WASTED FOOD MEASUREMENT METHODOLOGY SCOPING MEMO

Expanding EPA's measurement methodology in order to fully capture all potential sources of wasted food in the industrial, residential, commercial, and institutional sectors, as well as develop estimates for the full spectrum of methods used for managing wasted food.

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AD	Anaerobic digestion
AHA	American Hospital Association
ANR	Agency of Natural Resources
BJS	U.S. Bureau of Justice Statistics
BLS	Bureau of Labor Statistics
BSR	Business for Social Responsibility
CBECS	Commercial Buildings Energy Consumption Survey
CBP	U.S. Census Bureau's County Business Patterns
CDC	U.S. Centers for Disease Control and Prevention
DEC	Department of Environmental Conservation
DENR	Department of Environment and Natural Resources
DEP	Department of Environmental Protection
DNR	Department of Natural Resources
DOC	Department of Commerce
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
ERC	Energy Recovery Council
ERS	USDA's Economic Research Service
FAO	Food and Agriculture Organization of the United Nations
FWRA	Food Waste Reduction Alliance
IEc	Industrial Economics, Incorporated
LAFA	Loss-Adjusted Food Availability
MSW	Municipal Solid Waste
NAICS	North American Industry Classification System
NCES	National Center for Educational Statistics
NRDC	Natural Resources Defense Council
NSLP	National School Lunch Program
NYS DOCS	New York State Department of Correctional Services

ReFED	Rethink Food Waste Through Economics and Data
SUSB	Statistics of U.S. Businesses
SMP	State Data Measurement Sharing Program
USDA	U.S. Department of Agriculture
U.S. EPA	U.S. Environmental Protection Agency

Executive Summary

In 2017, the U.S. Environmental Protection Agency (EPA) set out to revise its food measurement methodology to more fully capture flows of excess food and food waste[1] throughout the food system, and to provide more granular annual estimates of generation and management of excess food and food waste to the public. This Scoping Memo describes the measurement methodology EPA has used to date, as well as the enhanced methodology that EPA developed between 2017 and 2019. This enhanced methodology was used to calculate sector-specific estimates of excess food and food waste generation, as well as estimates of how much excess food and food waste was sent to each management pathway, for the year 2016. This Scoping Memo provides detail on the methodologies and studies used, the resulting 2016 estimates, and describes how EPA plans to use the enhanced methodology in its estimates for the "Advancing Sustainable Materials Management: Facts and Figures" report (hereafter referred to as the "Facts and Figures Report").

EPA has collected and reported data on the generation and management of municipal solid waste (MSW) in the United States for more than 30 years. EPA publishes estimates of food waste generation and management in the United States annually in its "Facts and Figures Report". This annual report includes estimates of how much food waste in the commercial, residential, and institutional sectors is generated and managed by composting, landfilling, and combustion with energy recovery.[2]

In order to more accurately estimate how excess food and food waste are managed in the United States, EPA set out to expand its estimation methodology to capture the various methods in which excess food and food waste are managed and to align with the Food Loss and Waste Accounting and Reporting Standard (or "FLW Standard"), which is a global standard that provides requirements and guidance for quantifying and reporting on the weight of food and/or associated inedible parts removed from the food supply chain (Food Loss and Waste Protocol, 2016).

EPA's enhanced food measurement methodology has a broader scope than the "Facts and Figures Report" methodology. On the generation side, the enhanced methodology includes the industrial sector, as well as additional commercial and institutional sectors, including office buildings, military bases, sports venues, food banks, and certain classes of retailers. On the management side, the enhanced methodology includes several additional management pathways.

EPA included the following food waste generating sectors in the enhanced methodology:

- the industrial sector, which is comprised of the food and beverage manufacturing and processing sectors;
- the residential sector;
- the commercial sector, which includes:
    - food retail/wholesale sectors, including supermarkets, supercenters, and food wholesalers;
    - hospitality sectors, including restaurants/food services, hotels, and sports venues;

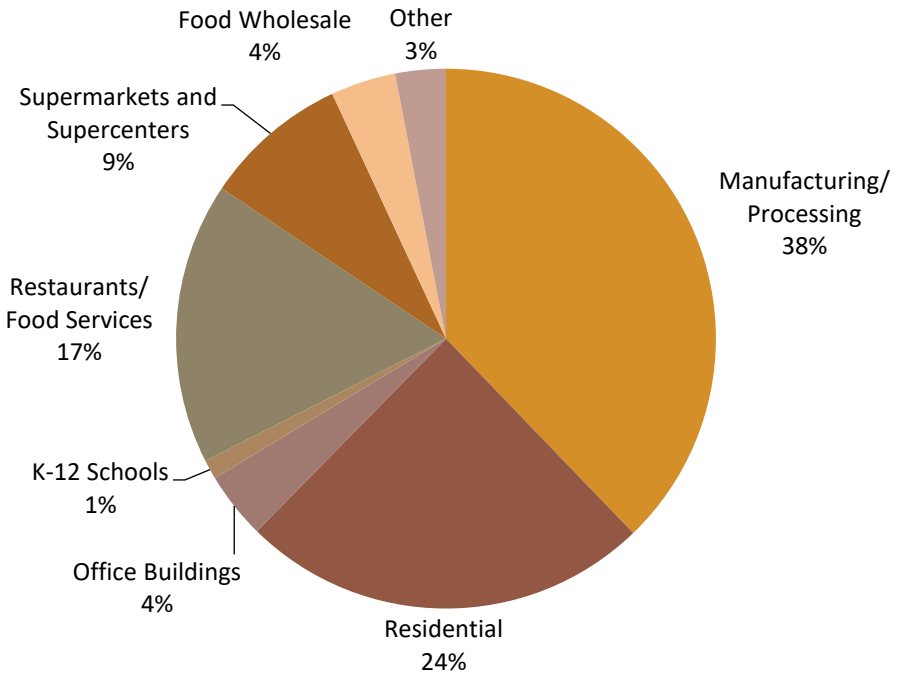
[1] The term "excess food" refers to food that is donated to feed people, while the term "food waste" refers to food such as plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered inedible that are managed in a variety of methods other than donation to feed people. Section 6.1 Appendix A contains a glossary of terms used throughout this memo.

[2] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainable-materials-management

- the institutional sector, including hospitals, nursing homes, military installations, office buildings, correctional facilities, colleges and universities, and K-12 schools; and
- food banks.

Using the enhanced methodology, EPA estimates that in 2016, just over 100 million tons of excess food and food waste were generated in the industrial, residential, commercial, and institutional sectors. Figure 1 shows the percentage of excess food and food waste generated by each sector.

FIGURE 1. PERCENTAGE DISTRIBUTION OF EXCESS FOOD AND FOOD WASTE GENERATION (2016)



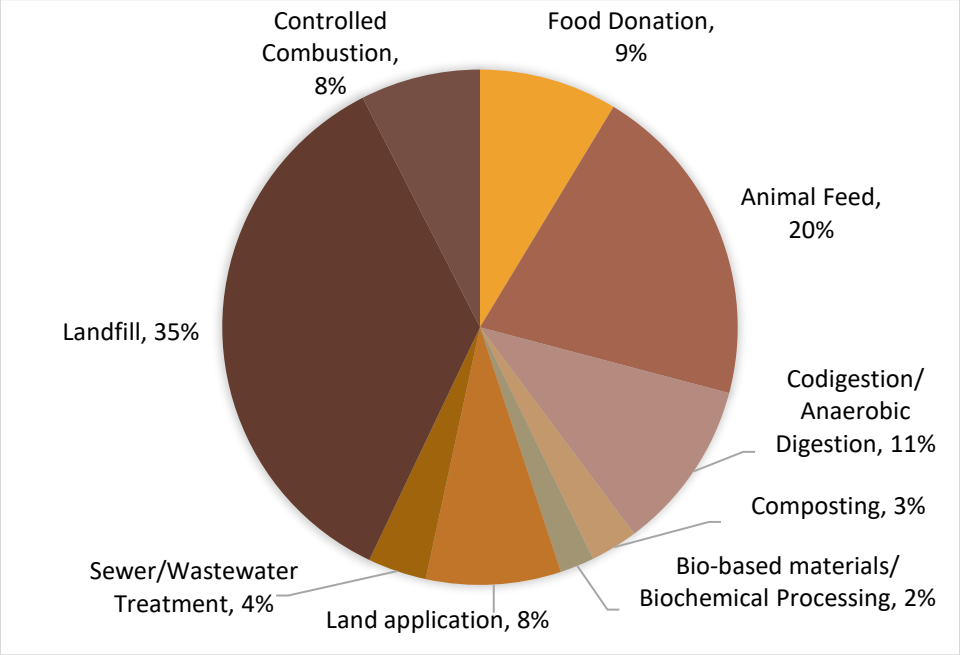
Excess food and food waste are managed in a variety of ways. EPA's enhanced methodology examined the following management pathways (See Section 6.1: Appendix A for definitions of each management pathway), which significantly expand the scope beyond EPA's previous set of management pathways for food waste (i.e., composting, landfill, and combustion) in the "Facts and Figures Report":

- animal feed;
- bio-based materials/biochemical processing;
- codigestion/anaerobic digestion;
- composting/aerobic processes;
- controlled combustion;
- donation
- land application;
- landfill; and
- sewer/wastewater treatment

Using the enhanced methodology, EPA estimates that in 2016, of the excess food and food waste generated in the industrial, residential, commercial, and institutional sectors, just over one third was landfilled, approximately 20% was sent to animal feed, approximately 11% was sent to

codigestion/anaerobic digestion, and approximately 9% was donated. The remaining management pathways each account for 8% or less of total food waste managed. Figure 2 shows the percentage of excess food and food waste that was managed by each management pathway.

FIGURE 2. PERCENTAGE DISTRIBUTION OF EXCESS FOOD AND FOOD WASTE MANAGEMENT (2016)



EPA will use the enhanced measurement methodology, with one exception, to derive updated estimates of excess food and food waste generation and management for the "Facts and Figures Report" starting with the 2018 estimates, which are anticipated to be published in late 2020. The exception is the industrial sector (i.e., food manufacturing/processing), which will not be included in the "Facts and Figures Report". While the food manufacturing/processing sector is an important component of the entire food system, it will not be included in EPA's annual "Facts and Figures Report" because industrial sources of waste are out of scope for the "Facts and Figures Report". Therefore, the "Facts and Figures Report" will include excess food and food waste generation estimates for the residential, commercial and institutional sectors, and estimates of how much excess food and food waste is managed by the following pathways: animal feed, bio-based materials/biochemical processing, co-digestion/anaerobic digestion, composting/aerobic processes, controlled combustion, donation, land application, landfill, and sewer/wastewater treatment.

EPA compared the 2016 food waste estimates published in the "Facts and Figures Report" (U.S. EPA, 2019a) with the 2016 estimates developed using the enhanced methodology (excluding the manufacturing/processing sector). The enhanced methodology results in higher estimates than the "Facts and Figures Report" estimates due to:

- the use of newer studies that often result in higher generation factors;
- the inclusion of additional generator sectors in the commercial and institutional sectors; and
- the inclusion of additional management pathways.

For 2016, the enhanced methodology results in an estimate of 62.23 million tons of excess food and food waste generated in the residential, commercial, and institutional sectors, compared to 40.31 million tons of

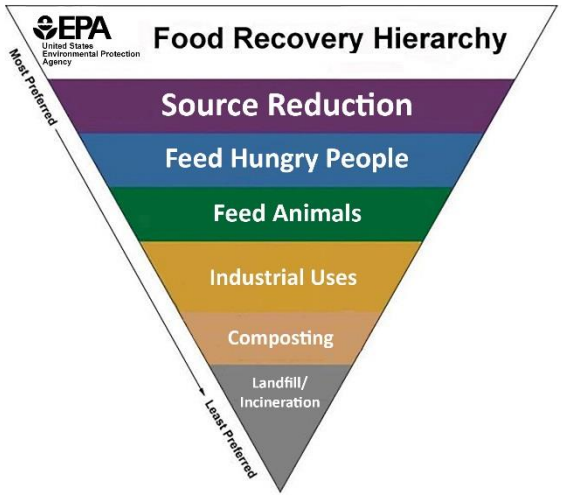
food waste generated in the 2016 “Facts and Figures Report” (U.S. EPA, 2019a). The estimates of the portion of food waste that was sent to landfill are similar: 35.43 million tons using the enhanced methodology, compared to 30.68 million tons in the “Facts and Figures Report” (U.S. EPA. 2019a). Of the 21.92 million tons difference between the two generation estimates for the residential, commercial, and institutional sectors, the majority (18.54 million tons) was managed by methods other than composting, controlled combustion, and landfill. This is due to the fact that the “Facts and Figures Report” methodology would not necessarily have captured excess food and food waste on the generation side that was managed by animal feed, bio-based materials/biochemical processing, co-digestion/anaerobic digestion, donation, land application, and sewer/wastewater treatment.

1 Background

Wasted food is both a growing problem in our society and a largely untapped opportunity. EPA's most recent estimates in its "Advancing Sustainable Materials Management: Facts and Figures" report (hereafter referred to as the "Facts and Figures Report") show that American households, businesses, and institutions generated approximately 40.67 million tons of food waste in 2017 alone and diverted 6.3% for composting (U.S. EPA, 2019b). EPA estimates that more food reaches landfills and combustion facilities than any other single material in our everyday trash, constituting 22% of discarded municipal solid waste (U.S. EPA, 2019b). Additionally, the U.S. Department of Agriculture (USDA) estimates that in 2010, 31% - or 133 billion pounds of the 430 billion pounds of food produced - was not available for human consumption at the retail and consumer levels (i.e., one-third of the food available was not eaten) (Buzby et al., 2014). While the two estimates are quite different due to different methodologies and scopes, they begin to portray the size of this immense challenge.

Through its Sustainable Materials Management Program, EPA is identifying ways to reduce wasted food and thereby limit its negative environmental consequences. 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 how the waste is managed. EPA works to promote innovation and highlight the value and efficient management of food as a resource. Building on the familiar concept of "Reduce, Reuse, Recycle," this approach shifts the view on environmental protection to the entire life cycle of materials to more fully recognize the impacts of the food we waste.

FIGURE 3. EPA'S FOOD RECOVERY HIERARCHY



Increasingly, food is managed in a variety of methods beyond landfilling, combustion and composting. EPA has long recognized that wasted food is handled in a variety of ways, with some methods more preferred than others, as laid out in the food recovery hierarchy. In order to more accurately estimate how wasted food is managed in the United States, EPA set out to expand its estimation methodology to capture the various methods in which wasted food is managed and to align with the Food Loss and Waste Accounting and Reporting Standard (or "FLW Standard"), which is a global standard that provides requirements and guidance for quantifying and reporting on the weight of food and/or associated inedible parts removed from the food supply chain (Food Loss and Waste Protocol, 2016).

EPA, with support from Industrial Economics, Incorporated (IEc), has developed an enhanced measurement methodology, updating the data sources used for estimating excess food and food waste[3] generation and management, and estimating the amount

[3] The term "excess food" refers to food that is donated to feed people, while the term "food waste" refers to food such as plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered

of excess food and food waste that is managed by a variety of methods, including animal feed, bio-based materials/biochemical processing, codigestion/anaerobic digestion (hereafter referred to as "AD"), composting/aerobic processes, controlled combustion, donation, land application, landfill, and sewer/wastewater treatment.[4]

2 Food Measurement Methodology Used to Date in EPA's "Facts and Figures Report"

EPA has collected and reported data on the generation and management of waste in the United States for more than 30 years. EPA publishes estimates of food waste generation and management in the United States annually in its "Facts and Figures Report". This annual report includes estimates of how much food waste is generated, composted, landfilled, and combusted with energy recovery.[5] EPA's most recent articulation of its methodology for the "Facts and Figures Report" is in the memo entitled, "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures – A Methodology Document" (U.S. EPA, 2014).

2.1 Generation Methodology in EPA's "Facts and Figures Report"

In the "Facts and Figures Report", EPA's estimates of food waste generation tonnages from the residential, commercial, and institutional sectors have relied on existing studies conducted by state and municipal governments, industry groups, universities, and other groups. These studies generally measure food waste at the point it is ready to be managed by the traditional MSW system (i.e., composting, landfilling, and combustion), which excludes food that is donated to feed people, used to feed animals, sent down the drain (e.g. via residential food waste disposers), or managed in ways other than landfilling, combustion, and composting.

EPA has estimated residential food waste generation in the "Facts and Figures Report" by establishing a nation-wide per capita estimate, which is then multiplied by the United States population. The estimates were based on curbside sampling studies and household diaries published over the past two decades.

Commercial sector industries that were covered in the "Facts and Figures Report" include grocery stores, full- and limited-service restaurants, and hotels. Institutional sector industries included public and private elementary schools, colleges and universities, correctional facilities, nursing homes, residential hospitals, and short-term stay hospitals. The commercial and institutional food waste generation estimates were based on dozens of industry-specific studies from across the nation that measured food waste generated at specific facilities and businesses and correlated it to facility-specific characteristics (e.g., revenue or the number of employees) to establish equations expressing generation factors (e.g., 3,000 pounds of food waste generated/employee/year in grocery stores). There were multiple studies, and therefore multiple generation factors, available for each industry. EPA scaled up these rates by applying national, industry-specific business statistics (e.g., U.S. Census-reported store sales, number of employees in restaurants, number of patients in hospitals, number of inmates in correctional facilities), which resulted in multiple

inedible that are managed in a variety of methods other than donation to feed people. Section 6.1 Appendix A contains a glossary of terms used throughout this memo.

[4] See Appendix A: Glossary for definitions

[5] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainable-materials-management

food waste generation estimates per industry. An average annual generation estimate was then calculated for each industry, and these values were summed to calculate overall commercial or institutional sector estimates of food waste generated. The national food waste generation estimate in EPA's annual "Facts and Figures Report" was derived by adding the figures calculated for the residential, commercial, and institutional sectors.

2.2 Management Pathway Methodology in EPA's "Facts and Figures Report"

On the management pathways side, EPA developed estimates of food waste composted based on summarizing state-specific data available from state environmental agency websites, published reports, and reported values from EPA's State Data Measurement Sharing Program[6] (SMP). EPA did not extrapolate this data to account for activity in the remaining states, tribes, and territories for which no data were available. MSW compost, which is when single-stream MSW is collected and organics are sorted out for processing at the composting facility, was also included in the total compost estimate, and reflected production from all known sources based on published literature.[7]

EPA then subtracted the estimate of food waste composted from the estimate of food waste generated. This resulted in the estimate of total food waste that was landfilled and combusted with energy recovery.

In 2015, 19.6% of MSW after recycling and composting was combusted with energy recovery, except for major appliances, tires, and lead-acid batteries. Therefore, combustion with energy recovery was estimated to be 19.6% of the food waste not composted. This estimate was derived from the Energy Recovery Council's (ERC) Directory of Waste-to-Energy facilities (ERC, 2018). EPA used this estimate because there is no available material-specific data on combustion with energy recovery for food waste. The combustion with energy recovery rate was calculated by dividing the ERC annual combustion tonnage figure by the sum of ERC annual combustion with energy recovery plus national landfill tonnage. Using a mass balance approach, food waste landfilled was equal to 80.4% of the difference between material generated and recycled.

In summary, EPA's management pathway mass balance approach for food waste has been the following:

- Generation = Composted + Combusted with energy recovery + Landfilled
- Combusted with energy recovery = 19.6% * [Generation – Composted]
- Landfilled = 80.4% * [Generation – Composted]

3 Enhanced Food Measurement Methodology

In 2017, EPA set out to expand its wasted food measurement methodology in order to fully capture as many potential sources of food waste as possible in the industrial, residential, commercial, and institutional sectors, as well as develop estimates for the full spectrum of management pathways used for managing excess food and food waste. This builds on previous scoping work that was summarized in a 2016 memo entitled "Food Waste Management in the United States, 2014" that examined food donation data,

[6] https://www.epa.gov/smm/sustainable-materials-management-us-state-data-measurement-sharing-program
[7] MSW compost may contain some non-food waste.

composting infrastructure, food waste regulations, food waste used to feed animals, and anaerobic digestion of food waste (U.S. EPA, 2016a).

3.1 Terms

EPA uses the definition of "food" from the FLW Standard (Food Loss and Waste Protocol, n.d.). Food includes any substance—whether processed, semi-processed, or raw—that is intended for human consumption; this includes drink, and any substance that has been used in the manufacture, preparation, or treatment of food. EPA uses the term "wasted food" to describe food that was not used for its intended purpose and is managed in a variety of ways, such as donation to feed people, creation of animal feed, composting, anaerobic digestion, or sending to landfills or combustion facilities. Examples include unsold food from retail stores; plate waste, uneaten prepared food, or kitchen trimmings from restaurants, cafeterias, and households; or by-products from food and beverage processing facilities. The term "excess food" refers to food that is donated to feed people, while the term "food waste" refers to food such as plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered inedible that are managed in a variety of methods other than donation to feed people. "Food loss" refers to unused product from the agricultural sector, such as unharvested crops. When referring to both "excess food" and "food waste", EPA uses the term "wasted food" as an overall term referring to both. Section 6.1, Appendix A contains a glossary of terms used throughout this document.

3.2 Scope

The scope of EPA's enhanced methodology includes excess food and food waste generated by the industrial[8], residential, commercial, and institutional sectors, and does not include food loss from the agricultural sector. The enhanced methodology does not differentiate between different types of food or food commodities.

The following food-waste generating sectors are included in EPA's enhanced methodology:

- the industrial sector, which is comprised of the food and beverage manufacturing and processing sectors;
- the residential sector, which includes multi-family and single family housing;
- the commercial sector, which includes:
    - food retail/wholesale sectors, including supermarkets, supercenters, and food wholesalers;
    - hospitality sectors, including restaurants/food services, hotels, and sports venues;
- institutional sectors, including hospitals, nursing homes, military installations, office buildings, correctional facilities, colleges and universities, and K-12 schools; and
- food banks.

These sectors significantly expand the scope of the methodology compared to the "Facts and Figures Report". The "Facts and Figures Report" does not include the food and beverage manufacturing and processing sector, which is a significant generator of excess food and food waste, as well as other generator sectors (office buildings, military bases, sports venues, food banks, and certain classes of retailers).

[8] Note that EPA's "Facts and Figures Report" will not include the industrial sector estimates, as they are out of scope. See Section 4 for more information.

On the management side, EPA's enhanced food methodology includes the following pathways: animal feed, bio-based materials/biochemical processing, codigestion/anaerobic digestion, composting/aerobic processes, controlled combustion, donation, land application, landfill, and sewer/wastewater treatment (See Section 6.1: Appendix A for definitions of each management pathway). These management pathways significantly expand the scope beyond EPA's previous set of management pathways for food waste (i.e., composting, landfill, and combustion) in the Facts and Figures Reports.

3.3 Enhanced Generation Methodology

EPA undertook the following steps in order to develop estimates of how much food waste was generated in the United States in 2016.[9] The analyses apply methods that can be readily updated in the future.

- **Conduct Detailed Literature search:** EPA focused primarily on literature published in or after 2007 and gave preference to U.S. studies (although EPA selectively examined older and international literature to fill key data gaps). The literature search results provide the foundation for a series of detailed, sector-specific analyses that estimate annual quantities of food waste generation in the U.S. and trace current management practices.

- **Identify Generation Factors**: Generation factors are the quantitative parameters that allow estimation of food waste generation relative to a sector's activity or size. For example, studies of residential food waste generation may frame the generation on the basis of annual pounds per household. Likewise, a study of generation at restaurants may frame the findings as annual pounds per restaurant employee. EPA performed a detailed review of the literature for each sector to identify studies providing original, empirically derived generation factors. For most sectors, EPA identified several estimates that were robust enough to include in the analysis.

- **Establish Extrapolation Basis**: Extrapolation is necessary to translate specific study findings into national food waste generation estimates. For example, a study of supermarkets in a given city may find that those stores generate two tons of food waste per employee per year. That generation factor must be multiplied by the number of supermarket employees nationwide in order to develop a national-level estimate of food waste generation. The number of supermarket employees is the "extrapolation basis." The extrapolation basis is largely dictated by generation factors developed in the original research. In researching each extrapolation basis, however, EPA gave preference to data sources that are readily accessible, free, and updated regularly (preferably annually). Therefore, for instance, EPA uses Census Bureau data for numbers of supermarket employees, rather than proprietary data or one-time research reports from the grocery industry.

- **Develop Annual Generation Estimates**: Each generation factor was multiplied by the relevant extrapolation basis to obtain an annual food waste generation estimate for the sector.

- **Average Generation Estimates**: After developing the annual food waste generation estimate for each generation factor, EPA averaged these estimates together to arrive at a final, average estimate of annual (2016) food waste generation for the sector.

Figure 4 summarizes the general methodological approach.

[9] EPA used data for 2016 where it was available, but in a few cases the data are older or newer.

FIGURE 4. GENERAL GENERATION ESTIMATION METHODOLOGY

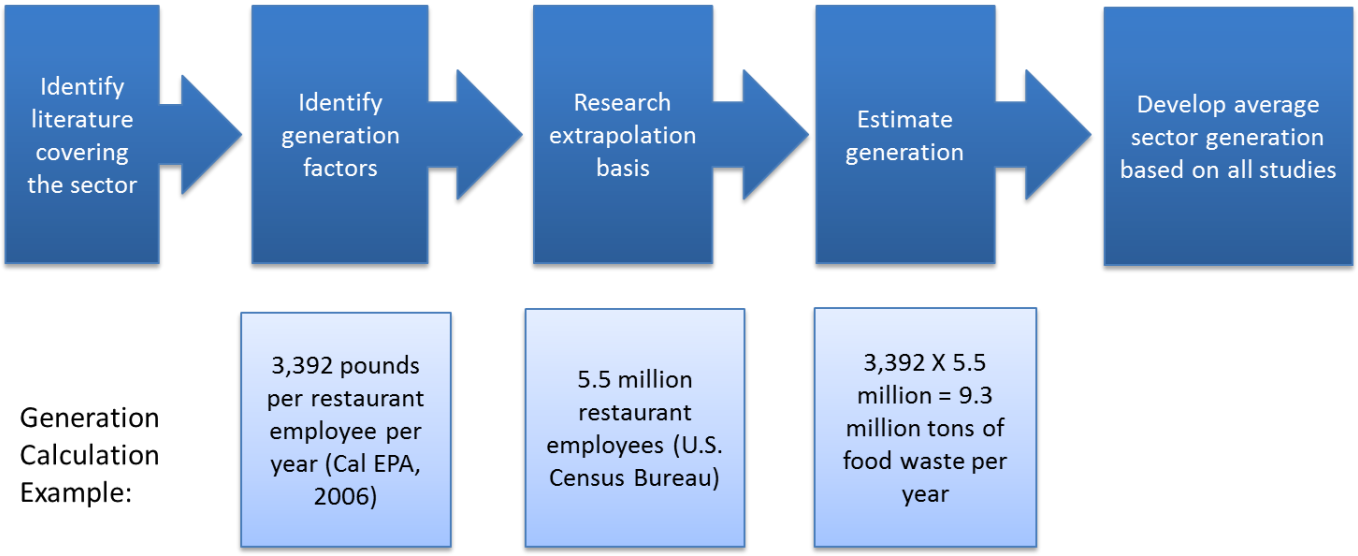


Table 1 summarizes the generation factors developed for each sector. Detailed methodological considerations for each sector are contained in Section 6.2: Appendix B. When the literature allowed, the methodology incorporated multiple generation factors (with different units) and averaged the resulting generation estimates together.

