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Downstream Management of Organic Waste in the United States: Strategies for Methane Mitigation

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Photo courtesy of Gershman, Brickner & Bratton, Inc.

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Abbreviations, Acronyms and Units of Measure

AD	anaerobic digestion
CAR	Climate Action Reserve
CHP	combined heat and power
CI	carbon intensity
CMSA	Central Marin Sanitation Agency
CNG	compressed natural gas
CoEAT	Co-Digestion Economic Analysis Tool
CRMC	CommonWealth Resource Management Corporation
D3	Renewable Identification Number category for cellulosic biofuel
D5	Renewable Identification Number category for advanced biofuel
DSIRE	Database of State Incentives for Renewables and Efficiency
EBCI	Eastern Band of Cherokee Indians
F2E	Food 2 Energy
FLW Protocol	Food Loss & Waste Protocol
FLW Standard	Food Loss and Waste Accounting and Reporting Standard
FOG	fats, oils and grease
GHG	greenhouse gas
ICI	industrial, commercial and institutional
k	methane generation rate
kW	kilowatt
kWh	kilowatt-hour
LACSD	Sanitation Districts of Los Angeles County
LCFS	Low Carbon Fuel Standard
LFG	landfill gas
LMOP	Landfill Methane Outreach Program
L_0	Potential methane generation capacity
Mg	megagram
MMBtu	million British thermal units
$MMTCO_2e$	million metric tons of carbon dioxide equivalent
MSW	municipal solid waste
$MTCO_2e$	metric tons of carbon dioxide equivalent
MW	megawatt
NMOC	non-methane organic compound
NRDC	Natural Resources Defense Council
OrganEcs	Cost Estimating Tool for Managing Source-Separated Organic Waste
PAYT	Pay-As-You-Throw

REAP	Rural Energy for America Program
RFS	Renewable Fuel Standard
RIN	Renewable Identification Number
RNG	renewable natural gas
RPS	Renewable Portfolio Standard
SMM	Sustainable Materials Management
SSO	source-separated organics
USDA	U.S. Department of Agriculture
WARM	Waste Reduction Model
WM	Waste Management, Inc.
WRRF	water resource recovery facility
ZWEDC	Zero Waste Energy Development Company

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Introduction

Diverting organic waste from landfills can achieve significant environmental, public health and economic benefits. When organics end up in landfills, they release methane—a potent greenhouse gas (GHG) that is 28 to 36 times more effective than carbon dioxide at trapping heat in the atmosphere over a 100-year period.[1] Less organic waste in a landfill will lower emissions of methane and non-methane organic compounds (NMOCs), reduce odors, minimize leachate generation and conserve landfill space. Methane is of particular concern because it is very effective at retaining heat in the Earth's atmosphere, and landfills are the third-largest source of human-caused methane emissions in the United States. Increasing levels of methane and other GHGs in our atmosphere are contributing to changing Earth's climate—rising temperatures, changes in precipitation and more extreme climate events. The NMOC portion of landfill gas (LFG) contains a variety of hazardous air pollutants and volatile organic compounds, all of which can cause adverse health effects if the exposure is sufficient.

Key Findings
• *Keeping food and other organics out of landfills will help the United States address climate change, as more than 15 percent of total U.S. human-caused methane emissions come from municipal solid waste (MSW) landfills, which emitted 99.4 million metric tons of carbon dioxide equivalent (MMTCO_2e) of methane in 2019.*[2]   • *The amount of food waste generated in the United States continues to increase: food made up 21.6 percent of MSW generated in the country in 2018, with yard trimmings accounting for an additional 12.1 percent.*[3] *Notably, food waste is the single largest component of MSW disposed of in landfills.*[4]

1 U.S. EPA. Understanding Global Warming Potentials. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials. Accessed November 8, 2021.

2 U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019. Chapter 7: Waste. April 2021. https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-chapter-7-waste.pdf.

3 U.S. EPA. Advancing Sustainable Materials Management: 2018 Fact Sheet. December 2020. p. 8. https://www.epa.gov/sites/production/files/2020-11/documents/2018_ff_fact_sheet.pdf.

4 Ibid. p. 9.

The food waste estimate comprises residential, commercial and institutional sources, but not industrial or on-farm sources. Commercial and institutional industries covered include grocery stores, full- and limited-service restaurants, public and private elementary schools, colleges and universities, prisons, nursing homes, residential hospitals, short-term stay hospitals, and hotels. Estimates of wasted food generated by the industrial sector (i.e., food and beverage manufacturing and processing) are not included in this statistic. EPA estimates industrial sector wasted food generation and management separately (see the 2018 Wasted Food Report).

Key Findings
• *Food waste decays quickly in landfills. An analysis using EPA's Waste Reduction Model (WARM) shows that diverting just 25 percent of the food waste currently sent to U.S. landfills would reduce life cycle GHG emissions by about 30 percent.*[5]

There are many options for preventing or mitigating methane emissions from organic waste, including food donation, animal feed and land application. Technologies such as anaerobic digestion (AD) and composting can produce renewable energy or other useful end products that can improve soil health and reduce erosion. Implementing alternatives to landfills for organic waste management will also spur investment and new job creation in local economies.

Key Findings
• *Local governments and municipalities are successfully using different methods of treatment and disposal for organic waste. Some municipalities with LFG energy projects as well as diversion programs treat a portion of their organic waste by sending it to AD facilities to generate biogas or composting facilities to produce soil amendments. Landfills provide excellent opportunities for siting new AD or compost facilities. Diverting organic waste to generate biogas or compost can be part of an integrated solid waste management approach using multiple options for disposal or treatment.*
• *Co-digestion of food waste with manure or water resource recovery facility (WRRF) sludge allows facilities to use existing assets and infrastructure to meet the growing interest in food waste management. With co-digestion, facilities can more efficiently use process equipment and lower costs when they process multiple waste streams together. Facilities can also use co-digestion to adjust the solids percentage to improve digestion and increase biogas production. Between 60 and 70 percent of the operational AD projects accepting food waste in 2018 were co-digestion facilities, although stand-alone digesters processed the bulk (84 percent) of the food waste.*[6]

Sustainable downstream management of organic waste is a challenge facing local waste management authorities and private haulers, as well as waste disposal, composting and AD companies. Because all sectors of the economy (industrial, commercial and institutional [ICI] and residential) generate organic waste, a comprehensive set of solutions is required to catalyze large-scale behavior changes from each waste generator, tailor collection approaches to meet the needs of each community and mobilize significant investment in new organic waste processing and treatment infrastructure.

5 U.S. EPA. Waste Reduction Model (WARM). Version 15. https://www.epa.gov/warm. Accessed February 24, 2021.

6 U.S. EPA. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). EPA/903/S-21/001. January 2021. Tables ES-1 and ES-2. https://www.epa.gov/sites/production/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf.

Key Findings

- *In 2016, approximately 74 percent of MSW food waste (excludes industrial sector) ended up in either landfills, controlled combustion or sewer/wastewater treatment, suggesting there is significant room for improving existing organic waste diversion programs and implementing new organic waste diversion initiatives.*[7]
- *State and local policies and programs are emerging, gaining momentum and driving actions to divert food waste away from landfills. However, there are still many barriers, including lack of infrastructure for collecting, processing and treating the wastes; therefore, the practice is not widespread throughout the United States.*
- *The success of source-separated organics (SSO) collection programs depends on several factors, including ensuring the collection techniques are tailored to the needs of the local community. Community involvement, education and outreach are also critical.*
- *A variety of incentives and funding resources are available to promote organic waste diversion from landfills. Grants and low-interest loans for integrated solid waste management approaches, as well as more traditional incentives for energy produced from biogas, can help facilities make these projects economically feasible.*

Purpose and Audience

This document provides an overview of downstream organic waste management in the United States, focusing on alternatives to landfilling organic waste including composting and AD, for the primary purpose of reducing or mitigating methane emissions. More specifically, it contains technical information about collection practices and processing technologies, potential benefits of and barriers to organic waste diversion, policies and incentives for increasing diversion rates, and tools and resources for evaluating organic waste management options in communities. It includes brief case studies of policies and programs to highlight successful examples, lessons learned and best management practices, as well as links to resources and tools (found in the appendices).

The intended audience is primarily municipalities and other local governments seeking information about downstream organic waste management options that reduce methane emissions from the solid waste sector, and particularly those jurisdictions that own or operate landfills. State agencies, private waste management companies and LFG energy project developers will also find this document useful, as emerging solid waste management trends, practices and policies may affect landfill or LFG energy operations.

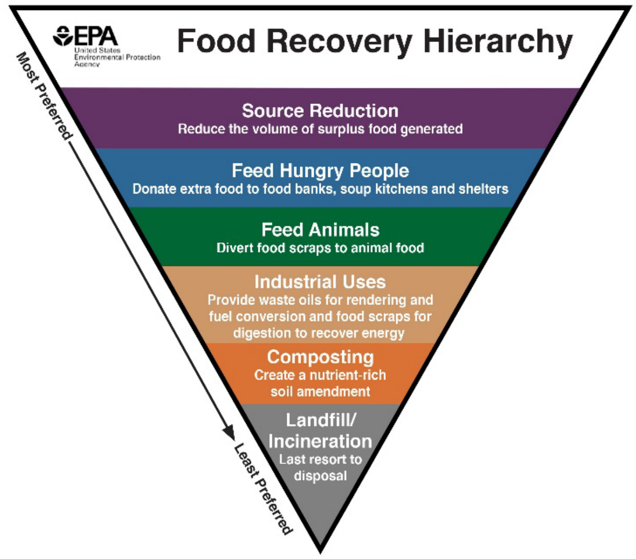
Scope

This document provides information about the downstream management of food waste (i.e., discarded food and any inedible parts of food) and yard and garden debris (e.g., leaves, grass clippings); it does not address wood, paper, livestock manure or WRRF sludge.

The management strategies presented in this document include the last three levels of the EPA Sustainable Materials Management (SMM) Program's Food Recovery Hierarchy: industrial uses,

[7] U.S. EPA. 2018 Wasted Food Report. November 2020. p. 19. https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf.

composting and landfill/incineration.[8] This document does not include discussion or analysis of source reduction, feeding hungry people or feeding animals. The Food Recovery Hierarchy presents prioritized actions that organizations can take to prevent and divert wasted food. Each tier of the hierarchy focuses on a different management strategy. The top levels of the hierarchy are the best ways to prevent and divert wasted food because they create the most benefits for the environment, society and the economy. Source reduction is the most preferred option as it not only mitigates the environmental impacts associated with management of excess food, but also minimizes the impacts associated with food production, processing and delivery to the end user. Any management option chosen in a particular situation is dependent on the characteristics and the source of the excess food. For example, some food preparation residuals and/or post-consumer food discards may not be suitable for human consumption, so the next most preferred use is for animal feed. Feeding people is the most preferred option and landfill/incineration is the least preferred option for managing the edible fraction of excess food.



Contributing EPA Programs

The Landfill Methane Outreach Program (LMOP) is a voluntary EPA program that works with stakeholders to reduce or avoid landfill methane emissions. To reduce methane emissions, LMOP encourages the recovery and beneficial use of biogas generated from organic MSW. To help avoid excess or uncontrolled methane generation, organic waste can be managed in other ways besides landfilling.

AgSTAR is EPA's voluntary program that promotes the use of biogas recovery systems to reduce methane emissions from livestock waste. Many manure-based AD projects co-digest other organic wastes; AgSTAR's information and resources about AD technology and biogas recovery are therefore often applicable to stand-alone organic waste AD projects as well.

EPA's SMM Program focuses on protecting human health and the environment by advancing the sustainable use of materials to minimize waste. Sustainable Management of Food is a systematic approach that seeks to reduce wasted food and its associated impacts over the entire life cycle, starting with the use of natural resources, manufacturing, sales and consumption and ending with decisions on recovery or final disposal. EPA works to promote innovation and highlight the value and efficient management of food as a resource as part of the SMM Program.

8 For more information on the hierarchy, see www.epa.gov/sustainable-management-food.

Section 1: Organic Waste in the United States

In 2018, residential, commercial and institutional sources in the United States generated about 292 million tons of MSW.[9] The organic fraction—food, yard, paper and wood wastes—constituted more than 63 percent of the total solid waste generated from these sources, while food and yard wastes made up more than 33 percent of the total solid waste generated.[10]

Organic waste typically includes yard, wood and food wastes, paper, livestock manure and WRRF sludge. It does not include metals, glass, textiles, leather or petroleum-based plastic. This document focuses on managing food waste (i.e., plate waste, spoiled food and any inedible parts of food) and yard and garden debris (e.g., leaves, grass clippings).[11] It does not address the other main types of organic waste, which are either managed differently or are generated by a sector other than ICI and residential sectors: wood packaging or wood from furniture is likely to be recycled or used for fuel, paper has more value as a recyclable material, and livestock manure and WRRF sludge are not considered MSW.

As defined by EPA in its *Wasted Food Report*, the following sectors generate food waste:

- Industrial: food and beverage manufacturing and processing
- Commercial:
  - Food retail/wholesale, including supermarkets, supercenters and food wholesalers
  - Hospitality, including restaurants/food services, hotels and sports venues
- Institutional: hospitals, nursing homes, military installations, office buildings, correctional facilities, colleges and universities, and K–12 schools
- Residential
- Food banks[12]

Notably, EPA does *not* include "food loss" in its definition of food waste—that is, unused products from the agricultural sector, such as unharvested crops.[13]

In the United States, food and yard wastes together constitute more than 50 percent of organic waste generated, as shown in Figure 1-1.[14] This suggests that preventing more food and yard wastes from entering the waste stream would significantly affect the overall amount of organic waste generated, and in turn the amount of methane emitted from the MSW sector. Food and yard wastes diverted from

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9 U.S. EPA. Advancing Sustainable Materials Management: 2018 Fact Sheet. December 2020. p. 2. https://www.epa.gov/sites/production/files/2020-11/documents/2018_ff_fact_sheet.pdf.

10 Ibid. p. 4.

11 U.S. EPA. Sustainable Management of Food Basics. https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics#Food%20Waste. Accessed February 15, 2021.

12 U.S. EPA. 2018 Wasted Food Report. November 2020. https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf.

13 U.S. EPA. Sustainable Management of Food Basics. https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics#Food%20Waste. Accessed February 15, 2021.

14 U.S. EPA. Advancing Sustainable Materials Management: 2018 Fact Sheet. December 2020. https://www.epa.gov/sites/production/files/2020-11/documents/2018_ff_fact_sheet.pdf.

landfills constitute more than 60 percent of the total organic waste, as shown in Figure 1-1.[15] In 2018, of total landfilled MSW, 24 percent was food waste and 7 percent was yard waste.[16]

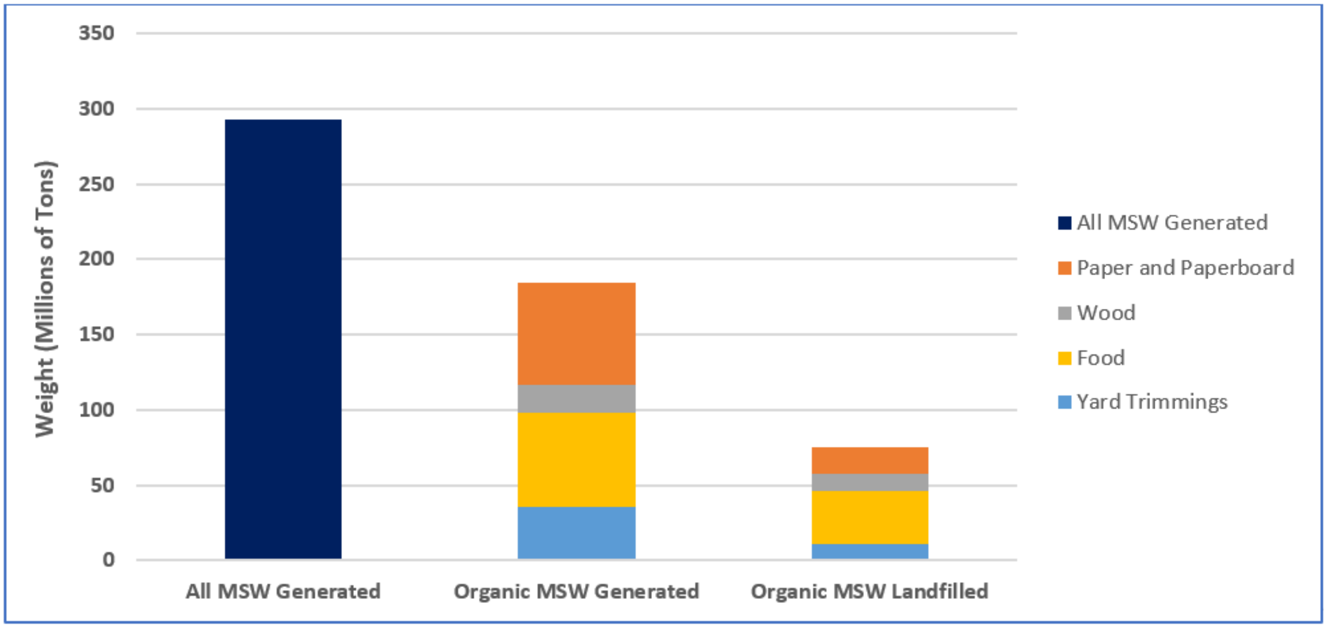

Figure 1-1. All MSW Generated, Organic Waste Generated and Organic Waste Landfilled in the United States, 2018.

EPA has encouraged the reduction of food waste going to landfills through the SMM Program's Sustainable Management of Food efforts. These efforts include food waste measurement improvement; coordination with federal agencies; working with industry to reduce food loss and waste in the supply chain; connecting and convening stakeholders such as state, local and tribal governments with public and private partners; and sharing funding opportunities. On September 16, 2015, in coordination with Target 12.3 of the United Nations Sustainable Development Goals, the U.S. Department of Agriculture (USDA) and EPA announced the first ever domestic goal to reduce food loss and waste by half by 2030. In December 2020, USDA, EPA, and the U.S. Food and Drug Administration renewed a joint agency formal agreement to affirm their shared commitment to work toward the national goal of reducing food loss and waste by 50 percent by 2030.

Trends in Organic Waste Generation, Diversion and Disposal

The amount of food waste generated annually increased 70 percent from 1990 to 2017, while yard waste generation has remained relatively flat, as shown in Figure 1-2. Yard waste composting increased 373 percent from 1990 to 2005, and then experienced only slight gains between 2005 and 2017. Food waste composting, while substantially smaller in volume than yard waste, grew by 278 percent between 2000 and 2017.[17,18] Despite this growth in composting, a large percentage of food waste generated is still

[15] Ibid.

[16] Ibid. p. 9.

[17] U.S. EPA. Advancing Sustainable Materials Management: 2018 Tables and Figures. December 2020. Tables 1 and 2. https://www.epa.gov/sites/production/files/2021-01/documents/2018_tables_and_figures_dec_2020_fnl_508.pdf.

[18] U.S. EPA. Advancing Sustainable Materials Management: Facts and Figures 2013. June 2015. Tables 1 and 2. https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_rpt.pdf.

disposed. In 2017, about 6.3 percent of the food waste generated was composted compared to about 69 percent of yard waste generated.[19]

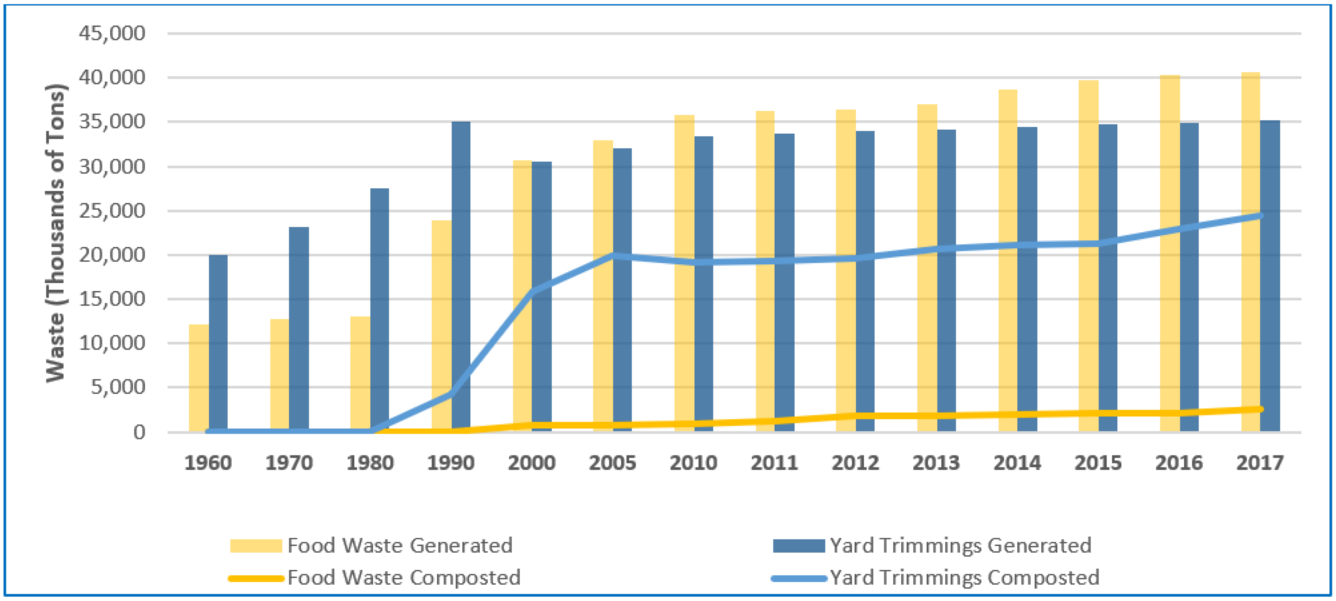

Figure 1-2. Food and Yard Wastes Generated and Composted in the United States, 1960 to 2017.

