to 70 wet tons per day EBS® via tanker trucks (approximately 3,800 dry short tons in 2017). The food waste receiving facility constructed in 2013 consisted of two identical receiving stations for redundancy. Operation of the receiving station began in February of 2014. Four of JWPCP's 24 digesters were dedicated to the demonstration project - two served as control digesters and the other two rotated between being a control or test digester. The demonstration project ran from February 2014 to December 2017.

During the demonstration project, EBS® was the only external feedstock added to the test digesters. To determine the change in biogas and biosolids production before and after co-digestion of EBS®, we examined the operational data for a 70-day period: from September 16, 2016 through November 24, 2016 (Figure 6.2). During that period, two digesters were used as control and two were used as test, and the system ran continuously. The amount of EBS® added to the digesters averaged 16,500 gallons per day, or 10 dry tons per day.

6.2.2 Biogas Benefits and Challenges

Based on the operational data from September 16, 2016 to November 24, 2016, LACSD test digesters produced 43 percent more biogas than the control digesters. The left panel in Figure 6.2 shows the average weekly biogas production for the two test digesters (combined) and the two control digesters (combined). This increase in biogas production is a direct result of adding EBS® (i.e., the food waste).

The estimated value of avoided natural gas costs over that 70-day period is approximately $61,000[3]. For the entire year, the total value of avoided natural gas costs would be approximately $319,000. These savings would be from the co-digestion demonstration project alone.

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[3] For this calculation, we assumed the energy content of biogas is 600 British thermal units per standard cubic foot (Btu/scf) and the natural gas offset price is $5.16/million Btu (MMBtu) (LACSD 2017).

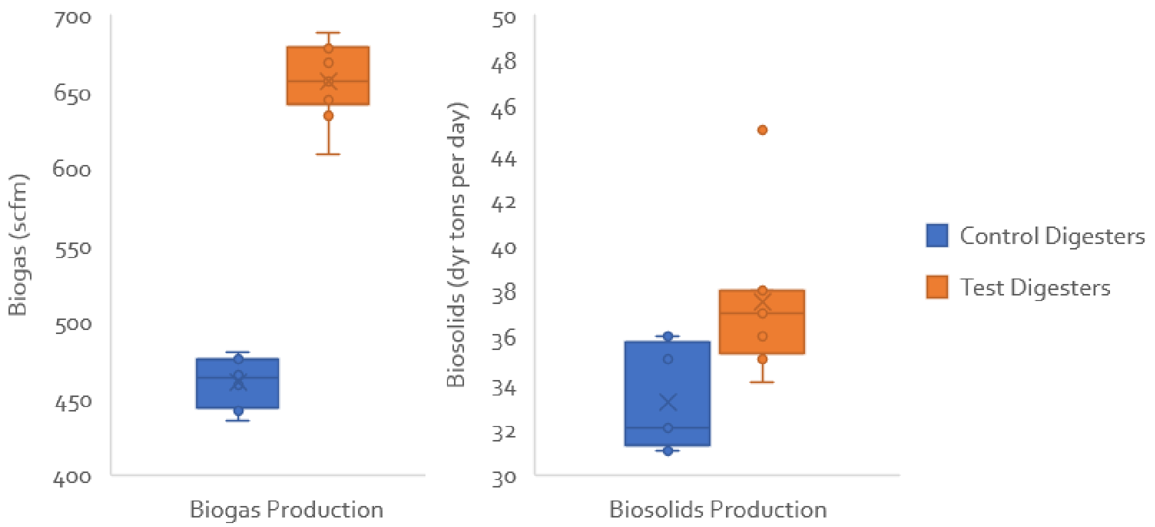

Figure 6.2 LACSD JWPCP Comparison of Average Weekly Biogas Production, and Biosolids Production from Control and Test Digesters (September-November 2016 Demonstration Project)

6.2.3 Biosolids Benefits and Challenges

The right panel in Figure 6.2 shows the total biosolids produced by the control and test digesters from September 16, 2016 to November 24, 2016. On average, the test digesters produced 13 percent more biosolids on a dry weight basis. The typical solids content of dewatered biosolids at LACSD ranges between 28 and 30 percent. LACSD did not conduct a dewaterability study as part of the demonstration project and does not know whether co-digestion affected the solids content of the biosolids.

In 2017, approximately 90 percent of the JWPCP biosolids were beneficially used, either as Class B land application or via third party composting (Table 6.4).

Table 6.4 Summary of JWPCP 2017 Reported Biosolids End Uses and Disposal⁽¹⁾

End Use or Disposal	Biosolids (total wet tons)	Percent of Total
Land Application (Class B)	51,687	12
Third Party Compost	336,033	78
Landfill Disposal	42,756	10

Notes:
(1) (Carollo 2018).

One of the challenges with co-digesting of food waste (as EBS®) was the accumulation of glass and grit in the test digesters. Pre-processing did not effectively remove the glass and grit, which accumulate in the digester, potentially damaging pumps, valves, and piping, as well as requiring more frequent digester cleaning (which increases operations and maintenance costs). As a result, LACSD has been considering how to improve the removal and capture of inerts during pre-processing.

6.3 Summary

There are several large WWTPs in California that either are co-digesting or are getting ready to co-digest municipal food waste.

The agency with the largest and the longest running co-digestion program is EBMUD. Since 2002, the EBMUD Resource Recovery program has sought ways to increase biogas production through the co-digestion of additional feedstocks. Less than 5 percent of the high-strength organic feedstock EBMUD currently accepts is municipal food waste. As a result of co-digestion of the combined feedstock, EBMUD has seen a significant increase in biogas production, an average increase of 140 percent. EBMUD has also observed an increase in biosolids production, approximately 25 percent on a wet weight basis.

The other large agency that has extensively investigated co-digestion is the LACSD. Following a bench scale test to quantify the biogas production potential in 2012, LACSD operated a co-digestion demonstration project for several years. Co-digestion at LACSD's JWPCP facility increased biogas production by 43 percent, and biosolids production by 13 percent, on a dry weight basis.

There are two other agencies getting municipal food waste co-digestion projects off the ground, and another that has piloted a program. The Orange County Sanitation District's (OCSD) Plant 2 (144 mgd ADWF) and the Riverside Regional Water Quality Control Plant (46 mgd ADWF) are in the design and planning stages, respectively. The City of Los Angeles' Hyperion Water Reclamation Plant (450 mgd ADWF) conducted a brief co-digestion pilot using its existing FOG receiving station. Subsequently, Hyperion completed an "In-Sink" pilot, evaluating the receipt of ground food waste through the sewer system. Specific facility information on how co-digestion has affected biogas and biosolids production will become available as these projects evolve.

WWTPs have compelling reasons to co-digest food waste - and equally compelling reasons to proceed cautiously. The challenges confronting EBMUD and LACSD (e.g., anticipated nitrogen limits, uncertainty of renewable electricity prices, and feedstock contamination) are but a few of the obstacles WWTPs must navigate to co-digest with municipal food waste. For nascent programs such as those at the OCSD, Riverside and Hyperion to succeed, the wastewater and waste industries as well as state and local agencies must holistically consider and address these challenges.

6.4 References

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