TABLE 1. AVERAGE FOOD WASTE AND EXCESS FOOD GENERATION FACTORS (2016)

HIGH LEVEL SECTOR	CATEGORY	SECTOR	GENERATION FACTOR	UNITS
Industrial	N/A	Manufacturing/ Processing	0.09	Lbs/sales $/year
Residential	N/A	Residential	340.42	Lbs/household/year
			17.04	Percent food waste (of total household waste)
Commercial	Food Retail/Wholesale	Supermarkets	2.04	Tons/employee/year
			0.38	Tons/employee/year
			104.88	Tons/establishment/year
		Supercenters	10.00	Lbs/thousand $ revenue
		Food Wholesale	120.68	Tons/facility/year
			0.005	Tons/thousand $ revenue
	Hospitality	Hotels	1,137.83	Lbs/employee/year
		Restaurants/Food Services (full service)	3,050.67	Lbs/employee/year
			39.13	Tons/facility/year
			33.00	Lbs/thousand $ revenue/year
		Restaurants/Food Services (limited service)	2,751.33	Lbs/employees/year
			40.91	Tons/facility/year
			33.00	Lbs/thousand $ revenue/year
		Sports Venues	0.31	Lbs/visitor/year
Institutional	N/A	Hospitals	653.14	Lbs/bed/year
			0.47	Lbs/meal
		Nursing Homes	657.00	Lbs/bed/year
			0.55	Lbs/meal
		Military Installations	105.27	Lbs/person/year

HIGH LEVEL SECTOR	CATEGORY	SECTOR	GENERATION FACTOR	UNITS
		Office Buildings	169.85	Lbs/employee/year
			0.22	Tons/1000 sq ft/year
		Correctional Facilities	1.12	Lbs/inmate/day
		Colleges and Universities	0.36	Lbs/student/meal
			0.44	Lbs/student/meal
			0.01	Tons/student/year
		K-12 Schools	21.99	Lbs/student/year
			0.43	Lbs/meal
N/A	N/A	Food Banks	299	Tons/establishment

Table 2 summarizes annual excess food and food waste generation estimates for each of the sectors, as well as contextual information on each sector. First, for each sector, the table identifies, where appropriate, the North American Industry Classification System (NAICS) codes used to define the sector. For most of the sectors, these NAICS codes are the basis for compiling extrapolation data used in estimating generation. Second, the table lists the number of unique empirical studies on which the generation estimate is based. Finally, the table provides estimated generation in tons per year, as well as the percent of all generation that the sector represents.

EPA estimates that just over 100 million tons of excess food and food waste were generated in the industrial, residential, commercial, and institutional sectors in 2016. As shown in Table 2 and Figure 5, food manufacturing/processing accounts for over one-third of estimated generation. Several other sectors, however, are also significant contributors to overall generation. Residential generation makes up about one quarter of total generation. Restaurants/food services, and food retail/wholesale (supermarkets, supercenters, and food wholesale) are also major generators. Of the remaining sectors, most are in the institutional and hospitality groups, and each have annual generation that accounts for less than 1% of total generation, with the exception of hotels, office buildings and K-12 schools, which each exceed 1% of total generation.

TABLE 2. ESTIMATED ANNUAL EXCESS FOOD AND FOOD WASTE GENERATION BY SECTOR (2016)

HIGH LEVEL SECTOR	CATEGORY	SECTOR	NAICS CODES	NUMBER OF STUDIES INFORMING GENERATION FACTOR	ESTIMATED ANNUAL GENERATION (TONS PER YEAR)	PERCENT OF TOTAL GENERATION
Industrial	N/A	Manufacturing/ Processing	311 and 3121 (excluding 311111, 311119, 312112, and 312113)	3	37,813,294	37.80%
Residential	N/A	Residential	N/A	12	24,568,660	24.56%
Commercial	Food Retail/ Wholesale	Supermarkets and Supercenters	445110, 445120, 445210, 445220, 445230, 445291, 445292, 445299, 452910	9	8,681,999	8.68%

HIGH LEVEL SECTOR	CATEGORY	SECTOR	NAICS CODES	NUMBER OF STUDIES INFORMING GENERATION FACTOR	ESTIMATED ANNUAL GENERATION (TONS PER YEAR)	PERCENT OF TOTAL GENERATION
		Food Wholesale	424410, 424420, 424430, 424440, 424450, 424460, 424470, 424480, 424490	3	3,901,677	3.90%
	Hospitality	Hotels	7211	4	1,114,011	1.11%
		Restaurants/ Food Services	722511, 722320, 722514, 722513, 722330, 722515	8	16,886,535	16.88%
		Sports Venues	N/A	3	38,088	0.04%
Institutional	N/A	Hospitals	622[1]	6	288,401	0.29%
		Nursing Homes	6239, 6233, 6232, 6231[1]	3	465,932	0.47%
		Military Installations	N/A	2	58,944	0.06%
		Office Buildings	N/A	3	4,004,430	4.00%
		Correctional Facilities	922140, 561210[1]	6	443,002	0.44%
		Colleges and Universities	N/A	10	617,634	0.62%
		K-12 Schools	N/A	5	1,162,683	1.16%
	TOTAL GENERATION[2]				**100,045,291**	**100.0%[3]**

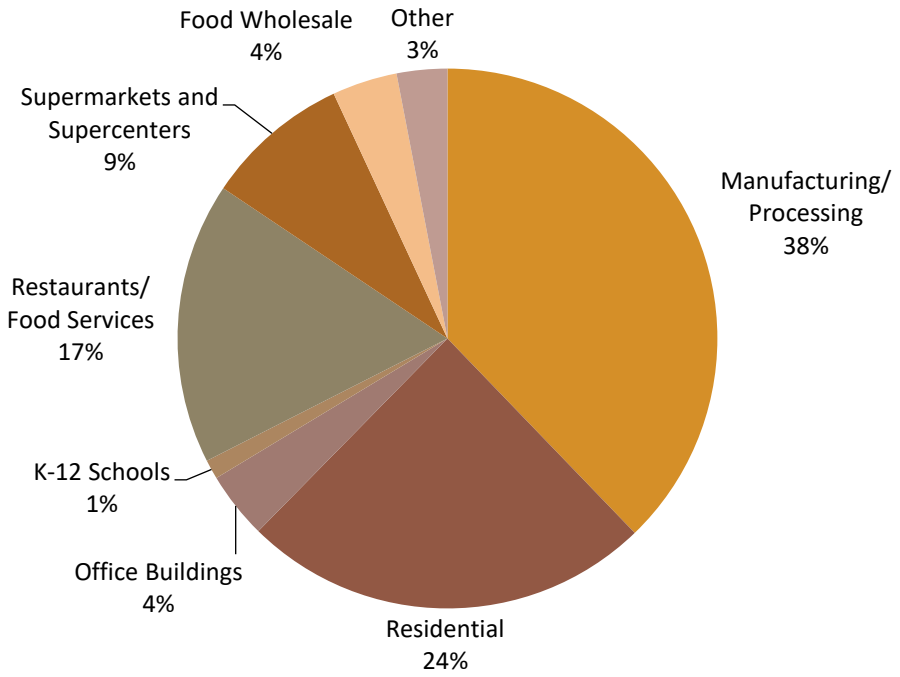
Notes:

[1] In several instances (hospitals, nursing homes, correctional facilities), the sector has a NAICS code, but the extrapolation data are not strictly delineated by NAICS code as with Census data. For instance, nursing homes are aligned with several NAICS codes, but data on nursing home populations is compiled by U.S. Centers for Disease Control and Prevention (CDC), not by the U.S. Census Bureau.

[2] This total includes excess food donated to food banks by the industrial and commercial sectors. Food banks also generate some food waste (378,198 tons) due to spoilage and other factors. This 378,198 tons is not added to total generation because it would represent "double counting," i.e., it is already accounted for in Total Generation. See Section 6.2.6 for more information.

[3]Totals do not add up due to rounding.

FIGURE 5. PERCENTAGE DISTRIBUTION OF EXCESS FOOD AND FOOD WASTE GENERATION (2016)



The total generation estimate for 2016 using EPA's enhanced methodology is higher than EPA's previous estimates (see Section 4 for a more detailed comparison), primarily due to the expanded scope of the enhanced methodology. While few national studies similar in scope exist, the available information suggests that EPA's enhanced methodology estimates are consistent with other research:

- The USDA's Economic Research Service (ERS) has developed the Loss-Adjusted Food Availability (LAFA) data series to consider food loss (spoilage, plate waste, etc.) as an element of tracking nutrition and food in the U.S. Based on 2010 data, the LAFA research suggests about 66.5 million tons of food loss (i.e., food waste as defined in this memo) annually in retail and consumer settings (with consumer settings including households, restaurants, school cafeterias, and various institutional sectors) (Buzby et al., 2014). EPA's estimates for the analogous sectors (residential, commercial, and institutional) total about 62.2 million tons, a difference of 6%.
- Dou et al. (2016) estimated food waste generation in the U.S., including industrial, retail, and consumer sectors. This research found approximately 106 million tons of food waste was generated per year[10], a difference of 6% from the total estimated by the enhanced EPA methodology.

EPA plans to update the excess food and food waste generation estimates on an annual basis as part of the "Facts and Figures Report" (See Section 4 for more detail). Doing so will require updating the extrapolation basis applied for each sector, and, where relevant, updating reference literature. Table 3 summarizes the extrapolation basis for each sector and the associated data source. Section 6.2: Appendix B provides additional detail on each sector's generation method, including internet links for key information sources.

[10] Note that portions of Dou et al. (2016) incorporated data from Buzby et al. (2014); hence, Dou et al. (2016) does not represent an entirely independent empirical estimate.

TABLE 3. DATA FOR MAINTAINING ANNUAL GENERATION ESTIMATES

HIGH LEVEL SECTOR	CATEGORY	SECTOR	EXTRAPOLATION BASIS	DATA SOURCE
Industrial	N/A	Manufacturing/ Processing	Sales revenue in relevant NAICS codes	U.S. Census Bureau, 2016 Annual Survey of Manufacturers
Residential	N/A	Residential	U.S. households	U.S. Census Bureau, Historical Household Tables
Commercial	Food Retail/ Wholesale	Supermarkets	Method 1: Employees in relevant NAICS codes	U.S. Census Bureau, County Business Patterns (CBP)
			Method 2: Establishments in relevant NAICS codes	U.S. Census Bureau, CBP
			Method 3: Sales revenue in relevant NAICS codes	U.S. Census Bureau, Annual Retail Trade Survey
		Supercenters	Employees in relevant NAICS codes	U.S. Census Bureau, CBP
		Food Wholesale	Method 1: Establishments in relevant NAICS codes	U.S. Census Bureau, CBP
			Method 2: Sales revenue in relevant NAICS codes	U.S. Census Bureau, Monthly Wholesale Trade Report
	Hospitality	Restaurants/ Food Services	Method 1: Employees in relevant NAICS codes	U.S. Census Bureau, Statistics of U.S. Businesses (SUSB) datasets
			Method 2: Establishments in relevant NAICS codes	U.S. Census Bureau, SUSB datasets
			Method 3: Sales revenue	National Restaurant Association, Restaurant Industry Outlook
		Hotels	Employees in relevant NAICS codes	Bureau of Labor Statistics (BLS), National Industry-Specific Occupational Employment and Wage Estimates
		Sports Venues	Number of annual visitors	Annual attendance statistics from professional and college league organizations
Institutional	N/A	Hospitals	Method 1: Hospital beds	American Hospital Association (AHA), Fast Facts for U.S. Hospitals
			Method 2: Meals served based on occupancy rate	CDC, National Center for Health Statistics
		Nursing Homes	Nursing home beds	CDC
		Military Installations	Number of active-duty military stationed in U.S.	Defense Manpower Data Center
		Office Buildings	Method 1: Number of employees in office-oriented sectors	BLS, Employment Projections, Employment by Major Industry
			Method 2: Office square footage	Energy Information Administration (EIA), Commercial Buildings Energy Consumption Survey (CBECS)

HIGH LEVEL SECTOR	CATEGORY	SECTOR	EXTRAPOLATION BASIS	DATA SOURCE
		Correctional Facilities	Incarcerated population (federal, state, and local facilities)	U.S. Bureau of Justice Statistics (BJS)
		Colleges and Universities	Meals per year based on number of enrolled students	National Center for Education Statistics (NCES)
		K-12 Schools	Number of students	NCES
N/A	N/A	Food Banks and Other Donation Centers	Food waste estimated as share of total donations; donations extrapolated based on Feeding America and nationwide number of food bank facilities	Hoovers data for NAICS 624210

3.4 Enhanced Management Pathway Methodology

In addition to updating and expanding the generation methodology, EPA greatly expanded the scope of the management pathways included in its methodology to capture more accurately how excess food and food waste are managed throughout the food system. EPA's enhanced methodology largely aligns with the FLW Standard (Food Loss and Waste Protocol, 2016). The FLW Standard includes the following food waste "destinations": animal feed, bio-based materials/biochemical processing, co-digestion/anaerobic digestion, composting/aerobic processes, controlled combustion, land application, landfill, not harvested/plowed in, refuse/discards/litter, sewer/wastewater treatment, and other (Food Loss and Waste Protocol, 2016). EPA uses the term, "management pathway" instead of the term, "destination," which is used in the FLW Standard. EPA's enhanced methodology does not include estimates for the following FLW Standard destinations: not harvested/plowed in, refuse/discards/litter, and other, due to farm-level loss being out of scope (in the case of not harvested/plowed in) and lack of available data (in the case of refuse/discards/litter and other); the enhanced methodology does include estimates for one additional pathway that is not one of the FLW Standard destinations: food donation.

3.4.1 Initial Excess Food and Food Waste Management Characterization

EPA first analyzed the literature used for the generation methodologies to establish approximate percentage distributions for each sector across management pathways.

- **Manufacturing/processing, retail/wholesale, and restaurants/food services:** Annual surveys performed by Business for Social Responsibility (BSR) in 2013 and 2014 and the Food Waste Reduction Alliance (FWRA) in 2016 provided the management distribution. These three studies surveyed food waste generators in the manufacturing/processing, retail/wholesale, and restaurants/food services sectors and provide detail on how those sectors manage their excess food and food waste.
- **Residential food waste**: EPA developed a distribution based on a variety of studies examining composting rates in different geographic locations, as well as studies on the use of household food waste disposers (e.g., in-sink disposals). EPA then assumed that the remaining food waste is either landfilled or combusted, with the proportion based on various literature sources.

- **All remaining sectors:** For institutional sectors, hotels, sports venues, and food banks, the initial management pathway characterization relies on the general food waste management distribution estimated in EPA's 2018 report, "Advancing Sustainable Materials Management: 2015 Fact Sheet" (U.S. EPA, 2018)."[11]

Table 4 summarizes the percentage distributions used in the initial 2016 waste management characterization.

TABLE 4. INITIAL EXCESS FOOD AND FOOD WASTE MANAGEMENT PROFILE, BY SECTOR (2016)

FOOD FRACTION	MANAGEMENT PATHWAY	PERCENTAGE MANAGED				
		MANU-FACTURING/ PROCESSING	RESIDENTIAL	RESTAURANTS/ FOOD SERVICES	FOOD RETAIL/ WHOLESALE	DEFAULT DISTRIBU-TION[1]
Excess Food	**Food Donation**	1.52%	0.00%	1.69%	13.99%	0.00%
Food Waste	**Animal Feed**	61.46%	0.00%	0.02%	14.23%	0.00%
	Co-digestion/Anaerobic Digestion	0.33%	0.00%	0.02%	4.66%	0.04%
	Composting/Aerobic Processes	2.12%	5.00%	1.71%	13.71%	5.95%
	Bio-based Materials/Biochemical Processing	0.85%	0.00%	7.52%	4.37%	0.00%
	Land Application	27.08%	0.00%	0.00%	2.04%	0.00%
	Wastewater Treatment	0.00%	15.00%	0.00%	0.00%	0.00%
	Other	1.98%	0.00%	0.02%	0.66%	0.00%
	Landfill	4.07%	65.10%	72.47%	42.62%	75.76%
	Controlled Combustion	0.59%	14.90%	16.56%	3.73%	18.25%
TOTAL		100.00%	100.00%	100.00%	100.00%	100.00%

Note:
[1] The default distribution is based on the food waste management profile estimated for "Advancing Sustainable Materials Management: 2015 Fact Sheet" (U.S. EPA, 2018), with a minor refinement for military bases and correctional facilities. Sectors to which this default distribution was applied include all institutional sectors, hotels, sports venues, and food banks.

EPA developed initial estimates of the quantity of excess food and food waste routed to each management pathway by applying each sector's percentage distribution to the estimated quantity of food waste generated annually.

[11] In developing the initial waste management characterization, EPA refined the default distribution in two minor institutional sectors. In the case of military bases and correctional facilities, qualitative evidence suggested that internal waste management policies may result in higher rates of composting and anaerobic digestion. Military bases were assigned a composting rate of 25% and an anaerobic digestion rate of 5%; correctional facilities were assigned a composting rate of 15%.

3.4.2 Revised Excess Food and Food Waste Management Characterization

EPA built upon these initial estimates using additional data for certain management pathways (food donation, animal feed, co-digestion/anaerobic digestion, and composting/aerobic processes).[12] EPA estimates that in 2016, of the excess food and food waste generated in the industrial, residential, commercial, and institutional sectors, just over one third was landfilled, approximately 20% was sent to animal feed, approximately 11% was sent to codigestion/anaerobic digestion, and approximately 9% was donated. The remaining management pathways each account for approximately 8% or less of total food waste managed. The revised estimated excess food and food waste management profile for 2016 is summarized in Table 5 and Figure 6. Table 48 (in Section 6.3: Appendix C) contains estimates of the amount of food waste and excess food generated by each sector, and the amount managed by each management pathway, per sector.

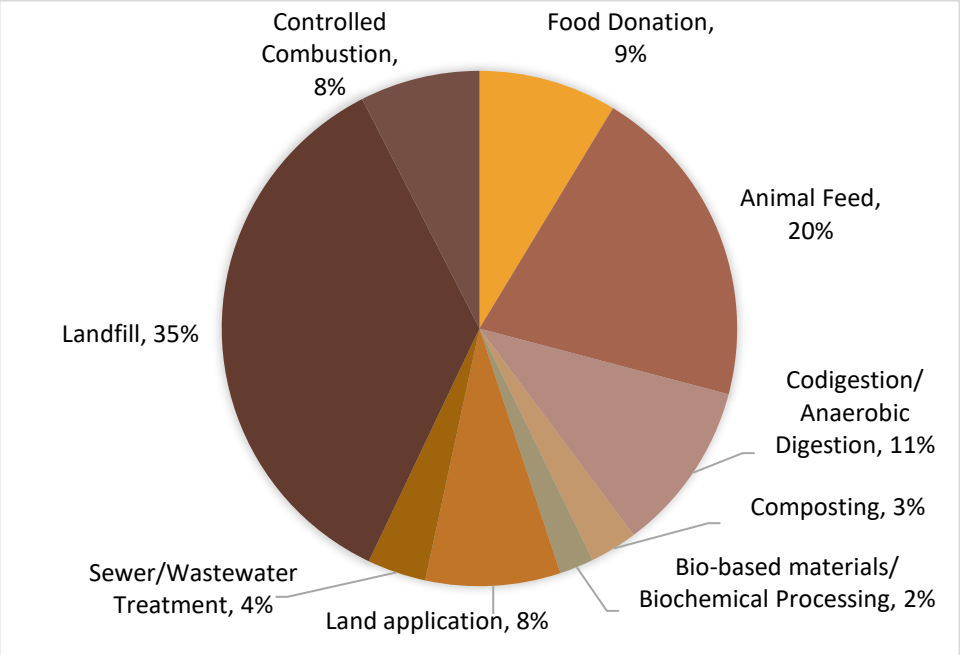
TABLE 5. ESTIMATES OF EXCESS FOOD AND FOOD WASTE MANAGED BASED ON REVISED MANAGEMENT PROFILE (2016)

FOOD FRACTION	MANAGEMENT PATHWAY	ESTIMATED QUANTITY OF EXCESS FOOD/FOOD WASTE MANAGED (TONS)	PERCENTAGE OF EXCESS FOOD/FOOD WASTE MANAGED
Excess Food	**Food Donation**	8,675,167[1]	8.7%
Food Waste	**Animal Feed**	20,447,709	20.4%
	Codigestion/Anaerobic Digestion	10,691,756	10.7%
	Composting/Aerobic Processes	2,969,173	3.0%
	Bio-based Materials/ Biochemical Processing	2,151,119	2.2%
	Land Application	8,472,542	8.5%
	Sewer/Wastewater Treatment	3,685,299	3.7%
	Landfill	35,425,617	35.4%
	Controlled Combustion	7,526,909	7.5%
TOTAL[2]		100,045,291	100.0%

Note:
[1] The total amount of food donated to food banks is estimated to be 9,053,365. However, food banks are not able to distribute 100% of their food. EPA estimates that of the 9,053,365 tons, 378,198 tons are not able to be distributed by food banks and ultimately become food waste that is managed through conventional means (landfilling, combustion, composting, and anaerobic digestion). Therefore, the 378,198 tons is accounted for in the estimates for those four management pathways. See Section 3.4.2.6 and 6.2.6 for more information.
[2] Totals do not add up due to rounding.

[12] EPA's initial excess food and food waste management characterization included a very small percentage of food waste being managed by "other" methods due to survey respondents indicating some tonnage was managed by "other" methods in the FWRA (2016) survey. However, EPA was not able to confirm what methods were included in the "other" category and therefore did not ultimately include this pathway in the revised management characterization.

FIGURE 6. PERCENTAGE DISTRIBUTION OF EXCESS FOOD AND FOOD WASTE MANAGEMENT (2016)



The following sections provide management pathway descriptions as well as more detail about the derivation of these estimates.

3.4.2.1 Co-digestion/Anaerobic Digestion

Co-digestion/anaerobic digestion (hereafter referred to as "AD") entails the breakdown of food waste by bacteria in the absence of oxygen to create biogas and nutrient-rich matter. This biogas can be used via combustion to generate electricity and heat or can be processed into renewable natural gas and transportation fuels. There are three major types of anaerobic digestion facilities:

- **Stand-alone digesters**: Digesters primarily built to manage food waste but can accept other organic materials such as manure or wastewater solids.
- **On-farm digesters:** Digesters located on-site in operating livestock farms. These digesters typically process manure; EPA's analysis includes only on-farm digesters that also accept food waste.
- **Water resource recovery facility digesters**: Digesters located at water resource recovery facilities (i.e., wastewater treatment plants). These digesters typically process biosolids; EPA's analysis includes only water resource recovery facility digesters that also accept food waste.

EPA's initial characterization of food waste management applied general economy-wide percentage distributions of waste management to generation in each sector to estimate the quantity of food waste managed through AD and other pathways.[13] To improve upon this approach, EPA explored available data on AD facilities and the absolute quantity of food waste accepted. The literature search identified 27

[13] The sources for these percentage distributions vary by management pathway. Most are taken from industry surveys conducted by BSR and FWRA, which covered generator sectors such as manufacturing/processing, food services/restaurants, and food retail/wholesale (BSR, 2013; BSR, 2014; FWRA, 2016).

studies that discuss food waste managed by AD, but many of these studies are not directly useful to methods development. Some lack quantitative information on management quantities and rates, while others provide point estimates of food waste managed by AD for a subset of generation sectors (e.g., manufacturing/processing).

Only one report series, authored by EPA, provides nation-wide food waste management estimates for AD. In the latest report, EPA conducted a nation-wide survey of AD facilities in the U.S. in 2018, the results of which reflect 2016 data and were published in September 2019 (U.S. EPA, 2019c). Of the 232 surveys distributed to AD facilities, 134 were returned by operational facilities. Another 64 facilities are believed to be operating, for a total of 198, resulting in a survey response rate of 67%. Of the 134 facilities who responded to the survey, 126 facilities provided information about the amount of food waste they processed. These facilities reported a total of 10.7 million tons of food waste managed by AD annually in 2016 (U.S. EPA, 2019c). Table 6 summarizes the total quantity of food waste processed by digester type.

TABLE 6. TOTAL QUANTITY OF FOOD WASTE PROCESSED BY DIGESTER TYPE (2016)

DIGESTER TYPE	2016 REPORTED QUANTITY PROCESSED (TONS PER YEAR)
Stand-alone digesters	9,222,413
On-farm digesters	154,789
Water resource recovery facility digesters	1,314,554
TOTAL	**10,691,756**

EPA's analysis considered which sectors are likely to have hauling contracts with AD facilities, and assumes that food waste being managed by AD originates in all generator sectors, except the residential sector.[14] EPA assigned the quantities of food waste managed by AD to each generator sector in proportion to the sector's contribution to the overall food waste generation profile. For all generator sectors other than manufacturing/processing, the amount is netted out of the sector's landfill and combustion quantity. For manufacturing/processing, the analysis assumes that the AD quantity is netted out of the two largest management pathways used by the sector (land application and animal feed), as well as from landfilling. The quantity is netted out in proportion to the original percentage distribution established for these three management pathways. See Section 3.4.2.3: Animal Feed for more information.