In 2020, EPA released an enhanced methodology to measure food waste to analyze additional food waste generation sectors and destinations for the food waste, called waste management pathways.[20] Using this enhanced methodology, EPA estimates that in 2018, residential, commercial and institutional sectors generated just over 63 million tons of wasted food, plus an additional 40 million tons from the industrial sector, a sector not traditionally included in EPA's MSW reports.[21] Food waste is managed through many different management pathways beyond landfilling and composting, as shown in Figures 1-3 and 1-4. Figure 1-3 is organized by level of the food recovery hierarchy; donation and animal feed are not the focus of this report.

[19] U.S. EPA. Advancing Sustainable Materials Management: 2018 Tables and Figures. December 2020. Tables 1 and 2. https://www.epa.gov/sites/production/files/2021-01/documents/2018_tables_and_figures_dec_2020_fnl_508.pdf.

[20] U.S. EPA. Wasted Food Measurement Methodology Scoping Memo. July 2020. https://www.epa.gov/sites/production/files/2020-06/documents/food_measurement_methodology_scoping_memo-6-18-20.pdf.

[21] U.S. EPA. 2018 Wasted Food Report. November 2020. https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf.

MANAGEMENT PATHWAY	QUANTITY MANAGED (TONS)	PERCENTAGE MANAGED	QUANTITY MANAGED (TONS)	PERCENTAGE MANAGED
	INCLUDING INDUSTRIAL SECTOR		EXCLUDING INDUSTRIAL SECTOR	
Donation[1]	7,394,096	7.2%	4,787,378	7.6%
Animal Feed	21,978,346	21.3%	1,814,984	2.9%
Bio-based Materials/ Biochemical Processing	2,186,873	2.1%	1,841,411	2.9%
Codigestion/Anaerobic Digestion	10,691,756	10.4%	5,262,857	8.3%
Composting/Aerobic Processes	3,455,273	3.4%	2,592,566	4.1%
Land Application	9,144,093	8.9%	259,448	0.4%
Controlled Combustion	7,747,441	7.5%	7,552,705	12.0%
Landfill	36,612,263	35.6%	35,277,543	55.9%
Sewer/Wastewater Treatment	3,743,229	3.6%	3,743,229	5.9%
TOTAL	**102,953,370**	**100%**	**63,132,123**	**100%**

[1] These figures exclude the small share of excess food (426,057 tons) that food banks cannot distribute and is therefore food waste that is routed to other management pathways. The food waste fraction is managed through conventional means (landfilling, controlled combustion, composting/aerobic processes, and codigestion/anaerobic digestion).

Figure 1-3. Quantity of Wasted Food Managed, 2018.[22]

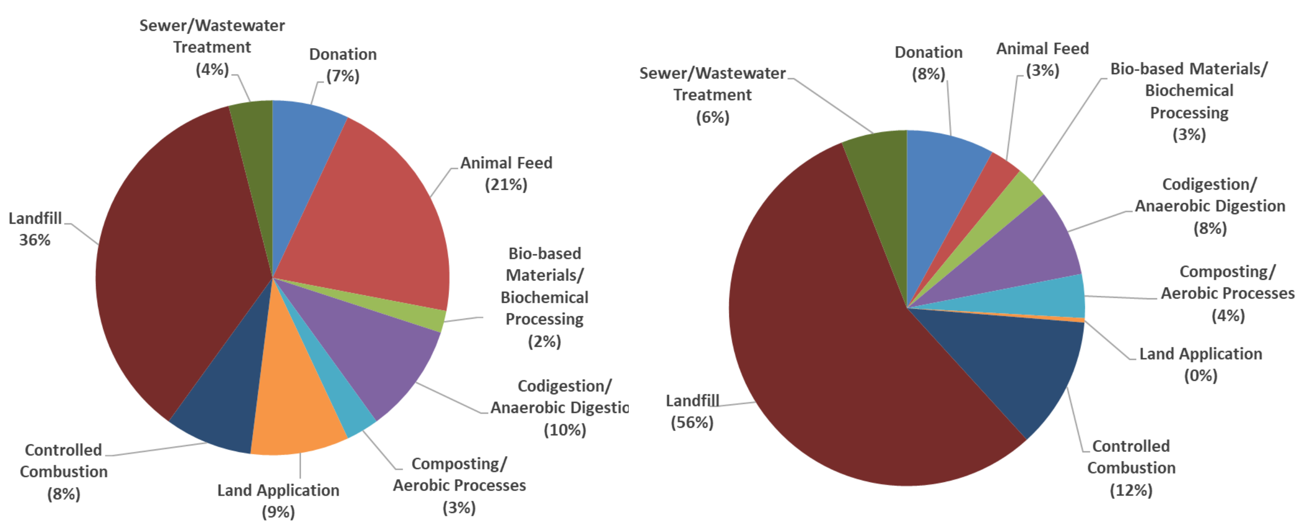

Figure 1-4. Percentage Distribution of Wasted Food Management, Including (left) and Excluding (right) the Industrial Sector, 2018.[23]

22 U.S. EPA. 2018 Wasted Food Report. November 2020. p.19. https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf.

23 Ibid.

Opportunities to Divert Organic Waste from Disposal

All sectors of the economy generate organic waste, from single- and multi-family residences to industrial establishments (primarily food and beverage processing facilities), as well as commercial and institutional sources such as schools, restaurants and hotels. The source from which the organic waste is generated has unique implications for how the diverted material is best collected, processed and treated.

EPA's Food Recovery Hierarchy lists source reduction, or reducing the volume of excess food generated, as the most preferred way to avoid placement of organics in landfills. However, organic waste that *is* generated can be diverted from its path to a landfill or waste incinerator and processed in a more environmentally beneficial way, including through industrial uses (e.g., animal feed), AD, aerobic processing (e.g., composting) or co-digestion with livestock manure or WRRF sludge. Managing organic waste without landfilling provides various water, energy, climate and air quality benefits. Efforts at the state and local level to divert organic waste from landfills have spurred interest in establishing and promoting policies, incentives, practices and technologies that advance diversion and processing of organic waste, as discussed in Section 6.

Climate Impacts of Organic Waste Management

The climate impacts of organic waste management are significant. Globally, the food loss and waste portion alone of organic waste (including the food loss associated with unused products from the agricultural sector, such as unharvested crops, which are beyond the scope of this document) accounts for about 8 percent of human-caused GHG emissions.[24] If wasted food were a country, it would be the third-largest emitter of global GHG emissions, behind China (21 percent) and the United States (13 percent).[25] Project Drawdown, a 501(c)(3) nonprofit organization founded in 2014 to communicate the most substantive solutions to stop climate change, estimates that reducing food waste is the number one solution (out of more than 80 analyzed) to avoid catastrophic climate change, where the temperature rise causes great adverse effects for humanity, such as the frequency and severity of extreme climate events.[26]

The potential climate impact on a life cycle basis of diverting food waste from U.S. landfills is illustrated in Figure 1-5, which presents a food waste diversion analysis using EPA's WARM.[27] The food waste that was placed in U.S. landfills in 2018 will generate about 17.6 million MMTCO_2e in GHG life cycle emissions over its lifetime in the landfills. Food waste decays very quickly in landfills, often before a gas collection is installed. With even just part of the food waste diverted to composting or AD, the avoided methane emissions (composting) or higher methane collection rate (AD) results in a significant decrease in GHG emissions.

[24] Food and Agriculture Organization of the United Nations. Food Wastage Footprint & Climate Change. 2015. https://www.fao.org/3/bb144e/bb144e.pdf.

[25] World Resources Institute. ClimateWatch. Historical GHG Emissions. https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990. Accessed July 13, 2021.

[26] Project Drawdown. https://drawdown.org/solutions/table-of-solutions. Scenario 1. Accessed July 13, 2021.

[27] U.S. EPA. Waste Reduction Model (WARM). Version 15. https://www.epa.gov/warm. Accessed February 24, 2021.

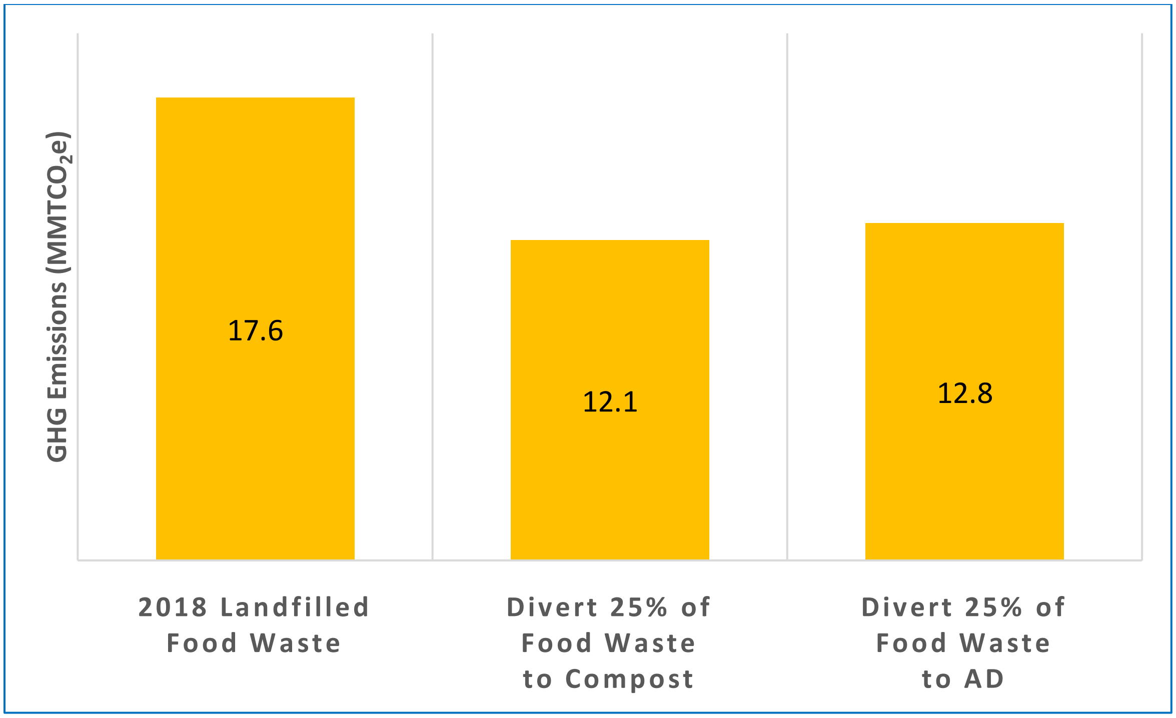

Figure 1-5. Comparison of Life Cycle GHG Emissions for U.S. Food Waste Diversion from Landfills.

Notes on WARM analysis scenarios:

- Baseline: 35.3 million tons of food waste disposed of in landfills in 2018[28]
- Divert 25 percent (8.8 million tons) to compost and landfill 26.5 million tons of food waste
- Divert 25 percent (8.8 million tons) to AD and landfill 26.5 million tons of food waste

In 2018, about 44 percent of food waste was diverted away from landfills.[29] Diverting another 25 percent (8.8 million tons) of landfilled food waste would reduce life cycle GHG emissions by approximately 30 percent compared to the baseline. The extent of emission reductions is dependent on the alternative waste management process used for the diverted waste although both diversion scenarios have a similar impact, as shown in Figure 1-5. Based on the assumptions and calculations within WARM, composting all the diverted food waste would yield lower overall life cycle GHG emissions than digesting it.

Section 2: Organic Waste Collection Practices—Residential, Commercial and Institutional Sectors

This section discusses SSO collection programs and technologies associated with the residential, commercial and institutional sectors. Collection is a significant and critical component of the overall process to manage organic waste. To develop an SSO collection program for residential, commercial or institutional customers, waste managers should evaluate a variety of factors that will affect current solid waste management services (e.g., current collection practices) and assess the impacts of adding SSO collection (e.g., routing changes, increased vehicle traffic, vehicle maintenance or new vehicles, personnel and training, collection frequency, materials acceptance and enforcement). Ultimately, waste managers should tailor the collection techniques to the needs of the local community generating the

[28] U.S. EPA. Advancing Sustainable Materials Management: 2018 Fact Sheet. December 2020. Table 1. https://www.epa.gov/sites/production/files/2020-11/documents/2018_ff_fact_sheet.pdf.

[29] Ibid.

wastes while ensuring that the collected organic waste meets the needs of the processing facility(ies). SSO collection programs are not a "one-size-fits-all" approach. A successful program design depends on factors such as geography and size as well as which of the three sectors constitute the program's customer base.

Collection Programs

Curbside[30]

Curbside residential and commercial SSO organic waste collection programs are growing in popularity. Since 2005, access to residential curbside collection of food waste has increased steadily, growing from just over 500,000 households in 2005 to 2.74 million households in 2014, then leaping to nearly 5.1 million households in 2017.[31]

Collection typically occurs weekly for residential and smaller commercial customers to minimize odors and may be on the same schedule as trash or recycling collection. Some jurisdictions may reduce SSO collection to every other week during winter months when odor or volume issues are less likely. Collection may be more frequent for large commercial generators such as restaurants, hotels and cafeterias.

Residential Source Separated Curbside Collection
Austin, Texas, instituted source-separated curbside collection of organic waste for some residential customers in 2017 as part of its Zero Waste Initiative to divert 90 percent of waste from landfills by 2040. By July 2019, nearly three-quarters of the city's residential curbside customers had curbside collection of food scraps, yard trimmings, food-soiled paper and natural fibers for composting by Austin Resource Recovery, and the final expansion to include all residential curbside customers was completed in 2021.[32] This full-scale project followed the city's successful pilot program, launched in 2013 at a cost of $485,000 to the city for new 96-gallon composting carts but no cost to participants.[33] Now that the program has reached the goal of being citywide, the cost to residents is $4 per month.[34] Austin updates its community GHG emissions inventory every three years;[35] the 2018 emissions from the waste sector were 268,000 metric tons CO_2e ($MTCO_2e$) as compared

30 U.S. EPA. Managing and Transforming Waste Streams—A Tool for Communities. Community Implementation Examples and Resources. 37. Expanded Municipal Collection—Food Waste. https://www.epa.gov/transforming-waste-tool/community-implementation-examples-and-resources-1-50#37 provides several examples.

31 Streeter, Virginia, and Brenda Platt. Residential Food Waste Collection Access in the U.S. BioCycle. December 2017. Residential Food Waste Collection Access in the U.S. December 2017. https://www.biocycle.net/2017/12/06/residential-food-waste-collection-access-u-s/.

32 City of Austin, Texas. Curbside Composting Collection. https://www.austintexas.gov/composting. Accessed July 23, 2021.

33 Price, Asher. Austin Starts Pilot Program for Curbside Compost Collection. Austin American Statesman. January 2, 2013. https://www.statesman.com/story/news/2013/01/02/austin-starts-pilot-program-for-curbside-compost-collection/9848074007/. Accessed November 29, 2021.

34 Rosengren, Cole, and Cody Boteler. Austin, TX Set to Expand Curbside Composting to 38,000 More Homes. Waste Dive. August 3, 2017. https://www.wastedive.com/news/update-austin-tx-set-to-expand-curbside-composting-to-38000-more-homes/445748/. Accessed July 23, 2021.

35 City of Austin, Texas. Austin Community Climate Plan 2015. http://www.austintexas.gov/edims/document.cfm?id=269714. Accessed July 23, 2021.

to 340,000 $MTCO_2e$ in 2013.[36] *A portion of the 72,000 $MTCO_2e$ net reduction in the waste sector over these years is attributable to the reduced landfilling of organic waste, as the amount of organic waste collected for composting increased from about 622,000 tons in 2013 to about 10.3 million tons in 2020.*[37]

Residential Mixed Curbside Collection

Cedar Rapids, Iowa, offers curbside collection of co-mingled yard and food waste from single-family residences. Collection happens weekly (on the regular trash day); every household is given a green cart (nicknamed a "YARDY" cart), either 65-gallon or 95-gallon in size. Allowed items include leaves, sticks, grass clippings, fruit and vegetable peelings, paper plates, napkins, paper towels, dryer lint and baked goods. The Cedar Rapids–Linn County Solid Waste Agency composts the collected organic items, and the finished product is sampled and tested for quality before being provided for free to residents and sold to businesses.[38,39,40] *Cedar Rapids set a goal in its Sustainability Action Plan to reduce landfilled waste from city operations 10 percent from fiscal year 2020 baseline by fiscal year 2022*[41]*—and this curbside collection of organics will help the city meet that goal.*

Mixed Food and Yard Wastes

Some regions offer year-round curbside yard waste collection based on their climate, while others may offer only seasonal yard waste management (e.g., fall leaf gathering or Christmas tree pickup). In areas that offer year-round yard waste collection services, and sufficient local processing capacity exists to accept co-mingled food and yard wastes, adding food waste to an existing yard waste collection program can take advantage of existing containers and routes and be the most economical option on a cost-per-ton basis. Studies found that having customers add food waste to an existing yard waste bin increases participation and the amount of organic waste collected, likely because customers are already accustomed to the separate collection process and setting out a yard waste cart.[42,43,44]

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[36] Merski, Cavan. Community Inventory MetricSprint Dashboard. May 1, 2020. https://public.tableau.com/app/profile/cavan.merski/viz/CommunityInventoryMetricSprintDashboard/CommunityInventoryMetricSprintDashboard. Accessed July 23, 2021.

[37] City of Austin, Texas. Waste Collection & Diversion Report (daily). July 11, 2021. https://data.austintexas.gov/Utilities-and-City-Services/Waste-Collection-Diversion-Report-daily-/mbnu-4wq9. Accessed July 14, 2021.

[38] Cedar Rapids, Iowa. Yard Waste. http://www.cedar-rapids.org/residents/utilities/yard_waste.php. Accessed September 3, 2020.

[39] Cedar Rapids, Iowa. Collection Cart Information. http://www.cedar-rapids.org/residents/utilities/collection_cart_sizes_and_weight_limits.php. Accessed September 3, 2020.

[40] Cedar Rapids Linn County Solid Waste Agency. Compost & Wood Chips. https://www.solidwasteagency.org/compost-yard-waste/compost-wood-chips. Accessed September 3, 2020.

[41] Cedar Rapids, Iowa. iGreenCR Action Plan. January 2020. https://www.cedar-rapids.org/Sustainability/iGreenCR%20Action%20Plan_Web.pdf. Accessed August 17, 2021.

[42] RRS. District of Columbia Compost Feasibility Study. April 2017. https://dpw.dc.gov/compostfeasibilitystudy. Accessed November 29, 2021.

[43] Layzer, Judith A., and Alexis Schulman. 2014. Municipal Curbside Compostables Collection: What Works and Why? 2014. Work product of the Urban Sustainability Assessment (USA) Project. Department of Urban Studies and Planning. Massachusetts Institute of Technology. https://dusp.mit.edu/sites/dusp.mit.edu/files/attachments/project/Municipal%20Curbside%20Compostables%20Collection%20%20What%20Works%20and%20Why.pdf.

[44] Assessment of Residential Source Separated Organics Collection Options. A Study for the City of Minneapolis, Minnesota. Project ID: 13M030. October 2013 (revised). Previously available at http://www2.ci.minneapolis.mn.us/www/groups/public/@clerk/documents/webcontent/wcms1p-115115.pdf.

Residential Mixed Curbside Collection
Seattle, Washington, requires that all residents and businesses keep their organic waste such as food scraps, compostable paper products and yard waste separate from other garbage. These organic materials are collected at the curb weekly on the regular trash collection day. The city offers three cart sizes (13-, 32- and 96-gallon) with varying collection fees. Seattle initially began collection of food waste in 2005, when single-family households could start putting fruit and vegetable scraps into existing green waste carts. The city expanded the program in 2009 to allow all types of food scraps and compostable paper and made this separation mandatory for single-family households. The mandate expanded in 2011 to multi-family households and, in 2015, Seattle prohibited food waste from the garbage.[45,46,47] Seattle's GHG inventory shows a 25 percent reduction in GHG emissions from the food waste and mixed organics portion of its waste sector from 2008 to 2018,[48] mostly reflecting reduced landfill methane emissions from lower food waste disposal rates.