The estimates of food waste being managed by AD in 2016 assume that the facilities responding to EPA's survey provided accurate information on the quantity of food waste processed. Not all AD facilities in the U.S. responded to EPA's survey; therefore, the estimated food waste quantities likely understate the total quantity of food waste managed by AD in the U.S. EPA has conducted its third annual AD survey and will publish its third report in 2020 that will contain data for both 2017 and 2018.

3.4.2.2 Composting/Aerobic Processes

Food waste can be managed through composting/aerobic processes (hereafter referred to as "composting"), in which bacteria break down organic material in oxygen-rich environments. The resulting

[14] EPA did not find sufficient data to determine what proportion of food waste being managed by AD came from the residential sector, but it is assumed to be negligible.

product is typically used as a soil amendment. Composting can range from small-scale backyard composting piles to large facilities composting thousands of tons of organic matter per year.

As with AD, the initial characterization of food waste management applied national percentage distributions to generation to estimate the quantity of food waste composted for each sector.[15] To refine this approach, EPA explored the availability of data on composting facilities and the absolute quantity of food waste accepted at those facilities. The literature search identified 85 studies that discuss food waste managed by composting, but many of these studies are not directly useful to methods development. Some studies lack quantitative information on quantities and rates managed, while others provide point estimates of food waste managed by composting for a subset of generation sectors (e.g., retail).

Therefore, EPA used data available through state environmental agency websites, published reports, and reported values via EPA's SMP (a voluntary data alignment initiative), and summed the reported food waste composting tonnages from each state. The state-reported data yields a total of 1.8 million tons of food waste composted in 2016. EPA gathered information from 37 states but did not extrapolate to account for activity in the other 13 states or tribes and territories for which data are not available. EPA also estimated a quantity of mixed MSW that is composted annually (306,019 tons in 2016).[16] Mixed MSW compost is when single-stream MSW is collected and organics are sorted out for processing at the composting facility (Sullivan, 2011). In total, EPA's dataset yields 2.15 million tons of food waste from the residential, commercial, and institutional sectors composted in 2016 (U.S. EPA, 2019a).[17]

These estimates do not include food waste composted from various industrial sectors, such as food manufacturing/processing. To estimate food waste composted from the food manufacturing/processing sector, EPA used the results of surveys conducted by BSR and FWRA of food manufacturers around the nation. These studies surveyed food manufacturers regarding their excess food and food waste management practices. EPA averaged the percentage composting distributions from all the surveys conducted in 2013, 2014, and 2016 to capture variation in management practices across manufacturing/processing subsectors and applied this average composting percentage to the estimated quantity of food waste generated by food manufacturers and processors in 2016. Based on this analysis, EPA estimates that food manufacturers and processors composted approximately 820,000 tons of food waste in 2016.

EPA added the estimate of food waste composted by food manufacturers and processors (820,000 tons) to the state-reported composting estimate (2.15 million tons), to arrive at a nation-wide food waste composting estimate of approximately 3.0 million tons in 2016. Table 7 summarizes the resulting estimates of food waste composted.

TABLE 7. SUMMARY OF QUANTITIES OF FOOD WASTE COMPOSTED (2016)

STATE	REPORTED QUANTITY (TONS)	STATE	REPORTED QUANTITY (TONS)
Alabama	1	Missouri	16,000

[15] The sources for these percentage distributions vary by management pathway. Some pathways rely on percentage distributions from the *Advancing Sustainable Materials Management: 2015 Fact Sheet* (U.S. EPA, 2018) while others rely on industry-wide waste management surveys conducted.
[16] Mixed MSW that is composted includes food and also non-food waste.
[17] This includes mixed MSW compost, which includes some non-food waste.

STATE	REPORTED QUANTITY (TONS)	STATE	REPORTED QUANTITY (TONS)
Arizona	1,700	Nebraska	294
Arkansas	437	Nevada	17,083
California	277,000	New Hampshire	110
Colorado	97,835	New Jersey	17,413
Connecticut	1,082	New York	16,648
Delaware	2,125	North Carolina	84,502
Florida	167,425	Ohio	68,807
Georgia	552	Oregon	56,055
Hawaii	42,109	Pennsylvania	306,682
Illinois	277	Rhode Island	150
Indiana	961	South Carolina	10,157
Maine	2,853	Tennessee	138,884
Maryland	86,197	Texas	100,740
Massachusetts	166,000	Vermont	16,723
Michigan	9,395	Virginia	1,677
Minnesota	58,234	Washington	72,423
Mississippi	364	Wisconsin	5,053
Subtotal		***1,843,949***	
Mixed MSW Composting[1]		306,019	
Subtotal		***2,149,968***	
Food Waste Composted by Food Manufacturers/Processors		819,205	
TOTAL		**2,969,173**	
Note: [1] Includes a small portion of non-food waste.			

EPA's initial approach in applying percentage distributions to each generation sector resulted in a higher estimate of food waste composted in 2016, but EPA ultimately used the estimate derived from state-reported values, as shown in Table 7. The net difference between the two estimates was distributed to landfill and controlled combustion.

EPA's estimate does not include backyard composting or community composting, nor does it include any quantities of food waste composted by states, tribes, and territories that do not report food waste composting tonnages, so it likely understates the total quantity of food waste managed by composting in 2016.

3.4.2.3 Animal Feed

Certain types of food waste, including unsold retail food, residuals from food preparation (e.g., vegetable trimmings), and post-consumer food waste, can be collected and re-purposed as animal feed by heat treating and dehydrating the food waste. This treated food waste can either be mixed with dry feed or directly fed to livestock (e.g., chickens, cows, pigs, goats). The composition of food waste fed to animals differs by animal and by U.S. state. For instance, meat-based food waste cannot be fed to ruminants (e.g.,

cattle, sheep, goats, deer, elk and antelopes) under the Food and Drug Administration's Bovine Spongiform Encephalopathy (BSE)/Ruminant Feed Ban Rule (Broad Leib et al., 2016). Meat-based food waste can be fed to swine in some states; 16 states prohibit this practice.[18]

The literature search identified a total of 19 studies examining food waste managed by animal feed. Many of these studies, however, are not directly useful to methods development. Some lack quantitative information on management rates, while others apply management rates from older studies. EPA ultimately relied on a small subset of three studies that involved original research (e.g., surveying food waste generators)—the 2013 and 2014 BSR studies, and the 2016 FWRA study. These studies provide a clear definition of animal feed that is based on the FLW Standard.

These three studies determined the percentage of food waste managed by animal feed for the manufacturing/processing, restaurants/food services, and retail/wholesale sectors by surveying establishments around the nation. The facilities included in the studies for each sector vary each year; because the samples change, the studies are independent, allowing EPA to incorporate all three data points into average management rate estimates per sector. Averaging across the multiple surveys helps capture variation in management practices across each sector.

Table 8 details the percentage of food waste that each sector reported managing by animal feed. As shown, for the manufacturing/processing sector, the three animal feed management rates from the studies range from 32.9% to 82.4% with an average of 61.4%.[19] The fraction of food waste that the retail/wholesale sector manages as animal feed ranges from 11.1% to 17.3%, with an average of 14.2%.[20] Finally, restaurants/food services divert a very small fraction, about 0.02%, to animal feed.

TABLE 8. PERCENTAGE OF FOOD WASTE MANAGED AS ANIMAL FEED BY SECTOR (2016)

SECTOR	STUDY	YEAR	PERCENTAGE OF FOOD WASTE MANAGED AS ANIMAL FEED
Manufacturing/ Processing	Food Waste Reduction Alliance	2016	32.9%
	BSR	2014	82.4%
	BSR	2013	69.0%
	AVERAGE		**61.4%[1]**
Retail/Wholesale	Food Waste Reduction Alliance	2016	17.3%
	BSR	2014	11.1%
	AVERAGE		**14.2%**
Restaurants/Food Services	Food Waste Reduction Alliance	2016	0.02%
	BSR	2014	0.02%

[18] The sixteen states that prohibit feeding meat-based food waste to swine include: Alabama, Delaware, Idaho, Illinois, Kansas, Kentucky, Louisiana, Mississippi, Nebraska, North Dakota, Oregon, South Carolina, South Dakota, Texas, Vermont, and Wisconsin.

[19] The range of food waste managed through animal feed is quite large as the rate can be heavily influenced by the food product types and manufacturing/processing processes of the facilities surveyed for a given year. For instance, facilities that process vegetable products are likely to produce more organic waste, such as vegetable trimmings; these operations are more likely to manage their food waste through animal feed when compared to operations that process meat products.

[20] BSR included animal feed as a retail food waste management pathway in its 2013 survey. However, the limited set of pathways covered in the 2013 survey did not align with the more detailed set of pathways examined in subsequent surveys, precluding an average across all three survey years. Therefore, EPA's analysis incorporates only the 2014 and 2016 surveys in developing an average management distribution for the food retail/wholesale sector.

SECTOR	STUDY	YEAR	PERCENTAGE OF FOOD WASTE MANAGED AS ANIMAL FEED
	BSR	2013	Survey not conducted for sector
	AVERAGE		**0.02%**

Note:
[1] This rate was revised when EPA revised the management pathway characterization. The final rate of food waste going to animal feed by the manufacturing/processing sector is 49.8%.

EPA initially multiplied the average animal feed management rate for each sector by the estimated quantity of food waste generated in 2016 for that sector. However, when EPA revised the management pathway characterization due to revised AD estimates (see Section 3.4.2.1: Codigestion/Anaerobic Digestion), EPA assigned the quantities of food waste managed by AD to each generator sector in proportion to the sector's contribution to the overall food waste generation profile. For the manufacturing/processing sector, the analysis assumed that the AD quantity is netted out of the two largest management pathways used by the sector (land application and animal feed), as well as from landfilling. The quantity was netted out in proportion to the original percentage distribution established for these three management pathways. Therefore, EPA's final estimate for how much food waste was managed by animal feed by the manufacturing/processing sector (49.8%) differs from the percentages in Table 8.

As summarized in Table 9, 18.6 million tons of food waste was estimated to be managed by animal feed for manufacturing/processing, 1.8 million tons for retail/wholesale, and 3,000 tons for restaurants/food services in 2016. The total food waste managed by animal feed in 2016 was approximately 20.4 million tons.

TABLE 9. ESTIMATES OF FOOD WASTE MANAGED AS ANIMAL FEED BY SECTOR (2016)

PARAMETER	SECTOR			TOTAL
	MANUFACTURING/PROCESSING	RETAIL/ WHOLESALE	RESTAURANTS/FOOD SERVICES	
Average Management Rate	49.3%	14.2%	0.02%	N/A
Estimated Generation Quantity (tons)	37,813,294	12,583,676	16,886,535	67,283,505
Total Quantity Managed by Animal Feed (tons)[1]	18,642,450	1,802,205	3,054	**20,447,709**

Note:
[1] Totals do not add up due to rounding.

Most food waste managed by animal feed originates from the food manufacturing sector (91%). This trend is consistent with the nature of food waste generated from the manufacturing/processing sector. Food waste diverted for animal feed must be free of packaging and, depending on the animal being fed, separated by food type (e.g., meat-based separated from vegetable-based food waste). Of these three sectors, food waste generated from the manufacturing/processing sector is likely to be free of packaging and of a homogenous food type, making the food separation process physically easier and therefore less costly.

EPA's estimates of food waste managed by animal feed rely on two key assumptions and reflect a number of data limitations. First, EPA assumes the survey data reported by BSR and FWRA capture a representative

sample of the universe of establishments and form a reasonable basis for extrapolation. Second, EPA assumes the respondents have accurately reported the rates of food waste managed by animal feed. Finally, EPA's analysis of food waste being managed by animal feed compiles estimates already presented in the manufacturing/processing, retail/wholesale, and restaurants/food services sector analyses. An alternative, "bottom-up" estimation method would involve a full accounting of the number of animals thought to consume food waste, as well as estimates of the total food waste fed per animal type. EPA did not find such information readily available.

3.4.2.4 Sewer/Wastewater Treatment

Food waste is often sent down the sewer (with or without prior treatment) through the sewage conduit system or via haulers for processing at wastewater treatment plants. The processed waste is then managed through landfill, incineration, compost, AD, or land application, the implications of which are discussed later on in this section. Typically, this waste originates from residential housing or commercial facilities.

As part of the residential food waste generation analysis, EPA reviewed literature on residential food waste disposers, which are devices installed under a kitchen sink that shred food waste into small pieces that can pass through plumbing. Out of four studies that discussed wastewater treatment as a management pathway in the residential sector, three provided rates of food waste management by food waste disposers. The studies suggest that between 1.5% (Johnston, 2013) and 34.4% (InSinkErator, 2016) of all residential food waste is sent down the sewer via food waste disposers. The rates of residential food waste management by sewer/wastewater treatment examined by EPA are presented in Table 10.

These studies suggest that, on average, households send roughly 15% of their food waste to sewer/wastewater treatment via food waste disposers. Applied to total residential generation (about 24.6 million tons), this results in an estimate of about 3.7 million tons of food waste sent from the residential sector to sewer/wastewater treatment in 2016.

TABLE 10. RATES OF RESIDENTIAL FOOD WASTE MANAGEMENT BY SEWER/WASTEWATER TREATMENT (VIA FOOD WASTE DISPOSERS) (2016)

STUDY	AUTHOR	YEAR	PERCENTAGE
Getting the Public Tuned in to Food Waste Reduction	Johnston	2013	1.5%
The Food Waste Disposer as a Municipal Tool for Waste Diversion: An evaluation in Five Cities[21]	InSinkErator	2016	34.1% (Philadelphia, PA)
			25% (Tacoma, WA)
			27.3% (Milwaukee, WI)
			34.4% (Boston, MA)
The Household Use of Food Waste Disposal Units as a Waste Management Option: A Review	Iacovidou et al.	2012	Range (7 to 18.7%)
Estimating Quantities and Types of Food Waste at the City Level	Natural Resources Defense Council (NRDC)	2017	7% (New York City, NY)
			16% (Denver, CO)
			15% (Nashville, TN)

There are data limitations for the sewer/wastewater treatment management pathway. First, this estimate is specific to the residential sector, so it may understate the total quantity of food waste managed by

[21] The study had insufficient data for one of the five cities (Chicago).

sewer/wastewater treatment as it does not include estimates from any other sector (e.g., restaurants/food services). EPA did not find studies that provided rates of food waste management by sewer/wastewater treatment in the industrial, commercial, or institutional sector. Wastewater treatment plants ultimately serve as an intermediate stage where food waste is treated before reaching its final destination. These final destinations typically include landfill, controlled combustion, land application, composting, and AD. However, the amount of food waste estimated to be sent down the drain to sewer/wastewater treatment is not reflected in any of the other management pathways, and is therefore not being double counted.

3.4.2.5 Bio-based Materials/Biochemical Processing and Land Application

Bio-based materials/biochemical processing converts material into industrial products. Examples include creating fibers for packaging material, creating bioplastics (e.g., polylactic acid), making "traditional" materials such as leather or feathers (e.g., for pillows), and rendering fat, oil, or grease into a raw material to make products such as soaps, biodiesel, or cosmetics. Land application is the spreading, spraying, injecting, or incorporating organic material onto or below the surface of the land to enhance soil quality. EPA's literature search did not reveal any systematic information on food waste managed through bio-based materials/biochemical processing, land application, or other minor management pathways. The literature search identified 14 studies that discussed food waste managed by bio-based materials/biochemical processing, five studies that discussed food waste managed by land application, and three studies that discussed food managed by other means (e.g., food re-use/re-processing). However, these studies are not directly useful to methods development as most lack comprehensive quantitative information on management quantities and rates.

Since bio-based materials/biochemical processing and land application management pathways likely account for minor quantities of food waste, EPA applied the estimates developed in the initial generation studies. All the estimates were developed by applying the results of food waste management surveys conducted by BSR in 2013 and 2014, and by the FWRA in 2016[22]. Averaging across the surveys provides, for example, the average percent of retailer/wholesaler food waste routed to land application. Multiplying the average percentages by total 2016 generation for each sector yields an estimate of the total food waste managed via these two pathways. As shown in Table 11, the resulting estimates are about 2.2 million tons going to bio-based materials/biochemical processing, and 8.5 million tons going to land application. The estimated amounts are relatively minor, except in the case of food waste from the manufacturing/processing sector managed through land application.

[22] While FWRA (2016) did ask survey respondents to report tonnage of food waste managed by any other means besides the FLW Standard destinations, it did not report what methods survey respondents were referring to as "other". Because there is no data available about what these other methods might have been, EPA did not include the proportion of food waste reported to be managed by "other" methods.

TABLE 11. ESTIMATES OF FOOD WASTE MANAGED VIA BIO-BASED MATERIALS/BIOCHEMICAL PROCESSING AND LAND APPLICATION (2016)

	GENERATION SECTOR				TOTAL FOOD WASTE TO MANAGEMENT PATHWAY (TONS)
	MANUFACTURING/ PROCESSING	RETAIL	WHOLESALE	RESTAURANTS/ FOOD SERVICES	
Total Excess Food and Food Waste Generation (tons)	37,813,294	8,681,999	3,901,677	16,886,535	
Percent of food waste routed to bio-based materials/biochemical processing	0.9%	4.4%	4.4%	7.5%	**2,151,119**
Percent of food waste routed to land application	21.7%	2.1%	2.1%	-	**8,472,542**

3.4.2.6 Food Donation

Unspoiled excess food can be collected and redistributed to those in need through food pantries, food banks and other food rescue programs.[23] This analysis examines food donation as a management pathway for excess food.[24]

EPA's literature search identified a total of 39 studies examining excess food managed through food donation. Many of these studies, however, are not directly useful to methods development because they lack quantitative information on management rates and/or apply management rates from earlier studies.

Therefore, EPA's estimation method is primarily based on a dataset from Feeding America, the largest domestic hunger relief organization with a nationwide network of more than 200 food banks. Feeding America secures food from corporate manufacturers, retailers, and produce suppliers nationwide; stores excess food temporarily in warehouses; and then distributes the excess food to families and individuals through food assistance agencies such as soup kitchens, youth or senior centers, shelters, and food pantries.

The Feeding America dataset details food rescue data from FY2014 for 203 food banks (Feeding America, 2015). Feeding America provided data for food banks of various sizes in all 50 states. As a result, it is inclusive and likely captures the inherent excess food management variation associated with diverse excess food donation, demand, and operations management practices.

The Feeding America data provide the total quantity of food received at each food bank for donation as well as the quantity of donated food that was disposed of due to spoilage, expiration, or other quality and safety considerations (Feeding America, 2015). Feeding America also noted that 67.5% of the food received

[23] To the extent that this excess food is not able to be successfully distributed, food banks themselves are also (minor) generators of food waste. Food waste generated by food banks is detailed in Section 6.2.6.
[24] EPA defines "excess food" as food that is donated to feed people.

for donation is food that otherwise would have been thrown away (i.e., the remaining 32.5% of food received for donation is food originally purchased for the sole purpose of food donation).[25]

Based on the provided data, EPA developed the following approach to estimate total excess food donated to food banks:

- EPA calculated the total quantity of excess food received by food banks that would have otherwise been thrown away by the establishments donating the food, but which was instead donated to Feeding America, and then developed an estimate of excess food managed per food bank establishment.[26]
- EPA then multiplied excess food received per food bank by the total number of food bank establishments nationwide (1,263) to estimate total excess food managed through food donation. The number of food banks is based on data available from Hoovers, a research company that provides information on companies and industries.[27]

As a result, based on the most recently available data from Feeding America and recent food bank establishment data, excess food managed by donation to food banks was approximately 9 million tons in 2016. Table 12 details the calculations and corresponding estimates.

TABLE 12. EXCESS FOOD MANAGED BY FOOD DONATION

SCOPE	PARAMETER	QUANTITY[1]	SOURCE
Feeding America	Food received (tons)	2,156,243	Feeding America, 2015
	Percentage of food received that is food that would otherwise been thrown away	67.5%	Feeding America, 2017
	Net quantity of excess food donated (tons)	1,455,133	Calculated
	Number of Feeding America locations providing excess food data	203	Feeding America, 2015
	Excess food donated per food bank (tons/food bank)	7,168	Calculated
National	Total number of food banks nationwide (NAICS 624210)	1,263	Hoovers, 2017
	Total quantity of excess food managed by food donation (tons)[2]	**9,053,365**	Extrapolation calculation

Note:
[1] Totals do not add up due to rounding.
[2] This includes an estimated 378,198 tons of food that is not able to be distributed by food banks and is ultimately managed as food waste. For more detail on food waste generated by food banks, see Section 6.2.6.

[25] Feeding America (2017) reports that 3.3 billion pounds of food were rescued from going to waste (see page 6). Feeding America confirmed that of 4.89 billion lbs of food received by Feeding America, 3.3 billion lbs (i.e., 67.5%) were rescued (L. Baldridge, personal communication, July 2, 2018).
[26] EPA did not include data from the Food Donation Connection to avoid double-counting. The Food Donation Connection supplies excess food to many organizations, including some Feeding America food banks. The Food Donation Connection noted that their partners donated 30,674 tons of excess food in 2017.
[27] Food banks are listed under the NAICS code 624210. The U.S. Census Bureau's County Business Patterns data indicate that 4,660 establishments exist in NAICS 624210, Community Food Services. However, these data include food shelters, pantries, and other organizations that distribute food originally routed through food banks. Hoovers splits out Community Food Services into more granular sub-categories, one of which includes food banks. Therefore, EPA only includes the 1,263 food banks, and excludes the other organizations, in order to avoid double counting.

The estimates of excess food managed by donation to food banks rely on several key assumptions:

- The data reported by Feeding America capture a representative sample of the food donation universe and Feeding America food banks are comparable in size to other food banks, forming a reasonable basis for extrapolation.
- Feeding America accurately reported the quantity of excess food donated.
- The quantity of direct local, informal donations (e.g., food donated directly to a local food bank) is negligible in comparison to the quantity of food managed by Feeding America and food banks nationwide.
- Any packaging included in the excess food tonnage received by food banks reported by Feeding America is significantly lower in comparison to the overall quantity of excess food managed and is therefore negligible.

3.4.2.7 Landfill and Controlled Combustion

As discussed in Section 3.4.1, EPA's initial excess food and food waste management pathway characterization resulted in estimates of percent of food waste managed by various management pathways, including landfill and combustion. EPA built upon these initial estimates using additional data for certain management pathways (food donation, animal feed, AD, and composting/aerobic processes). The revised estimates for composting/aerobic processes and AD resulted in changes to the initial characterization of the proportion of food waste managed by landfill and combustion. See Sections 3.4.2.1 and 3.4.2.2. As a result, total food waste estimated to be managed by controlled combustion in 2016 was 7.5 million tons and total food waste estimated to be sent to landfill in 2016 was 34.5 million tons. For more detailed estimates, see Section 6.3: Appendix C, which contains estimates of the amount of food waste and excess food generated by each sector, and the amount managed by each management pathway, per sector.

3.5 Summary of Sector-Specific Generation and Management Estimates

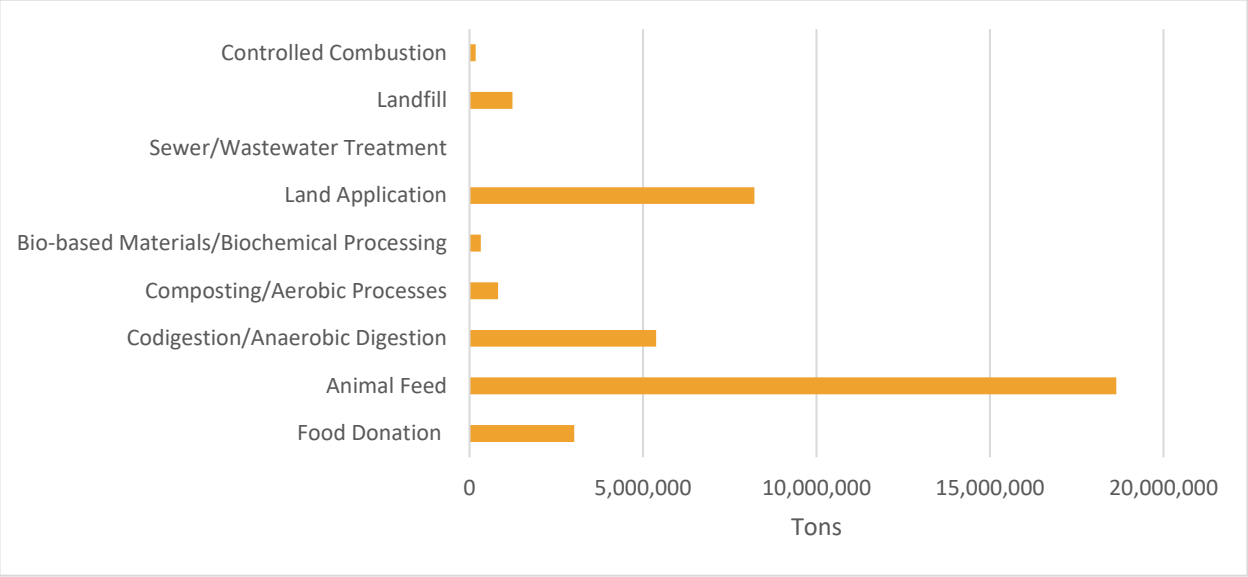
Based on EPA's enhanced methodology, EPA estimates that just over 100 million tons of excess food and food waste were generated in the industrial, residential, commercial, and institutional sectors in 2016. The industrial (i.e., manufacturing/processing) sector accounts for about 38% and the residential sector accounts for about 25% of total generation. The largest generator in the commercial sector is restaurants/food services, which accounts for about 17% of generation, and the largest generator in the institutional sector is office buildings, which accounts for 4% of generation.

Each of these generator sectors manage their excess food and food waste in a variety of ways. Figures 7 through 13 depict how much of each sector's excess food and food waste is estimated to be managed by each pathway. Table 48 (in Section 6.3: Appendix C) contains estimates of the amount of food waste and excess food generated by each sector, and the amount managed by each management pathway, per sector.