Adding Food Waste to Residential Curbside Collection of Yard Waste
Palo Alto, California, has an advanced and comprehensive organic waste curbside collection program as part of its Zero Waste initiative. Its 2018 plan set a goal to virtually end all burning or burying of city waste (95 percent diversion of materials from landfilling) by 2030.[49] Single- and multi-family households as well as businesses and schools have access to collection of several organic materials including food scraps, soiled paper, yard trimmings, waxed cardboard and wood, all in a single green cart.[50,51] Food waste collection was added in 2015 to the existing yard waste curbside collection program.[52] The waste is collected by a city contractor and transported to the Zero Waste Energy Development Company facility in San Jose, California, to be anaerobically digested.[53] The city council reported in 2019 that Palo Alto's GHG emissions from the landfilling of organic waste decreased 36 percent since 2017, as a direct result of less organic waste being placed into garbage collection containers due to the city's "continued residential food scrap collection and outreach efforts, and enforcement of and compliance with a new ordinance requiring commercial businesses to compost their organic wastes."[54]

45 City of Seattle, Washington. Food Waste Requirements. http://www.seattle.gov/utilities/your-services/collection-and-disposal/food-and-yard/food-waste-requirements. Accessed September 3, 2020.

46 City of Seattle, Washington. Food & Yard. http://www.seattle.gov/utilities/your-services/collection-and-disposal/food-and-yard. Accessed January 14, 2022.

47 Fickes, Mike. Scrappy in Seattle. Waste360. January 28, 2013. https://www.waste360.com/food-waste/scrappy-seattle.

48 City of Seattle, Washington. Climate Data Visualizations. Total Annual Emissions by Sector. https://www.seattle.gov/environment/climate-change/climate-planning/performance-monitoring#data. Accessed July 23, 2021.

49 City of Palo Alto, California. Zero Waste Plan. August 2018. p. 1. https://www.cityofpaloalto.org/files/assets/public/zero-waste/zero-waste-website-files/2018-zero-waste-plan.pdf. Accessed August 10, 2021.

50 City of Palo Alto, California. What is Zero Waste. https://www.cityofpaloalto.org/Departments/Public-Works/Zero-Waste/About-Us/What-Is-Zero-Waste. Accessed September 3, 2020.

51 City of Palo Alto, California. Curbside Collection Services. https://www.cityofpaloalto.org/gov/depts/pwd/zerowaste/whatgoeswhere/curbside.asp. Accessed September 3, 2020.

52 Malmberg, Brenna. Palo Alto Residents Adapt to New Food-Scrap Collection Program. Palo Alto Online. August 28, 2015. https://www.paloaltoonline.com/news/2015/08/28/palo-alto-residents-adapt-to-new-food-scrap-collection-program. Accessed February 23, 2021.

53 City of Palo Alto, California. Zero Waste Plan. August 2018. p. 5. https://www.cityofpaloalto.org/files/assets/public/zero-waste/zero-waste-website-files/2018-zero-waste-plan.pdf. Accessed February 23, 2021.

54 City of Palo Alto, California. City Council Staff Report. ID # 10095. April 15, 2019. https://www.cityofpaloalto.org/files/assets/public/agendas-minutes-reports/reports/city-manager-reports-cmrs/year-archive/2019/id-10095.pdf.

Drop-off[55,56]

Drop-off centers, while not as common, are an inexpensive alternative to curbside SSO collection especially in areas where customers are accustomed to dropping off MSW or recyclable materials. For areas that don't provide year-round yard waste collection, a dedicated food waste drop-off program may be more feasible. A crucial element of a successful drop-off program is providing convenient operating hours and locations for customers.

Yard Waste Drop off Center
Emmet County, Michigan, has operated a municipal yard waste drop-off center since 2005, where it composts the materials in rows of long piles (commonly referred to as windrows). The compost facility is next to the county's waste transfer station and recycling drop-off center for convenience.[57] *In 2015, the county conducted a pilot project for collecting and incorporating food scraps into its yard waste composting facility,*[58] *which developed into an ongoing, successful program that includes selling compost as a revenue source.*[59]
Food Waste Drop off Centers
Since 2017, Washington, D.C., has hosted food waste drop-off centers at farmers markets in each of the city's eight wards. The drop-off locations include information on items that can be composted.[60] *The DC Department of Parks and Recreation (DPR) also has more than 50 community compost cooperative networks that use critter- and smell-proof compost bins to allow trained community members to compost food scraps and garden waste from DPR gardens.*[61] *DC also provides residents with free compost.*[62] *These activities fit into its goal to achieve 80 percent waste diversion citywide without the use of landfills, waste-to-energy or incineration by 2032. The District is also working to establish a new organics processing facility to capture food and other organic waste as part of the Sustainable DC and Climate Ready DC Plans.*[63]

55 Freeman, Juri, and Lisa A. Skumatz. Best Management Practices in Food Scrap Programs: Final Report. Econservation Institute. 2010. Submitted to EPA Region 5. Previously available at http://www.foodscrapsrecovery.com/EPA_FoodWasteReport_EI_Region5_v11_Final.pdf.

56 U.S. EPA. Managing and Transforming Waste Streams—A Tool for Communities. Community Implementation Examples and Resources. 85. Drop-off Compostables. https://www.epa.gov/transforming-waste-tool/community-implementation-examples-and-resources-51-100#85 offers additional examples.

57 Walker, Lindsey. Sowing the Future of Food Scraps: A 20 week Pilot Collection & Composting Program. Emmet County Recycling. Presented at Michigan Recycling Coalition Annual Conference. May 5, 2016. Learning from Food Scrap Collection Pilots. https://newsite.michiganrecycles.org/images/Docs/Conf2016/presentations/22_Learning_From_Food_Scrap_Collection_Pilots.pdf.

58 Seltzer, Elisa. Emmet County Department of Public Works. Rockin' Rural Food Scrap Commercial Collection Program. Presented at BioCycle REFOR16. October 19, 2016.

59 Emmet County Recycling. Compost for Sale. https://www.emmetrecycling.org/for-sale/compost. Accessed November 29, 2021.

60 DC Government Department of Public Works. Food Waste Drop Off. November 2020. https://dpw.dc.gov/foodwastedropoff. Accessed December 15, 2020.

61 DC Government Department of Parks and Recreation. Community Compost Cooperative Network. https://dpr.dc.gov/page/community-compost-cooperative-network. Accessed December 15, 2020.

62 DC Government Department of Public Works. Fort Totten Transfer Station. https://dpw.dc.gov/node/414922. Accessed December 15, 2020.

63 Sustainable DC. 2021 Progress Report. https://sustainable.dc.gov/sites/default/files/dc/sites/sustainable/page_content/attachments/DOEE_SDC_ProgressReport2021_Digital_Final.pdf.

Single-family vs. Multi-family

Because organic waste and recycling collection from multi-family dwellings is more complicated than from single-family residences, many collection programs start with single-family dwellings and phase in multi-family dwellings over time. Multi-family dwellings can have a more complicated infrastructure (trash chutes, space constraints) and, in some ways, are more like commercial food waste generators than single-family residences. In addition, property management companies, landlords and homeowner associations of multi-family dwellings, and often the parties in charge of contracting for waste collection services, must be educated alongside the building residents. Finally, due to the turnover in multi-family buildings, repeated outreach and education plus signage in public areas of the building are very important to maintain program participation.[64,65] Despite these challenges, the high-density population of these buildings makes them an important target population for increasing diversion of organic waste.

Multi family Food Waste Collection

In Alameda County, California, a mandatory recycling ordinance required all multi-family buildings with five or more units to have SSO programs by 2015. Due to implementation challenges at multi-family buildings, many of these units received compliance extensions or waivers. In 2015, Global Green worked with the county to deploy a food waste reduction and recovery outreach project at 15 multi-family buildings, ranging from 12 to 170 units per building. The project provided compost collection pails and conducted outreach to residents on both food waste reduction strategies and food waste recycling. The project measured how much SSO waste was captured, contamination rates in the compost pails, how much organic waste was still being disposed of in the garbage, and other metrics. On average, each building increased its organic waste diversion by 44.6 pounds during the month-long project, for an approximate 91 percent increase in organic waste diversion across all buildings.[66,67] *Alameda County's Community Climate Action Plan established a target of diverting 90 percent of all waste from landfills by 2030, with an interim goal of 82.5 percent by 2020, to reduce the community's waste-related GHG emissions. Waste is responsible for approximately 2,510 MTCO$_2$e per year in the county, the equivalent of taking nearly 550 passenger cars off the road.*[68]

Collection Technologies

Several considerations go into designing and selecting the appropriate technologies for an organic waste collection program. Food waste is typically high in moisture and heavier than other types of MSW; therefore, customers will be more likely to use containers that minimize odor and are easily maneuvered. In addition, customers need to have room to store the container between pickups, so cart size is important.

64 Global Green USA. Piloting Food Scrap Recovery in Alameda County—Food Scrap Reduction and Recovery at Multi-Facility Dwellings: Deploying and Assessing Enhanced Tenant Outreach. https://static1.squarespace.com/static/5548ed90e4b0b0a763d0e704/t/58fe7a12e6f2e1e1f7da96db/1493231516967/AlamedaReport.

65 Best, Jordan. Recycling Council of British Columbia. RCBC Background Paper: Best Practices for Multi-Family Food Scraps Collection. February 2011. https://www.rcbc.ca/files/u7/policy_110207_mforganicsreport.pdf.

66 Belev, Anastas. Global Green USA. Global Green's Food Waste Prevention and Recycling Outreach Materials. May 30, 2017. http://globalgreen.squarespace.com/blog/fwwy2xl6szx4gkssjra53glg4wzrck.

67 Global Green USA. Piloting Food Scrap Recovery in Alameda County—Food Scrap Reduction and Recovery at Multi-Facility Dwellings: Deploying and Assessing Enhanced Tenant Outreach. https://static1.squarespace.com/static/5548ed90e4b0b0a763d0e704/t/58fe7a12e6f2e1e1f7da96db/1493231516967/AlamedaReport.

68 Alameda County. Community Climate Action Plan. February 4, 2014. https://www.acgov.org/cda/planning/sustainability/documents/110603_Alameda_CCAP_Final.pdf.

Containers

As shown in Figure 2-1, common collection containers for residential customers include kitchen buckets that they can place on the curb and larger curbside carts ranging from 32 to 48 gallons for dedicated food waste or up to 96 gallons for combined food and yard wastes. The cost, including initial delivery, repair and maintenance, can range from about $15 per bucket to about $50 per cart.[69] Alternatively, some municipalities allow customers to use any container with a locking lid, such as a common 5-gallon bucket. Commercial or multi-family customers typically use larger four-wheeled carts (64-gallon) or containers (3 cubic yards).

Some municipalities provide or subsidize backyard composter containers for residents who prefer a "do-it-yourself" approach. If participation is significant, this type of container can reduce costs for a city after it provides the initial container, as it diverts organic waste from the MSW stream and may avoid the need for SSO collection. For example, the [City of Orlando, Florida,](https://www.orlando.gov/Trash-Recycling/Food-Waste) has delivered more than 7,000 composters to residences since February 2015 and also offers a free oil recycling jug for kitchen grease and cooking oil, which the city converts into biodiesel, reducing GHG emissions.[70,71,72]

Figure 2-1. Containers for Food Waste Collection Programs.

Trucks[73,74]

Garbage trucks can be and have been adapted to haul organic waste while minimizing odors and risk of leaking liquid waste more effectively. Despite additional capital costs, the following enhancements can speed up collection times, reduce equipment failures and reduce the number of staff needed to operate each vehicle.

- Since many routing plans collect SSO on the same day as normal MSW or yard waste pickup, some routes use extra leak-proof compartments on standard collection vehicles. Trucks are also available with container-washing capabilities.
- Trucks can be equipped with more robust lifting systems to handle the weight of high-density organic waste, especially for the larger containers used in commercial collections. Some vehicles also have scales to ensure the containers' weight will not damage them.

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69 Cost range for containers is based on expert knowledge of the industry.

70 Yale Climate Connections. Orlando Gives Away Composting Kits. February 15, 2019. https://yaleclimateconnections.org/2019/02/orlando-gives-away-composting-kits/. Accessed September 4, 2020.

71 City of Orlando. Recycle Your Cooking Oil. https://www.orlando.gov/Trash-Recycling/Recycle-Your-Cooking-Oil. Accessed February 17, 2021.

72 City of Orlando. Food Waste. https://www.orlando.gov/Trash-Recycling/Food-Waste. Accessed September 4, 2020.

73 Hesselgrave, Barbara. Food Waste Collection Truck Innovations. BioCycle 58(2): 24. February 14, 2017. https://www.biocycle.net/2017/02/14/food-waste-collection-truck-innovations/.

74 Goldstein, Nora. Demand Grows for Food Waste Collection Trucks. BioCycle 55(7): 41. August 14, 2014. https://www.biocycle.net/2014/08/14/demand-grows-for-food-waste-collection-trucks/.

- Another enhancement involves replacing conventional packing blades used in recycling and MSW trucks with an auger. The auger can shred organic waste more effectively without jamming and possibly prevent the need for equipment to extract the organic waste from collection bags once the waste reaches the processing facility.

Waste Pretreatment/Feedstock Preparation

As discussed further in Section 5, community outreach and education are effective for minimizing contamination of organic waste by keeping the contaminants out of the SSO stream in the first place. A second way to minimize contamination is training and regular communication with collection crews on keeping the SSO stream clean. For example, when collection crews identify customers improperly using non-compostable plastic bags to line their containers, they could refuse pickup or provide a warning tag. Once collected, contaminants (e.g., gloves, packaging, utensils, wrappers and plastic) can be difficult to remove. Post-collection pretreatment requirements will vary depending on the source (residential, institutional, commercial) of the food waste and how the organic waste will be processed (compost or AD). If pretreatment is required, waste managers should evaluate available techniques and technologies, including bag openers, mechanical sorting, grinders, pulpers or manual sorting.[75]

Section 3: Organic Waste Processing

This section describes the primary technologies used for downstream processing of organic waste. These technologies are generally categorized in two main groups: composting (an aerobic process) and AD (an anaerobic process). This section also briefly discusses pilot projects for dedicated organic waste cells at landfills and using organic waste as feedstock for industrial processes.

Composting

Composting is the aerobic decomposition of organic waste by microorganisms into humus, a usable, soil-like byproduct. Composting involves energy input and process control but does not generate energy that could be captured and beneficially used. Composting systems manage the moisture content, oxygen flow and mixture ratio of organic materials for optimal conditions. The composting process emits heat, water vapor and carbon dioxide, reducing the raw organic materials in mass and volume.

Composting systems can range in expense, with several classification levels, but are broadly categorized as passively aerated (including turned) or actively aerated. Examples of passively aerated systems include static piles, bunkers and windrows. Examples of actively aerated systems include aerated static piles and in-vessel composting such as tunnels, drums or other containers that are turned, mixed or injected with air. EPA's "Types of Composting and Understanding the Process" webpage provides more technical information and descriptions of composting technologies.

Turned windrows (i.e., organic materials piled in rows that are turned periodically to maintain aerobic conditions and allow oxygen to flow to their cores) are the most common yard waste composting systems used in the United States, due to their low capital costs (e.g., site improvements, equipment), their low operating costs (e.g., labor, vehicle fuel, equipment maintenance), and the wide variety and large volume of materials they can process (they are suitable for yard waste, food waste and other types of green wastes

75 McKiernan, Christine. Containing Food Waste Contamination Essential for Anaerobic Digestion. Waste360. January 27, 2015. https://www.waste360.com/organics/containing-food-waste-contamination-essential-anaerobic-digestion.

with high concentrations of nitrogen). This type of composting is ideal for co-locating at landfills to take advantage of the space and infrastructure available. Co-location can also lower transport costs and truck traffic (to or from offsite locations) for disposing of contaminants or other non-compostable materials removed from the process, which may be used for landfill alternative daily cover.

Given the long operating history and large number of yard waste compost facilities nationwide, one cost-effective option available to many communities is to use existing yard waste facilities to accept food waste. This may require modifications to a facility's permit as well as to site operations to accommodate higher-moisture food waste, reduce odor and vector risks, and adjust for differences in material handling. The way that food waste is defined can affect its ability to be accepted in a compost facility, based on state or local regulations. Some examples of changes that a site may consider making are using smaller windrows, increasing the turning frequency, blending food waste with carbon-rich materials or using covered compost piles or forced aeration techniques.[76]

Composting at a Landfill
Lee County, Florida, built a composting facility with six covered windrow buildings adjacent to its landfill. The facility processes a combination of yard waste and biosolids from seven WRRFs in neighboring municipalities to produce Class AA (highest treatment level) compost sold as OrganicLee®. The compost facility shares an onsite stormwater system with the Lee/Hendry Landfill and can also use the landfill's monitoring network to evaluate any potential nutrient loading impact.[77,78]
Expanding a Yard Waste Compost Facility to Accept Food Waste
Prince George's County, Maryland, has used windrow composting for yard waste since 1990. In 2013, the county piloted a food waste composting system using Gore Cover technology. Following the successful pilot, the county expanded its food waste handling capacity in 2014 and again in 2017. The county mixes yard and food wastes in a receiving pile to control odors and reduce vectors, then places the co-mingled materials under a cover and carefully monitors temperature and oxygen. The covered system traps odors and volatile organic compounds while reducing the time to produce final compost.[79,80,81,82] *As of 2018, annual compost sales were about $500,000 and the demand for food scrap disposal is so high that there is a waiting list of 30 institutions and communities. One client, the University of Maryland's College Park campus, delivered 950 tons of organic*

76 Christiansen, Eva M. Best Management Practices (BMPs) for Incorporating Food Residuals into Existing Yard Waste Composting Operations. 1st ed. 2009. Published by the US Composting Council, Bethesda, MD. Funded by U.S. EPA Region IV. https://compostfoundation.org/Portals/1/Documents/BMP-for-FW-to-YW.pdf.

77 OrganicLee® Compost. https://www.flsustainability.com/organiclee-compost/. Accessed February 17, 2021.

78 Lee County, Florida. Compost Production Facility. https://www.leegov.com/solidwaste/facilities/compost. Accessed February 17, 2021.

79 Prince George's County, Maryland. Department of Environmental Resources. Prince George's County Yard Waste Composting Facility. September 2013. https://www.mwcog.org/uploads/committee-documents/kV1aWl9d20130920144752.pdf.

80 Prince George's County, Maryland. Prince George's Organics Composting Facility. https://www.princegeorgescountymd.gov/583/Organics-Composting-Facility. Accessed January 13, 2022.

81 Sustainable Generation. Prince George's County, MD Organics Composting Facility: Systematically Scaling from Mobile Pilot Project to Full Scale Facility. 2021. https://d3tuzpe5s27et8.cloudfront.net/wp-content/uploads/mes-project-profile_2019_2.pdf.

82 Prince George's County, Maryland. Comprehensive Ten-Year Solid Waste Management Plan. January 2017. https://www.princegeorgescountymd.gov/DocumentCenter/View/17161/Ten-Year-Solid-Waste-2017-2026---JPG-Edits-8-as-of-January-4-2017.

material to the facility in 2017 and uses the compost to grow vegetables for its dining hall. The facility's 2018 expansion increased its total organic waste capacity to 57,000 tons per year, of which 8,000 tons is food waste, contributing to the county's goal to reduce GHG emissions by 80 percent below 2008 levels by 2050.[83,84]

Composting Biosolids and Food Waste Separately

The Eastern Band of Cherokee Indians (EBCI) began composting WRRF biosolids in 1995 to avoid expensive landfill disposal costs for this special waste; dewatered biosolids are mixed with ground wood from yard trimmings and the finished compost is sold to area landscapers and farms. In 1997, with grant funding from EPA, EBCI started the first food waste composting project on Indian Country in the United States. As of 2005, EBCI was composting about 1,100 dry tons of biosolids and 860 tons of food waste per year. EBCI utility staff collect food waste more than once per day from multiple restaurants, already separated and decontaminated by restaurant staff, and transport it to the windrow composting site for weighing and mixing with woodchips, sawdust and shredded paper. To solve initial odor problems resulting from lack of sufficient oxygen in the piles, EBCI simply changed the equipment used to turn the piles. The two composting operations save EBCI thousands of dollars annually in tipping fees, and the Qualla Boundary community benefits from high-quality, low-cost compost for gardening. EBCI focuses on training for its compost operators and knowledge sharing, including developing a composting guide for EPA to distribute to other Tribes.[85,86,87,88]

Anaerobic Digestion

AD is the process that breaks down organic waste in the absence of oxygen to release a gas known as biogas and leave an organic residue called digestate.[89] AD facilities have a variety of configuration options for the type of feedstock, type of loading, number of process stages and temperature within the digester. EPA's "Types of Anaerobic Digesters" webpage has more information about AD systems.

AD facility costs are significant and will vary depending on factors, including the location of the facility, feedstock source(s), pretreatment of feedstock, the selected AD configuration and treatment of the AD products.[90] A 2018 fact sheet from Ohio State University provides a capital cost range of about $450 to $600 per short ton of feedstock, and an operational cost range of about $35 to $90 per ton of feedstock,

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83 Karidis, Arlene. Prince George's County, Md., Ramps up Composting with Major Expansions. Waste360. August 2018. https://www.waste360.com/composting/prince-george-s-county-md-ramps-composting-major-expansion.

84 Prince George's County, Maryland. Sustainable Energy. https://www.princegeorgescountymd.gov/936/Sustainable-Energy-Program. Accessed August 17, 2021.

85 U.S. EPA. Tribal Composting Nourishes Land and Tradition. Tribal Waste Journal. Issue 4. EPA530-N-05-001. June 2005. https://nepis.epa.gov/Exe/ZyPDF.cgi/30006P0B.PDF?Dockey=30006P0B.PDF.

86 Food and Agriculture Organization of the United Nations. Cherokee Indians' Premier Food Waste Compost. https://www.fao.org/nr/sustainability/food-loss-and-waste/database/projects-detail/en/c/135015/. Accessed November 24, 2021.

87 Long, John. Composting Operations at Cherokee Tribal Facilities. Cherokee Tribal Utilities. https://www.fao.org/fileadmin/user_upload/nr/sustainability_pathways/docs/COMPOSTING%20OPERATIONS%20AT%20CHEROKEE%20TRIBE.pdf.

88 Eastern Band of Cherokee Indians. Solid Waste Management. https://ebci.com/services/departments/department-of-housing/infrastructure-and-public-facilities/. Accessed November 24, 2021.

89 U.S. EPA AgSTAR. How Does Anaerobic Digestion Work? https://www.epa.gov/agstar/how-does-anaerobic-digestion-work. Accessed July 28, 2021.

90 U.S. EPA. Global Methane Initiative: Overview of Anaerobic Digestion for Municipal Solid Waste. October 2016. https://www.globalmethane.org/documents/AD-Training-Presentation_Oct2016.pdf.

for a food waste AD plant.[91] Similarly, a 2013 feasibility study showed capital costs for food waste digester projects ranged from about $300 to $600 per short ton of annual throughput capacity and operational costs ranged from about $30 to $90 per short ton.[92] A 2018 AD project evaluation study by Great Plains Institute included interviews with various types of organic waste digester project operators in Minnesota on topics including capital and operations and maintenance costs. This study shows a range of capital costs from about $140 to $360 per short ton of design capacity and an operating cost range of about $15 to $40 per short ton of throughput.[93]

AD is also commonly used to treat municipal or industrial wastewater and sewage sludge and helps manage the volume of manure generated on livestock and poultry farms.[94] Some AD facilities co-digest multiple types of organic materials by supplementing their onsite inputs with food or yard wastes.[95] The main benefit of co-digestion projects is the use of existing assets and infrastructure, which allows these facilities to use process equipment more efficiently and lower costs when one facility processes multiple waste streams. Facilities can also use co-digestion to adjust the solids percentage to improve digestion and significantly increase biogas production, relative to sludge alone.[96] However, because the bacteria breaking down the waste are sensitive to the type and quantity of feedstocks added to a digester, several factors (e.g., composition and pH of the waste, retention time of the waste in the AD, operating temperature of the reactor and the rate at which the materials are added to the digester) affect the feasibility of co-digesting food waste with other materials.[97]

Starting in 2017, EPA has annually surveyed operators of AD facilities that accept food waste and provided reports on the findings online. Collecting data about food waste digestion will help EPA, states and other stakeholders better understand the alternatives to landfilling food waste. EPA's survey includes three types of facilities: stand-alone food waste digesters, on-farm digesters that co-digest food waste and WRRF digesters that co-digest food waste. EPA's report published in January 2021 provided 2018 and 2017 operational data for 118 facilities that responded to the survey during 2019. These facilities comprised 45 stand-alone food waste digesters, 10 on-farm digesters co-digesting food waste and 63 WRRF digesters co-digesting food waste.[98]

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91 Vasco-Correa, Juliana, Manandhar, Ashish, and Ajay Shah. Economic Implications of Anaerobic Digestion for Bioenergy Production and Waste Management. The Ohio State University, Department of Food, Agricultural and Biological Engineering. June 2018. https://ohioline.osu.edu/factsheet/fabe-6611.

92 Moriarty, Kristy. Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana. National Renewable Energy Laboratory. January 2013. https://www.nrel.gov/docs/fy13osti/57082.pdf.

93 Great Plains Institute. Anaerobic Digestion Evaluation Study. Prepared for the Partnership on Waste and Energy. September 2018. https://recyclingandenergy.org/wp-content/uploads/2021/01/2018-09-GPI-Anaerobic-Digestion-White-Paper-Final-Report-1.pdf.

94 U.S. EPA AgSTAR. The Benefits of Anaerobic Digestion. https://www.epa.gov/agstar/benefits-anaerobic-digestion. Accessed July 28, 2021.

95 U.S. EPA AgSTAR. Increasing Anaerobic Digester Performance with Codigestion. September 2012. https://www.epa.gov/sites/default/files/2014-12/documents/codigestion.pdf.

96 U.S. EPA. Anaerobic Digestion and Its Applications. EPA/600/R-15/304. October 2015. https://www.epa.gov/sites/production/files/2016-07/documents/ad_and_applications-final_0.pdf.

97 U.S. Army Corps of Engineers. Feasibility Study of Food Waste Co-Digestion at U.S Army Installations. Engineer Research and Development Center. ERDC/CERL TR-17-7. March 2017. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=338053.

98 U.S. EPA. January 2021. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). EPA/903/S-21/001. January 2021. Table ES-1. https://www.epa.gov/sites/production/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf.

WRRF Co Digestion

In 2014, Waste Management, Inc. (WM) entered into an agreement with the Sanitation Districts of Los Angeles County (LACSD), California, to conduct a two-year demonstration project for co-digesting food waste at a WRRF. WM delivered up to 25,000 gallons per day of food waste slurry to the Joint Water Pollution Control Plant in Carson, California, paying a tipping fee of about $10 per ton. The additional food waste slurry produced an additional 100,000 cubic feet per day of biogas from one of the plant's AD systems.[99,100] *The operation transitioned from pilot phase to full commercial operation in 2019, with capacity to process about 14 percent of the food waste generated in the Los Angeles Basin.*[101] *In 2020, LACSD was co-digesting about 300 tons per day of food waste at the plant, with the slurry delivered by nine suppliers including LACSD's own Puente Hills Materials Recovery Facility. The slurry is fed into two of 24 digesters and, at optimal feed rate, doubled biogas production. The biogas supplies onsite thermal and electrical demands and, beginning in December 2020, is also used to produce compressed natural gas (CNG) for LACSD's nearby public fueling station. The site's renewable natural gas (RNG) purification equipment was designed to produce up to 2,000 gasoline gallon equivalents per day from 400 cubic feet per minute of digester gas.*[102,103]

Farm Based Co Digestion

Using AD to process animal manure is well demonstrated but often is not economical due to the relatively low biogas yield from manure. However, adding food waste can increase biogas yield. In 2010, Reinford Farms in Mifflintown, Pennsylvania, began receiving 60 to 70 tons of food waste per week from 40 nearby Walmart and Sam's Club stores where employees separated the waste from packaging. In 2017, the farm installed a de-packaging unit to also take waste from food distribution centers without pre-separation and in 2019, added a second, larger digester. Reinford also added a 50,000-gallon food waste holding tank to help balance the addition of food waste into the digesters. The farm receives tipping fees for accepting waste, has reduced its heating bill to zero and generates renewable electricity for onsite use and sells excess to the grid. As of 2020, the two digesters produce a total of 288,000 cubic feet per day of biogas. The original 140-kilowatt (kW) generator is still in use as well as a newer 499-kW combined heat and power (CHP) engine. Engine waste heat is recovered to dry corn for feed and heat water and buildings.[104,105,106,107]

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[99] Coker, Craig. Los Angeles County WRRF Embraces Codigestion. BioCycle 58(1): 53. January 12, 2017. https://www.biocycle.net/2017/01/12/los-angeles-county-wrrf-embraces-codigestion/.

[100] Los Angeles County Sanitation District. Joint Water Pollution Plant, Carson, California. Fact sheet. May 12, 2016. https://www.epa.gov/sites/production/files/2016-05/documents/la_county_digester_project.pdf.

[101] Sarber, Kelly. Sanitation Districts Gear Up for Food Waste Codigestion. BioCycle. December 4, 2019. https://www.biocycle.net/sanitation-districts-gear-food-waste-codigestion/. Accessed September 4, 2020.

[102] McDannel, Mark. LACSD. Collection and Treatment of Food Wastes to Reduce Methane Emissions. Presented during webinar by American Academy of Environmental Engineers and Scientists (AAEES). March 3, 2021.

[103] BioCycle. Los Angeles County Producing RNG For Vehicle Fuel. December 8, 2020. https://www.biocycle.net/los-angeles-county-producing-rng-for-vehicle-fuel/. Accessed March 11, 2021.

[104] Tucker, Mary Farrell. Dairy Farm Succeeds with Codigestion. BioCycle 52(3): 74. March 23, 2011. https://www.biocycle.net/2011/03/23/dairy-farm-succeeds-with-codigestion/.

[105] Goldstein, Nora. The Art and Science of Codigestion on Dairy Farms. BioCycle. October 12, 2020. https://www.biocycle.net/the-art-and-science-of-codigestion-on-dairy-farms/. Accessed February 24, 2021.

[106] Yu, Alan. Waste Not, Want Not: Why Aren't More Farms Putting Poop to Good Use? The Salt. April 23, 2017. https://www.npr.org/sections/thesalt/2017/04/23/524878531/waste-not-want-not-why-arent-more-farms-putting-poop-to-good-use. Accessed February 24, 2021.

[107] Colby, Sally. Innovation with Cow Comfort In Mind. Country Folks. February 14, 2020. https://countryfolks.com/innovation-with-cow-comfort-in-mind/. Accessed February 24, 2021.

Industrial Co Digestion
In 2013, the Campbell Soup facility in Napoleon, Ohio, partnered with CH4 Biogas LLC to build an AD system to process its waste, including spoiled vegetables and other products that did not meet quality standards. The AD facility also accepts manure from nearby farms, waste from other food processors and food waste from grocery stores and schools—up to a total of 425 tons per day. Only slightly larger than another of CH4 Biogas' manure-only AD systems, the Napoleon AD facility produces twice as much electricity due to the mix of manure and food waste—2.8 megawatt (MW)-hours per hour, about 25 percent of the soup plant's energy needs.[108]

As with composting, landfills provide excellent opportunities for siting new AD facilities due to the existing space and infrastructure available, including waste handling, storage and (potentially) the adaptation of existing LFG energy systems to use AD biogas.

Siting ADs at Landfills
The Zanker Road Resource Recovery Operation and Landfill near San Jose, California, built an adjacent AD system in 2013. Zero Waste Energy Development Company (ZWEDC)'s dry fermentation AD system processes about 90,000 tons of organic waste per year (about 250 tons per day) in addition to creating about 30,000 tons of compost per year. The AD system's energy recovery capacity is 1.6 MW from two 800-kW CHP units; the renewable electricity powers operations at ZWEDC and at the landfill next door, with any surplus going to the grid. ZWEDC processes wet organic commercial waste from the City of San Jose as well as commercial and residential organics from the City of Palo Alto. The City of San Jose's 2007 Green Vision plan included the goal of diverting 100 percent of the city's waste away from landfilling by 2022 and using waste to create renewable energy.[109,110,111] *The City of Palo Alto officially instituted its recycling and composting ordinance in April 2016 but began researching organic waste diversion options as early as November 2011 as part of its zero-waste initiative.*[112,113]

Segregated Organic Waste Landfill Cells

Another possibility for processing organic waste is a "biocell" (also called "biomodule" or "digester cell") at existing landfills. This concept uses the available infrastructure in and around existing landfills and involves constructing a separate lined cell with leachate recirculation that is dedicated to organic waste. As the organic waste degrades anaerobically within the cell with leachate recirculation, it produces LFG at a faster rate than in a landfill with mixed MSW. The facility can collect and use the LFG as in a traditional LFG collection and control system until the LFG supply is depleted. When the gas runs out, the facility can use the LFG collection wells to inject air into the biocell to facilitate aerobic

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[108] Emerson, Dan. Entrepreneur Connects Generator to AD. BioCycle 56(6): 34. July 14, 2015. https://www.biocycle.net/2015/07/14/entrepreneur-connects-generators-to-ad/.

[109] Zanker Recycling. Zero Waste Energy Development. https://www.zankerrecycling.com/zwedc/facility/. Accessed March 12, 2021.

[110] Zanker Recycling. About Us. https://www.zankerrecycling.com/zanker-recycling/about-us/. Accessed March 12, 2021.

[111] Goldstein, Nora. High Solids Anaerobic Digestion + Composting in San Jose. BioCycle. March/April 2014. https://www.zankerrecycling.com/wp-content/uploads/zwedc-biocycle-highsolidsad-april-2014.pdf.

[112] City of Palo Alto, California. Zero Waste. https://www.cityofpaloalto.org/gov/depts/pwd/zerowaste/default.asp. Accessed March 12, 2021.

[113] City of Palo Alto, California. Recycling and Composting Ordinance Begins April 1. https://www.cityofpaloalto.org/files/assets/public/utilities/bill-inserts/rc-ordinance-commercial-april.pdf.

composting. Once the composting is complete, it can be mined for beneficial use. Examples of this technique are found in Yolo County, California;[114] Calgary, Alberta; and Leon County, Florida.[115] Yolo County's 2010 pilot project involved only manure and green waste in its dedicated biocell. The county's report on the project considered the pilot to be a success (e.g., the process was cost-effective, the pilot is transferable to a larger scale, it produced high-quality compost product) and recommended additional pilot projects involving food waste to address the challenges that this higher-moisture feedstock will present.[116]

Feedstock for Industrial Processes

In addition to composting and AD, pre-consumer organic waste from industrial sources such as the food supply industry can often be used as a feedstock to other industrial processes given its homogenous nature and low contamination levels. For example, the animal processing industry generates byproducts (e.g., fats, blood, meat or bone meals) that are usually not suitable for human consumption and would end up in landfills or incinerated, where they might contribute to public health or environmental concerns (e.g., air or water pollution). However, rendering is a recycling process that turns many animal byproducts into beneficial products. Rendering is the cooking and drying process that converts livestock and poultry animal parts not intended for human consumption into edible (e.g., lard, tallow) and inedible (e.g., meat meal and bone meal) byproducts, thereby providing additional revenue for the meat industry and avoiding costly disposal. Uses of rendered animal products include meat meal as an animal feed ingredient and bone meal as natural fertilizer. Other byproducts of rendering may be used as feedstocks for industrial products (e.g., paints and varnishes, explosives, lubricants), health and beauty goods (e.g., soaps, cosmetics, toothpaste, pharmaceuticals), apparel (e.g., leather, textiles) and pet food.[117]

Markets

Markets for the organic waste feedstock and the end products(s) of the process used (e.g., compost, biogas, digestate) in organic waste processing are a key component of a successful organic waste processing facility. When developing a new project, one must carefully consider these markets to properly design the system (e.g., feedstock pre-processing equipment, type of compost or AD system, end use of byproducts) and ensure long-term project operation and economic viability. There can be challenges in selling end products—for example, public perception of the quality and safety of compost or digestate given the lack of federal quality standards or regulating body for these products. In general, the markets for organic waste feedstocks and end products are growing in the United States due to regulatory requirements and public interest in sustainable waste management and renewable energy, as evidenced by growing numbers of state and local organic waste diversion regulations as well as composting facilities and SSO collection programs (see Section 6).

[114] Yazdani, P.E., Ramin, and Yolo County Planning & Public Works. Landfill-Based Anaerobic Digester—Compost Pilot Project at Yolo County Central Landfill. Prepared for California Department of Resources Recycling and Recovery. April 2010. https://www2.calrecycle.ca.gov/Publications/Details/1354.

[115] Waste Recovery Technology Review for the Toronto, Canada Long Term Waste Strategy. p. 81. https://www.toronto.ca/legdocs/mmis/2015/pw/bgrd/backgroundfile-83453.pdf.

[116] Yazdani, P.E., Ramin, and Yolo County Planning & Public Works. Landfill-Based Anaerobic Digester—Compost Pilot Project at Yolo County Central Landfill. Prepared for California Department of Resources Recycling and Recovery. April 2010. https://www2.calrecycle.ca.gov/Publications/Details/1354.

[117] National Renderers Association. North American Rendering: The Source of Essential, High-Quality Products. 2nd ed. 2016. http://assets.nationalrenderers.org/north_american_rendering_v2.pdf.

Section 4: Benefits of Diverting Organic Waste from Landfills

Diverting organic waste from landfills can reduce methane emissions, reduce the costs of landfill operations or waste disposal, achieve local economic benefits from new jobs and revenue, demonstrate sustainability to the community, improve public health and create environmental benefits (e.g., to water, air and soil conditions). This section explores many of the benefits of diverting organic waste from landfills.

Climate, Public Health and Other Environmental Benefits

Diverting organic waste from landfills reduces the amount of methane produced by landfills, providing a benefit in reduced GHG emissions from the waste sector. Methane is a potent GHG, 28 to 36 times more effective than carbon dioxide at trapping heat in the atmosphere over a 100-year period.[118] Keeping organic wastes out of landfills will help the United States address climate change, as more than 15 percent of total U.S. human-caused methane emissions in 2019 came from landfills, the third-largest source of methane in the United States. [119] In 2019, MSW landfills were responsible for emitting 99.4 $MMTCO_2e$.[120]

By diverting organic waste before it enters a landfill, facilities can process that waste via composting which does not produce significant amounts of methane or by AD wherein biogas production can be carefully controlled. See the "Climate Impacts of Organic Waste Management" subsection of Section 1 for an analysis of how diversion of food waste would affect landfill GHG emissions.

Similarly, organic waste disposal facilities can more easily control, manage and treat the digestate (solids and liquids) they produce for their intended end use before reintroducing them into the environment. Composting can avoid the environmental consequences of nutrient overload, including algal blooms and drinking water contamination associated with synthetic fertilizers. Diverting organic waste to other processing facilities also reduces the generation of odors and pests at landfills. While odors and pests can also be potential problems at composting and AD facilities as discussed in Section 5, proper management can make those issues easier to control than at landfills.

It is well known that landfills can pose certain risks to public health and the environment.[121] Many of these risks are directly associated with landfilling organic waste, which can lead to water or air pollution, odors, and rodents or other pests. Reducing organic waste disposal in landfills can therefore minimize some of these potential hazards and more easily control them at organic waste processing facilities. Benefits of less organic waste in landfills include, for example, lower emissions of methane and NMOCs and reductions in odor and leachate generation. Since organic waste accounts for a large portion of the MSW stream, the potential for realizing these benefits is significant.

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[118] U.S. EPA. Understanding Global Warming Potentials. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials. Accessed November 8, 2021.

[119] U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019. Chapter 7: Waste. April 2021. https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-chapter-7-waste.pdf.

[120] Ibid.

[121] U.S. Agency for Toxic Substances and Disease Registry (ATSDR). Landfill Gas Primer—An Overview for Environmental Health Professionals. Chapter 3: Landfill Gas Safety and Health Issues. November 2001. https://www.atsdr.cdc.gov/HAC/landfill/PDFs/Landfill_2001_ch3.pdf.

While federal[122,123] regulations require LFG to be collected and combusted at landfills above a certain size threshold, smaller landfills that do not meet the threshold requirements are not subject to the control requirements. Further, even at landfills with a robust gas collection system, the collection system can never capture 100 percent of the gas so the remainder escapes to the atmosphere. In contrast, AD facilities are estimated to collect 95 to 98 percent of their methane generated.[124]

Economic Benefits

As well as improving landfill operations through organic waste diversion, processing organic waste can provide economic benefits. The two most common methods of processing organic waste (AD and composting) produce useful end products that the owner of the processing facility can use or sell to customers, as summarized below and shown in Figure 4-1. Organics recycling contributed more than 50,000 jobs, more than $2 billion in wages and a little under $500 million in tax revenue to the U.S. economy in 2012.[125]

Anaerobic Digestion

- Recover and use biogas to produce electricity, heat or RNG for use as transportation fuel or in place of fossil natural gas. Projects can enhance biogas potential by:
  - Adding other organic wastes such as fats, oils and grease (FOG).
  - Co-locating an AD plant near an existing LFG energy project to support opportunities for combining AD biogas and LFG.
  - Exploring co-digestion of food waste at a WRRF.[126,127] Section 3 discusses co-digestion.
- Use the digestate (solid fraction) in many ways, including:
  - Feedstock in compost production.
  - Land application.
- Use the digestate (liquid fraction) as a liquid fertilizer or for irrigation.

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122 U.S. EPA. Municipal Solid Waste Landfills: New Source Performance Standards (NSPS), Emission Guidelines (EG) and Compliance Times. https://www.epa.gov/stationary-sources-air-pollution/municipal-solid-waste-landfills-new-source-performance-standards. Accessed February 22, 2021.