The industrial sector, which is comprised of food and beverage manufacturers and processors, was estimated to generate 37.8 million tons of excess food and food waste in 2016. About half (49%) of the

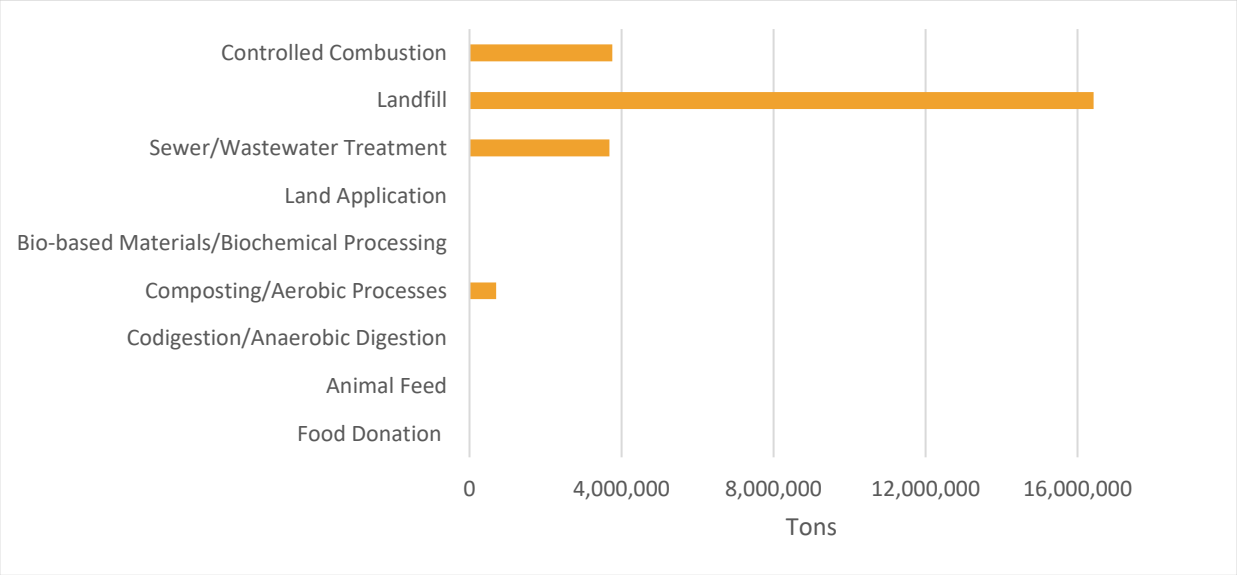
manufacturing/processing sector's excess food and food waste was managed by animal feed, 22% by land application, 14% by AD, with smaller proportions managed by other methods. Food manufacturing/processing industries are unique from the other sectors EPA analyzed in the methods they use to manage their food waste and excess food. Figure 7 depicts the proportion of the manufacturing/processing sector's excess food and food waste managed by each pathway.

FIGURE 7. MANUFACTURING/PROCESSING SECTOR EXCESS FOOD AND FOOD WASTE MANAGEMENT PROFILE (2016)



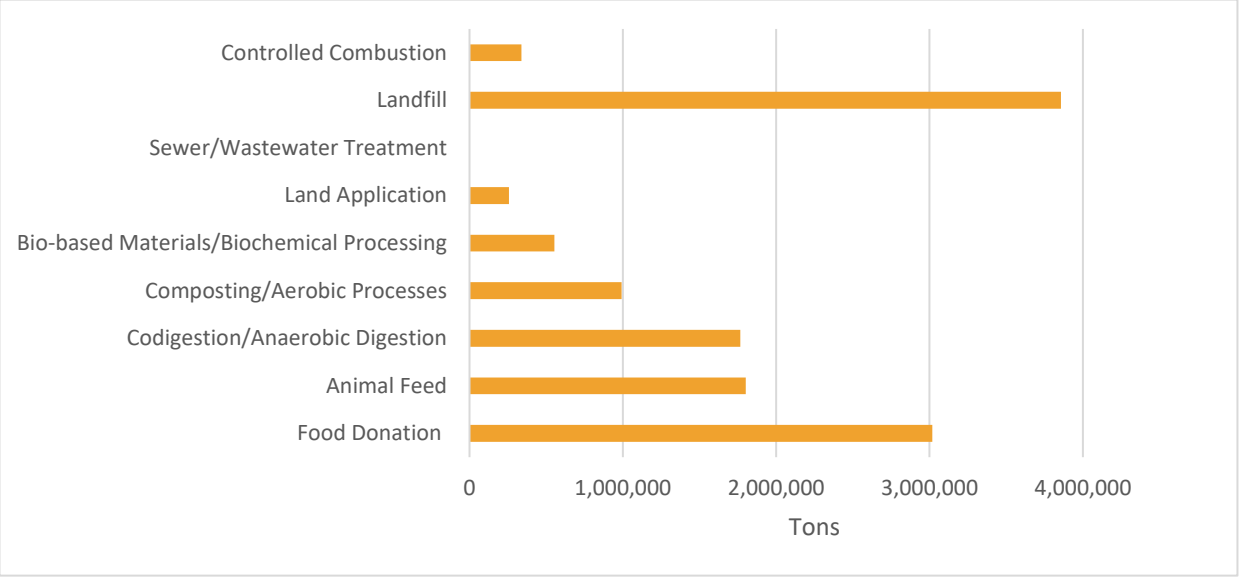
The residential sector, which includes single family and multi-family dwellings, was estimated to generate 24.6 million tons of food waste. The majority (67%) of this food waste was landfilled; 15% was combusted, and 15% was sent to sewer/wastewater treatment. Only 3% was composted. Figure 8 depicts the proportion of the residential sector's food waste managed by each pathway.

FIGURE 8. RESIDENTIAL SECTOR FOOD WASTE MANAGEMENT PROFILE (2016)



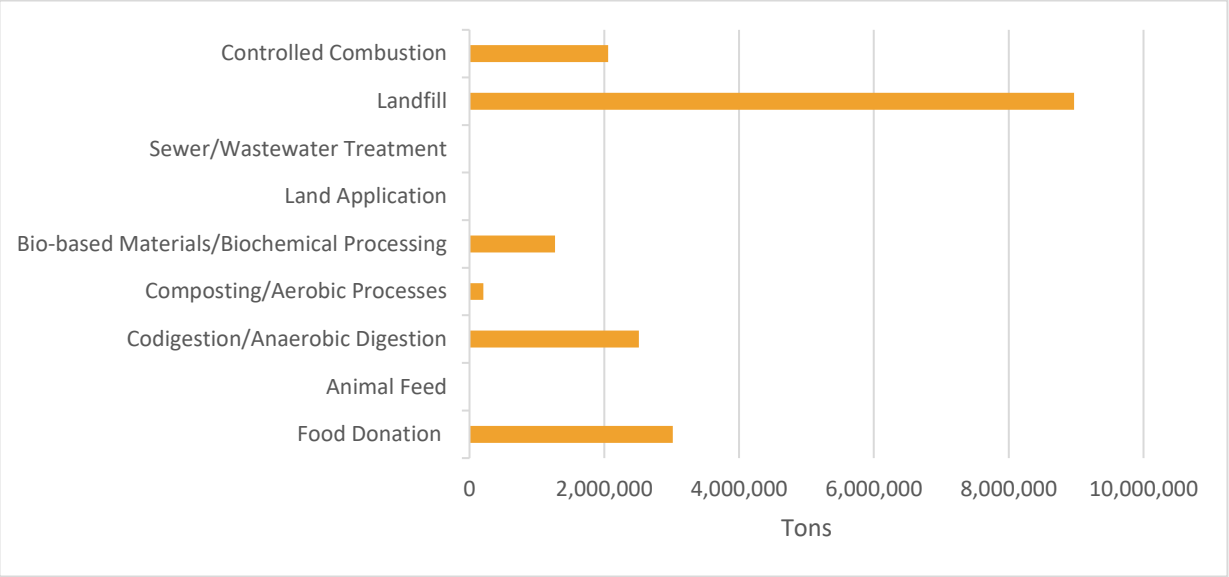
The commercial sector includes food retail/wholesale (supermarkets, supercenters, and food wholesale) and hospitality (restaurants/food services, hotels, and sports venues). The food retail/wholesale sector was estimated to generate 12.6 million tons of excess food and food waste (8.7 million tons from supermarkets and supercenters, and 3.9 million tons from food wholesale). About one third (31%) of the food retail/wholesale sector's excess food and food waste was landfilled, about one quarter (24%) was donated, 14% was sent to animal feed, 14% was sent to AD, and smaller proportions were managed by other methods. Figure 9 depicts the proportion of the food retail/wholesale sector's excess food and food waste managed by each pathway.

FIGURE 9. FOOD RETAIL/WHOLESALE SECTOR EXCESS FOOD AND FOOD WASTE MANAGEMENT PROFILE (2016)



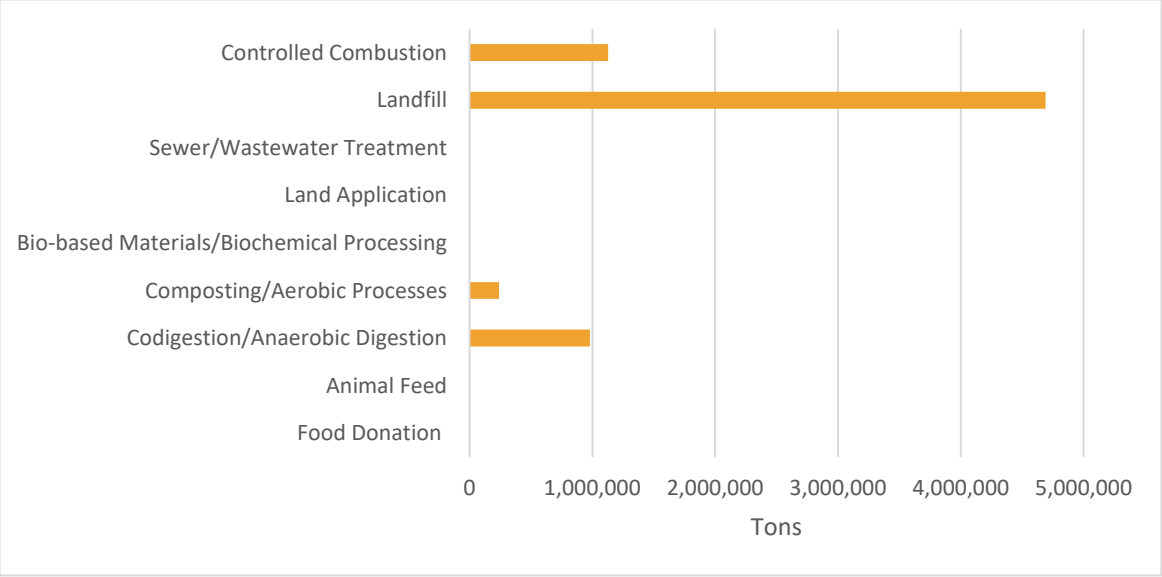
The hospitality sector was estimated to generate 18.0 million tons of excess food and food waste. Restaurants/food services accounts for 16.9 million tons, or 94%, of the excess food and food waste generated in the hospitality sector; hotels account for 1.1 million tons and sports venues account for approximately 38,000 tons. Half of the excess food and food waste generated in the hospitality sector was landfilled, 17% was donated, 14% was sent to AD, and smaller proportions were managed by other methods. Figure 10 depicts the proportion of the hospitality sector's excess food and food waste managed by each pathway.

FIGURE 10. HOSPITALITY SECTOR EXCESS FOOD AND FOOD WASTE MANAGEMENT PROFILE (2016)



The institutional sector includes hospitals, nursing homes, military institutions, office buildings, correctional facilities, colleges and universities, and K-12 schools. The institutional sector was estimated to generate 7.0 million tons of food waste. Office buildings account for 4.0 million tons, or 57%, of the food waste generated in the institutional sector; K-12 schools account for 1.1 million tons and all other sectors account for less than one million tons each. About two thirds (67%) of the food waste generated in the institutional sector was landfilled, 16% was combusted, 14% was sent to AD, and 3% was composted. Figure 11 depicts the proportion of the institutional sector's food waste managed by each pathway.

FIGURE 11. INSTITUTIONAL SECTOR FOOD WASTE MANAGEMENT PROFILE (2016)



Food banks are also a minor generator or food waste, because they receive excess food that is unfit for distribution due to damage, spoiling, and other reasons. Food banks were estimated to generate about

378,000 tons of food waste.[28] About two thirds (67%) of the food waste generated in food banks was landfilled, 16% was combusted, 14% was sent to AD, and 3% was composted. Figure 12 depicts the proportion of food banks' food waste managed by each pathway.

FIGURE 12. FOOD BANK FOOD WASTE MANAGEMENT PROFILE (2016)

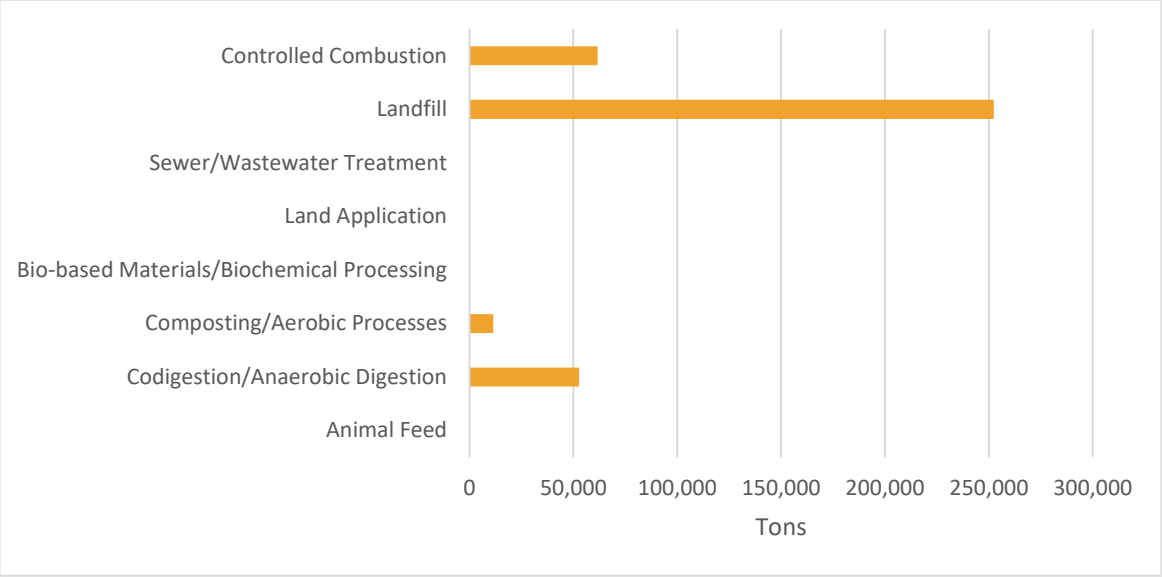
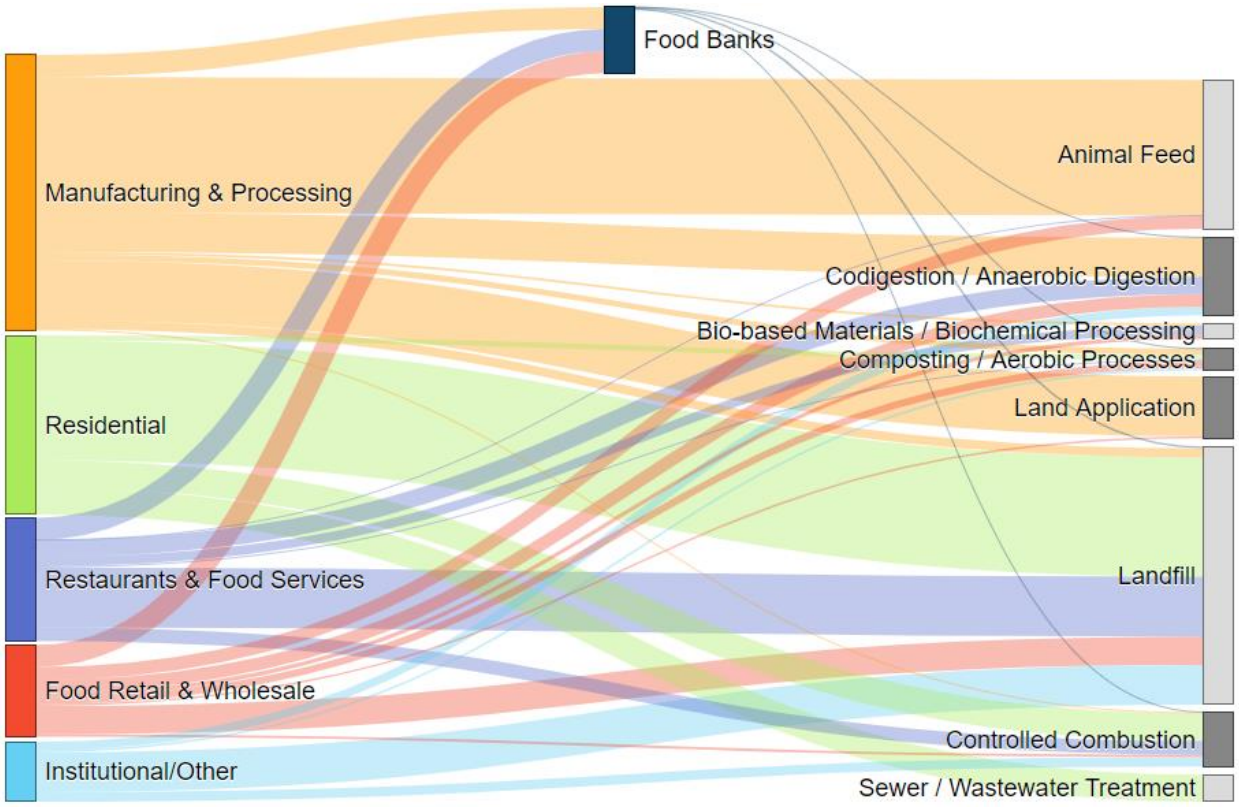


Figure 13 depicts the flows of excess food and food waste from each sector to each management pathway and gives an overall view of how excess food and food waste is handled in the industrial, residential, commercial and institutional sectors.

[28] This tonnage is already accounted for in the excess food and food waste generated in the industrial and commercial sectors, because establishments in those sectors donate excess food to the food banks (i.e., 378,198 tons of the excess food that is donated to food banks ends up becoming food waste).

FIGURE 13. FLOW OF INDUSTRIAL, RESIDENTIAL, COMMERCIAL, AND INSTITUTIONAL EXCESS FOOD AND FOOD WASTE TO VARIOUS MANAGEMENT PATHWAYS (2016)



4 Integration of Enhanced Methodology into EPA's "Facts and Figures Report"

EPA publishes estimates of food waste generation and management annually in its "Facts and Figures Report", which presents estimates of generation, recycling, composting, combustion with energy recovery, and landfilling of MSW, or trash. (See Section 2 for a description of the food measurement methodology used to date in EPA's "Facts and Figures Report".) MSW is comprised of various items consumers throw away. These items include packaging, food, yard trimmings, furniture, electronics, tires and appliances. Sources of MSW include residential waste, including waste from multi-family housing, as well as waste from commercial and institutional locations, such as businesses, schools and hospitals. MSW does not include industrial, hazardous or construction and demolition waste (U.S. EPA, 2019b).

EPA's enhanced food measurement methodology expands the scope of EPA's previous food measurement efforts reflected in the Facts and Figures Reports by including:

- industrial sources of food waste (i.e., food and beverage manufacturing/processing);
- additional commercial and institutional generators of excess food and food waste (e.g., office buildings, military bases, sports venues, food banks, and certain classes of retailers); and

- several new management pathways for excess food and food waste (e.g., animal feed, bio-based materials/biochemical processing, co-digestion/anaerobic digestion, donation, land application, and sewer/wastewater treatment).

There are three main reasons why the enhanced methodology results in higher estimates of food waste than EPA's previous estimates in the "Facts and Figures Report":

1. EPA's enhanced methodology uses more recent studies and dropped older studies. In some cases, these studies result in higher generation factors.

2. EPA's enhanced methodology includes additional generator sectors (i.e., NAICS codes) that generate excess food and food waste.

3. EPA's enhanced methodology includes several additional management pathways. EPA's food measurement methodology that has been used for the "Facts and Figures Report" to-date measures food waste at the point it is ready to be managed by the traditional MSW system (i.e., composting, landfilling, and combustion), which excludes food that is donated to feed people, used to feed animals, sent down the drain, or managed by other methods. Therefore, excess food and food waste that was managed by methods other than composting, landfilling, and combustion would not necessarily have been captured on the generation side of the estimate in EPA's previous estimates.

EPA will use the enhanced measurement methodology, with one exception, to derive updated estimates of excess food and food waste generation and management for the "Facts and Figures Report" starting with the 2018 estimates, which are anticipated to be published in late 2020. The exception is the industrial sector (i.e., food manufacturing/processing), which will not be included in the "Facts and Figures Report". While the food manufacturing/processing sector is an important component of the entire food system, it will not be included in EPA's annual "Facts and Figures Report" because industrial sources of waste are out of the scope of the report. Therefore, the "Facts and Figures Report" will include excess food and food waste generation estimates for the residential, commercial and institutional sectors, and estimates of how much excess food and food waste is managed by the following pathways: animal feed, bio-based materials/biochemical processing, co-digestion/anaerobic digestion, composting/aerobic processes, controlled combustion, donation[29], land application, landfill, and sewer/wastewater treatment.

EPA compared the 2016 food waste estimates published in the "Facts and Figures Report" (U.S. EPA, 2019a) with the 2016 estimates developed using the enhanced methodology (excluding the manufacturing/processing sector). As shown in Table 13 and Figure 14, for 2016, the enhanced methodology results in an estimate of 62.23 million tons of excess food and food waste generated in the

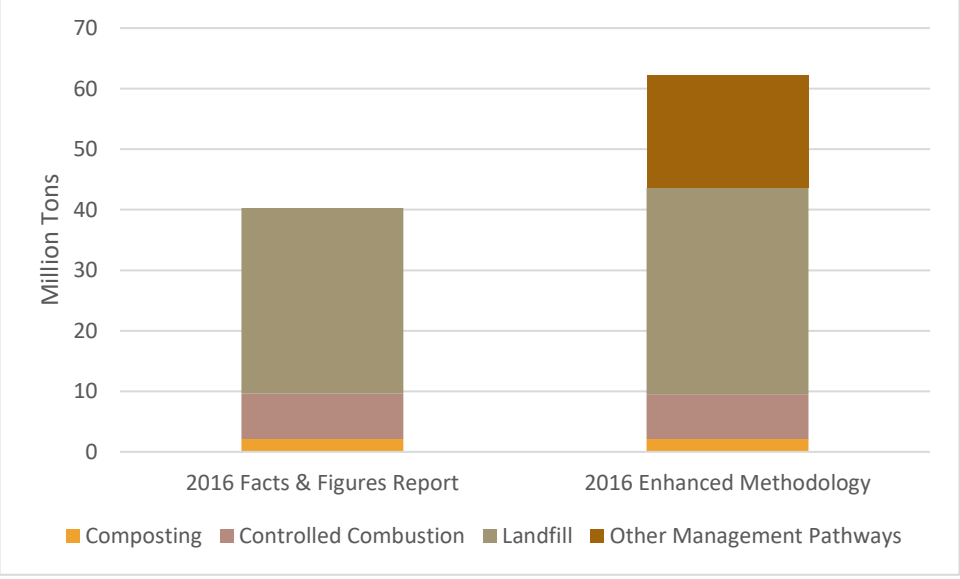
[29] Food donation is different from the other management pathways, in that it is the only one that routes excess food to be re-distributed to people (as opposed to sending food waste to facilities that turn the material into animal feed, energy, or compost, for example). However, it is important to capture this pathway in the "Facts and Figures Report" as it is a common practice for many sectors of the food system, and after source reduction it is the best use of edible food (see EPA's Food Recovery Hierarchy: https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy). Therefore, EPA will include the estimates of excess food donated to food banks along with the other management pathways in its "Facts and Figures Report".

residential, commercial, and institutional sectors, compared to 40.31 million tons of food waste generated in the 2016 "Facts and Figures Report" (U.S. EPA, 2019a). The estimates of the portion of food waste that was sent to landfill are similar: 35.43 million tons using the enhanced methodology, compared to 30.68 million tons in the "Facts and Figures Report" (U.S. EPA, 2019a). Of the 21.92 million tons difference between the two generation estimates for the residential, commercial, and institutional sectors, the majority (18.54 million tons, or about 85%) was managed by methods other than composting, controlled combustion, and landfill. This is due to the fact that the "Facts and Figures Report" methodology would not necessarily have captured excess food and food waste on the generation side that was managed by methods other than composting, landfilling, and combustion, as discussed above.

TABLE 13. COMPARISON OF "FACTS AND FIGURES REPORT" ESTIMATES WITH ENHANCED METHODOLOGY ESTIMATES FOR THE RESIDENTIAL, COMMERCIAL, AND INSTITUTIONAL SECTORS (EXCLUDES INDUSTRIAL SECTOR) (2016)

MANAGEMENT PATHWAY	2016 "FACTS AND FIGURES REPORT" (MILLION TONS)	2016 ENHANCED METHODOLOGY (MILLION TONS)
Composting	2.15	2.15
Controlled Combustion	7.48	7.35
Landfill	30.68	34.19
Other Management Pathways	N/A	18.54
TOTAL	**40.31**	**62.23**

FIGURE 14. COMPARISON OF 2016 FACTS AND FIGURES ESTIMATES WITH 2016 ENHANCED METHODOLOGY ESTIMATES FOR THE RESIDENTIAL, COMMERCIAL, AND INSTITUTIONAL SECTORS (EXCLUDES INDUSTRIAL SECTOR)



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6 Appendices

6.1 Appendix A: Glossary of Terms

Animal Feed: Diverting material from the food supply chain (directly or after processing) to animals (excludes crops intentionally grown for bioenergy, animal feed, seed, or industrial use). (Food Loss and Waste Protocol, n.d.)

Bio-based Materials / Biochemical Processing: Converting material into industrial products. Examples include creating fibers for packaging material, creating bioplastics (e.g., polylactic acid), making "traditional" materials such as leather or feathers (e.g., for pillows), and rendering fat, oil, or grease into a raw material to make products such as soaps, biodiesel, or cosmetics. "Biochemical processing" does not refer to anaerobic digestion or production of bioethanol through fermentation. (Food Loss and Waste Protocol, n.d.)