123 U.S. EPA. Municipal Solid Waste Landfills: National Emission Standards for Hazardous Air Pollutants (NESHAP). https://www.epa.gov/stationary-sources-air-pollution/municipal-solid-waste-landfills-national-emission-standards. Accessed February 22, 2021.

124 U.S. EPA. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM). Management Practice Chapters. November 2020. https://www.epa.gov/sites/default/files/2020-12/documents/warm_management_practices_v15_10-29-2020.pdf.

125 U.S. EPA. Recycling Economic Information (REI) Report. November 2020. https://www.epa.gov/sites/production/files/2020-11/documents/rei_report_508_compliant.pdf.

126 U.S. EPA. Food Waste to Energy: How Six Water Resource Recovery Facilities are Boosting Biogas Production and the Bottom Line. EPA 600/R-14/240. September 2014. https://www.epa.gov/anaerobic-digestion/food-waste-energy-how-six-water-resource-recovery-facilities-are-boosting-biogas.

127 Coker, Craig. Los Angeles County WRRF Embraces Codigestion. BioCycle 58(1): 53. January 12, 2017. https://www.biocycle.net/2017/01/12/los-angeles-county-wrrf-embraces-codigestion/.

Anaerobic Co Digestion at Wooster WRRF in Ohio

Quasar partnered with the City of Wooster, Ohio, to upgrade its old WRRF which was experiencing operational and compliance issues. After updating the AD system and introducing FOG and food waste, the facility went "off the grid" for electricity needs, saving about $300,000 per year in electricity costs and getting back in compliance. The digester also generates revenue from acceptance of waste, which in 2018 totaled $889,500. Biosolids from the AD system are also being land applied as a nutrient source for farmers. All the biogas generated by the AD system is used in a 1.1-MW CHP unit for electricity generation, half of which powers the WRRF and the AD system and the rest of which is sold to the grid.[128,129,130,131]

Compost

- Use the compost as a soil amendment (supplying nutrients, improving water retention).
- Help restore wetlands (increasing water filtration, plant growth).[132]
- Help control erosion (reducing runoff) or use the compost in roadside stabilization land reclamation projects.[133] For example, Marin County, California, applied compost to rangeland to sequester carbon while also increasing the soil's water holding capacity by 17 to 25 percent and increasing production of plants for grazing livestock by 40 to 70 percent.[134]

Baltimore Compost Collective, Maryland

In 2016–2017, the Institute for Local Self-Reliance began the Baltimore Compost Collective. This youth-led food scrap collection service operates in Curtis Bay, Maryland, a historically disenfranchised neighborhood in Baltimore with high poverty levels and low access to fresh food. The Collective's high school student employees gather food scraps weekly from residents and a local juice bar to create compost for use in growing produce for the community at Filbert Street Garden. As of 2018, about 30 customers were paying $25 per month to have their food scraps collected by the Collective. Originally launched with a grant, the Collective seeks to become financially self-sustaining by increasing its customer base. It has already built a second

[128] Contipelli, Renato. The Impact of Co-Digestion on Water Resource Recovery Facilities In Order to Achieve Energy Neutrality. quasar energy group. http://www.ohiowea.org/docs/Renato_quasar.pdf.

[129] Kurtz, Mel. The City of Wooster, Ohio: Water Resource Recovery Facility. quasar energy group. https://www.epa.gov/sites/production/files/2015-09/documents/presenation_kurtz.pdf.

[130] Givins, Kevin P. City of Wooster Utilities Division: Annual Report for Year 2015. March 1, 2016. https://www.woosteroh.com/sites/default/files/2018-11/Utilities%20Division%20Annual%20Report_0.pdf.

[131] Coey, Nathan. City of Wooster Utilities Department: 2018 Annual Report. https://www.woosteroh.com/sites/default/files/2019-04/2018%20Utilities%20Annual%20Report.pdf.

[132] U.S. EPA. Innovative Uses of Compost: Reforestation, Wetlands Restoration, and Habitat Revitalization. October 1997. https://www.epa.gov/sites/production/files/2015-08/documents/reforest.pdf.

[133] Cogburn, Barrie, and Scott McCoy. USCC Factsheets on Innovative Uses of Compost by State DOTs: Texas DOT—Revegetating Difficult Slopes. Project conducted for TXDOT. 2008. https://nrcne.org/wp-content/uploads/2019/12/TxDOT_Revegetating_Difficult.pdf.

[134] Scolari, Nancy. Carbon Farming. Presentation at 2016 California Adaptation Forum. September 2016. http://www.californiaadaptationforum.org/2016/wp-content/uploads/2016/09/Scolari.pdf.

composting system to accommodate more food scraps. Students are taught financial, customer service and other workforce skills in this entrepreneurship program.[135,136,137,138]

Economic Benefits for the Local Economy

In Massachusetts, a commercial food waste disposal ban (in place since October 2014) has significantly affected the state-wide economy. A 2016 analysis found that several affected industry segments, including waste haulers and processors, had experienced significant growth in the first two years and expected additional job growth in 2017. More specifically, the study found approximately 400 direct jobs attributable to organic waste hauling and processing in 2016, $68 million in added value to the state, and $4.9 million in state and local taxes.[139]

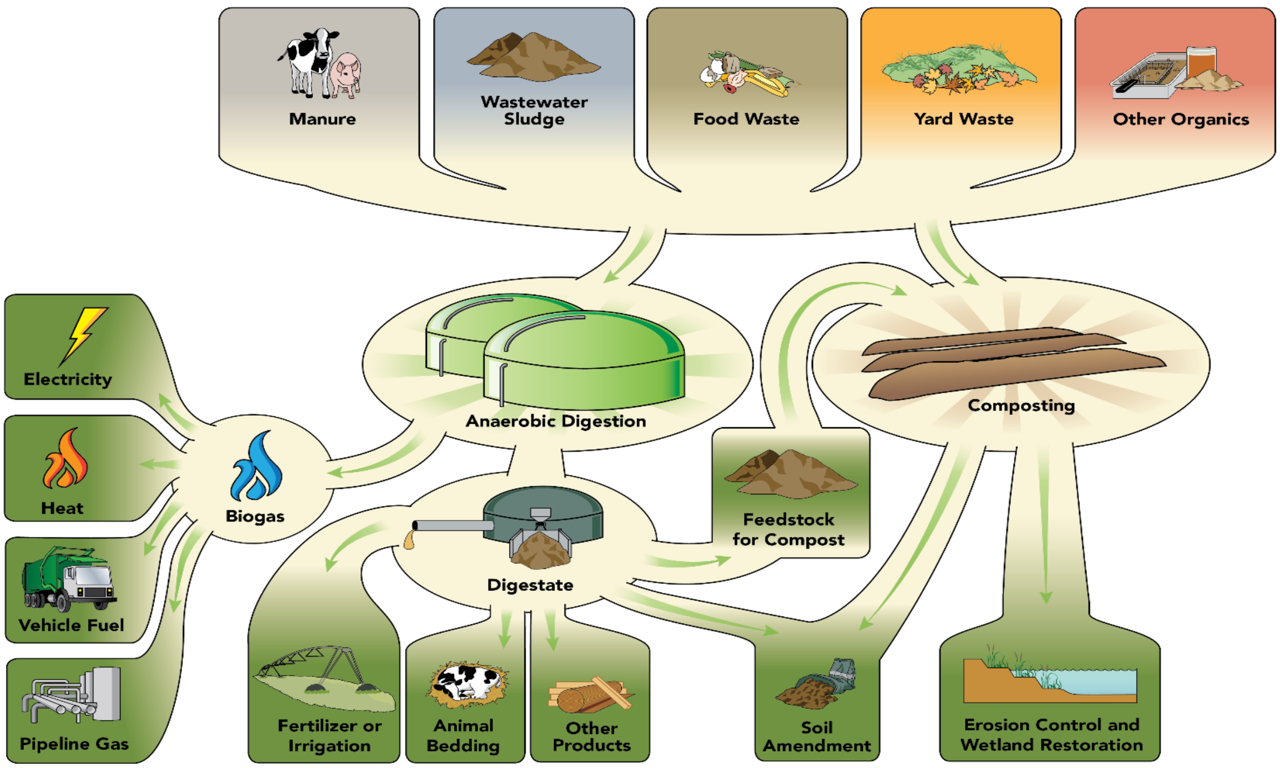

Figure 4-1. Byproducts and Beneficial Uses of Diverted Organic Waste.

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135 Brolis, Linda Bilsens. Institute for Local Self-Reliance. Fighting Food Waste and Employing Youth in Baltimore. August 9, 2018. https://ilsr.org/fight-food-waste-employ-youth-baltimore/.

136 The Baltimore Office of Sustainability. Baltimore Food Waste & Recovery Strategy. September 2018. https://mayor.baltimorecity.gov/sites/default/files/BaltimoreFoodWaste&RecoveryStrategy_Sept2018.pdf.

137 WYPR News. Baltimore Plans to Expand Composting Citywide. September 17, 2018. https://www.wypr.org/wypr-news/2018-09-17/baltimore-plans-to-expand-composting-citywide. Accessed November 12, 2021.

138 Natural Resources Defense Council. Food Scrap Recycling. 2019 Landscape Assessment. Baltimore, Maryland. https://www.nrdc.org/sites/default/files/baltimore-food-scrap-recycling-assessment-report.pdf.

139 ICF. Massachusetts Commercial Food Waste Ban Economic Impact Analysis. Prepared for the Massachusetts Department of Environmental Protection. December 2016. Tables 3 and 4. https://www.mass.gov/files/documents/2016/12/nx/orgecon-study.pdf.

Economic Benefits to Business
The Santa Ynez Band of Chumash Indians, California, has been recognized as EPA's WasteWise Tribal Partner of the Year more than once for their sustainable materials management practices involving food recovery, landfill diversion, composting and recycling. The Band took the initiative to audit their resort's waste stream annually and focus on the areas of highest waste reduction potential, learning some lessons along the way on what worked and what did not. In 2012, the Band's Chumash Casino Resort generated more than 6 million pounds of waste and spent about $255,000 on waste management; in 2017, the resort generated only 2.3 million pounds of waste (a 60 percent reduction) and spent $165,000 in waste management (a 35 percent reduction). The resort diverted more than 2.9 million pounds of waste from landfilling in 2018, about 90 percent of its overall waste stream. Resort leaders started a free sustainability program for Native American properties to share knowledge with other casinos and resorts who are interested in replicating Chumash' waste successes.[140,141,142,143,144]

The economic activity associated with diverting and processing organic waste and use of beneficial byproducts also creates jobs. A 2016 ReFED analysis estimated five to 10 permanent jobs are created for constructing, managing and operating each food waste composting center, plus an additional 1,600 ancillary jobs related to using the compost in green infrastructure or agriculture for every million tons of processed compost. For AD, this same study estimated four to six new jobs for every 10,000 tons of processing capacity in addition to jobs related to processing digestate.[145]

Section 5: Considerations for Implementing Organic Waste Diversion Programs

There are economic and technical barriers to diverting organic waste from landfills. This section explores some of these barriers and provides examples of how communities are overcoming them to implement successful organic waste management programs.

Alternative Organic Waste Management Infrastructure

In some areas, there is limited capacity for organic waste receiving, processing and treatment facilities (e.g., composters, anaerobic digesters). Estimates indicate there are between 3,000 and 5,000 active

[140] U.S. EPA. Sustainable Materials Management on Tribal Lands. EPA 530-F-19-001. March 2019. https://www.epa.gov/sites/default/files/2019-03/documents/smm_on_tribal_lands_brochure_march_2019_0.pdf.

[141] Chumash Casino Resort. Sustainability. https://www.chumashcasino.com/about-us/sustainability. Accessed November 24, 2021.

[142] U.S. EPA. U.S. EPA Recognizes Santa Ynez Band of Chumash Indians for Zero Waste and Recycling Accomplishments. November 12, 2019. https://www.epa.gov/newsreleases/us-epa-recognizes-santa-ynez-band-chumash-indians-zero-waste-and-recycling. Accessed November 24, 2021.

[143] U.S. EPA. 2019 WasteWise National Award Winners. https://www.epa.gov/smm/2019-wastewise-national-award-winners#09. Accessed November 24, 2021.

[144] Fehrenbach, Pete. One of a Kind: California Casino Resort Earns Zero Waste Certification. Waste360. May 20, 2019. https://www.waste360.com/business-operations/one-kind-california-casino-resort-earns-zero-waste-certification. Accessed November 24, 2021.

[145] ReFED. A Roadmap to Reduce U.S. Food Waste by 20 Percent. 2016. p. 24-25. https://www.refed.com/downloads/ReFED_Report_2016.pdf.

composting operations in the United States.[146,147] with between 465 and 880 of these facilities accepting food waste.[148,149] An estimated 185 are "full-scale" municipal or commercial composting facilities, with the majority of these believed to be able to accept food waste.[150,151] Using existing composting infrastructure when feasible can help offset the need for new facilities and reduce the costs and logistical burdens of handling this waste stream in a new way (e.g., adding food waste collection to an existing yard waste collection program or using existing capacity at a waste processing facility for mixed waste composting or WRRF for co-digestion).

Municipal organic waste can also be processed at stand-alone AD facilities or co-digested with agricultural or WRRF sludge. There are an estimated 1,600 AD facilities in the country; about 200 to 210 of these accept food waste, though more potentially could.[152,153] Based on EPA survey data, of the approximately 200 AD facilities processing food waste in 2019, about 32 percent were stand-alone facilities, 28 percent were on-farm co-digesters and 40 percent were WRRF co-digesters. Based on the 117 facilities that responded to EPA's AD survey in 2019, about 9.8 million tons of food waste were processed in 2018 (84 percent of it at stand-alone facilities) but those facilities' total capacity for food waste is about 24.3 million tons.[154]

Collection

Diverting organic waste from landfills, whether by collecting SSO at the curb or separating organic wastes from other MSW at a centralized location, entails additional costs for collection, handling and disposal. SSO collection may require additional receptacles, truck routes, and personnel and public outreach and education to maximize separation and minimize contamination, as discussed in Section 2.

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[146] Goldstein, Nora. The State of Organics Recycling in The U.S. BioCycle 58(9): 22. October 4, 2017. https://www.biocycle.net/2017/10/04/state-organics-recycling-u-s/. Count of 4,713 composting facilities.

[147] U.S. EPA. Excess Food Opportunities Map V2.1. Frequent Questions about the Excess Food Opportunities Map. https://www.epa.gov/sustainable-management-food/frequent-questions-about-us-epa-excess-food-opportunities-map. Accessed March 12, 2021. Filename CompostingFacilities.xlsx within ExcessFoodPublic_USTer_2020_R9.gdb.zip file. Count of 3,013 composting facilities.

[148] Goldstein, Nora. The State of Organics Recycling in The U.S. BioCycle 58(9): 22. October 4, 2017. https://www.biocycle.net/2017/10/04/state-organics-recycling-u-s/. Count of 880 is those indicating yard trimming and food scraps, multiple organics or mixed MSW accepted.

[149] U.S. EPA. Excess Food Opportunities Map V2.1. Frequent Questions about the Excess Food Opportunities Map. https://www.epa.gov/sustainable-management-food/frequent-questions-about-us-epa-excess-food-opportunities-map. Accessed March 12, 2021. Filename CompostingFacilities.xlsx within ExcessFoodPublic_USTer_2020_R9.gdb.zip file. Count of 465 composting facilities accepting food waste based on feedstocks including "food," "source separate organic," "vegetable," "household," "grain," or "crop."

[150] Sloan, Willona. BioCycle Tracks U.S. Composting Infrastructure in New Report. Waste360. January 29, 2019. https://www.waste360.com/composting/biocycle-tracks-us-composting-infrastructure-new-report.

[151] Goldstein, Nora. Quantifying Existing Food Waste Composting Infrastructure in the U.S. BioCycle. November 29, 2018. https://www.compostingcollaborative.org/wp-content/uploads/2018/11/Task3_rev181129.pdf.

[152] U.S. EPA. Excess Food Opportunities Map V2.1. Frequent Questions about the Excess Food Opportunities Map. https://www.epa.gov/sustainable-management-food/frequent-questions-about-us-epa-excess-food-opportunities-map. Accessed March 12, 2021. Filename AnaerobicDigestionFacilities.xlsx within ExcessFoodPublic_USTer_2020_R9.gdb.zip file. Count of 1,607 AD facilities total. Count of 200 AD facilities accepting food waste based on feedstocks including "food," "source separate organic," "vegetable," "household," "grain," or "crop."

[153] U.S. EPA. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). EPA/903/S-21/001. January 2021. https://www.epa.gov/sites/production/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf. Count of 209 in Table ES-1.

[154] Ibid. Tables ES-1 and ES-2.

Collection costs can be 50 to 75 percent of the total costs for collecting and processing food waste.[155] A community can minimize these costs by leveraging existing infrastructure and operations (e.g., combining collection of food and yard wastes), moving from manual to automated or semi-automated collection, using collection vehicles with dual compartments or adjusting the frequency of waste collection. Since the collection strategies are tailored to each community's needs, implementing a pilot SSO program can help phase in a program before investing too much in infrastructure and operations that do not work for the community.

Processing

Once organic waste is collected, it must be processed or pretreated before disposal via AD or composting. Depending on the effectiveness of the source separation (i.e., the types or amounts of contaminants remaining) and the type of collection that was used, the technologies used for pretreatment may include a combination of bag opening; manual or mechanical sorting using screens, trommels or magnets; or chemical or biological treatment. Educating the public about organic waste separation is one of the most effective and least expensive methods of both decreasing pretreatment costs and increasing diversion rates.[156] Section 2 provides more detail about minimizing contamination of the feedstock and pretreatment requirements; there is more information below in this section about community outreach.

Disposal

Traditionally, waste disposal costs in the United States have been based on landfill tipping fees—the fees a waste collector or hauler pays to discard waste in a landfill. These fees vary widely across the country, with state averages ranging from $30 to $142 per ton in 2020 and a 2020 national average of about $54 per ton, an increase of 11.3 percent compared to 2016.[157] Anaerobic digesters require significant capital investment and often rely on tipping fees to recover costs to construct and operate the facility. Costs for individual AD systems depend on several site-specific variables, including but not limited to the size of the system, climate, gas use, and state and local regulations.[158] Capital costs for organic waste AD systems can range from $8 million to $34 million, based on interviews done with existing projects in Minnesota.[159] In areas of the country with low landfill tipping fees, it can be challenging for AD facilities to compete. However, some AD facilities maintain a competitive tipping fee against traditional disposal by supplementing with other revenue sources, such as selling biogas.

Landfill owners may lose revenue from landfill tipping fees if organic waste is diverted. However, landfill owners who elect to also have alternative organic waste management infrastructure (as opposed to a private entity in the area) can collect revenue from those tipping fees. These fees collected for organic

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[155] ReFED. A Roadmap to Reduce U.S. Food Waste by 20 Percent. 2016. https://www.refed.com/downloads/ReFED_Report_2016.pdf.

[156] Ibid.

[157] Environmental Research & Education Foundation (EREF). Analysis of MSW Landfill Tipping Fees—2020. January 2021. https://erefdn.org/wp-content/uploads/woocommerce_uploads/2017/12/MSWLF-Tipping-Fees-2020_FINAL-m2yyxt.pdf.

[158] U.S. EPA. AgSTAR Project Development Handbook. 3rd ed. EPA 430-B-20-001. https://www.epa.gov/sites/production/files/2014-12/documents/agstar-handbook.pdf.

[159] Great Plains Institute. Anaerobic Digestion Evaluation Study. Prepared for the Partnership on Waste and Energy. September 2018. https://recyclingandenergy.org/wp-content/uploads/2021/01/2018-09-GPI-Anaerobic-Digestion-White-Paper-Final-Report-1.pdf.

waste treatment and the sale of compost or AD byproducts can offset the lost landfill fee revenue and help pay for the organic waste processing.

In some instances, local solid waste agencies have offered reduced fees for source-separated loads of organic waste at composting facilities. For example, Charleston County, South Carolina, has a $25 per ton fee to drop off food and organic waste for composting, compared to $66 per ton for traditional waste sent to the landfill.[160] In addition, variable rate fees, or "pay-as-you-throw" pricing, incentivize separate collection of organic waste and recyclables, as trash collection is typically priced at a higher fee than SSO and recyclables (as discussed in Section 6).

Co Digestion of Commercial Food Waste at WRRF in California

The Central Marin Sanitation Agency (CMSA) Treatment Plant in San Rafael, California, already had two anaerobic digesters with captured biogas fueling a 750-kW engine to power and heat the facility, but was looking for a way to use its extra digester and engine capacity. Local private waste company Marin Sanitary Services, meanwhile, needed help with Marin County's 2025 zero waste goals plus California's state goal to reduce organic waste landfilling by 50 percent by 2020. Following a grant-funded GHG reduction feasibility study, the public-private partnership's Food 2 Energy (F2E) program launched in January 2014. CMSA invested in a new food waste and FOG receiving station and designed the collection process to ensure a clean feedstock, benefiting from a nearby co-digestion project's experiences with contamination. The amount of organic waste processed through the F2E program increased from 1,165 tons (from 70 customers) in 2014 to 2,420 tons (from 209 customers) in 2018. As of 2018, co-digestion had increased CMSA's biogas production 180 percent over baseline and the CHP system was powering the facility an average of 23 hours per day as compared to 8 hours per day previously. The F2E project reduces about 2,000 metric tons of GHGs per year.[161,162,163,164,165,166]

If there is opposition to siting an organic waste processing facility in densely populated areas (e.g., due to public concerns about odors, vectors or vehicle traffic), waste managers can have difficulty obtaining permits to build facilities near the waste source(s), which increases costs to transport feedstock to the digester.[167] Co-locating a digester or composting facility with a landfill may reduce siting and permitting

160 Tucker, Molly Farrell. Charleston County Fosters Food Waste Composting. BioCycle 54(1): 47. January 23, 2013. https://www.biocycle.net/2013/01/23/charleston-county-fosters-food-waste-composting/.

161 The Water Research Foundation. Food Waste Co-Digestion at Water Resource Recovery Facilities: Business Case Analysis. 2019. https://www.waterrf.org/system/files/resource/2019-12/DRPT-4792.pdf.

162 Dow, Jason and Kim Scheibly. Central Marin Commercial Food-to-Energy (F2E) Program. March 12, 2015. https://www.epa.gov/sites/default/files/2015-09/documents/dow_0.pdf.

163 California Water Environment Association (CWEA). Co-Digestion of Organic Wastes at Central Marin Sanitation Agency. https://www.cwea.org/news/co-digestion-of-organic-wastes-at-central-marin-sanitation-agency/. Accessed December 23, 2021.

164 Goldstein, Nora. Codigestion at Water Resource Recovery Facilities. BioCycle. March 12, 2018. https://www.biocycle.net/codigestion-water-resource-recovery-facilities/. Accessed December 23, 2021.

165 Marin Sanitary Service. Food 2 Energy Program. https://marinsanitaryservice.com/food2energy/. Accessed December 23, 2021.

166 Central Marin Sanitation Agency. A Virtual Tour of the Treatment Plant. https://www.cmsa.us/public-ed/virtualtour. Accessed December 23, 2021.

167 Coalition for Resource Recovery. Managing Food Waste in New York City: A Development Framework for Organic Waste Facilities. 2014. https://www.sipa.columbia.edu/sites/default/files/migrated/documents/Food%20Waste%20Report.pdf.

obstacles and associated costs. Leveraging the infrastructure of the hundreds of municipally owned WRRFs already in place, many with additional capacity for co-digesting other wastes, is one way to increase food waste treatment. For example, in 2018 amendments the State of New York streamlined its environmental quality review process for organic waste digesters co-located at publicly owned landfills[168] and Texas incentivizes the co-location of compost facilities at landfills using a rebate program for state fees.[169] In addition, some states have provided permitting flexibilities for small or pilot composting facilities.[170]

Electricity and Natural Gas Prices

Energy market conditions when natural gas and/or electricity prices are relatively low present economic challenges to siting and operating new AD projects. Aside from tipping fees, the major revenue source for an AD project is selling biogas as renewable energy in the form of electricity or RNG. So when prices are low, the projects are not economically favorable and it is harder to justify investment in a new project.

While the price of electricity depends on several factors specific to the project's location and the needs of the local utility, the forecasted buy-back rate (the rate projected for selling electricity to the grid) for 2021 ranges from 2.8 to 8.8 cents per kilowatt-hour (kWh), and the forecasted rate remains low over the next 10 years, ranging from 2.3 to 8.7 cents per kWh in 2031.[171]

Likewise, natural gas prices are depressed due to abundant domestic supply and efficient methods of production. In 2020, the Henry Hub spot price averaged about $2.04 per million British thermal units (MMBtu) (and averaged $2.57 per MMBtu in 2019). For comparison, natural gas prices peaked in 2008 with an average of nearly $9 per MMBtu. Modest increases in natural gas prices up to $3.36 per MMBtu in 2021 are expected as electric power consumption of natural gas increases demand.[172,173]

Financial incentives such as tax credits, environmental market credits and grants may be available to encourage investment in biogas energy derived from organic waste, as discussed in Appendix A. EPA's Renewable Fuel Standard (RFS) and state-level fuel standards have been market drivers for the production of renewable vehicle fuels sourced from biogas; more information about these policies is available in EPA's "Overview of RNG from Biogas" document.

[168] NY Department of Environmental Conservation. The SEQR Handbook. 4th ed. 2020. Chapter 2: Changes to 617.5(c)(41). p. 41. https://www.dec.ny.gov/docs/permits_ej_operations_pdf/seqrhandbook.pdf.

[169] Texas Commission on Environmental Quality. Composting and Mulching: Am I Regulated? https://www.tceq.texas.gov/permitting/waste_permits/msw_permits/MSW_amIregulatedcomposting.html. Accessed November 19, 2021.

[170] US Composting Council. State Regulations. https://www.compostingcouncil.org/page/StateRegulations. Accessed November 18, 2021.

[171] U.S. Energy Information Administration. Annual Energy Outlook 2020. Table 54: Electric Power Projections by Electricity Market Module Region. https://www.eia.gov/outlooks/aeo/data/browser/#/?id=62-AEO2020&region=5-0&cases=ref2020&start=2018&end=2050&f=A&linechart=ref2020-d112119a.5-62-AEO2020.5-0&map=&sourcekey=0. Prices by service category and generation.

[172] U.S. Energy Information Administration (EIA). Annual Energy Outlook 2021. Table 13: Natural Gas Supply, Disposition, and Prices. Release Date: February 3, 2021. https://www.eia.gov/outlooks/aeo/tables_ref.php.

[173] U.S. EIA. Henry Hub Natural Gas Spot Price. https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm. Accessed February 22, 2021.

Impacts on Existing Landfill and Landfill Gas Energy Infrastructure and Operations

Considerations for a given landfill or LFG energy project that diverts a significant portion of organic waste to alternative management options may include:

- Lower methane and NMOC emission rates
- Existing equipment costs and contractual obligations for LFG volumes
- Landfill airspace and life expectancy
- Decrease in leachate generation and its disposal cost and environmental risks

Diverting organic waste from landfill disposal will reduce a landfill's gas generation rate, thus reducing the amount of methane and NMOCs emitted. Figure 5-1 depicts the time horizon when a typical landfill (that stops accepting waste in 2040) would exceed the control emission threshold of 34 megagrams (Mg) of NMOCs per year, with and without organic waste diversion.[174] In this example, the landfill has a 60 percent organic waste fraction in 2013 and meets a goal of reducing the disposed organic waste by 50 percent between 2013 and 2030 by reducing the fraction of organic waste disposed of in equal increments of 2.9 percent each year. As a result, the landfill reduces the time it exceeds the modeled NMOC emission threshold by nine years. It is important to note that, while a landfill can reduce the years it is required to control LFG under federal regulations, lower gas flows than originally planned could affect the LFG collection and control system design and routine operations. To this end, solid waste managers must consider those impacts and their potential effects—as discussed in more detail below.

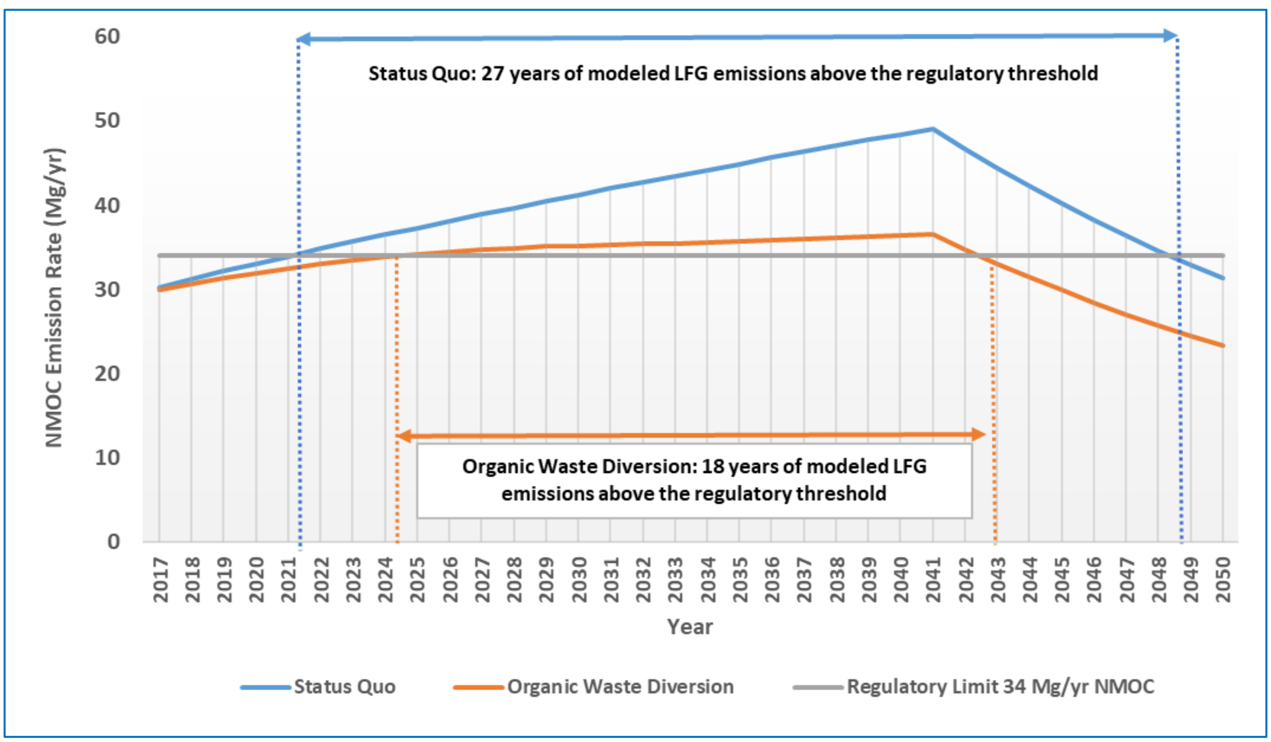

Figure 5-1. LFG Generation Curve Showing Effect of Organic Waste Diversion on a Typical Landfill's NMOC Emission Profile.

[174] For federal MSW landfill regulations with an emissions threshold of 34 Mg of NMOCs per year, see 40 CFR part 60, subpart XXX; 40 CFR part 62, subpart OOO; or state plans implementing 40 CFR part 60, subpart Cf.

Combining LFG Energy and AD in Massachusetts

Anticipating the long-term challenges of decreased gas availability for its LFG electricity project due to the state food waste disposal ban, the Greater New Bedford Regional Refuse Management District and its private partner, CommonWealth Resource Management Corporation (CRMC), co-located a new food waste AD facility at the Crapo Hill Landfill. The biogas from the AD facility ties into the LFG generating facility where the two sources of gas are combined prior to combustion in the engines. After a successful pilot phase, the project expanded to increase the digester's capacity from about 5,000 gallons to about 30,000 gallons of liquids per day and boost energy production from 3.3 to 4.1 MW.[175,176,177]

Communities make an investment in the infrastructure for an LFG energy project or enter into a contractual agreement with a third-party LFG energy project developer based in part on forecasted gas quantity and quality to fuel the energy recovery equipment over the lifetime of the project. Landfill owners may lose revenue from planned gas royalty sales or energy sales if less gas is available due to organic waste diversion.

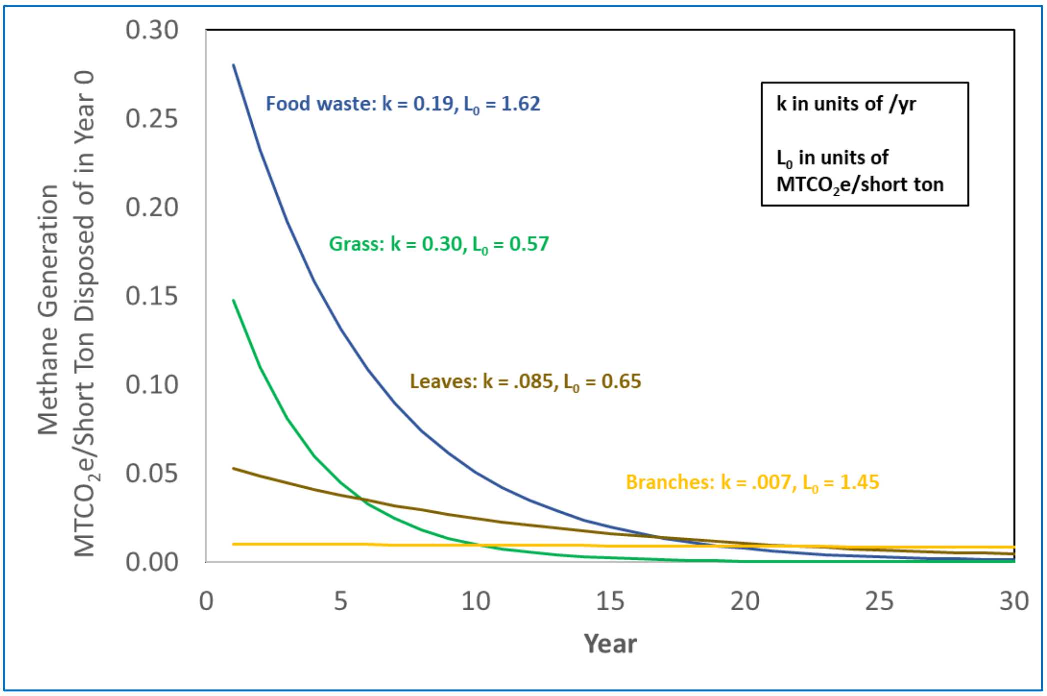

Figure 5-2. Decay Rates for Organic Waste Materials.

LFG production is highly sensitive to the amount and composition of waste disposed of in a landfill. Since food wastes decay more rapidly than other MSW components, these wastes generate methane more quickly than other waste types. Figure 5-2 illustrates this decay pattern, based on national defaults

175 CRMC Bioenergy LLC. Final Construction Project Report for the CRMC Bioenergy Facility. Prepared for the Massachusetts Clean Energy Center. February 13, 2015. https://files.masscec.com/research/CRMCPilot.pdf.

176 Fletcher, Katie. Pilot Biogas Project at Massachusetts Landfill Site Complete. Biomass Magazine. October 10, 2014. http://biomassmagazine.com/articles/11044/pilot-biogas-project-at-massachusetts-landfill-site-complete.

177 Karidis, Arlene. Massachusetts Landfill Operator Teams with Energy Project Developer for AD Project Expansion. Waste360. February 20, 2018. https://www.waste360.com/design-and-construction/massachusetts-landfill-operator-teams-energy-project-developer-ad-project.

for methane generation rate or decay rate (k) and potential methane generation capacity (L_0) values for each waste type.[178,179]

One 2014 study modeled the long-term national impacts of food waste diversion programs in the United States on LFG generation, looking at disposal patterns from 2000 through 2024. To establish the modeling parameters, the study determined the decline in methane generation potential of MSW disposed of over time, based on changes in MSW composition. The study also factored in a range of diversion rate scenarios and material-specific decay rates. The baseline scenario for this study assumed typical increases in organic waste diversion based on historical trends. Under a scenario with moderate increases (over baseline) in diversion of food and yard wastes, the maximum LFG generation rate was reached in year 2025 and was about 9.4 percent less than the baseline's maximum LFG rate; under a more aggressive diversion scenario, the maximum rate was reached in year 2020 and was about 9.1 percent less than baseline.[180]

Ongoing research by EPA's Office of Research and Development has shown that diverting all food waste from landfilling can decrease L_0 by 33 percent and also slow the waste decay rate. Both changes can reduce landfill methane emissions.[181,182]

In addition to the impacts on LFG generation, diverting organic waste from a landfill can extend the landfill's life and save valuable airspace. However, since food waste has a much higher moisture content and degrades more quickly than other wastes, it occupies less space than other MSW waste types.[183]

Rural localities may be particularly interested in extending the life of a landfill by diverting organic waste because alternative disposal facilities may be many miles away and the cost to dispose of waste over long distances or across state lines may be prohibitive or undesirable. For example, Pitkin County, Colorado, has a single landfill with 20 to 30 years of remaining life, so the county embarked on a plan to divert organic waste to preserve landfill capacity.[184]

Because organic waste has such a high moisture content, reducing its amount in landfills also reduces the amount of leachate generated. This in turn lowers the operational costs to manage leachate, which

178 U.S. EPA. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM). November 2020. Management Practices Chapters. https://www.epa.gov/sites/production/files/2020-12/documents/warm_management_practices_v15_10-29-2020.pdf.

179 U.S. EPA. WARM Component-Specific Decay Rate Methods. October 2009. Table 6. https://www.epa.gov/sites/production/files/2016-03/documents/warm_decay_rate_structure_10_30_2009.pdf.

180 Stege, Alex. The Effects of Organic Waste Diversion on LFG Generation and Recovery from U.S. Landfills. Solid Waste Association of North America (SWANA) 37th Annual Landfill Gas Symposium. 2014. Figures 11 and 13.

181 Jordan, Page, Krause, Max J., Chickering, Giles, Carson, David, and Thabet Tolaymat. Impact of Food Waste Diversion on Landfill Emissions. U.S. EPA. Office of Research and Development. February 2020. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CESER&dirEntryId=348317. Accessed August 11, 2021.

182 Krause, Max J., and Thabet Tolaymat. Impact of Food Waste Diversion on Landfill Gas and Leachate from Simulated Landfills. U.S. EPA. Office of Research and Development. July 2019. https://www.epa.gov/sites/default/files/2019-08/documents/1025am_krause_508.pdf.

183 Solid Waste Association of North America (SWANA) Applied Research Foundation. Food Waste Diversion Programs & Their Impacts on MSW Systems. April 2016 (full report available for purchase). https://www.mswmanagement.com/landfills/article/13025743/the-landfill-impacts-of-food-waste-diversion-programs.

184 Best, Allen. Diverting the Rot from Aspen. Mountain Town News. January 10, 2015. http://mountaintownnews.net/2015/01/20/diverting-smelly-stuff/.

can account for up to 30 percent of a landfill's operational expenses in areas with temperate climates.[185] Reducing leachate generation also lowers any potential environmental harm caused by accidental releases of leachate, which typically contains very high concentrations of dissolved organic matter and inorganic macro components—often by a factor of 1,000 to 5,000 times higher than concentrations found in ground water.[186]

Other Potential Barriers

Complexity of Local and Regional Waste Management Entities

The existing solid waste management structure can pose a barrier to diverting organic waste depending on how local solid waste organizations are structured and financed. Some waste management may be organized regionally, which makes changes to that structure more difficult to effect (i.e., buy-in is needed from multiple municipalities). In addition, municipal entities generally focus on funding day-to-day operations and can be averse to developing new projects. Further, many municipalities work with private companies to haul their wastes; without the proper policies in place, this limits their ability to direct where the waste is taken and could affect feedstock available to organic waste processing or treatment. However, there are examples of successful public-private partnerships that show how municipalities can limit their risk while allowing business opportunities for companies.

Risk vs. Reward: Public Private Partnerships

Prince William County, Virginia, worked with a private developer, who expanded and operates an organic waste processing facility to handle county waste. The county provided the site and access to the local organic waste market but took on very little risk, as the project was developed and operated by a private entity. The facility is estimated to divert more than 80,000 tons of organic waste per year from the landfill by turning it into compost, mulch and soil amendments. The facility will help extend the life of the county's landfill by 10 to 15 years and more than doubled the county's annual composting capabilities.[187,188] The county benefits from the facility including the addition of 20 to 25 new jobs.[189]

Co-digestion of food waste often involves additional complexity, as solid waste management and wastewater infrastructure are usually operated by separate entities. Each agency has its own operating funds, priorities and perceptions (e.g., impacts of accepting food waste), and it can be a challenge deciding which entity will pay for infrastructure improvements and routine operations.

[185] Kremen, Arie. Getting a Handle on Landfill Leachate. Tetra Tech. February 1, 2020. https://www.tetratech.com/en/blog/getting-a-handle-on-landfill-leachate.

[186] Kjeldsen, Peter, Barlaz, Morton A., Rooker, Alix P., Baun, Anders, Ledin, Anna, and Thomas H. Christensen. 2002. Present and Long-Term Composition of MSW Landfill Leachate: A Review. Critical Reviews in Environmental Science and Technology 32(4): 297-336. doi: 10.1080/10643380290813462.

[187] Prince William County. Balls Ford Road Composting Facility Now Able to Process More Organic Waste. Prince William Living. September 17, 2020. https://princewilliamliving.com/balls-ford-road-composting-facility-now-able-to-process-more-organic-waste/.

[188] Prince William County. The Buzz: Balls Ford Road Compost Facility Ribbon Cutting. YouTube video. September 17, 2020. https://www.youtube.com/watch?v=Xrsod0M3U6s. Accessed November 29, 2021.