Codigestion/anaerobic digestion: Breaking down material via bacteria in the absence of oxygen. This process generates biogas and nutrient-rich matter. Codigestion refers to the simultaneous anaerobic digestion of food loss and waste and other organic material in one digester. This destination includes fermentation (converting carbohydrates—such as glucose, fructose, and sucrose—via microbes into alcohols in the absence of oxygen to create products such as biofuels). (Food Loss and Waste Protocol, n.d.) Often referred to as "anaerobic digestion" or "AD".

Composting/aerobic processes: Breaking down material via bacteria in oxygen-rich environments. Composting refers to the production of organic material (via aerobic processes) that can be used as a soil amendment. (Food Loss and Waste Protocol, n.d.) Often referred to as simply "composting".

Controlled combustion: Sending material to a facility that is specifically designed for combustion in a controlled manner, which may include some form of energy recovery (this may also be referred to as incineration). (Food Loss and Waste Protocol, n.d.)

Excess food: food that is donated to feed people.

Food: Any substance—whether processed, semi-processed, or raw—that is intended for human consumption. "Food" includes drink, and any substance that has been used in the manufacture, preparation, or treatment of food. "Food" also includes material that has spoiled and is therefore no longer fit for human consumption. It does not include cosmetics, tobacco, or substances used only as drugs. It does not include processing agents used along the food supply chain, for example, water to clean or cook raw materials in factories or at home. (Food Loss and Waste Protocol, n.d.)

Food donation: collection and redistribution of unspoiled excess food to feed people through food pantries, food banks and other food rescue programs.

Food loss: unused product from the agricultural sector, such as unharvested crops.

Food waste: food such as plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered inedible.

Land Application: Spreading, spraying, injecting, or incorporating organic material onto or below the surface of the land to enhance soil quality. (Food Loss and Waste Protocol, n.d.)

Landfill: Sending material to an area of land or an excavated site that is specifically designed and built to receive wastes. (Food Loss and Waste Protocol, n.d.)

Sewer/wastewater treatment: Sending material down the sewer (with or without prior treatment), including that which may go to a facility designed to treat wastewater. (Food Loss and Waste Protocol, n.d.)

Wasted food: food that was not used for its intended purpose and is managed in a variety of ways, such as donation to feed people, creation of animal feed, composting, anaerobic digestion, or sending to landfills or combustion facilities. Examples include unsold food from retail stores; plate waste, uneaten prepared food, or kitchen trimmings from restaurants, cafeterias, and households; or by-products from food and beverage processing facilities.

6.2 Appendix B: Food Waste Generation By Sector

This Appendix reviews analytic methods for estimating food waste generation in industrial, residential, commercial, and institutional sectors. Specifically, each section:

- Reviews the recommended approach, citing key literature used in developing a generation factor and other parameters;
- Presents a 2016[30] food waste generation estimate for the sector; and
- Discusses data limitations.

6.2.1 Food Manufacturing/Processing Sector

EPA's enhanced methodology uses the following generation factor for food waste in the food manufacturing/processing[31] sector:

- 0.095 lbs/sales dollar/year applied to food and beverage manufacturing/processing sector sales.

This metric is based on a series of national food waste surveys of food manufacturers. Using the 2016 estimate of food manufacturing/processing sector sales, the estimate of food waste generated from the food manufacturing/processing sector is:

- **37.8 million tons per year**, reflecting 2016 generation.

The following section provides more detail about the derivation of this estimate and other methods considered.

6.2.1.1 Analytic Methods for Food Manufacturing/Processing Food Waste Generation

Food manufacturing and processing involves transforming raw ingredients into marketable food and beverage products that can be easily prepared and served by the consumer. Food waste can occur due to operational inefficiencies or from standard food processing operations (e.g., corn husks from producing canned corn). The methods for estimating food waste generation from food manufacturing/processing

[30] Most data are from 2016, but there are some exceptions where 2016 data were not available.
[31] EPA includes beverage manufacturers in the "food manufacturing/processing" sector. Note that beverages are included in the definition of food (see Section 6.1 for a Glossary of Terms).

facilities define the sector consistent with NAICS codes 311 (food manufacturing) and 3121 (beverage manufacturing), with some exceptions as described later in this section.

The literature search identified a total of 55 studies examining food waste generation at the food and beverage manufacturing/processing level. Many of these studies, however, are not directly useful to methods development as some lack quantitative information on generation factors, while others apply generation factors from earlier studies. The methods EPA chose are based on a relatively small subset of seven studies that involved original research (e.g., surveying food manufacturers/processors or directly measuring food waste generated from a sample of food manufacturers/processors).

EPA initially considered three different methods from the seven studies, as summarized in Table 14:

- Method 1 is built on three studies that allow consideration of the quantity of food waste generated per dollar of annual sales revenue in the food manufacturing/processing sector. The 2013 and 2014 studies were developed by BSR for FWRA, while the 2016 study was published with FWRA as the author. These three studies are heavily cited in other food waste analyses (see NRDC, 2017; Garcia-Garcia, 2016; Rethink Food Waste Through Economics and Data (ReFED), 2016).
- Method 2 is built on two studies that estimate the annual quantity of food waste generated per food manufacturing/processing establishment. These two studies are also widely cited (see Hodge, 2016; South Carolina Department of Commerce (DOC), 2015).
- Method 3 is built on measurements of the quantity of food waste generated per industry employee, as reported in two studies.

TABLE 14. FOOD MANUFACTURING/PROCESSING EXCESS FOOD/FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
Method 1	FWRA	2016	Lbs/sales $/year	0.17
	BSR	2014	Lbs/sales $/year	0.053
	BSR	2013	Lbs/sales $/year	0.062
	AVERAGE			**0.095**
Method 2 (Not Used)	Massachusetts DEP	2002	Lbs/establishment/year	367,038
	Connecticut DEP	2001	Lbs/establishment/year	1,358,179
	AVERAGE			**862,608**
Method 3 (Not Used)	CalRecycle	2015	Lbs/employee/year	1,692
	Metro Vancouver	2015	Lbs/employee/year	1,618
	AVERAGE			**1,655**

The studies in Method 1 estimated generation factors by surveying food manufacturers around the nation. Depending on the year of the survey, the surveyed manufacturers represent anywhere between 6.2% to 17% of the national food manufacturing/processing industry, based on sales. The manufacturing/processing facilities included in the studies vary each year; because the samples change, the studies are independent, allowing incorporation of all three data points into the average generation factor

estimate.[32] As shown, the three generation factor estimates from the studies range from 0.053 to 0.17 lbs per dollar of annual industry sales revenue, with an average of 0.095.[33] The FWRA and BSR studies provide a clear definition of food waste that is based on the FLW Standard.

In contrast, the studies in Method 2 estimated generation factors at a state level by surveying food manufacturers in Massachusetts and Connecticut, while the studies in Method 3 estimated generation factors at a city level by directly measuring food waste generated from a sample of food manufacturers in select areas in California (e.g., the Bay, Coastal, Mountain, Southern, and Central Valley areas) and Metro Vancouver.

EPA multiplied the generation factors for each method by the relevant "denominator" metric (e.g., annual sales) to estimate total excess food/food waste generated in the food manufacturing/processing sector. The annual sales and employee figures for Method 1 and Method 3 are provided by the U.S. Census Bureau in its Annual Survey of Manufacturers (ASM). The annual number of food manufacturing/processing establishments for Method 2 is provided by a food manufacturing/processing industry report conducted annually by Hoovers. The primary NAICS codes incorporated into these metrics are 311 (food manufacturing) and 3121 (beverage manufacturing). Several detailed manufacturing sectors are excluded from the totals, however, including animal food manufacturing (NAICS 311111 and 311119), bottled water manufacturing (312112), and ice manufacturing (312113). The underlying rational for this adjustment is that these manufacturing sectors are not engaged in production of food for human consumption (in the case of the animal food sectors) or are unlikely to generate food waste at all (in the case of the water and ice sectors). This adjustment has a relatively minor impact on the estimates given that the excluded sectors represent less than 8% of sales, and an even smaller share of employment and establishments.

As summarized in Table 15, Method 1 yields an excess food/food waste generation estimate of 38.6 million tons[34]; Method 2 yields an estimate of 39.7 million tons; and Method 3 yields an estimate of 1.3 million tons.

TABLE 15. FOOD MANUFACTURING/PROCESSING EXCESS FOOD/FOOD WASTE GENERATION ESTIMATES

METHOD	PARAMETER	ESTIMATE	UNITS	SOURCE
Method 1	Average Generation Factor	0.095	Lbs/sales $/year	Average

[32] Unlike some other sectors, EPA did not weight the Method 1 studies in developing an average generation rate. The three sources are relatively recent and national in scope, and are therefore given equal weight.

[33] BSR (2014) explicitly reports the generation factor on page 10 of the study. In contrast, FWRA (2016) and BSR (2013) do not explicitly report generation factors; however, generation factors can be calculated from the survey findings described in the studies. FWRA (2016) identifies 10.6 billion pounds of food waste from nine survey respondents. The reported sales figure is $55.8 billion, but that figure covers only eight of the nine facilities (one facility did not report data). EPA adjusted for this missing sales information by estimating the average sales for the eight facilities reporting, and then multiplying by all nine facilities. Hence, the calculation is: 10.6 billion lbs/((55.5 billion/8)*9) = 0.17. BSR (2013) reports neither a generation factor nor survey data totals for waste generation. Instead, it reports national waste generation figures extrapolated from the survey data. BSR (2013) states that survey respondents represent 17% of all facilities nationwide. Hence, EPA estimated waste generation for survey respondents by multiplying the extrapolated national figure (44.3 billion pounds) by 0.17 to yield a waste generation estimate of 7.53 billion pounds. Dividing this figure by the respondents' sales revenue ($122 billion) yields the generation rate: 7.53 billion lbs/122 billion = 0.062.

[34] This estimate was ultimately adjusted. See explanation at the end of this section.

METHOD	PARAMETER	ESTIMATE	UNITS	SOURCE
	Metric Estimate	$814,033,997,000	Sales, 2016	U.S. Census Bureau, 2016 Annual Survey of Manufacturers[35], NAICS 311 and 3121 (excluding 311111, 311119, 312112, 312113)
	Annual Generation Quantity	38,578,587[1]	Tons	Product of generation factor and metric value
	Number of studies (N) with original generation factors	3	Number	
Method 2 (Not Used)	Average Generation Factor	862,608	Lbs/establishment/ year	Average
	Metric Estimate	91,994	Establishments, 2016	DandB Hoovers food manufacturing industry report
	Annual Generation Quantity	39,677,393	Tons	Product of generation factor and metric value
	Number of studies (N) with original generation factors	2	Number	
Method 3 (Not Used)	Average Generation Factor	1,655	Lbs/employee/year	Average
	Metric Estimate	1,510,433	Employees, 2016	U.S. Census Bureau, 2016 Annual Survey of Manufacturers, NAICS 311 and 3121 (excluding 311111, 311119, 312112, 312113)
	Annual Generation Quantity	1,250,080	Tons	Product of generation factor and metric value
	Number of studies (N) with original generation factors	2	Number	

Note:
[1] The final estimate is slightly lower (37,813,294 tons), due to an adjustment that was made to exclude a portion that was reported to be managed by "other" methods. See explanation at the end of this section. See explanation at the end of this section.

Based on a review of each study's analytic rigor, EPA chose Method 1 to estimate food manufacturing/processing sector food waste generation. EPA considered the following in choosing Method 1:

- The rate at which specific food manufacturing/processing establishments generate excess food and food waste varies widely with the type of food being produced and the processes used. For instance, a food manufacturing process for cream of corn soup is likely to produce more food waste (in the form of corn husks and hulls) than a process that produces frozen string beans. Method 1 surveyed food manufacturers/processors across the nation and across multiple kinds of food types manufactured. As a result, it is inclusive and more likely captures the inherent food waste generation variation associated with diverse food manufacturing/processing practices and food types.

[35] The 2016 Census of Manufacturers Data can be accessed at https://www.census.gov/data/tables/2016/econ/asm/2016-asm.html. Searches for individual NAICS codes are most easily performed through the Census Bureau's American Fact Finder portal (https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml), using the "advanced search" area.

- The annual generation quantity estimated using Method 2 corroborates Method 1's results; estimated generation quantities only differed by 3%. While Method 2 may capture a reasonable degree of variation through the underlying statewide survey approaches used in Massachusetts Department of Environmental Conservation (DEP) (2002) and Connecticut Department of Environmental Conservation (DEP) (2001), Method 2 was not ultimately selected as its underlying dataset is older.[36] Production efficiency changes in the last decade may have altered (reduced) waste generation rates in the competitive food manufacturing/processor sector. In addition, Method 2 does not reflect the broad geographic scale that Method 1 has, and may therefore be less representative of national practices.

- EPA also chose not to apply Method 3 for the following reasons. First, the distribution of food manufacturers/processors sampled is geographically narrow and focused on urban areas; it is therefore less likely to represent average national conditions. Furthermore, the studies were conducted in cities that already were implementing food waste landfill bans around the time of data collection. Food waste landfill bans often motivate organizations to prevent food waste generation, resulting in lower food waste quantities generated. Therefore, the studies may not be representative of food manufacturers nationwide.

- Finally, the Method 1 studies adhere to a clearer definition of food waste relative to the other studies. Specifically, the FWRA and BSR studies align with the FLW Standard, providing an added degree of confidence in the estimated generation factors.[37]

Not that this estimate was ultimately adjusted. The FWRA (2016) study, which was used for management pathway distribution for the manufacturing/processing sector, asked survey respondents to report food waste managed by a variety of methods (i.e., the FLW Standard destinations), including a catch-all "other" category. The study did not report what methods survey respondents were referring to as "other" when they reported tonnage in that category. Because there is no information available about what management methods were used to manage tonnage reported in the "other" category, EPA did not include the proportion of food waste reported to be managed by "other" methods. As a result, based on the selected generation factor of 0.095 lbs/sales dollar/year and the 2016 estimate of food manufacturing sector sales, adjusted to exclude the proportion of food waste managed by "other" means by the manufacturing/processing sector in FWRA (2016), **EPA's estimate of excess food/food waste generated from the food manufacturing sector in 2016 is 37.8 million tons per year.**

Key Assumptions and Limitations

The generation estimates for this sector rely on two key assumptions:

- The survey data reported by FWRA and BSR capture a representative sample of the universe and form a reasonable basis for extrapolation.

[36] Note that while BSR and the FWRA, the two organizations that led the surveys in Method 1, caution against using survey results for national food waste extrapolation, EPA still used their data for extrapolation as our extrapolated results are corroborated with other robust methods.

[37] For example, see page 9 of FWRA (2016) which defines food waste as any "solid or liquid food substance, raw or cooked, which is discarded, or intended or required to be discarded. Food waste includes the organic residues (such as carrot or potato peels) generated by the processing, handling, storage, sale, preparation, cooking, and serving of food."

- Respondents have accurately reported the generation of and management of all food-related waste streams.

6.2.2 Residential Sector

EPA's enhanced methodology results in the following 2016 estimate of food waste generated from the residential sector:

- **24.6 million tons per year** of food waste from the residential sector.

The following section provides more detail about the derivation of this estimate.

6.2.2.1 Analytic Methods for Residential Food Waste Generation

The residential sector is the largest source of food waste in the United States after food manufacturing. National-level studies have estimated that about 40% of total food waste is generated by the residential sector (ReFED, 2016; NRDC, 2017). Food can be wasted prior to consumption, during meal preparation, or post-consumption from plate waste.

The literature search identified a total of 93 studies examining food waste generation at the residential level. Many of these studies, however, are not directly useful for methods development. Some lack quantitative information on generation factors, while others apply generation factors from earlier studies. The methods EPA developed are based on a subset of 14 studies that involved original research (e.g., direct analysis of household food waste).

EPA originally considered three different generation factors applied in the 14 studies, as summarized in Table 16:

- Method 1 is built on four studies that estimate the quantity of food waste generated per household, per year in the residential sector.[38] U.S. EPA (2016b), NRDC (2017), and InSinkErator (2016) surveyed and conducted bin digs at households in cities across the country. CalRecycle (2015) examined waste composition from residences in five regions across the state of California.
- Method 2 relies on estimates of the percentage of total residential MSW that is food waste. Seven studies estimate this percentage.
- Method 3 is built on three studies that are widely cited that estimate the annual quantity of food waste generated per capita in the residential sector.

TABLE 16. RESIDENTIAL FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	STUDY TYPE
Method 1	CalRecycle	2015	380	Lbs/household/year	Waste Audit
	U.S. EPA	2016b	241	Lbs/household/year	Self-reported waste measurement, photo diary

[38] A study by Schott et al. (2013) examined waste composition in ten different municipalities in Sweden, and the 2017 WRAP report estimated food waste generation in the United Kingdom. While the findings reported in these studies (400 lbs/household/year and 248 pounds/capita/year, respectively) generally are consistent with U.S. evidence, EPA excluded them because of their focus on communities outside the U.S.

METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	STUDY TYPE
	NRDC	2017	277	Lbs/household/year	Kitchen diary, self-reported survey, bin dig
	InSinkErator	2016	464	Lbs/household/year	Self-reported Survey
Method 2	Vermont DEC	2013	16.7	% of total sector waste	Waste audit
	King County, WA	2009	5.8	% of total sector waste	Waste audit
	Iowa DNR	2011	13.6	% of total sector waste	Waste audit
	Montgomery County, MD	2013	20.4	% of total sector waste	Waste audit
	City of San Diego	2014	20.1	% of total sector waste	Waste audit
	Seattle Public Utilities	2014	29.55	% of total sector waste	Waste audit
	Boulder Food Rescue	2016	13.1	% of total sector waste	Data analysis, self-reported survey
Method 3 (Not Used)	Buzby and Hyman	2012	273	Lbs/capita/year	Data analysis
	Buzby et al.	2014	290	Lbs/capita/year	Data analysis
	FAO	2011	231	Lbs/capita/year	Data analysis

Most of the studies conducted for the residential sector estimate food waste generation by conducting waste audits at a sample of households in the study area; several studies gathered these data through self-reported surveys. The studies examined for the residential sector span a number of cities and counties across the Northeast, mid-Atlantic, Midwest, and West; few studies were conducted in Southern states. In addition, San Francisco and Seattle adopted residential food waste bans in 2009 and 2015, respectively. While none of the studies in this analysis examined food waste in these two cities post-ban, the reduction in household waste should certainly be taken into consideration for forward-looking food waste projections.

The studies in Method 1 estimated generation factors between 241 and 462 pounds per household per year. The low estimate comes from U.S. EPA (2016b), which examined residential food waste in eleven cities/counties throughout the country. The average of these generation factors is 241 pounds per household per year. The high estimate was derived from InSinkErator, a manufacturer of food waste disposers. InSinkErator sampled a total of 380 households across four cities to measure the total amount of food waste generated per household with and without the use of a food waste disposer (InSinkErator, 2016). The average generation factor estimated by this study, for households that did not use food waste disposers, was 464 pounds per household per year. The remaining studies, produced by CalRecycle and NRDC, estimated residential food waste generation at 380 and 277 pounds per household per year, respectively.[39]

The studies in Method 2 measure household food waste as a percentage of total household solid waste. All but one of the estimates are derived from household waste audits, in which a household's waste stream

[39] The NRDC and U.S. EPA studies provide a clear definition of food waste that is based on the FLW Standard.

was directly sorted and measured. The estimates range from 5.8% in King County, Washington, to 29.55% in Seattle proper.[40]

Method 2 includes an adjustment to account for the fact that households with food waste disposers divert a fraction of food waste to these systems. Because the estimates cited in this method were primarily generated from bin digs or waste audits, they do not account for food waste already diverted to food waste disposers. The analysis adds a 15% increment to the residential food waste estimates in Method 2, consistent with the 15% sewer/wastewater treatment diversion rate estimated for the residential sector.

EPA also considered a per-capita method of estimating total residential sector food waste generation, referred to as Method 3. Three studies examined food waste generated on a per-capita basis. Two of these studies, Buzby and Hyman (2012) and Buzby et al. (2014), use data from the USDA ERS' LAFA series, which categorizes food losses at the primary production, retail, and consumer levels. In these studies, the consumer level is not synonymous with the residential level. Instead it includes residential food waste, as well as food waste generated at restaurants, schools, and other institutions. The third study in this method, conducted by the Food and Agriculture Organization of the United Nations (FAO), calculates global food waste generation based on USDA's estimates and FAO's own mass flow modeling assumptions. Estimates in this category ranged from 230 to 290 pounds per capita per year. Because residential food waste is considered at the overall "consumer" level and cannot otherwise be differentiated, these three studies are excluded from the overall analysis. Nevertheless, the LAFA data serve as a general point of comparison for our generation estimates.

EPA multiplied the generation factors for each method by the relevant extrapolation basis (total number of households in the U.S. or total residential MSW in the U.S.) to estimate total food waste generated in the residential sector.

- The extrapolation basis used in Method 1 is calculated annually by the U.S. Census Bureau; EPA's analysis uses the Census Bureau's 2016 estimate.
- For Method 2, a daily per-capita MSW generation rate of 4.44 pounds per person for residential, commercial, and institutional sources is provided in EPA's 2014 "Facts and Figures Report" (U.S. EPA, 2016c). To isolate the share of residential MSW within this overall 4.44 pound per person per day generation figure, it is multiplied by 51 percent, the average share of MSW associated with residential households (U.S. EPA, 2013). The resulting rate, 2.26 pounds per person per day, is multiplied by the total U.S. population and scaled to the annual level (i.e., multiplied by 365), providing annual nationwide residential MSW generation. This national estimate of residential MSW is multiplied by the food waste generation factor (percent of MSW that is food waste) to estimate national food waste generation.

Table 17 summarizes the resulting food waste generation estimates. Each figure was extrapolated to a total annual generation quantity (in millions of tons per year), and collectively averaged (i.e., each study is given equal weight).

[40] It is important to consider whether food waste is measured as a standalone waste category, or whether it is considered as a component of organic waste. Organic waste is often defined to include non-food wastes such as yard waste and non-recyclable paper. Studies that do not report the specific breakout of food waste within the larger category of organic waste were excluded from this analysis.

TABLE 17. RESIDENTIAL FOOD WASTE GENERATION ESTIMATES

METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	BASIS FOR EXTRAPOLATION	FOOD WASTE GENERATION (MILLION TONS/YEAR)
Method 1	CalRecycle	2015	380	Pounds per household per year	125,819,000 households (2016 estimate)	23.91
	U.S. EPA	2016b	241			15.13
	NRDC	2017	277			17.43
	InSinkErator	2016	464			29.19
Method 2	Vermont DEC	2013	16.7	Percent of total household MSW that is food waste	2.26 pounds of residential MSW generation per capita per day	25.85
	King County, WA	2009	5.8			8.98
	Iowa DNR	2011	13.6			21.05
	Montgomery County, MD	2013	20.4			31.58
	City of San Diego	2014	20.1			31.11
	Seattle Public Utilities	2014	29.55			45.74
	Boulder Food Rescue	2016	13.1			20.28
AVERAGE						**24.55**

EPA's estimate of food waste generated from the residential sector in 2016 is 24.6 million tons.

Key Assumptions and Limitations

The generation estimates for this sector are subject to the following assumptions and caveats:

- EPA assumes that the households surveyed capture a representative sample of the universe and form a reasonable basis for extrapolation, that respondents have accurately reported the generation and management of their food-related waste streams, and that results can be extrapolated across geographies (i.e., residential food waste in California is comparable to residential food waste in Florida).
- None of the studies examined in this analysis were conducted for cities or states with active food waste bans in place at the time of study. In 2009, San Francisco passed a residential food waste ban, and in 2015, Seattle followed suit. While the populations of these two cities are a small percentage of the total residential population in the United States, future food waste bans in the residential sector may impact food waste generation.

6.2.3 Retail/Wholesale Sector

EPA's enhanced methodology results in the following 2016 estimates of excess food/food waste generated from the food retail/wholesale sector:

- **12.6 million tons per year for the retail and wholesale sector in total**, reflecting 2016 generation
    - **8.7 million tons from the food retail sector**
    - **3.9 million tons from the food wholesale sector**

The following section provides more detail about the derivation of this estimate and other methods considered.

6.2.3.1 Analytic Methods for RetailWholesale Food Waste Generation

The food retail/wholesale sector includes several groups in NAICS. NAICS codes 4451 (grocery stores and convenience stores), 4452 (specialty food stores), and 45291 (warehouse clubs and supercenters) comprise the retail/wholesale sector. NAICS codes 4244 (grocery and related product merchant wholesalers) comprise the wholesale sector. A full list of the six-digit NAICS codes encompassed in each sector is provided in the sections below.

6.2.3.1.1 Analytic Methods for Retail Food Waste Generation

The food retail sector accounts for a substantial share of food waste generated in the United States. A 2012 assessment by BSR found that of all food waste from industrial, residential, commercial, and institutional sources, 11% originates from the food retail sector. EPA's literature search identified 54 studies examining food waste generation among food retailers. Many of these studies, however, are not directly useful for methods development. Some lack quantitative information on generation factors, while others apply generation factors from earlier studies. EPA's recommended methods are based on a subset of eight studies that involved original research (e.g., direct analysis of facility food waste).

In the relevant retail sector literature, several studies provide separate generation factors for supercenters and supermarkets (i.e., other types of retail food stores). Supercenters are defined as large retail establishments that sell a complete line of grocery merchandise in addition to non-grocery goods. Supercenters include big-box stores, such as Wal-Mart and warehouse clubs such as BJs and Costco. Supermarkets and supercenters exhibit different characteristics regarding the sale of food. Most notably, supercenters often sell food items in bulk and at a lower unit price relative to supermarkets. EPA's methods use the literature on supercenters to develop a separate estimate of food waste, which is then added to supermarkets to obtain an estimate for the overall retail sector.

EPA's food retail food waste generation methodology draws on three different extrapolation bases applied in the literature, as summarized in Table 18:

- Method 1 is built on five studies that estimate the quantity of food waste generated per employee, per year in the food retail sector. Within this method, four studies examined food waste generation at supermarkets and two examined food waste generation at supercenters (CalRecycle (2006) examined both). CalRecycle (2006), CalRecycle (2015), and the North Carolina Department of Environment and Natural Resources (now known as North Carolina Department of Environmental Quality) (2012) conducted audits of food retail sector waste.[41] Connecticut DEP (2001), Mecklenburg County (2012), Okazaki et al. (2008), and ReFED (2016) collected data through a series of surveys and interviews with store managers and other experts.
    - The studies in Method 1 estimated generation factors between 0.27 and 2.32 tons per employee per year. The low estimate was reported by CalRecycle (2006), which sampled waste at big-box retail stores. Another low estimate, 0.5 tons per employee per year, was

[41] North Carolina's state-specific estimate was provided by a North Carolina hauler who collected segregated food waste from a major grocery chain.

reported by ReFED (2016), who interviewed supercenters to estimate food waste per employee. It is noteworthy that the lowest two estimates apply to supercenters. To generate a per-employee food waste estimate, total food waste at supercenters was divided among all employees (rather than just grocery department employees) at the supercenter. The application of this estimate to total employees for each site may explain the relatively low generation factor found in supercenters.

  - The higher supermarket estimates were provided by CalRecycle (2006) and Mecklenburg County (2012), who conducted waste audits at supermarkets.

- Method 2 relies on two studies that estimate the quantity of food waste generated per establishment per year, relying upon Okazaki et al. (2008) and North Carolina Department of Environment and Natural Resources (DENR) (2012), separately estimates generation factors for convenience stores and supermarkets. Estimates range from 83 tons/establishment/year (for convenience stores) to 117 tons/establishment/year (for supermarkets).

- Method 3 draws on one study that quantifies food waste generated on a revenue basis. BSR (2014) collected industry generation data through a series of surveys targeted at large food retailers and estimated this metric to be 10 pounds of food waste (0.005 tons) per thousand dollars of company revenue.

Table 18 summarizes the methods, associated literature sources, and the type of establishment sampled for each study.

TABLE 18. FOOD RETAIL EXCESS FOOD/FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	ESTABLISHMENT TYPE	STUDY TYPE
Method 1	CalRecycle	2006	2.31	Tons/employee/year	Supermarket	Waste Audit
	Mecklenburg County	2012	2.32	Tons/employee/year	Supermarket	Survey
	CalRecycle	2015	2.02	Tons/employee/year	Supermarket	Waste Audit
	Connecticut DEP	2001	1.5	Tons/employee/year	Supermarket	Survey
	CalRecycle	2006	0.27	Tons/employee/year	Supercenter	Waste Audit
	ReFED	2016	0.5	Tons/employee/year	Supercenter	Interview/ Survey
Method 2	Okazaki et al.	2008	114.6	Tons/establishment/ year	Retail – Not Specified	Survey
	North Carolina DENR	2012	117	Tons/establishment/ year	Supermarket	Waste Audit
	North Carolina DENR	2012	83	Tons/establishment/ year	Convenience Store	Waste Audit
Method 3	BSR	2014	0.005	Tons food waste/ thousand $ revenue	Retail - Not Specified	Survey

EPA multiplied the generation factors for each method by the relevant extrapolation basis to estimate total food waste generated in the residential sector. Method 1 is based on the number of food retail employees in the United States, while Method 2 is based on the number of food retail establishments in the United

States. Data on both extrapolation bases are available from the U.S. Census Bureau's County Business Patterns (CBP) datasets.[42] CBP data are updated annually and classify the number of establishments, number of employees, and annual payroll of U.S. business establishments by NAICS code.[43] Food retail establishments are classified as supermarkets or supercenters according to their six-digit NAICS codes.

- The analysis defines supermarkets based on the following NAICS codes:
  - 445110 - Supermarkets and other grocery (except convenience stores)
  - 445120 - Convenience stores
  - 445210 - Meat markets
  - 445220 - Fish and seafood markets
  - 445230 - Fruit and vegetable markets
  - 445291 - Baked goods stores
  - 445292 - Confectionary and nut stores
  - 445299 - All other specialty food stores
- Supercenters align with NAICS code 452910, warehouse clubs and supercenters.

Table 19 presents the number of establishments and employees for each relevant NAICS code.

TABLE 19. FOOD RETAIL ESTABLISHMENTS AND EMPLOYMENT BY NAICS CODE

NAICS CODE	NAICS CODE DESCRIPTION	NUMBER OF ESTABLISHMENTS	PERCENT OF TOTAL	NUMBER OF EMPLOYEES	PERCENT OF TOTAL
445110	Supermarkets and Other Grocery (except Convenience) Stores	65,399	55.0%	2,690,541	89.4%
445120	Convenience Stores	29,988	25.2%	139,306	4.6%
445210	Meat Markets	5,279	4.4%	42,802	1.4%
445220	Fish and Seafood Markets	2,067	1.7%	12,114	0.4%
445230	Fruit and Vegetable Markets	2,777	2.3%	20,691	0.7%
445291	Baked Goods Stores	3,531	3.0%	28,173	0.9%
445292	Confectionery and Nut Stores	3,430	2.9%	24,297	0.8%
445299	All Other Specialty Food Stores	6,358	5.4%	50,912	1.7%
TOTAL: Supermarkets		**118,829**	**100%**	**3,008,836**	**100%**
452910	Warehouse Clubs and Supercenters	5,601	100%	1,556,821	100%
TOTAL: Supercenters		**5,601**	**100%**	**1,556,821**	**100%**

[42] United States Census Bureau. April 2018. County Business Patterns. Available: https://www.census.gov/programs-surveys/cbp.html

[43] EPA also considered the use of two other datasets for this extrapolation. Progressive Grocer, a grocery industry association, publishes an annual estimate of industry sales and establishments. However, these data are not as easily accessible as Census data and may contain analytic biases. The Census also publishes the SUSB dataset, which is updated every five years. While the SUSB data are very similar to the CBP data, the CBP data are updated annually and are therefore preferable.

Method 3 uses the annual U.S. Census estimate of food-related retail trade sales as its extrapolation basis.[44] Sales under NAICS codes 4451 and 4452 (which fully encompass the six-digit NAICS codes used in Method 1) totaled $647.6 billion in 2016.

Table 20 summarizes the resulting excess food/food waste generation estimates. Each figure was extrapolated to a total annual generation quantity (in millions of tons per year). National generation figures for supermarkets and supercenters were averaged separately and summed to yield a sector-wide estimate (i.e., each study was given equal weight).

[44] United States Census Bureau. March 2018. Annual Retail Trade Survey: 2016. Available: https://www.census.gov/data/tables/2016/econ/arts/annual-report.html

TABLE 20. FOOD RETAIL EXCESS FOOD/FOOD WASTE GENERATION ESTIMATES

SECTOR	METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	BASIS FOR EXTRAPOL-ATION	EXCESS FOOD/ FOOD WASTE GENERATION (TONS/YEAR) [1]	ESTABLISH-MENT TYPE
Super-markets	Method 1	CalRecycle	2006	2.31	Tons/ employee/ year	3,008,836 employees in 2016	6,957,933	Supermarket
		Mecklenburg County	2012	2.32			6,980,500	Supermarket
		CalRecycle	2015	2.02			6,077,849	Supermarket
		Connecticut DEP	2001	1.5			4,513,254	Supermarket
	Method 2	Okazaki et al.	2008	114.6	Tons/ establishment /year	118,829 establishments in 2016	13,622,585	Food Retail – Not Specified
		North Carolina DENR	2012	117			13,902,993	Supermarket
				83			9,862,807	Convenience Store
	Method 3	BSR	2014	0.005	Tons/ thousand $ revenue	$678 billion revenue in 2016	3,237,805	Food Retail - Not Specified
	Supermarket Average Generation						**8,144,466**	**Supermarkets**
Super-centers	Method 1	CalRecycle	2006	0.27	Tons/ employee/ year	1,556,821 employees in 2016	412,558	Supercenter
		ReFED	2016	0.5			778,411	Supercenter
	Supercenter Average Generation						**595,484**	**Supercenters**
FOOD RETAIL AVERAGE GENERATION							**8,739,950[2]**	**Food Retail**

Notes:
[1] Figures may not sum due to rounding.
[2] The final estimate is slightly lower (8,681,999 tons), due to an adjustment that was made to exclude a portion that was reported to be managed by "other" methods. See explanation at the end of this section.

Overall, this method yields an excess food/food waste generation estimate of 8,739,950 tons from the food retail sector based on data from 2016**.** However, the Food Waste Reduction Alliance (FWRA) (2016) study, which was used for management pathway distribution for the retail/wholesale sector, asked survey respondents to report food waste managed by a variety of methods (i.e., the FLW Standard destinations), including a catch-all "other" category. The study did not report what methods survey respondents were referring to as "other" when they reported tonnage in that category. Because there is no information available about what management methods were used to manage tonnage reported in the "other" category, EPA did not include the proportion of food waste reported to be managed by "other" methods. As a result, based on the methods above, adjusted to exclude the proportion of food waste reported to be managed by "other" means by the retail sector in the FWRA (2016) study, **EPA's estimate of excess food/food waste generated from the retail sector in 2016 is 8.7 million (8,681,999) tons**.

6.2.3.1.2 Analytic Metholds for Wholesale Food Waste Generation

The wholesale sector sells food to consumer-level operations, such as restaurants and retail supermarkets.[45] According to NRDC (2017), food wholesalers and distributors account for 4-9% of total food waste generation. The literature search identified 22 studies examining food waste generation among food wholesalers. Many of these studies, however, are not directly useful for methods development. Some lack quantitative information on generation factors, while others apply generation factors from earlier studies. Two studies conducted by CalRecycle defined the wholesale sector broadly, grouping food wholesalers with other non-durable wholesalers such as apparel and chemicals. Given that these other non-durables differ greatly from food in their waste generation patterns, the analysis excludes the two CalRecycle studies. Therefore, EPA's methods are based on a subset of three studies that focused on food wholesale and involved original research (e.g., direct analysis of facility food waste).

EPA's food wholesale food waste generation methodology relies on two different generation factors applied in the three studies, as summarized in Table 21:

- Method 1 relies on three studies that estimate the quantity of food waste generated per establishment per year. Okazaki et al. (2008) and U.S. EPA Region 1 (2011) present estimates of 94 and 147 tons per establishment per year, respectively. U.S. EPA Region 1 (2011) was an update to Massachusetts DEP (2002).
- Method 2 is built on a study that quantifies food waste generated on a revenue basis. BSR (2014) collected industry generation data through a series of surveys targeted at large food retailers and estimated this metric to be 10 pounds of food waste (0.005 tons) per thousand dollars of company revenue.

Table 21 summarizes the methods and associated literature sources for each study.

TABLE 21. FOOD WHOLESALE EXCESS FOOD/FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	STUDY TYPE
Method 1	Okazaki et al.	2008	94.4	Tons/establishment/ year	Survey
	U.S. EPA Region 1	2011	147	Tons/establishment/ year	Data analysis
Method 2	BSR	2014	0.005	Tons food waste/ thousand $ revenue	Survey

EPA multiplied the generation factors for each method by the relevant extrapolation basis to estimate total food waste generated in the wholesale sector. Method 1 is based on the number of wholesale establishments in the United States. Data on this extrapolation basis are available from CBP datasets.[46]

[45] As EPA defines it, this sector does not include warehouse clubs, such as Costco, that sell goods at the consumer level and are reflected in the retail "supercenter" category.

[46] U.S. Census Bureau. April 2018. County Business Patterns. Available: https://www.census.gov/programs-surveys/cbp.html

As noted, these annual data classify the number of establishments, number of employees, and annual payroll of U.S. business establishments by NAICS code.

- Food wholesale encompasses the following NAICS codes:
  - 424410, General Line Grocery Merchant Wholesalers;
  - 424420, Packaged Frozen Food Merchant Wholesalers;
  - 424430, Dairy Product Merchant Wholesalers;
  - 424440, Poultry and Poultry Product Merchant Wholesalers;
  - 424450, Confectionary Merchant Wholesalers;
  - 424460, Fish and Seafood Merchant Wholesalers;
  - 424470, Meat and Meat Product Merchant Wholesalers;
  - 424480, Fresh Fruit and Vegetable Merchant Wholesalers;
  - 424490; Other Grocery and Related Products Merchant Wholesalers.

Table 22 presents the number of establishments for each NAICS code listed above.

TABLE 22. FOOD WHOLESALE ESTABLISHMENTS BY NAICS CODE

NAICS CODE	NAICS CODE DESCRIPTION	NUMBER OF ESTABLISHMENTS	PERCENT OF TOTAL
424410	General Line Grocery Merchant Wholesalers	3,041	8.6%
424420	Packaged Frozen Food Merchant Wholesalers	3,164	8.9%
424430	Dairy Product (except Dried or Canned) Merchant Wholesalers	2,066	5.8%
424440	Poultry and Poultry Product Merchant Wholesalers	457	1.3%
424450	Confectionery Merchant Wholesalers	3,662	10.3%
424460	Fish and Seafood Merchant Wholesalers	2,176	6.1%
424470	Meat and Meat Product Merchant Wholesalers	2,320	6.6%
424480	Fresh Fruit and Vegetable Merchant Wholesalers	4,811	13.6%
424490	Other Grocery and Related Products Merchant Wholesalers	13,689	38.7%
TOTAL		**35,386**	**100%**

For Method 2, the analysis uses data from the U.S. Census Wholesale Trade Data Report, which is updated monthly. Wholesale sales under NAICS codes beginning with "4244" totaled $648 billion in 2017.[47]

Table 23 summarizes the resulting food waste generation estimates. Each figure was extrapolated to a total annual generation quantity (in millions of tons per year), and collectively averaged (i.e., each study is given equal weight).

[47] U.S. Census Bureau. June 2018. Monthly Wholesale Trade. Available: https://www.census.gov/wholesale/index.html

TABLE 23. FOOD WHOLESALE EXCESS FOOD/FOOD WASTE GENERATION ESTIMATES

METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	BASIS FOR EXTRAPOLATION	EXCESS FOOD/FOOD WASTE GENERATION (TONS/ YEAR)
Method 1	Okazaki et al.	2008	94.4	Tons/establishment/year	35,386 establishments in 2016	3,338,943
	U.S. EPA Region 1	2011	147			5,201,742
Method 2	BSR	2014	0.005	Tons/thousand $ revenue	$648 billion revenue in 2017	3,242,475
AVERAGE GENERATION						**3,927,720**[1]

Note:
[1]The final estimate is slightly lower (3,901,677 tons), due to an adjustment that was made to exclude a portion that was reported to be managed by "other" methods.

Overall, this method yields an excess food/food waste generation estimate of 3,927,720 tons from the food wholesale sector based on data from 2016 and 2017**.** However, the FWRA (2016) study, which was used for management pathway distribution for the retail/wholesale sector, asked survey respondents to report food waste managed by a variety of methods (i.e., the FLW Standard destinations), including a catch-all "other" category. The study did not report what methods survey respondents were referring to as "other" when they reported tonnage in that category. Because there is no information available about what management methods were used to manage tonnage reported in the "other" category, EPA did not include the proportion of food waste reported to be managed by "other" methods. As a result, based on the methods above, adjusted to exclude the proportion of food waste reported to be managed by "other" means by the wholesale sector in the FWRA (2016) study, **EPA's estimate of excess food/food waste generated from the wholesale sector in 2016 is 3.9 million (3,901,677) tons**.

Key Assumptions and Limitations

The generation estimates for the wholesale and retail sectors are subject to several important caveats and assumptions:

- None of the studies examined in this analysis were conducted for cities or states with active food waste bans in place at the time of study. Implementation of these policies will likely be gradual, but will certainly influence the future pattern of food waste generation and management.
- The aggregate extrapolation to supermarkets is based on employees and establishments at a range of retail operations, including convenience stores, meat markets, and other retailers. The literature primarily focuses on conventional supermarkets (although one study considers convenience stores). The analysis implicitly assumes that food waste generation patterns are similar across this set of establishments. This assumption may bias the estimates, but the direction of the bias is unclear.

6.2.4 Hospitality Sectors

This section presents analytic methods for estimating excess food/food waste associated with the hospitality sectors of the food system. The specific sectors include the following:

- Restaurants/food services;
- Hotels and other accommodations; and
- Sports venues (i.e., stadiums).

Table 24 summarizes the findings for the hospitality sectors. As shown, EPA's methods yield an estimate of approximately 18.0 million tons per year for all hospitality sectors combined, with restaurants/food services accounting for almost 94% of the total.

TABLE 24. SUMMARY OF EXCESS FOOD/FOOD WASTE GENERATION ESTIMATES FOR HOSPITALITY SECTORS

SECTOR	EXCESS FOOD/FOOD WASTE GENERATION (TONS/YEAR)
Restaurants/Food Services	16,886,535
Hotels	1,114,011
Sports Venues	38,088
TOTAL HOSPITALITY	**18,038,634**

6.2.4.1 Restaurants/Food Services

EPA's methods for estimating excess food/food waste generation from restaurant/food service establishments incorporate data consistent with several NAICS codes. Specifically, EPA's analysis encompasses the two largest classes of eateries – full-service establishments (722511) and limited-service establishments (722513). The analysis also includes several other classes of food service establishments that can generate food waste, including cafeterias, grill buffets, and buffets (722514); snack and nonalcoholic beverage bars (722515); mobile food services (722330) such as food trucks; and caterers (722320). EPA's analysis excludes NAICS 722410 (drinking places for alcoholic beverages), which comprises bars serving little or no food, as well as 722310 (food service contractors).[48]

6.2.4.1.1 Analytic Methods for Restaurants/Food Services Food Waste Generation

The literature search identified a total of 49 studies that address excess food/food waste generation in restaurant/food service settings. Many of these studies, however, do not provide directly useful generation data. Some lack quantitative information on generation factors, while others apply generation factors derived from earlier studies. EPA's generation estimate is based on a subset of eight

[48] NAICS 722310, food service contractors, consists of establishments engaged in providing food services at institutional, governmental, commercial, or industrial locations – including schools, hospitals, and sports venues. EPA considers the food waste generated by food service contractors in the sectors for which they are providing services.

studies that either involved original research (e.g., sorting/analysis of facility waste) or which present foundation estimates that are widely cited in the broader literature.

EPA's restaurant/food services generation methodology directly averages the results of eight estimates that are organized into three extrapolation methods:

- **Extrapolation Method 1** is built on measurements that quantify the amount of food waste generated per restaurant/food service employee per year. Three studies offer original estimates of this generation factor. Massachusetts DEP (2002), updated by U.S. EPA Region 1 in 2011, was widely cited (see RecyclingWorks Massachusetts, 2013; Mercer, 2013; South Carolina Department of Commerce, 2015; among others). While widely applied, the generation factors in Massachusetts DEP are built on original research developed in the 1990s; it is therefore critical to supplement this data point with information from other studies. Both the CalRecycle (2006) and CalRecycle (2015) studies are more recent and use waste sampling techniques to estimate of food waste generation.
- **Extrapolation Method 2** employs an estimation approach based on tons of food waste per establishment per year. The literature search identified four distinct estimates of food waste generation using this metric. The highest estimate comes from U.S. EPA Region 1 (2011), which is an update of Massachusetts DEP (2002), and estimates that 43 tons per establishment are generated per year. The lowest value from this set of studies came from North Carolina DENR (2012), which estimated a food waste generation factor of 32 tons per establishment per year at full-service establishments.
- **Extrapolation Method 3** uses an estimation approach based on tons of food waste per thousand dollars of company revenue. BSR (2014) provided an estimate of this metric, 33 pounds of food waste per thousand dollars of company revenue.

Table 25 summarizes the methods, the associated literature sources, and the type of establishment sampled for each study.

TABLE 25. RESTAURANTS/FOOD SERVICES EXCESS FOOD/FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR	GENERATION FACTOR UNIT	ESTABLISHMENT TYPE
Method 1	CalRecycle	2006	3,392 for full-service 2,494 for limited-service	Pounds/employee/year	Full-service and limited service estimated separately
	Massachusetts DEP	2002	3,000	Pounds/employee/year	Unspecified
	CalRecycle	2015	2,760	Pounds/employee/year	Full-service and limited-service estimated together
Method 2	U.S. EPA Region 1	2011	43	Tons/establishment/year	Unspecified
	Okazaki et al.	2008	38.8	Tons/establishment/year	Unspecified
	North Carolina DENR	2012	32	Tons/establishment/year	Full-service only
	Battelle	2015	42.7	Tons/establishment/year	Full-service only
Method 3	BSR	2014	33	Pounds/thousand $ in company revenue	Unspecified

To estimate annual nationwide generation, the recommended method combines average generation factors with the appropriate data to extrapolate to a national estimate of generation:

- Extrapolation Method 1 is based on the number of restaurants/food services sector employees in the United States. Data on restaurant/food service sector employees are available from the U.S. Census Bureau's SUSB datasets.[49] SUSB data are collected in years ending in 2 and 7. The SUSB data, last published in 2015, classifies the number of firms, number of establishments, employment, and annual payroll of U.S. business establishments by NAICS codes. Restaurant/food service establishments are classified as full-service or limited-service according to their six-digit NAICS codes.
    - Full-service establishments consist of NAICS codes 722511 (Full-service establishments), 722320 (Caterers), and 722514 (Cafeterias, Grill Buffets, and Buffets). The total employment in this group was 5,520,163 people in 2015.
    - Limited-service establishments consist of NAICS codes 722513 (Limited-service Establishments), 722330 (Mobile Food Services), and 722515 (Snack and Nonalcoholic Beverage Bars). The total employment in this group was 4,717,362 in 2015.[50]
- Extrapolation Method 2 requires an estimate of the number of restaurant/food service establishments in the United States. This figure is also available in the SUSB data. According to

[49] U.S. Census Bureau. January 2018. 2015 SUSB Annual Data tables by Establishment Industry. Available: https://www.census.gov/data/tables/2015/econ/susb/2015-susb-annual.html

[50] Regularly-published BLS data series corroborate the Census employment figures. The BLS estimates that in 2015, 11,065,700 people are employed in the food service sector, which is 828,000 more (8% higher) than the Census estimates. However, the BLS data series includes employees under NAICS 722410 (Alcoholic Drinking Places) and 722310 (Food Service Contractors). The BLS data series is available at: https://www.bls.gov/iag/tgs/iag722.htm

this data series, an estimated 260,671 full-service establishments and 297,568 limited-service establishments operated in the United States in 2015.[51]

- Extrapolation Method 3 requires an estimate of the total revenue across the restaurant/food service sector, including all types of restaurants and food service operations. The National Restaurant Association projects these revenues annually. In the 2017 Restaurant Industry Outlook report,[52] the National Restaurant Association estimates that 2017 revenues across full-service establishments total $277.3 billion, and revenues at limited-service establishments total $275.4 billion.[53] In total, revenues in the restaurant/food service sector total $552.7 billion.[54]

To develop a national generation estimate for the restaurants/food services sector, EPA first multiplied the generation factors by the appropriate extrapolation bases. The eight studies estimated generation factors for a combination of full-service and limited-service establishments. A number of the studies did not specify which type of establishment – full-service or limited-service – was sampled. Since the studies do not clearly differentiate full-service from limited-service sampling, the analysis applies the generation factors equally to both sub-sectors. One exception to this method is CalRecycle (2006), which developed separate generation factors for full-service and limited-service establishments. In addition, North Carolina DENR (2012) and Battelle (2015) focused only on full-service establishments (no studies focused only on limited-service establishments). EPA's analysis applies these generation factors only to the appropriate establishment types.

EPA's analysis then estimates total generation based on a straight average of generation estimates calculated for each study. Finally, the full-service and limited-service averages are summed to yield an estimate for the nationwide restaurants/food services sector.[55] Table 26 summarizes these steps and the resulting food waste generation estimates.

[51] This estimate is supported by findings from a 2018 First Research report by Dun & Bradstreet, which estimates that 620,000 total food service establishments operate currently in the United States. Additionally, the BLS estimates 630,299 establishments operate under NAICS 722.

[52] National Restaurant Association. 2017 Restaurant Industry Outlook. Available: https://www.restaurant.org/Downloads/PDFs/News-Research/2017_Restaurant_outlook_summary-FINAL.pdf

[53] Revenues for these two groups were calculated in accordance with the full-service and limited-service NAICS classification used throughout this analysis.

[54] These estimates are validated by the findings from First Research, which estimates the total revenue of the U.S. restaurant industry to be $550 billion in 2017.

[55] EPA also considered an alternative method for calculating generation. Generation factors for full-service and limited-service establishments were broken out separately, normalized to millions of tons, and multiplied by their corresponding extrapolation bases. Eight studies in this set were assumed to apply to full-service establishments. Only one study, CalRecycle 2006, specifically estimated generation for limited-service establishments. The ratio of generation between limited-service and full-service facilities in this study was about 0.75. EPA applied this ratio to the full-service generation factors to estimate a separate set of rates for limited-service establishments. This method estimated a total 15.1 million tons of food waste nationwide in 2015.

TABLE 26. RESTAURANTS/FOOD SERVICES EXCESS FOOD/FOOD WASTE GENERATION ESTIMATES

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	FULL-SERVICE			LIMITED-SERVICE			GENERATION (MILLION TONS/YEAR)
				GENERATION FACTOR	EXTRAPOLATION BASIS	GENERATION (MILLION TONS/YEAR)	GENERATION FACTOR	EXTRAPOLATION BASIS	GENERATION (MILLION TONS/YEAR)	
Method 1	CalRecycle	2006	Pounds/ employee/ year	3,392	5,520,163 employees	9.36	2,494	4,717,362 employees	5.88	15.24
	Massachusetts DEP	2002	Pounds/ employee/ year	3,000		8.28	3,000		7.08	15.36
	CalRecycle	2015	Pounds/ employee/ year	2,760		7.62	2,760		6.51	14.13
Method 2	U.S. EPA Region 1	2011	Tons/ facility/ year	43	260,671 establishments	11.21	43	297,568 Establishments	12.80	24.00
	Okazaki et al.	2008	Tons/ facility/ year	38.8		10.12	38.8		11.55	21.67
	North Carolina DENR	2012	Tons/ facility/ year	32		8.34	N/A		N/A	8.34
	Battelle	2015	Tons/ facility/ year	42.7		11.13	N/A		N/A	11.13
Method 3	BSR	2014	Pounds/ thousand $ revenue	33	$277.3 billion sector revenue	4.58	33	$275.4 billion sector revenue	4.54	9.12
AVERAGE						**8.83**			**8.06**	**16.89**

EPA's estimate of excess food/food waste generated from the restaurant/food service sector in 2016 is 16.9 million tons.[56]

Key Assumptions and Limitations

The methods draw on a variety of studies, but are limited by the rigor and accuracy of those studies. In particular, researchers have conducted few direct, empirical analyses of food service waste streams in

[56] The FWRA (2016) study, which was used for management pathway distribution for the restaurant/food services sector, asked survey respondents to report food waste managed by a variety of methods (i.e., the FLW Standard destinations), including a catch-all "other" category. The study did not report what methods survey respondents were referring to as "other" when they reported tonnage in that category. Because there is no information available about what management methods were used to manage tonnage reported in the "other" category, EPA did not include the proportion of food waste reported to be managed by "other" methods. However, this amount was very small (approximately 3,000 tons) and therefore has a negligible effect on the final generation estimate, which is still 16.9 million tons.

recent years. While BSR (2014), CalRecycle (2006; 2015), and North Carolina DENR (2012) directly sampled waste and/or conducted thorough surveys, other studies such as Draper/Lennon relied upon older research to synthesize their generation factors.