[189] Prince William County. Prince William County Approves New Organic Waste Processing Facility. January 2015. https://www.pwcva.gov/assets/2021-04/Organics%20Project%20Web%20Release%20Final%201-20-15.pdf.

Community Outreach and Involvement

Starting an SSO collection program can be difficult due to concerns about storing food waste, potential odors and other nuisances, and the additional effort required. In addition, contamination is possible if organic waste is not properly separated, which can lead to additional processing and sorting costs prior to disposal. The primary source of plastic contamination in food waste streams collected for processing at compost and anaerobic digestion facilities appears to be food packaging and containers, most likely from residential, commercial and institutional sources.[190] The presence of visible plastic particles in finished products reduces their value and marketability. Processing facilities sometimes prohibit food waste streams or reject incoming food waste streams collected for processing at compost and anaerobic digestion facilities due to plastic contamination levels, thus reducing the amount of food waste diverted from landfills.[191] An outreach and education campaign is essential to communicate the need for organic waste separation and diversion and any changes to solid waste program fees, and to educate the public on how to properly separate and store their organic waste for collection and alleviate concerns and misconceptions they might have. ReFED estimates that consumer education campaigns can potentially divert an additional 584,000 tons of food waste in the United States with an economic value of more than $2.6 billion, making them one of the most cost-effective approaches to food waste reduction.[192]

Food Waste Program Marketing

The City of Eugene, Oregon's Love Food Not Waste™ campaign, now servicing citywide residents and more than 150 businesses and 50 schools, has diverted 20,000 tons of material from the landfill since 2011.[193,194] *EPA calculates that diverting this food from the landfill to compost has saved 12,260 MTCO$_2$e in GHG emissions, the equivalent of removing 2,600 passenger cars from the road for a year.*

Key program components include:

- *A city ordinance allowing a 20 percent savings on commercial garbage rates for program participants.*
- *Onsite trainings for employees.*
- *Food scrap collection containers provided free of charge.*
- *Training manuals and marketing materials on reducing contamination for businesses and schools available on a dedicated website and in an interactive video.*

Manage Odor and Other Nuisance Complaints

Although minimizing the amount of organic waste in landfills can reduce issues with odors, pests and other nuisances, these issues can also arise at composting and AD facilities if not addressed proactively.

190 U.S. EPA. Emerging Issues in Food Waste Management: Plastic Contamination. August 2021. https://www.epa.gov/system/files/documents/2021-08/emerging-issues-in-food-waste-management-plastic-contamination.pdf.

191 Ibid.

192 ReFED. A Roadmap to Reduce U.S. Food Waste by 20 Percent. 2016. https://www.refed.com/downloads/ReFED_Report_2016.pdf.

193 City of Eugene, Oregon. Frequently Asked Questions. https://www.eugene-or.gov/Faq.aspx?QID=668. Accessed December 14, 2020.

194 Mattson, Anna. What Are Eugene's Favorite Businesses Doing to Limit Food Waste? Daily Emerald. November 15, 2019. https://www.dailyemerald.com/news/what-are-eugene-s-favorite-businesses-doing-to-limit-food-waste/article_828fc2aa-071f-11ea-9b68-d3f598f6edda.html. Accessed February 22, 2021.

Composting and AD produce many of the same chemical byproducts of organic waste degradation, and issues with odor have shut down composting programs across the country. However, proper management of these processes (e.g., aeration and turning of compost, containment and treatment of AD byproducts) can mitigate these potential issues. Before building a facility, developers could conduct an odor study and engage the community about the project to increase awareness and address community concerns. The facility design should also incorporate redundant odor mitigation systems.[195]

Section 6: Policies and Programs for Promoting Organic Waste Diversion

Policies and programs play an important role in the amount of organic waste diverted from landfills. This section summarizes example policies and programs that support organic waste management projects. This is not intended to be a comprehensive list.

Policies

State Disposal Bans

As of 2019, 28 states have banned yard waste from disposal in landfills; many of these bans have been in effect since the late 1980s or early 1990s.[196] The bans have spurred investment in processing facilities. In 1988, there were 651 composting facilities in the states with bans, compared with 2,981 in 1992, 3,357 in 2004, 3,453 in 2013 and 4,713 in 2017 (counts reflect the subset of states that responded to a national survey each year).[197,198,199,200] Furthermore, the five states with the largest number of yard waste composting facilities (Ohio, Wisconsin, Florida, New Hampshire and South Dakota, with 1,032 facilities total) also have yard waste disposal bans.[201]

> Harvard Law School's Food Law and Policy Clinic and the Center for EcoTechnology published a toolkit in 2019 named "Bans and Beyond: Designing and Implementing Organic Waste Bans and Mandatory Organics Recycling Laws." The toolkit compiles information about organic waste bans including current policies, costs and benefits, best practices, challenges and solutions, and alternatives to bans.

Five states (California, Connecticut, Massachusetts, Rhode Island and Vermont) have established food waste disposal bans. Since the requirements of these bans are still being phased in (the earliest implementation date was 2014), data are limited on how successful food waste bans are in spurring investment in organic waste collection and processing projects. However, a recent Massachusetts survey showed a 160 percent increase in organic waste collection employees and a 190 percent increase in processing employees between 2010 and 2016, as well as a nearly $200,000 per year capital investment

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195 Johnston, Marsha W. Managing Odors at Anaerobic Digestion Plants. BioCycle 58(3): 39. March 8, 2017. https://www.biocycle.net/2017/03/08/managing-odors-anaerobic-digestion-plants/.

196 Other organizations are tracking state-level disposal bans of food and yard wastes. One example is the map provided by the US Composting Council at https://www.compostingcouncil.org/page/organicsbans. Accessed November 29, 2021.

197 Simmons, P., Goldstein, N., Kaufman, S.M., and N.J. Themelis. The State of Garbage in America: 15th Nationwide Survey. BioCycle 47(4): 26. 2006.

198 Ibid.

199 Platt, Brenda, and Nora Goldstein. State of Composting in the U.S. BioCycle 55(6): 19. July 16, 2014. http://www.biocycle.net/2014/07/16/state-of-composting-in-the-u-s/. Survey results from 39 states that responded.

200 Goldstein, Nora. The State of Organics Recycling in The U.S. BioCycle 58(9): 22. October 4, 2017. https://www.biocycle.net/2017/10/04/state-organics-recycling-u-s/. Survey was completed by 43 states and D.C.

201 Ibid.

for organic waste processing during the same time.[202] Likewise, in Connecticut, Quantum Biopower reported the state's organic waste disposal ban was one of the factors it considered before investing in the food waste AD project in Southington.[203]

Local Organic Waste Diversion Goals or Bans

Solid waste management has historically been a locally driven issue; many communities have announced or established waste reduction or diversion goals (e.g., zero waste), with an emphasis on organic waste reduction, in recent years. Several of these local efforts are voluntary programs, but some larger cities including New York City, San Francisco, Seattle and Austin (Texas), have passed ordinances prohibiting disposal of food wastes, particularly commercial and institutional organic wastes, recognizing more food waste is collected from schools, restaurants, hotels and multi-family residences.

Example Voluntary Program
In 2011, Portland, Oregon, expanded its residential yard waste program to include food waste. Yard debris and food scraps are collected weekly from roll carts at residences. The combined organic waste is sent to nearby commercial composting facilities. In 2010, prior to this change, diversion of yard waste averaged 523 pounds per household; the rate nearly doubled by 2018, to 1,030 pounds per household, due to both the inclusion of food waste in the program and a change to weekly collection. During the first 10 years since food waste started being accepted, the city has collected nearly 800,000 tons of food and yard wastes and created enough compost to benefit 1,500 acres of farmland.[204,205,206]
Example Required Program
The City of Palo Alto, California, collects food and yard wastes and other degradable materials through a contractor company as part of the city's goal to reduce GHG emissions 80 percent below 1990 levels by 2030. The city phased in a composting and recycling ordinance requiring recyclables and composting in April 2016 for larger commercial sector generators, multi-family buildings and food service generators. In 2017, it expanded to smaller commercial generators and by January 2018 covered all commercial customers. To comply, the ordinance requires customers to subscribe to the recycling and compost collection, place collection containers in convenient locations, train and educate stakeholders about waste sorting, and sort the waste. The city sends the organic materials to the ZWEDC facility in San Jose, where they are anaerobically digested.[207,208]

202 ICF. Massachusetts Commercial Food Waste Ban Economic Impact Analysis. Prepared for the Massachusetts Department of Environmental Protection. December 2016. Table 1. https://www.mass.gov/doc/massachusetts-commercial-food-waste-ban-economic-impact-analysis/download.

203 Portz, Tim. Diversion Dynamics. April 12, 2017. http://biomassmagazine.com/articles/14306/diversion-dynamics. Accessed November 29, 2021.

204 City of Portland, Oregon. Residential Compost Tips. https://www.portland.gov/bps/garbage-recycling/residential-compost-tips. Accessed November 12, 2021.

205 City of Portland, Oregon. Bureau of Planning and Sustainability. FY 2020-21 Requested Budget. January 29, 2020. p. 99. https://www.portlandoregon.gov/cbo/article/752708. Accessed November 12, 2021.

206 City of Portland, Oregon. Happy 10-year Compost-iversary, Portlanders! https://www.portland.gov/bps/garbage-recycling/news/2021/10/27/happy-10-year-compost-iversary-portlanders. Accessed November 12, 2021.

207 City of Palo Alto, California. Recycling and Composting Ordinance. Last updated October 13, 2021. https://www.cityofpaloalto.org/Departments/Public-Works/Zero-Waste/Zero-Waste-Requirements-Guidelines/Recycling-and-Composting-Ordinance.

208 City of Palo Alto, California. Zero Waste FAQs. https://www.cityofpaloalto.org/Departments/Public-Works/Zero-Waste/What-Goes-Where/FAQ#section-3.

The following stakeholder groups track additional information about state and local policies:

- The American Biogas Council maintains a brief summary of key policy implementation milestones of state and local policies with mandatory or voluntary organic waste diversion policies that may help spur investment in biogas opportunities.
- The Northeast Recycling Council has developed a state-level report on disposal bans and mandatory recycling in the United States, which catalogues policies affecting a wide variety of waste materials banned by landfills, including food and yard wastes.
- ReFED's Food Waste Policy Finder tracks several types of state policies to reduce food waste, including organic waste bans and recycling laws.

Diversion Goals

California's AB 939 law in 1989 required local jurisdictions to meet incremental organic waste diversion goals, setting a goal of 25 percent diversion by 1995 and 50 percent by 2000. The legislation also required local jurisdictions to establish integrated solid waste management planning and implementation programs. The legislation included penalties of up to $10,000 per day for municipalities in noncompliance with the goals. Built into the legislation were extension provisions if a municipality had a plan in place to meet the extended timeline. This policy, along with a network of strong partners, helped make San Francisco the first major city to institute an SSO waste program.[209]

Programs

Voluntary or Mandatory SSO

For more information on specific programs, *BioCycle* conducts a periodic survey of residential food waste collection programs in U.S. municipalities.

Between 2009 and 2017, the number of communities with access to SSO collection more than tripled (from 90 to 326) and the number of households with access to SSO collection grew by about 170 percent from 1.86 million to nearly 5.1 million.[210,211] There are residential organic waste diversion programs across the United States—about 200 curbside food waste collection programs, as documented in several studies or reports. A 2017 survey found these programs served about 5 million households, or about 4 percent of the U.S. population.[212]

Mandatory SSO subscription services require either all customers or a targeted subset of customers such as commercial entities above a certain size to register for organic waste collection. This approach, while mandated, recognizes that different customers have different organic waste generation profiles and can match the appropriate hauler and ultimate end use to the volume and type of organic waste generated.

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209 Platt, Brenda, and Nora Goldstein. State of Composting in the U.S. BioCycle 55(6): 19. July 16, 2014. http://www.biocycle.net/2014/07/16/state-of-composting-in-the-u-s/.

210 Streeter, Virginia and Brenda Platt. Nationwide Biocycle Survey: Residential Food Waste Collection Access in the U.S. BioCycle. December 2017. http://www.biocycle.net/17_10_06_1/0002/BioCycle_ResidentialFoodWaste_2017.pdf.

211 Streeter, Virginia and Brenda Platt. Residential Food Waste Collection Access in the U.S. BioCycle 58(11): 20. December 6, 2017. https://www.biocycle.net/2017/12/06/residential-food-waste-collection-access-u-s/. Accessed February 22, 2021. Tables found in print edition only.

212 Streeter, Virginia and Brenda Platt. Nationwide Biocycle Survey: Residential Food Waste Collection Access in the U.S. BioCycle. December 2017. http://www.biocycle.net/17_10_06_1/0002/BioCycle_ResidentialFoodWaste_2017.pdf.

The number of voluntary SSO programs has also been growing and expanding the service to additional households. In this model, there is no requirement to participate, but municipalities with high recycling rates, existing yard waste collection programs or high tipping fees for traditional MSW disposal may be good candidates for SSO because the jurisdiction is likely to see high participation in the program, in the absence of any mandate. In addition, these municipalities can leverage some existing collection infrastructure and logistics and offset costs of the program by avoided disposal fees. With a voluntary program, effective marketing of the program and providing incentives can increase participation rates to achieve economies of scale to operate the program. For example, Takoma Park, Maryland, offers program participants complimentary kitchen collection containers and the opportunity to obtain free compost each year.[213] Repeated outreach efforts may be needed to maintain long-term participation in voluntary programs. In 2016, WM and the King County Solid Waste Division, Washington, conducted a study of 450 households to assess how tagging curbside collection carts with SSO program information affects how many households participate in the program as well as how much SSO is collected.[214] Results showed that cart tagging increased the number of new households participating in the program. In addition, tagging increased food capture rates by approximately 9 percent.

Pay-As-You-Throw

Pay-As-You-Throw (PAYT) programs require waste generators to pay for waste disposal services as a function of the amount and types of waste disposed of instead of a flat fee structure. In these programs, the rate to dispose of trash is typically higher than the rate to put items in recycling or SSO collection, or there may be no fee for recyclables or SSO. The purpose of PAYT programs is to create an economic incentive to generate less waste and recycle more.[215] The size of containers for each material type and the collection frequency of each material type may vary under this type of program. Communities that implement unit-based PAYT pricing generally see a decrease in overall waste production.[216] With regard to a specific impact on organic waste, a 2017 study found that cities with PAYT are more likely than those without to prioritize waste diversion and have a curbside food scrap collection program. The study also concluded that given the strong association between PAYT and SSO, municipalities may want to expend their efforts on piloting holistic PAYT unit-pricing schemes first, which can then serve as a foundation for organic waste management as well as other waste diversion pilot programs.[217]

Reduced Trash Collection

Reducing MSW collection frequencies can provide more incentive for program participants to place all organic materials in the proper SSO container to avoid smells and odors. For example, Portland, Oregon, offers trash collection every other week and weekly organic waste collection, depending on the type of customer. In addition to directly "nudging" participants to put more of their organic waste in the SSO container, this program can also help reduce collection costs for traditional trash pickup.

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[213] City of Takoma Park, Maryland. Food Waste Collection. https://takomaparkmd.gov/government/public-works/curbside-collection-services/food-waste-collection/. Accessed December 29, 2021.

[214] Morrigan, McKenna, Hervin, Kirstin, and Omkar Aphale. Increasing Residential Food Waste Diversion Behavior through Promotional Cart Tags. Poster presentation at 2017 ISWA World Congress and WASTECON. September 2017.

[215] U.S. EPA. Pay-As-You-Throw. https://archive.epa.gov/wastes/conserve/tools/payt/web/html/index.html.

[216] Connecticut Department of Energy & Environmental Protection. Save Money and Reduce Trash (SMART). https://portal.ct.gov/DEEP/Reduce-Reuse-Recycle/Payt/Save-Money-and-Reduce-Trash.

[217] Pollans, Lily Baum, Krones, Jonathan S., and Eran Ben-Joseph. 2017. Patterns in Municipal Food Scrap Programming in Mid-Sized U.S. Cities. Resources, Conservation & Recycling 125(2017): 308-314. https://doi.org/10.1016/j.resconrec.2017.07.001.

Pilot Programs

Because SSO waste management can be such a significant change from historical waste disposal practice, pilot programs can provide meaningful data to better understand local waste generation habits to inform service delivery options and necessary investments in organic waste infrastructure. A pilot program may gather real-time data on participation rates, set-out rates, truck capacity, route timing and seasonal variations as well as provide lessons learned. In addition, a pilot program may ask participants for feedback via survey to gather input on behavior changes and perceptions of the program.

Phased Approach in San Antonio, Texas[218]

In 2010, the City of San Antonio adopted its 10-year plan to enhance recycling efforts, with a focus on providing each resident convenient access to recycling services while also improving recycling options in the ICI sector.

The city initiated a pilot organic waste collection program with 28,000 households. The program expanded to 190,000 households after the initial phase and, in 2017, expanded to all 350,000 residential customers, with weekly curbside recycling (blue), organic waste (green) and garbage (brown) collection in a three-cart, color-coded collection program. The organic waste is sent to a nearby compost facility operated by New Earth.

The city conducted extensive outreach and took a phased approach throughout the scale-up of the program. Figure 6-1 outlines the timeline for the three components of the plan: residential recycling, organic waste collection and PAYT pricing systems. City officials held more than 80 community meetings to educate the public about the switch to a PAYT pricing structure, commissioned an ad campaign, "Trim Your 'Waste' Line," on its collection vehicles and issued cart tags with pamphlets to help residents choose the appropriate cart size.

As of 2017, the city had increased its overall waste diversion to 33 percent, substantially up from 4 percent in 2005 and on the way to 60 percent by 2025.

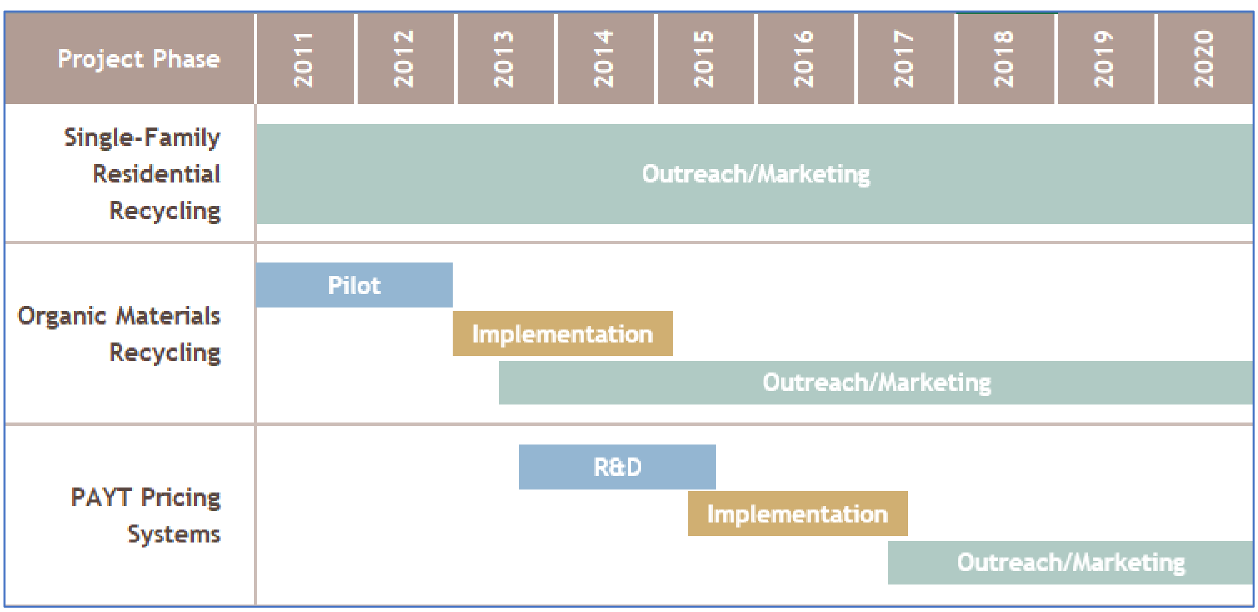

Figure 6-1. Timeline for Implementing San Antonio's Solid Waste Management Plan.[219]

[218] McCary, David. San Antonio, Texas. San Antonio's Recycling and Resource Recovery Plan. Presented at 2017 TCEQ Conference. San Antonio, Texas. May 17, 2017. https://slideplayer.com/slide/13517752/.

[219] Figure adapted from McCary, David. Creating a Pathway to Zero Waste in the City of San Antonio. U.S. Mayors Conference. October 2011.

Programs Focused on ICI Sources

The large quantity of organic waste generated from the ICI sector offers significant opportunities for emission reductions. Waste disposal is peripheral to the core missions of ICI sources, though, so organic waste diversion programs should be designed to make a business case for participating in the program while minimizing the costs and labor time required for ICI stakeholders to participate. As discussed in Section 3, some jurisdictions provide free or subsidized containers or training assistance to increase participation from this sector. In addition, ICI waste generators who participate in organic waste diversion can save directly on regular trash collection because they will need smaller trash containers or reduced trash pickup frequency. In some areas, lower tipping fees at composting facilities than at landfills can also reduce the costs charged to ICI generators through their hauling contracts.

Franchise Agreements to Increase Diversion in ICI Sector: recycLA

Many municipalities do not directly provide collection services to the ICI sector, rather they contract with a private third party. The City of Los Angeles, California, awarded seven vendors contracts to provide collection to nearly 65,000 customer accounts in 11 franchise zones serving the ICI sector. Each vendor was required to demonstrate its ability to achieve the city's cost-effective service delivery goals while also achieving waste diversion from landfills. Collectively, the franchises must divert 1 million tons annually from landfills by 2025 or face heavy penalties. The agreements include stipulations for monitoring the segregation of collected materials and the diversion requirements for landfill reduction, recycling and organic waste programs.[220,221]

Conclusion

Food waste is the single largest component of landfilled MSW in the United States and it decays quickly, generating LFG, which is typically about 50 percent methane. Methane is 28 to 36 times more effective than carbon dioxide at trapping heat in the atmosphere over a 100-year timeframe. This means keeping food (and other organic) waste out of landfills will help the United States address climate change by reducing methane emissions from the waste sector, the third-largest source of U.S. anthropogenic methane emissions. Modeling shows that diverting just 25 percent of the currently landfilled U.S. food waste would reduce life cycle GHG emissions by approximately 30 percent. Cities that have reduced the amount of organic waste being landfilled have seen a decrease in GHG emissions in their inventories—for example, Seattle saw a 25 percent reduction in GHG emissions in the food waste and mixed organics portion of its waste sector inventory from 2008 to 2018, reflecting reduced landfill methane emissions.

There are many options for preventing or mitigating methane emissions from organic waste. Effective organic waste management solutions for an individual community can vary widely depending on many factors including the size of the program, types of generator customers, local market conditions for compost and AD end products, feasibility of incorporating organic waste into existing processing and treatment infrastructure, and state and local policies and regulations affecting those programs. There is no one-size-fits-all program, but the examples of best practices included in this document from small towns to large cities across the United States may help communities adopt a more sustainable approach to organic waste management and reduce GHG emissions.

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220 Coca, Karen, et al. City of Los Angeles Exclusive Franchise System for Municipal Solid Waste Collection and Handling. Presented at 2017 SWANApalooza: Road to Zero Waste Conference. March 27–30, 2017.

221 Zaldivar, Enrique. Message from the Director. LA Sanitation & Environment. https://www.lacitysan.org/san/faces/wcnav_externalId/s-lsh-au-i-md?_adf.ctrl-state=10107msbz0_9&_afrLoop=3829284438389672#!.

Appendix A
Incentives and Funding Resources

This appendix summarizes example incentives and other funding-related items, offering links to more information. It includes incentives and funding sources that encourage diversion of organic waste as well as those that encourage energy generation from organic waste such as biogas from AD. This is not intended to be a comprehensive list of incentives and funding sources that can be used for organic waste management projects.

Waste Management Grants and Loans

California: The Greenhouse Gas Reduction Grant and Loan Programs offer competitive grants and loans to reduce GHGs and divert materials from landfills by expanding existing capacity or establishing new facilities within the state.

- The purpose of the Organics Grant Program is to reduce the amount of California-generated green materials, food materials or alternative daily cover being landfilled.
- One purpose of the Greenhouse Gas Reduction Loan Program is to provide funds to support new or expanded organic waste management infrastructure, such as composting and AD facilities.

California Organics Grant
CR&R Incorporated received a $3 million grant in 2014[222] to double the capacity of its under-construction AD project in Perris, California. Initially, when the digester began operations in 2016, it was using nearly 230 tons per day of high-solid yard and food waste feedstocks to produce biogas for conversion to RNG.[223,224] As of 2017, CR&R was using the CNG in 320 of its waste and recycling collecting vehicles and planned to expand CNG to be the designated fuel for its full 900-vehicle fleet.[225] A pipeline also transports the RNG to a natural gas pipeline.[226,227]

Iowa: The Solid Waste Alternatives Program offers financial assistance in the form of forgivable loans, zero-interest loans and 3 percent interest loans for projects that reduce the amount of solid waste generated or landfilled in the state.

Massachusetts: The Sustainable Materials Recovery Program offers grants for recycling, composting, reuse and source reduction activities that will increase diversion of MSW from disposal. The program's

222 CalRecycle. Fiscal Year 2014–15 Organics Grant Program (ORG1) Awards. https://www2.calrecycle.ca.gov/Docs/Web/113976. Accessed February 23, 2021.

223 Relis, Paul. CR&R Anaerobic Digestion Project. CR&R Environmental Services. CR&R Anaerobic Digestion Project. Presented at Act Expo & NGV Global 2014. May 7, 2014. http://www.gladstein.org/pdfs/ACTE2014Presentations/3-5RenNatGasLowCarbonOps/4PaulRelis.pdf.

224 Miller-Coleman, Nicole. Perris Facility to Meet State's Environmental Goals. San Diego Tribune. July 29, 2017. http://www.sandiegouniontribune.com/news/sd-tm-0729-digester-20170719-story.html.

225 Energy Vision. 2017. Case Study: CR&R Perris Biodigester. 2017. https://energy-vision.org/case-studies/crr-perris-biodigester/. Accessed December 15, 2020.

226 Coker, Craig. Pipeline Injection of Biomethane in California. BioCycle. March 12, 2018. https://www.biocycle.net/pipeline-injection-biomethane-california/.

227 Relis, Paul. The Law Policy and Regulatory Matrix Driving Biomethane in California. CR&R. Panel discussion at U.S. Biogas 2017. October 27, 2017.

grants are organized into several categories, including waste reduction and organics capacity projects. Additionally, the Office of Energy and Environmental Affairs provides a matrix of financial and technical assistance options for AD projects.

New York: Various state agencies administer funds or award grants using the Environmental Protection Fund. Eligible projects include infrastructure for composting or AD facilities for food scraps.[228,229]

Federal: EPA's Sustainable Management of Food effort includes a webpage about funding opportunities related to the food system, including EPA grants and other federal agency grants. EPA's SMM Program offered an opportunity for AD-related funding in 2020; the Program announced that 12 organizations received a total of $3 million to support AD projects in this funding opportunity's inaugural year.

The USDA Rural Development program offers solid waste management grants focused on reducing water pollution by providing funding, technical assistance and training to improve the planning and management of solid waste sites.

USDA Solid Waste Management Grant

The Hancock County Planning Commission in Maine was awarded $17,000 in 2016 to fund technical assistance to communities to reduce the food disposal rate through composting, providing collection bins and holding collection events.[230]

The Database of State Incentives for Renewables and Efficiency (DSIRE), funded by the U.S. Department of Energy, is a comprehensive source of information on state, local, utility and select federal incentives that promote renewable energy resources. DSIRE offers further details on the example incentives included in this section as well as others.

Renewable Energy Incentives

Massachusetts: The state's Clean Energy Center supports the development of facilities that convert SSO materials and sewage sludge into heat, electricity or CNG through its Commonwealth Organics-to-Energy program. This program awards grants for implementation and pilot projects, feasibility studies, and technical studies/services.

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228 State of New York. Methane Reduction Plan. May 2017. https://www.dec.ny.gov/docs/administration_pdf/mrpfinal.pdf.

229 New York Department of Environmental Conservation. State Assistance Programs (Grants) for Waste Reduction, Recycling and Household Hazardous Waste Programs. https://www.dec.ny.gov/chemical/4776.html. Accessed December 29, 2021.

230 USDA. Solid Waste Management FY 2016 Grant Recipients. https://www.rd.usda.gov/files/UWP-SWMrecipients2016.pdf.

Massachusetts Organics to Energy Grant
CRMC received grant funding in late 2012 to construct its CRMC Bioenergy Facility, located at the Crapo Hill Landfill in New Bedford, Massachusetts. CRMC applied the funding toward purchasing and installing equipment in the facility.[231] This AD facility generates biogas that supplements an existing LFG electricity project at the landfill.

Multiple States: A renewable portfolio standard (RPS) is a legislative requirement for utilities to generate or sell a certain percentage (which varies widely by state) of their electricity from renewable energy sources. Many of the state RPSs include MSW, biomass, biogas, LFG and RNG as eligible renewable resources. In a few instances, cities or utilities have implemented their own RPSs in the absence of state-wide programs. Some states or territories have enacted renewable portfolio goals in lieu of actual mandates.

Federal: USDA's Rural Energy for America Program (REAP) includes a Renewable Energy Systems & Energy Efficiency Improvement Loans & Grants program to provide guaranteed loan financing and grant funding to eligible projects. Funds can be used to purchase, install and construct renewable energy systems including AD projects.

Fuel Credits

California: The Low Carbon Fuel Standard (LCFS) was designed to encourage the use and production of cleaner low-carbon fuels in the state. The LCFS parameters are expressed in terms of the "carbon intensity" (CI) of gasoline and diesel and the fuels that replace them. A fuel's CI is the measure of emissions associated with producing and consuming the fuel and is based on a complete life cycle analysis. Fuels with a CI lower than the annual standard set by the LCFS generate credits, while fuels with a CI higher than the annual standard generate deficits. The LCFS includes various fuel pathways, including options for feedstocks of AD biogas or LFG.[232]

Oregon: The Clean Fuels Program seeks to reduce the CI of transportation fuels in Oregon. It functions very similarly to California's LCFS described above and includes pathways with AD biogas or LFG as the feedstock.[233] The program includes a standard for gasoline and its fuel substitutes and a standard for diesel and its fuel substitutes.

Federal: Congress created the RFS program to expand the nation's renewable fuels sector (for transportation) and reduce reliance on imported oil. The program requires obligated parties to meet a Renewable Volume Obligation based on the amount of petroleum-based fuels they produce or import annually, and one way to meet the obligation is by obtaining credits known as Renewable Identification Numbers (RINs). To generate RINs, the fuel must meet one of the EPA-approved pathways. One of these is cellulosic biofuel (RIN category D3), which can be produced from biogas from landfills,

[231] CRMC Bioenergy LLC. Final Construction Project Report for the CRMC Bioenergy Facility. Prepared for the Massachusetts Clean Energy Center. February 13, 2015. https://files.masscec.com/research/CRMCPilot.pdf.

[232] California Low Carbon Fuel Standard. California Code of Regulations, Title 17, Sections 95480-95489; 95491-95497. https://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf.

[233] Oregon Department of Environmental Quality. Oregon Approved Carbon Intensity Values. File cfp-All-CIs.xlsx. July 22, 2016. https://www.oregon.gov/deq/ghgp/cfp/Pages/Clean-Fuel-Pathways.aspx. Accessed February 24, 2021.

municipal WRRF digesters, agricultural digesters and separated MSW digesters. Another is advanced biofuel (RIN category D5), which can be produced from separated food waste digesters.

Renewable Fuel Standard

The Ohio Bio-Energy Digester project in Columbus, Ohio, is producing biogas from wastewater, food scraps and FOG. The biogas is recovered to generate electricity and renewable CNG for vehicle fuel. The facility is a registered renewable fuel producer of biogas under the RFS program.[234] This project also received Ohio state funds related to alternative energy and green job creation.[235]

Voluntary Carbon Markets

A carbon offset (or credit) is equivalent to 1 $MTCO_2e$ of emission reductions from an unregulated source (i.e., an entity that voluntarily reduces its emissions). The voluntary destruction of biogas methane has market value and can be sold in voluntary or compliance markets. There is not a single market or single standard for the trading of these credits.[236] Voluntary markets operate using several different standards and protocols for determining eligibility and verifying credits.

- Carbon standards include the American Carbon Registry, The Climate Registry, Gold Standard and Verified Carbon Standard. Organizations like these certify qualifying emission reduction projects so entities needing to mitigate their own carbon footprints can buy the credits.
- Protocols outline eligibility, monitoring, recordkeeping, quantification and reporting requirements. Many are applicable to biogas projects, including Climate Action Reserve (CAR) Organic Waste Digestion, CAR Organic Waste Composting, Greenhouse Gas Protocol and Recycling and Composting Protocol.

Carbon Credits

Lenz Enterprises' organic waste composting project in Stanwood, Washington, registered more than 10,600 emission reduction credits through CAR for 2014 and more than 17,900 credits for 2015. By composting food waste and food-soiled paper that would otherwise be landfilled, the facility avoids methane generation and produces an organic compost product with multiple environmental benefits.[237,238]

234 U.S. EPA. Registered Companies and Facilities in Fuel Programs. https://www.epa.gov/fuels-registration-reporting-and-compliance-help/registered-companies-and-facilities-fuel-programs. Accessed March 27, 2017.

235 Energy Vision and CALSTART. 2012. Renewable Natural Gas (RNG)—The Solution to a Major Transportation Challenge. 2012. https://energy-vision.org/wp-content/uploads/2019/10/EV-RNG-Facts-and-Case-Studies.pdf.

236 U.S. EPA. Landfill Gas Energy Project Development Handbook. Chapter 5: Landfill Gas Contracts and Regulations. LMOP. https://www.epa.gov/lmop/landfill-gas-energy-project-development-handbook.

237 ClimeCo. ClimeCo Announces 1st Carbon Offset Credit Registration for Lenz Composting Project: Washington State Organic Waste Composting Project Receives 10,611 Climate Action Reserve CRTs. January 4, 2016. https://www.prweb.com/releases/2016/01/prweb13148347.htm. Accessed February 24, 2021.

238 Climate Action Reserve Project Database. Project ID: CAR1096. https://thereserve2.apx.com/mymodule/reg/prjView.asp?id1=1096. Accessed February 24, 2021.

Appendix B
Tools and Resources for Evaluating Organic Waste Management Options

EPA and other organizations have developed many pertinent tools and resources to help public or private entities involved in making decisions or policies related to organic waste management. This appendix describes a selection of these items as a resource to stakeholders.

EPA Tools and Resources

Anaerobic Digestion—Project Screening Tool. EPA and the Climate & Clean Air Coalition developed this Excel-based tool to help with feasibility assessments of AD projects for a variety of feedstocks including organic MSW, agricultural residues and wastewater. Users of the tool can estimate the biogas and digestate production potential of a proposed AD project and end use options for each.

Anaerobic Digestion Facilities Processing Food Waste in the United States: Survey Results. Beginning in 2017, EPA has annually surveyed operators of AD facilities that accept food waste and published reports on the findings. EPA includes three types of AD facilities in the survey: stand-alone food waste digesters, on-farm digesters that co-digest food waste and WRRF digesters that co-digest food waste. The reports provide information such as facility processing capacity, amount of food waste processed, feedstock types and sources, biogas cleaning systems, biogas production and use, and digestate use.

Biogas Toolkit. EPA designed the Biogas Toolkit as a centralized knowledge hub for biogas project stakeholders to search and browse for information and resources that meet their specific needs. At its launch in 2020, it included more than 30 tools and other resources compiled from several EPA programs.

Co-Digestion Economic Analysis Tool (CoEAT). EPA developed an initial economic feasibility tool and corresponding user's manual to assist decision-makers who are considering adding food waste or other organic feedstocks into co-digestion applications at water resource recovery facilities, farms or food processing facilities.

Cost Estimating Tool for Managing Source-Separated Organic Waste (OrganEcs). The Climate & Clean Air Coalition and EPA developed this Excel-based tool for estimating the costs associated with an organic waste management project, including high-tech wet or dry AD, low-tech wet AD and open air composting with or without forced aeration. Local governments, waste professionals, policymakers, facility operators and project developers can use the tool to help in making financial decisions related to organic waste management.

Excess Food Opportunities Map. EPA developed the Excess Food Opportunities Map with the goal of diverting excess food away from landfilling and toward beneficial use. The map helps bridge the gap between potential generators of excess food and potential recipients who can use it. It displays the locations of nearly 1.2 million excess food generators in the ICI sector and about 5,000 potential recipients, as well as communities with SSO programs.

Managing and Transforming Waste Streams: A Tool for Communities. EPA developed this planning tool (available in web and spreadsheet format) featuring a table of 100 measures communities can use to reduce waste and recover materials. The tool can help local and tribal governments learn how to shift their communities' solid waste stream away from disposal and toward waste reduction, materials reuse and recovery. The tool includes a "Material or Product Group" field with a category named "Organics" that can be used to filter for policies or programs involving organic waste. It also offers a browse by topic feature that shows all the topic options on a single page.

Municipal Solid Waste Decision Support Tool (MSW DST). EPA and the U.S. Department of Energy developed this comprehensive tool to aid solid waste planners in evaluating the cost and environmental aspects of integrated MSW management strategies. The tool enables users to simulate existing MSW management practices and conduct scenario analyses of new strategies based on cost and environmental objectives. The tool includes multiple design options for waste collection, transfer, materials recovery, composting, waste-to-energy and landfilling.

Overview of RNG from Biogas. This resource from LMOP, AgSTAR and Natural Gas STAR provides key information about the creation of RNG from biogas, including feedstocks, delivery and use options, benefits, counts and examples of RNG projects, processes for upgrading biogas to RNG, and policies and incentives for RNG project development.

Tribal Waste Management Program Sustainability Evaluation Tool. EPA developed this Excel-based tool to help Tribal leaders assess their current waste management practices and identify areas where sustainability could be introduced. Tribes can self-evaluate or have a third party evaluate their program using the tool's seven key indicators.

Waste Reduction Model (WARM). EPA created WARM to help solid waste planners and organizations track and voluntarily report emission reductions from several different waste management practices. WARM calculates emissions from baseline waste management practices and various alternatives—source reduction, recycling, AD, combustion, composting and landfilling. The tool allows for data inputs for several specific waste types such as food waste, mixed organic waste and yard trimmings.

Other Tools and Resources

Commission for Environmental Cooperation Reports and Resources. The Commission has worked with partners in Canada, Mexico and the United States to help reduce the amount of food loss and waste in North America. They have published several reports on the characterization and management of food loss and waste, as well as a Food Matters Action Kit to teach youth about actions to reduce food waste.

Community Toolkit: Adding Food Waste to a Yard Trimmings Compost Facility. *BioCycle* and the Center for EcoTechnology co-developed this resource to help municipal yard trimmings composting site operators determine if incorporating food waste is feasible. The toolkit includes information on topics such as best practices, regulatory requirements and costs.

Food Loss & Waste (FLW) Protocol. Seven institutions launched the FLW Protocol in 2013 and developed the global Food Loss and Waste Accounting and Reporting Standard (FLW Standard) to provide common language and requirements for quantifying food loss and waste. The FLW Standard includes requirements, guidance, a sample reporting template, case studies and trainings.

Food Matters. The Natural Resources Defense Council (NRDC) partners with cities and other local coordinators to reduce food waste through policies and programs. The Food Matters website offers several guides and other tools and resources to help cities navigate the complexities of this process.

ReFED Tools and Resources. ReFED, a nonprofit organization created to reduce U.S. food waste, offers several tools and other resources on its website. The Food Waste Solution Provider Directory includes information about hundreds of nonprofit and for-profit organizations ready to help implement food waste reduction initiatives. The Food Waste Policy Finder is a tool to research current food waste policies at the federal and state levels and discover best practices for preventing, recovering and recycling more food waste. The Insights Engine is an information hub for food loss and waste data and solutions.

EPA and Other Tools and Resources for the ICI Sector

While the ICI waste generating sector is not the primary audience of this document, jurisdictions may be looking for ways to improve recovery rates for ICI-generated organic waste as the sector produces a large volume of it. There is a variety of outreach tools to encourage behavior change and increase participation in organic waste reduction and diversion programs. Jurisdictions may want to publicize these resources to their ICI customers.

The Center for Ecological Technology developed a toolkit to support organic waste diversion in restaurants and schools.

Fighting Food Waste in Hotels Toolkit. In 2017, the World Wildlife Fund partnered with the American Hotel and Lodging Association and The Rockefeller Foundation to conduct a 12-week pilot study on organic waste in the hotel industry, with plans to compile a report on the data collected during the pilot and create a toolkit to engage the hotel industry in best practices. Hotels in the study saw their food waste decrease between 10 and 38 percent. The resulting Fighting Food Waste in Hotels Toolkit is geared toward full-service hotels but also beneficial to other food service institutions. The toolkit provides the background, tools and resources to help prevent food waste, donate what cannot be prevented but is safe to consume, and divert the remainder from landfilling.

The Food Waste Reduction Alliance released a *Lessons Learned from Fighting Food Waste* guide in 2020 to keep waste from the food manufacturing and processing, food transportation and food retail sectors out of landfills. The Alliance's "Resources" webpage also provides links to many other organizations active in the food waste prevention, reduction or diversion space.

Managing and Transforming Waste Streams: A Tool for Communities. A section of EPA's Transforming Waste Tool is dedicated to resources for training and outreach materials focused on business and institutions as well as recognition programs.

Massachusetts' Supermarket Composting Handbook provides a step-by-step guide to the grocery sector on developing and maintaining an effective food waste composting program.

NRDC released a 10-step quick start guide with examples for starting a compost program at sporting events.