6.2.4.2 Hotels

EPA's methods for estimating food waste generation from hotels define the sector consistent with NAICS code 7211, which comprises short-term lodging in hotels and motels (721110), casino hotels (721120), bed-and-breakfast inns (721191), and all other traveler accommodations (721199).[57] Traveler accommodations comprise establishments with full-service dining, establishments with limited food service (e.g., breakfast only), and establishments that do not serve food. Establishments that do not serve food are included because the analysis covers not only food waste from kitchens or on-site restaurants, but also from guest rooms where food purchased off-site may be consumed.

6.2.4.2.1 Analytic Methods for Hotel Food Waste Generation

The literature search identified 25 studies on food waste generation in hotels and other traveler accommodation facilities. EPA's methodology focuses on a subset of four studies that provide food waste generation factors based on empirical data collected directly from sampled hotels.[58] Most of the relevant studies reported pounds of food waste generated per hotel employee per year. In addition, a hotel food waste study from Hawaii (Okazaki et al., 2008) estimated food waste generated per hotel food service employee, unlike the other studies that consider food waste generated per general hotel employee. To apply data from Okazaki et al. (2008), the analysis divides the total amount of food waste generated in Hawaii hotels (as estimated by Okazaki et al., 2008) by the total number of hotel employees under NAICS 7211 in Hawaii, to make the generation factor consistent with the other studies.

Table 27 summarizes the selected generation factors. EPA's analysis computes the average of four waste generation factors, which range from about 375 to 1,983 pounds per employee per year. These studies were published between 2006 and 2015 using data from two states (California and Hawaii) and Vancouver, Canada.

TABLE 27. HOTEL FOOD WASTE GENERATION FACTORS

SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
CalRecycle	2006	Lbs/employee/year	1,983
Okazaki et al.	2008	Lbs /employee/year	375
CalRecycle	2015	Lbs/employee/year	1,197
Metro Vancouver	2015	Lbs/employee/year	997
AVERAGE			**1,138**

[57] Office of Management and Budget. 2017. North American Industry Classification System. See: https://www.census.gov/eos/www/naics/2017NAICS/2017_NAICS_Manual.pdf

[58] Several studies report food waste generated per meal, or per guest or guest room. EPA excluded such studies from the calculations due to the difficulty in estimating the annual number of hotel guests or occupied guest rooms per year in the U.S. (Recycling Works Massachusetts, 2013; Carvalho, 2014; Coker, 2009).

To estimate food waste generation from hotels, EPA multiplied the average generation factor of 1,138 pounds/employee/year by the number of all employees associated with NAICS 7211, as reported by BLS.[59] As of May 2017, about 1.9 million individuals were working in NAICS 7211. Table 28 summarizes the food waste generation calculation for hotels.

TABLE 28. HOTEL FOOD WASTE GENERATION ESTIMATE

PARAMETER	ESTIMATE	UNITS	SOURCE
Average Generation Factor	1,138	Lbs/employee/year	Average
Basis for Extrapolation	1,958,130	Number of employees under NAICS 7211 in 2017	U.S. BLS, see https://www.bls.gov/oes/current/naics4_721100.htm#00-0000
Annual Generation Quantity	1,114,001	Tons	Product of generation factor and extrapolation basis
Number of studies (N) with original generation factor	4	Number	

EPA's estimate of food waste generated from the hotel sector in 2016 is 1.1 million tons.

Key Assumptions and Limitations

Two considerations suggest that the recommended methods may be overstating food waste generation from hotels:

- First, many hotels and traveler accommodations do not serve food. Guests may still generate food waste in their rooms, but establishment generation factors will be lower than at hotels with full-service restaurants. Most of the literature that EPA relied upon does not describe the type of food services provided at the sampled establishments. To the extent that only hotels with formal food services were sampled, the methods likely overstate total food waste generation.
- Second, some hotel restaurants operate as separate entities, serving guests as well as the general public. Depending upon ownership and other management arrangements, it is possible that a hotel restaurant could report to the economic census under NAICS 722 while the hotel itself reports separately under NAICS 721. If this reporting is not properly coordinated, the restaurant and hotel analyses could double-count activity and thus double-count food waste generation for some establishments.

6.2.4.3 Sports Venues

Food is served at an array of social, recreational, cultural, and professional events. A brief list of relevant venues includes sports stadiums; convention centers; theme parks; zoos; country clubs; performance

[59] May 2017 National Industry-Specific Occupational Employment and Wage Estimates. NAICS 721100 - Traveler Accommodation; See https://www.bls.gov/oes/current/naics4_721100.htm#00-0000

centers; charitable events (e.g., running races); agricultural fairs; and museums. For a variety of reasons, accounting for food waste generation at all such events is difficult:

- Systematic, recurring national-level data on attendance at most such events generally are lacking.
- The available studies offer generation factor estimates for specialized subsets of these events (primarily sports), but not all of them.
- Some venues host a mix of events, making attendance tracking difficult. For instance, some sports venues also host concerts, and food services may be available at all or only a subset of the hosted events.
- A broadly inclusive definition of such events creates the potential for double counting food waste accounted for elsewhere in this research. For instance, many professional conferences take place at hotels where participants are also hotel guests. Similarly, some non-hotel venues have permanent restaurants available to the general public (e.g., museum cafés).

For these reasons, EPA's recommended methods focus on a single, major event category – professional and collegiate sports. Available generation factor data align reasonably well with sporting venues and attendance data are updated consistently. This focus inevitably leads to an understatement of food waste generation at all mass events, although the exact degree of bias is not clear.[60]

6.2.4.3.1 Analytic Methods for Sports Venues Food Waste Generation

Literature citing empirically derived generation factors at large public events generally focuses on food waste generation per visitor. The literature search identified three studies that included original sampling and covered sporting event venues.[61] As shown in Table 29, Costello et al. (2017) focused on a football stadium at the University of Missouri, gathering samples for a full season (seven games). The other two studies, CalRecycle (2015) and CalRecycle (2006), sampled a variety of public venues (including sports stadiums). The primary uncertainty comes with respect to the types of venues at which sampling is performed and the extent to which those venues are representative of sports stadiums. The generation factors in the CalRecycle studies are significantly higher than in the one study exclusively focused on a sports venue (Costello et al., 2017), suggesting that generation may be somewhat overstated when applying these rates to sports venues exclusively.

[60] Agricultural fairs represent a major category that some other researchers have included in their sampling for public events (see CalRecycle, 2015). A cursory review of data for the 72 largest agricultural fairs in the U.S. suggests annual attendance of roughly 30 million, a figure that is only about 12% of sports attendance, suggesting that sports attendance likely outstrips other major categories of events.

[61] A fourth study by Hottle et al. (2015) considered food waste generation at four college baseball games. EPA excluded this study because: (1) it was based on a sports league that is not part of the set of larger leagues considered; (2) the sample size was small, with only about 2,500 attendees at each of the four games; and (3) the study estimates a very low generation rate (0.02 lbs/visitor) that is inconsistent with other evidence.

TABLE 29. SPORTS VENUES FOOD WASTE GENERATION FACTORS

SOURCE	YEAR	VENUES SAMPLED	GENERATION FACTOR UNITS	GENERATION FACTOR
CalRecycle	2015	Stadiums, performance centers, parks, fairgrounds, bowling alleys, movie theaters	Lbs/visitor	0.32
CalRecycle	2006	Convention centers, stadiums, theme parks, performing arts centers, movie theaters, fairgrounds, special event sites	Lbs/visitor	0.45
Costello et al.	2017	College football stadium	Lbs/visitor	0.16
AVERAGE				**0.31**

To estimate annual nationwide food waste generation associated with sports venues, EPA multiplied the generation factors above by the number of attendees at sports venues. Various organizations compile attendance at professional and Division I college sports events. Table 30 lists sources for the attendance figures.

TABLE 30. SPORTING EVENTS ATTENDANCE

LEVEL	LEAGUE	ANNUAL ATTENDANCE	YEAR	SOURCE
Professional	Major League Baseball	72,670,423	2017	http://www.ballparksofbaseball.com/baseball-ballpark-attendance/
	National Basketball Association	21,997,412	2016–17	http://www.insidehoops.com/attendance.shtml
	National Hockey League	21,429,412	2016–17	http://www.espn.com/nhl/attendance/_/year/2018/title=2017-2018
	National Football League	17,788,671	2016	http://www.espn.com/nfl/attendance
	Minor League Baseball (AAA)	13,822,138	2017	http://www.baseballpilgrimages.com/attendance/minor-leagues-2016.html
	Minor League Baseball (AA)	8,789,445	2017	http://www.baseballpilgrimages.com/attendance/minor-leagues-2016.html
	Major League Soccer	8,267,534	2017	https://soccerstadiumdigest.com/2017-mls-attendance/
College	NCAA Division I football (regular season)	36,632,625	2017	http://www.ncaa.org/championships/statistics/ncaa-football-attendance
	NCAA Division I football (bowl games)	5,509,277	2017	http://www.ncaa.org/championships/statistics/ncaa-football-attendance
	NCAA Division I men's basketball	26,983,888	2016–17	http://www.ncaa.org/championships/statistics/mens-basketball-statistics
	NCAA Division I men's hockey	3,580,513	2017-2018	http://www.ncaa.org/championships/statistics/mens-ice-hockey-statistics
	NCAA Division I women's basketball	8,300,103	2016–17	http://www.ncaa.org/championships/statistics/womens-basketball-attendance
TOTAL		**245,771,441**		

Table 31 summarizes the food waste generation calculation for sports venues.

TABLE 31. SPORTS VENUES FOOD WASTE GENERATION ESTIMATES

PARAMETER	ESTIMATE	UNITS	SOURCE
Average Generation Factor	0.31	Lbs/visitor	Average
Basis for Extrapolation	245,771,441	Attendance at major sports events	Various
Annual Generation Quantity	38,088	Tons	Product of generation factor and extrapolation basis
Number of studies (N) with original generation factors	3	Number	

EPA's estimate of food waste generated from sports venues in 2016 is 38,088 tons.

Key Assumptions and Limitations

Due to data availability for public venues and events, EPA focused on sports stadiums. Food waste generation undoubtedly occurs at a wide variety of other public venues. The collective significance of these other public events relative to sports is unclear, making it difficult to assess the degree to which food waste generation in the hospitality sector is understated.

6.2.5 Institutional Sectors

This section reviews analytic methods for estimating food waste associated with the institutional sectors of the food system. The institutional sectors include the following:

- Hospitals;
- Nursing homes and other senior care facilities;
- Military installations;
- Office buildings;
- Correctional facilities;
- Colleges and universities; and
- K-12 schools.

Table 32 summarizes the estimates of food waste generated in the institutional sectors. As shown, the generation methods yield an estimate of 7.0 million tons per year for all institutional sectors combined. Office buildings are responsible for the greatest share, while military installations appear to be the least significant.

TABLE 32. SUMMARY OF FOOD WASTE GENERATION ESTIMATES FOR INSTITUTIONAL SECTORS

SECTOR	FOOD WASTE GENERATION (TONS/YEAR)
Hospitals	288,401
Nursing Homes	465,932
Military Installations	58,944
Office Buildings	4,004,431

SECTOR	FOOD WASTE GENERATION (TONS/YEAR)
Correctional Facilities	443,002
Colleges and Universities	617,634
K-12 Schools	1,162,683
TOTAL INSTITUTIONAL	**7,041,028**

6.2.5.1 Hospitals

EPA's methods for estimating food waste generation from hospitals define the sector consistent with NAICS code 622, which includes general medical and surgical hospitals; psychiatric and substance abuse hospitals; and other specialty hospitals providing long-term care. It excludes nursing and residential care facilities, which are addressed separately.

6.2.5.1.1 Analytic Methods for Hospital Food Waste Generation

The literature search identified a total of 46 studies addressing food waste generation in hospital settings. Many of these studies, however, are not directly useful to methods development. Some lack quantitative information on generation factors, while others apply generation factors from earlier studies. Hence, EPA's recommended methods are based on a relatively small subset of seven studies that either involved original research (e.g., sorting/analysis of hospital waste) or which present foundation estimates widely cited in the literature.

EPA's methodology involves two separate, but related, generation factors to estimate food waste from hospitals. Method 1 is built on measurements of the quantity of food waste generated per hospital bed per year. As shown in Table 33, four studies offer distinct estimates of this generation factor. The highest figure is from Connecticut DEP (2001) which is widely cited in other studies estimating food waste (see RecyclingWorks Massachusetts, 2013 and NRDC, 2017, among others). While widely applied, the generation factors in Connecticut DEP (2001) are built on original research developed in the 1990s, hence EPA supplemented this data point with other studies. Both North Carolina DENR (2012) and CalRecycle (2015) are more recent and use original waste sampling. The Walsh et al. (1993) study is older, but provides an additional data point for corroboration of the generation per bed figures.[62]

The available literature supports analysis of a second generation factor, pounds per hospital meal. The literature search identified three distinct estimates of food waste per meal served. One is simply the assumption from the Connecticut DEP (2001) per-bed generation equation (0.6 lbs/meal). Other studies estimate somewhat lower rates of waste per meal.

[62] The analysis of hospitals in North Carolina DENR (2012) draws on a study of Orange County, North Carolina. The only hospital in the county is the University of North Carolina Medical Center, which has 803 beds (see https://www.uncmedicalcenter.org/uncmc/about/). EPA's analysis uses that figure to calculate pounds of food waste per bed. Both CalRecycle (2015) and Walsh et al. (1993) report total solid waste generation per hospital bed. CalRecycle (2015) provides a detailed composition analysis indicating that 20.4% of the hospital solid waste is food waste, allowing calculation of food waste per bed. EPA's analysis applies the same composition assumption (20.4%) to the Walsh et al. (1993) solid waste per bed figure to estimate food waste per bed.

TABLE 33. HOSPITAL FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
Method 1	Connecticut DEP	2001	Lbs/bed/year	1,248.3
	North Carolina DENR	2012	Lbs/bed/year	468.2
	Walsh et al.	1993	Lbs/bed/year	663.4
	CalRecycle	2015	Lbs/bed/year	232.6
	AVERAGE			**653.1**
Method 2	Chardoul & Coddington	2012	Lbs/meal	0.31
	Vermont ANR	2018	Lbs/meal	0.50
	Connecticut DEP	2001	Lbs/meal	0.60
	AVERAGE			**0.47**

To estimate annual nationwide generation, the average generation factor for each method must be combined with the appropriate scaling metric:

- Method 1 is based on the number of hospital beds in the U.S. This figure is based on data available from the AHA, which reports a total of 894,574 staffed beds in U.S. registered hospitals in 2016.[63]
- Method 2 requires an estimate of the number of hospital meals served per year. To estimate this figure, EPA multiplied hospital beds in the U.S. by the average national occupancy rate of 64.8 percent.[64] Connecticut DEP (2001) estimated that hospital patients are served an average of 5.7 meals per day, leading to an estimate of about 3.3 million meals per day or roughly 1.2 billion meals per year.

Table 34 summarizes the food waste generation estimates associated with the two methods, as well as a best estimate based on a simple average across all the studies applied. As shown, the methods yield similar generation quantities, although this result would be expected given shared information between the two approaches. For instance, the number of meals estimated under Method 2 is a function of the number of hospital beds, which underpins the Method 1 estimates.

TABLE 34. HOSPITAL FOOD WASTE GENERATION ESTIMATE

METHOD	PARAMETER	ESTIMATE	UNITS
Method 1	Average Generation Factor	653.1	Lbs/bed/year
	Basis for Extrapolation	894,574	Beds, 2016
	Annual Generation Quantity	292,139	Tons/year
	Number of studies (N) with original generation factors	4	Number
Method 2	Average Generation Factor	0.42	Lbs of waste/meal

[63] AHA, "Fast Facts for U.S. Hospitals 2018," accessed online at https://www.aha.org/statistics/2018-01-09-fast-facts-us-hospitals-2018.

[64] U.S. Centers for Disease Control, National Center for Health Statistics, Table 89. Hospitals, beds, and occupancy rates, by type of ownership and size of hospital: United States, selected years 1975–2014, accessed online at https://www.cdc.gov/nchs/data/hus/2016/089.pdf.

METHOD	PARAMETER	ESTIMATE	UNITS
	Basis for Extrapolation	1,206,032,462	Meals/year (based on 2016 beds and occupancy)
	Annual Generation Quantity	283,418	Tons/year
	Number of studies (N) with original generation factors	3	Number
AVERAGE GENERATION ESTIMATE		**288,401**	**Tons/year**

EPA's estimate of food waste generated from hospitals in 2016 is 288,401 tons.

6.2.5.2 Nursing Homes

Within the NAICS system, relevant nursing home facilities are defined by code 623, nursing and residential care facilities. Based on U.S. Census Bureau data, the industry is dominated by senior care facilities in NAICS codes 6231 (nursing care facilities) and 6233 (continuing care retirement communities and assisted living facilities for the elderly). However, the sector also includes NAICS codes 6232 (residential intellectual and developmental disability, mental health, and substance abuse facilities) and 6239 (other residential care facilities).

6.2.5.2.1 Analytic Methods for Nursing Home Food Waste Generation

The literature search identified a total of 16 studies addressing food waste generation in nursing home settings. While most of these developed quantitative estimates of generation, the majority share a single estimation method from Massachusetts DEP (2002). Using primary research findings from the 1990s, Massachusetts DEP (2002) specified the following equation:

Food waste (lbs/year) = N of beds *3.0 meals/bed/day * 0.6 lbs food waste/meal * 365 days/year

This equation collapses to a simple generation factor of 657 lbs/bed/year. Studies employing this equation for food waste estimation include Connecticut DEP (2001), South Carolina DOC (2015), NRDC (2017), Mercer (2013), and Labuzetta et al. (2016). Because this approach is widely recognized and applied, EPA incorporated this pounds-per-bed generation factor as Method 1.

Additional generation factor estimates are lacking, particularly those based on direct measurement of food waste generation at nursing homes. While not a U.S. study, Strotmann et al. (2017) included observations of food waste generation in a retirement home in Germany. Averaging across figures for three daily meals (measured in two separate analysis waves) from Strotmann et al. (2017) yields an estimated 0.13 pounds of plate waste per meal served at the subject facility. Kim et al. (1997) provides an additional empirical estimate of food waste generation per meal: about 0.965 pounds per meal. The estimate from Kim et al. (1997) is high compared to Strotmann et al. (2017), partly because it includes kitchen preparation waste as well as plate waste. EPA used these two per-meal generation factor estimates as the basis for Method 2.

Table 35 summarizes the literature and generation factors for the two methods.

TABLE 35. NURSING HOME FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
Method 1	Massachusetts DEP	2002	Lbs/bed/year	657.0
Method 2	Strotmann et al.	2017	Lbs/meal	0.13
	Kim et al.	1997	Lbs/meal	0.965
	AVERAGE			**0.55**

To estimate annual nationwide generation for nursing homes, the generation factors for each method must be combined with the appropriate extrapolation basis:

- Method 1 is based on the number of nursing home beds in the U.S. This figure is based on data available from the CDC which compiles nursing home statistics as part of its recordkeeping on long-term care facilities. CDC estimates 1.7 million licensed nursing home beds existed in 2014.[65]
- Method 2 requires an estimate of the number of nursing home meals served per year. To estimate this figure, EPA multiplied the total nursing home population by the number of meals per day (assumed to be three, based Massachusetts DEP (2002)) and the number of days in a year. The CDC estimated 1.4 million nursing home residents in 2014, based on the same research cited for Method 1. Therefore the estimated number of meals is about 1.53 billion annually.

Each of the three studies was weighted evenly. Table 36 summarizes the food waste generation estimates associated with the two methods.

TABLE 36. NURSING HOME FOOD WASTE GENERATION ESTIMATE

METHOD	PARAMETER	ESTIMATE	UNITS
Method 1	Average Generation Factor	657	Lbs/bed/year
	Basis for Extrapolation	1,700,000	Beds, 2014
	Annual Generation Quantity	558,450	Tons/year
	Number of studies (N) with original generation factors	1	Number
Method 2	Average Generation Factor	0.55	Lbs of waste/meal
	Basis for Extrapolation	1,533,000,000	Meals/year (based on 2014 nursing home population)
	Annual Generation Quantity	419,673	Tons/year
	Number of studies (N) with original generation factors	2	Number
AVERAGE GENERATION ESTIMATE		**465,932**	**Tons/year**

[65] Summary data accessed at https://www.cdc.gov/nchs/fastats/nursing-home-care.htm. These data are based on the CDC report "Long-Term Care Providers and Services Users in the United States: Data from the National Study of Long-Term Care Providers, 2013–2014," February 2016.

EPA's estimate of food waste generated from nursing homes in 2014 is 465,932 tons.[66]

Key Assumptions and Limitations

A number of factors create significant uncertainty for estimating food waste generated in nursing homes:

- First, the literature focusing on nursing homes is extremely limited and dated. Most studies with quantitative estimates rely upon the Massachusetts DEP (2002) approach, which is outdated. Few recent studies have directly measured food waste in a nursing home context.
- Second, the diversity of the nursing home sector makes uniform estimation of food waste generation difficult. Some nursing homes are akin to hospitals, with bed-ridden residents being served meals in their rooms. Other nursing homes are more akin to college dormitories, with residents dining in a cafeteria setting. It is possible that generation factors are higher in hospital-like settings and lower in settings where residents are younger, healthier, and more ambulatory.

6.2.5.3 Military Installations

Estimating food waste generation from military installations in the United States is challenging given the diversity of these institutions. Military bases encompass traditional facilities where military recruits live and train; equipment testing facilities; and intelligence and research facilities that function largely as daily workplaces for enlisted and civilian staff, many of whom live offsite. These functions and living arrangements have implications for food waste generation. EPA's analysis focused on enlisted personnel stationed full-time at military installations. These residents outnumber civilian workers and their full-time residency makes for greater generation potential. Furthermore, civilian personnel may be more likely to eat meals in franchise restaurants located on-base; the resulting food waste should therefore be captured in the restaurants/food services sector analysis. Overall, EPA's methods may underestimate food waste generation associated with military bases; however, the sector is small in comparison to other institutional sectors.

6.2.5.3.1 Analytic Methods for Military Installation Food Waste Generation

Literature citing empirically-derived generation factors at domestic military installations is limited. Three food waste generation factors from two studies are summarized in Table 37.[67] The analysis divides the annual food waste generation by the estimated population at the base to estimate generation factors in terms of pounds per person per year. The rates average approximately 105 pounds per person per year.[68]

[66] While EPA's estimates for almost all sectors are based on 2016 data, data for 2016 for this sector was not available at the time of analysis, so these estimates are for 2014.

[67] Battelle (2015) included an additional South Carolina military base. However, the base is a National Guard training facility where few troops are stationed year-round, and hence the facility may not provide representative food waste generation data.

[68] Note that the food waste generation rates for domestic military facilities differ substantively from those for forward base camps. Studies of food waste generation at base camps in either real or simulated battle conditions have found much higher generation rates ranging from 379 to 609 lbs/soldier/year. See, for example, U.S. Army Corps of Engineers (2008) and Cosper et al. (2013).

TABLE 37. DOMESTIC MILITARY BASES FOOD WASTE GENERATION FACTORS

SOURCE	YEAR	MILITARY BASE	ANNUAL TONS OF FOOD WASTE	ON-SITE POPULATION[1]	GENERATION FACTOR UNIT	GENERATION FACTOR
Battelle	2015	Shaw AFB (South Carolina)	389	5,400	Lbs/person/year	144.1
Battelle	2015	Fort Jackson (South Carolina)	1,200	48,600	Lbs/person/year	49.4
Evans-Cowley & Arroyo-Rodríguez	2013	Keesler AFB (Mississippi)	312	5,100	Lbs/person/year	122.4
AVERAGE						**105.3**

Note:
[1] Data for base population are taken from the website http://www.militarybases.us/, which compiles descriptive data on U.S. military installations. The population includes active-duty military and excludes civil service employees, contractors, and family members who may work or spend time on-base, but who are not full-time residents.

To estimate annual nationwide generation for domestic military bases, EPA multiplied the average generation factor by the relevant number of individuals. The Defense Manpower Data Center provides estimates of total active-duty military stationed at bases in the U.S. (as well as throughout the world). Specifically, the data report titled "Counts of Active Duty and Reserve Service Members and APF Civilians" summarizes active-duty personnel by state and in the U.S. overall. The data are updated quarterly and can be downloaded at https://www.dmdc.osd.mil/appj/dwp/dwp_reports.jsp. In September 2017, about 1.12 million activity-duty personnel were stationed at U.S. bases.[69]

Table 38 summarizes the food waste generation estimate calculation for military installations.

TABLE 38. DOMESTIC MILITARY BASES FOOD WASTE GENERATION ESTIMATE

PARAMETER	ESTIMATE	UNITS
Average Generation Factor	105.3	Lbs/person/year
Basis for Extrapolation	1,119,873	Active-duty personnel, 2017
Number of studies (N) with original generation factors	2 studies (3 bases)	Number
AVERAGE GENERATION ESTIMATE	**58,944**	**Tons/year**

EPA's estimate of food waste generated from military installations in 2017 is 58,944 tons.[70]

Key Assumptions and Limitations

[69] A portion of activity-duty personnel live in family housing, either on- or off-base. The Census Bureau states that the Current Population Survey covers only "civilian noninstitutionalized" households (see https://www.census.gov/topics/population/veterans/about/faq.html#par_textimage_9). Nonetheless, it is possible that the number of households used to estimate residential food waste may double-count a portion of military households.
[70] While EPA's estimates for almost all sectors are based on 2016 data, this estimate relied upon 2017 data.

The diverse nature of U.S. military bases introduces uncertainty into the estimation of food waste generation. Most notably, individuals other than active-duty enlisted personnel are present at military bases. Those present may include civilian staff (e.g., secretaries, janitors) as well as contractors supplying services such as construction, weapons testing, teaching, and landscaping. While civilian workers do not live on-base, some may eat meals in central cafeteria facilities, thereby adding to food waste generation. This analysis does not account for this generation.

The overall annual generation per person per year (105 pounds) for military installations appears low in comparison to other sectors. For instance, the figure is lower than the per-person-per-year equivalents estimated for hospital patients, nursing home residents, or incarcerated individuals, suggesting that the methods may understate overall generation for military installations.

6.2.5.4 Office Buildings

Millions of Americans work in office settings. Estimating food waste generation in the office environment is conceptually difficult, however. First, office workers are not easily associated with a well delineated set of NAICS codes, but may exist in numerous settings such as academic research, financial services, software development, and public administration. Second, office settings feature an array of food consumption and food waste generation conditions. Office workers may bring their own lunches, eat in an on-site cafeteria, or leave the premises entirely to eat in commercial restaurants. To be reliable, generation factor data must encompass and reflect these diverse options. Finally, it is even difficult to specify the number of meals consumed by typical office workers. On any given day, an office worker may consume any of his or her three major meals at the office; in the modern U.S. economy, office meals are not simply restricted to lunch.

EPA's methods rely on recent studies of food waste generation in office settings. In effect, the methods circumvent the complexities described above by pairing empirically derived generation factors with data characterizing the general size and significance of office-based economic activity.

6.2.5.4.1 Analytic Methods for Office Building Food Waste Generation

The literature search identified three studies that provide empirically derived generation factors for commercial office buildings. Each of these studies involved characterization of the overall solid waste stream in a sample of office buildings selected to be representative of predominant service industries in the study region, including identification of the percent of the solid waste stream that was food waste. In these studies, two distinct measures of generation factors are reported, and EPA used these measures to extrapolate to national figures:

- Method 1 uses estimates of the quantity of food waste generated per office employee. Both CalRecycle (2015) and Metro Vancouver (2015) reported generation factors in these terms. CalRecycle (2015) reported separate figures for several office sectors, including professional, technical, and financial; management, administrative, support, and social; and public administration.[71] EPA's analysis incorporates an average of these three groups to establish the

[71] The public administration sector includes office workers as well as services such as police and fire. Public administration had the lowest food waste generation of the three office-related subsectors considered in CalRecycle (2015). As a result, inclusion of public administration may bias the food waste estimates downward.

general office generation factors shown in Table 39. Metro Vancouver (2015) estimated food waste generation for a single category they titled "business commercial services."

- Method 2 considers food waste generation as a function of office square footage. Both CalRecycle (2015) and CalRecycle (2006) provide data in these terms. CalRecycle (2015) reported per-square-foot figures for both the professional, technical, and financial industry group, as well as the management, administrative, support, and social group. The analysis averages these two groups to establish a general office generation factor.

TABLE 39. OFFICE BUILDING FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
Method 1	CalRecycle	2015	Lbs/employee/year	258.8
	Metro Vancouver	2015	Lbs/employee/year	80.9
	AVERAGE			**169.9**
Method 2	CalRecycle	2015	Tons/1000 sq ft/ year	0.26
	CalRecycle	2006	Tons/1000 sq ft/ year	0.17
	AVERAGE			**0.22**

To estimate annual nationwide food waste generation associated with office buildings, EPA multiplied the generation factors above by the relevant extrapolation figure. While the number of office workers is not aligned with any particular subset of NAICS codes, the BLS does provide a recurring data series covering employment by major industry sector.[72] To estimate the number of office workers nationwide, EPA incorporated five BLS employment sectors into the analysis:

- Information;
- Financial activities;
- Professional and business services;
- Federal government; and
- State and local government.

These BLS groups align best with the office buildings sampled in the waste characterization studies. The associated number of workers is nonetheless subject to significant uncertainty. Specifically, the selected groups inevitably include non-office employees; for instance, the state and local government group may include public works employees who do not work in an office setting. Conversely, some employees of the groups not included in the analysis may work in office settings. For instance, some employees of the utilities sector may work in offices performing accounting and sales functions. Accepting these uncertainties, the Method 1 approach uses the BLS data to estimate a total of approximately 53 million office workers.

[72] See BLS, Employment Projections, Employment by major industry, Table 2.1 - Employment by major industry sector, 2006, 2016, and projected 2026, accessed at https://www.bls.gov/emp/ep_table_201.htm.

For Method 2, the analysis incorporates data compiled by the EIA as part of its CBECS. CBECS includes estimates of total floor space by principal building activity, one category of which is "office."[73] The survey estimates a total of about 16 billion square feet of office space in 2012.

As shown in Table 40, Method 1 yields a total food waste generation estimate of about 4.5 million tons based on numbers of office employees. Method 2 uses office square footage to arrive at a similar estimate of 3.5 million tons. To develop a final estimate of annual generation, EPA used a straight average of the two methods, giving equal weight to each of the available generation factors,

TABLE 40. OFFICE BUILDING FOOD WASTE GENERATION ESTIMATES

METHOD	PARAMETER	ESTIMATE	UNITS
Method 1	Average Generation Factor	169.9	Lbs/employee/year
	Basis for Extrapolation	53,415,600	Office employees, 2016
	Annual Generation Quantity	4,536,438	Tons
	Number of studies (N) with original generation factors	2	Number
Method 2	Average Generation Factor	0.22	Tons/1000 sq ft/year
	Basis for Extrapolation	15,952,000	1000 sq ft of office space, 2012
	Annual Generation Quantity	3,472,423	Tons
	Number of studies (N) with original generation factors	2	Number
AVERAGE GENERATION ESTIMATE		**4,004,430**	**Tons/year**

EPA's estimate of food waste generated from office buildings in 2016 is 4.0 million tons.

6.2.5.5 Correctional Facilities

The methods described in this section address food waste generation from state and federal prisons and correctional facilities (NAICS 922140) as well generation at privately operated correctional facilities (which are included as part of NAICS 561210). The number of prisoners in the U.S. has been declining at an average rate of 0.7% per year since 2007, and BJS estimates that at the end of 2015, there were approximately 2.2 million adults incarcerated in all correctional facilities.[74]

6.2.5.5.1 Analytic Methods for Correctional Facilities Food Waste Generation

The literature search identified 27 studies on food waste generation in correctional facilities. The generation methodology focuses on six studies that provide food waste generation factors based on

[73] See EIA, Commercial Buildings Energy Consumption Survey, at https://www.eia.gov/consumption/commercial/. Data used in this analysis are from Table B12, "Selected principal building activity: part 1, floorspace, 2012," accessed at https://www.eia.gov/consumption/commercial/data/2012/bc/pdf/b12.pdf.

[74] This count comprises offenders held in local jails and in state or federal prisons. See https://www.bjs.gov/content/pub/pdf/cpus15.pdf

empirical data collected from various correctional facilities.[75] Two of these studies (Marion, 2000; and Connecticut DEP, 2001) rely on data collected by the New York State Department of Correctional Services (NYS DOCS) Food Discard Recovery Program between 1990 and 1997. Using data collected by the NYS DOCS program, Marion (2000) found that approximately one pound per day of food scraps was recoverable per inmate.[76] Connecticut DEP (2001) used findings from Marion (2000), but also collected data from a prison food waste composting program in Connecticut; they also found that, on average, one prisoner generates one pound of food waste per day. Additionally, nine other sources published between 2002 and 2016 rely on the Marion (2000) one pound/inmate/day estimate in calculating food waste generated in correctional facilities in various states including Massachusetts, New Jersey, and South Carolina (Michaels, 2003; Mercer, 2013; South Carolina DOC, 2015).

EPA initially considered two methods for estimating food waste generation from correctional facilities, as summarized in Table 41:

- Method 1 computes the average of six waste generation factors ranging from 0.85 to 1.4 pounds per inmate per day, from studies that conducted original research and collected data from correctional facilities. In instances where the study provides a range in the amount of waste generated per inmate per day, EPA used the midpoint of the range in the calculations. These studies were published between 2000 and 2018 using data from six states.[77] While the Marion (2000) and Connecticut DEP (2001) studies are older, they are frequently cited in other food waste analyses (see BSR, 2012; RecyclingWorks Massachusetts, 2013; Labuzetta et al., 2016); therefore, EPA retained them in this analysis.
- Method 2 calculates waste generated per meal based on U.S. EPA (1998), a case study of the NYS DOCS Food Waste Recovery Program for FY 1997. This case study reports that participating correctional facilities providing 125,000 meals per day generated 6,889 tons of organic waste, for a rate of about 0.30 pounds/meal. The analysis implicitly assumes that the organic waste generated at the facilities is all food waste.

TABLE 41. CORRECTIONAL FACILITIES FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
Method 1	Marion	2000	Lbs/inmate/day	1.00
	Connecticut DEP	2001	Lbs/inmate/day	1.00
	Florida DEP	2004	Lbs/inmate/day	1.20
	Mendrey	2013	Lbs/inmate/day	1.25
	Goldstein	2015	Lbs/inmate/day	1.40
	CalRecycle	2018	Lbs/inmate/day	0.85
	AVERAGE			**1.12**

[75] Several studies report the role that food waste plays in the overall prison solid waste stream. In general, these studies find that food waste makes up about 30% of all waste generated (Marion, 2000; Florida DEP, 2004; Recycling Works Massachusetts, 2013; Hodge et al., 2016; CalRecycle, 2018).
[76] Marion's language is ambiguous as to whether the one pound/inmate/day estimate is the total food waste generated or the amount of food waste recovered. EPA's analysis assumes that the recoverable portion of food waste is equivalent to food waste generation in correctional facilities.
[77] California, Connecticut, Florida, New York, Pennsylvania, and Washington.

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
Method 2 (Not Used)	U.S. EPA	1998	Lbs/meal	0.30
	AVERAGE			**0.30**

To estimate total food waste generated in correctional facilities, EPA multiplied the generation factors for each method by the relevant extrapolation basis. For Method 1, EPA applied a count of prisoners reported by the BJS. This 2015 count includes prisoners in state and federal correctional facilities as well those housed in local jails.[78] For Method 2, EPA assumed that correctional facilities provide three meals per day. Therefore, the number of meals served per year equals the number of inmates, times three, times 365 days in the year.

As summarized in Table 42, Method 1 yields an annual food waste generation estimate of approximately 443,000 tons, while Method 2 yields an estimate of approximately 359,000 tons.

EPA relied on Method 1 for estimating food waste generation from correctional facilities. The Method 1 studies are diverse, and are based on waste stream analysis performed in several different locations. While some of the studies date back to 2000, more recent generation factor estimates are consistent with the older research.

TABLE 42. CORRECTIONAL FACILITIES FOOD WASTE GENERATION PROFILE

METHOD	PARAMETER	ESTIMATE	UNITS	SOURCE
Method 1	Average Generation Factor	1.12	Lbs/ inmate/ day	Average
	Metric Estimate	2,173,800	Number of inmates in the U.S., 2015	BJS, Correctional Populations in the United States Series[79]
	Annual Generation Quantity	443,002	Tons	Product of generation factor and metric value
	Number of studies (N) with original generation factors	6	Number	
Method 2 (Not Used)	Average Generation Factor	0.30	Lbs/employee/year	Average
	Metric Estimate	2,380,311,000	Number of meals for all inmates in the U.S., 2015	BJS, Correctional Populations in the United States Series; assuming 3 meals/ inmate/ day
	Annual Generation Quantity	359,407	Tons	Product of generation factor and metric value
	Number of studies (N) with original generation factors	1	Number	

[78] See https://www.bjs.gov/content/pub/pdf/cpus15.pdf

[79] Correctional Populations in the United States Series Data can be accessed at https://www.bjs.gov/index.cfm?ty=pbse&sid=5

Overall, based on the selected generation factor of 1.12 pounds/inmate/day and the 2015 estimate of the number of inmates in all U.S. correctional facilities, **EPA's estimate of food waste generated from correctional facilities in 2015 is 443,002 tons**.[80]

Key Assumptions and Limitations

EPA's method for estimating generation and management is based on empirical studies, and therefore confidence in the estimates is relatively high. Studies such as Marion (2000) and Connecticut DEP (2001), however, are growing outdated.

6.2.5.6 Colleges and Universities

EPA's methods for estimating food waste generation from colleges and universities cover all degree-granting postsecondary institutions, as defined by NCES. Degree-granting postsecondary institutions include 2-year and 4-year institutions that grant associates or higher degrees. The sector includes all public, private, and nonprofit institutions.

6.2.5.6.1 Analytic Methods for Colleges and Universities Food Waste Generation

The literature search identified a total of 44 studies addressing food waste generation in colleges and university settings. Many of these studies, however, are not directly useful to methods development. Some lack quantitative information on generation factors, while others apply generation factors from earlier studies. Hence, EPA's methodology is based on a subset of ten studies that either involved original research (e.g., directly weighing plate waste at a college dining hall) or which present estimates widely cited in the literature.

EPA's methodology incorporates two generation factors to estimate food waste from colleges and universities. The first generation factor is framed as pounds per meal, and is separated into two methodological variants. Method 1A is calculated using direct estimates of food waste generation per meal, including pre-consumer food waste (i.e., kitchen or preparation waste) as well as post-consumer food waste (i.e., plate waste). As shown in Table 43, five studies offer distinct estimates of this generation factor. The highest figure is from Vannet Group, LLC (2008), yielding an estimate of 0.47 pounds per meal. EPA included this study because it weighed food waste at all stages of the dining process, including the kitchen prep area, food serving stations, and consumer stations. The other studies in Method 1A include Ebner et al. (2014), Sarjahani et al. (2009), and Graunke and Wilke (2008), all of which conducted original research on food waste generated from college/university dining halls. EPA also included one study that did not directly measure food waste generation, Connecticut DEP (2001), because it is widely cited in the literature.[81]

[80] While EPA's estimates for almost all sectors are based on 2016 data, data for 2016 for this sector was not available at the time of analysis, so these estimates are for 2015.

[81] See NRDC (2017), Hodge et al. (2016), Battelle (2015), Moriarty (2013), Wellesley College (2013), and U.S. EPA Region 1 (2011).

TABLE 43. COLLEGES AND UNIVERSITIES FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR		
				PRE-CONSUMER[1]	POST-CONSUMER	TOTAL[4]
Method 1A	Ebner et al.	2014	Lbs/meal	0.07	0.15	0.22
	Sarjahani et al.[2]	2009	Lbs/meal	0.19	0.23	0.42
	Vannet Group, LLC	2008	Lbs/meal	0.16	0.31	0.47
	Graunke & Wilke	2008	Lbs/meal	0.16	0.19	0.35
	Connecticut DEP	2001	Lbs/meal	N/A	N/A	0.35
	AVERAGE					**0.36**
Method 1B	Thiagarajah & Getty	2013	Lbs/meal	0.16	0.25	0.40
	Whitehair et al.[3]	2013	Lbs/meal	0.09	0.14	0.23
	Kim & Morawski[2]	2012	Lbs/meal	0.13	0.21	0.34
	Caton et al.	2010	Lbs/meal	0.31	0.49	0.79
	AVERAGE					**0.44**
Method 2	CalRecycle	2015	Lbs/student/year	N/A	N/A	**22.0**

Notes:
[1] Pre-consumer values are estimated for Method 1B using the average proportion of pre-consumer waste from the studies in Method 1A.
[2] Sarjahani et al. (2009) and Kim & Morawski (2012) estimate food waste generation with and without trays. EPA used the average of the two estimates.
[3] Whitehair et al. (2013) studies the effect of a messaging campaign to reduce food waste. EPA used the baseline data as the basis for this generation factor.
[4] Totals may not add up due to rounding.

The available literature supports analysis of the same generation factor, pounds per meal, using a slightly different Method 1B. The literature search identified four additional high-quality studies that analyze only post-consumer food waste (i.e., plate waste). The studies in Method 1B have a larger range between the lowest estimate from Whitehair et al. (2013) with an estimate of only 0.14 pounds per meal, and Caton et al. (2010) with an estimate 0.49 pounds per meal. Because the studies in Method 1B only consider post-consumer waste, EPA scaled the post-consumer food waste generation factors in Method 1B upward using the average proportion of the food waste generated from post-consumer waste in the studies in Method 1A to estimate a total food waste generation factor. On average, the Method 1A studies showed post-consumer waste to be 61.4% of all waste. Applying this figure to the 1B post-consumer values yields an estimate of total waste generation per meal. For instance, dividing the Whitehair et al. (2013) estimate of 0.14 lbs/meal by 0.614 provides a total food waste estimate (pre- and post-consumer) of 0.23 lbs/meal. The pre-consumer value in Table 43 is simply the total waste generation factor minus the post-consumer factor.

Method 2 frames generation in terms of pounds per student per year, and is estimated from one source (CalRecycle, 2015). While CalRecycle (2015) does not differentiate between the K-12 and college/university sectors, EPA included the generation factor derived from "education sector" because the study is recent and the estimates are derived through direct waste sampling. EPA also used the same generation factor for K-12 schools. The generation factor developed from CalRecycle (2015) is 22.0 lbs/student/year, as shown in Table 43.

To estimate annual nationwide generation, the average generation factor must be scaled by an extrapolation figure. Because both Method 1A and Method 1B are in the same functional form, they use the same extrapolation basis of meals per year. Several steps are required to calculate meals per year:

- **Meals per Residential Student per Year** – Students living on campus consume more food on campus than non-residential students. Connecticut DEP (2001) apply two separate "meals per enrolled student per year" estimates for residential and non-residential institutions. Specifically, they assume a total of 405 meals per residential student per year. Two additional studies provide data on the number of meals served per enrolled student per year at residential institutions.[82] The analysis calculates the average meals per enrolled student at residential institutions as the average of the three estimates, equal to 285 meals per enrolled student per year.

- **Meals per Non-Residential Student per Year –** Lacking additional data on meals served per enrolled student at non-residential institutions, EPA retained the Connecticut DEP (2001) value of 108 meals per enrolled student at non-residential institutions.

- **Weighted Average Meals per Student –** EPA estimated a national average of 169 meals served per enrolled student as the average meals served per enrolled student between residential and non-residential institutions, weighted by the percent of students attending residential institutions and non-residential institutions.[83]

- **Number of Enrolled Students** – The number of enrolled students is from NCES.[84] Specifically, NCES reports a total of about 19,841,000 enrolled students for 2016.

- **Total Meals per Year –** Total meals served annually is the product of meals per student and total number of enrolled students. The analysis estimates about 3.34 billion meals per year in 2016.

For Method 2, the extrapolation basis is simply the number of students. The analysis applies the same source as in Methods 1A and 1B – the NCES estimate of 19,841,000 enrolled students in 2016.

Table 44 summarizes the food waste generation estimates associated with Methods 1A, 1B, and 2. As shown, Methods 1A and 1B yield similar generation quantities, although this result would be expected given the inter-dependent manner in which the generation factors are estimated and the use of the

[82] Ebner et al. (2014) reports two estimates: 180 and 270 meals per enrolled student per year according to two different methods. We use the average (225) as representative of Ebner et al. (2014). Whitehair et al. (2013) reports 19,046 meals served at a dining hall serving 540 students over a six-week period. Assuming an academic calendar of 270 days following Connecticut DEP (2001), EPA estimated an average of 226 meals per student per year as representative of Whitehair et al. (2013).

[83] EPA estimated that 34% of all enrolled students attend residential institutions. EPA calculated the percent of enrolled students attending residential institutions as the sum of enrolled students at "primarily residential" and "highly residential" institutions divided by the total number of enrolled students. See the Classification Summary Tables, Carnegie Classification of Institutions of Higher Education, Center for Postsecondary Research, Indiana University School of Education, available at: http://carnegieclassifications.iu.edu/downloads.php.

[84] While the Carnegie data on residential institutions has been updated every five years since 2000, EPA used the NCES data because it is updated annually. See Table 303.25: Total fall enrollment in degree-granting postsecondary institutions, by control and level of institution: 1970 through 2016, NCES, available at: https://nces.ed.gov/programs/digest/current_tables.asp.

same extrapolation basis of meals per year. The generation quantity estimated from Method 2 is lower by roughly a factor of three. EPA's methodology uses a simple average across all the studies applied, i.e., each study has equal weight in the average.

TABLE 44. COLLEGES AND UNIVERSITIES FOOD WASTE GENERATION ESTIMATE

METHOD	PARAMETER	ESTIMATE	UNITS
Method 1A	Average Generation Factor	0.36	Lbs/meal
	Basis for Extrapolation	3,344,374,796	Meals, 2016
	Annual Generation Quantity	604,219	Tons/year
	Number of studies (N) with original generation factors	5	Number
Method 1B	Average Generation Factor	0.44	Lbs/meal
	Basis for Extrapolation	3,344,374,796	Meals, 2016
	Annual Generation Quantity	734,200	Tons/year
	Number of studies (N) with original generation factors	4	Number
Method 2	Average Generation Factor	22.0	Lbs/student/year
	Basis for Extrapolation	19,841,014	Students, 2016
	Annual Generation Quantity	218,450	Tons/year
	Number of studies (N) with original generation factors	1	Number
AVERAGE GENERATION ESTIMATE		**617,634**	**Tons/year**

EPA's estimate of food waste generated from colleges and universities in 2016 is 617,634 tons.

Key Assumptions and Limitations

- The studies used to estimate generation factors for colleges and universities may not be representative of food waste generation at colleges and universities nationwide. Across the studies, generation rates vary, which could be the result of college-specific factors EPA is unable to control for in a national analysis, including the use of trays, campus food waste reduction initiatives, regional food supply systems, and/or the mode of food service.
- Multiple sources of food waste generation exist on college campuses. While EPA's methods account for food waste from dining hall meals, they do not consider food waste from residential waste streams within university campuses. For example, Caton et al. (2016) report that food waste represents a similar proportion of residential college waste as for total MSW, even after excluding cafeteria waste from the analysis. Because approximately 2.69 million students live in college/university housing, residential food waste on college and university campuses may represent a significant source of additional food waste generation.[85] This would be a source of underestimation in EPA's methodology.

[85] 2016 American Community Survey, U.S. Census. S2601B: Characteristics of the group quarters population by group quarters type.

- Some double counting likely occurs between the residential and colleges/universities analyses. Some of the residential methods are built on per-capita generation using the entire U.S. population. Most students will spend a portion of the year at home, contributing to residential food waste generation; however, the population of students who spend a portion of the year at school is not netted out of the residential population figures.

6.2.5.7 K-12 Schools

The methods for estimating food waste generation from K-12 schools cover all primary and secondary educational institutions, as defined by the NCES. Primary and secondary educational institutions include both public and private institutions.

6.2.5.7.1 Analytic Methods for K-12 Schools Food Waste Generation

The literature search identified a total of 32 studies addressing food waste generation in the K-12 school setting. Many of these studies, however, are not directly useful to methods development. Some lack quantitative information on generation factors, while others apply generation factors from earlier studies. Hence, EPA's methods are based on a subset of six studies that either involved original research (e.g., waste audits at an elementary school) or that present estimates widely cited in the literature.

EPA's methodology incorporates two generation factors: tons per student per year and pounds per meal. Method 1 (tons per student per year) is calculated using three studies.[86] Wilkie et al. (2015) estimate an average generation factor of 25.9 pounds per student per year based on sampling at three different Florida schools.[87] RecyclingWorks Massachusetts estimates an average generation factor of 18.0 pounds per student per year, based on waste audits conducted at seven public elementary, middle, and high schools. The final study included in Method 1 is CalRecycle (2015), which estimates a generation factor of 22.0 pounds per student per year.[88]

Method 2 uses a generation factor of pounds (per student) per meal. Byker et al. (2014) estimates an average generation factor of 0.52 pounds per meal at public pre-kindergarten and kindergarten classes. EPA also included one study that did not directly measure food waste generation at typical K-12 schools, Connecticut DEP (2001), because it is widely cited in the literature.[89] Connecticut DEP (2001) estimates an average of 0.35 pounds of food waste per meal.

[86] NRDC (2017) conducted bin digs at 12 different schools in three cities, resulting in an average generation factor of 24.6 pounds per student per year. These findings are commensurate with those in the literature directly used in the recommended analysis. However, the recommended analysis excludes the NRDC figures because NRDC only used the data to "ground truth" other generation factors and did not directly extrapolate from the bin dig findings.
[87] The three schools include one public elementary school, one public high school, and one private middle/high school.
[88] CalRecycle (2015) reports a generation rate of 3.67 tons of *total* waste per year per 100 students in Table 39. This is converted to food waste using the estimated percentage of total waste that is food waste of 30.0 percent, from Table 40. As noted earlier, the CalRecycle study pools all educational institutions, including colleges/universities and K-12 schools. EPA applied the same generation factor in both sectors.
[89] Connecticut DEP (2001) estimates food waste generation at colleges, universities, and independent preparatory schools. Cited in South Carolina DOC (2011), Mercer (2013), BSR (2012), and U.S. EPA Region 1 (2011).

Wilkie et al. (2015) and Byker et al. (2014) studies differentiate between food waste and milk waste. The recommended methods incorporate both food and milk waste, implicitly assuming that students dispose of milk waste in the same trash receptacles as other food waste.

Table 45 summarizes the two methods and food waste generation factors for K-12 schools.

TABLE 45. K-12 SCHOOLS FOOD WASTE GENERATION FACTORS

METHOD	SOURCE	YEAR	GENERATION FACTOR UNIT	GENERATION FACTOR
Method 1	Wilkie et al.	2015	Lbs/student/year	25.9
	RecyclingWorks MA	2013	Lbs/student/year	18.0
	CalRecycle	2015	Lbs/student/year	22.0
	AVERAGE			**22.0**
Method 2	Byker et al.	2014	Lbs/meal	0.52
	Connecticut DEP	2001	Lbs/meal	0.35
	AVERAGE			**0.43**

To estimate annual nationwide generation, the average generation factor must be scaled by an extrapolation figure. Method 1 and Method 2 use two separate extrapolation bases to develop estimates of total national food waste per year in the K-12 sector:

- **Method 1 – Number of Students:** The generation factor of pounds per student per year is simply multiplied by the total K-12 students to estimate the total food waste per year. EPA obtained estimates for the number of enrolled primary and secondary students from NCES. In 2014, NCES reported 56.1 million students.[90]
- **Method 2 – Meals per year:** The generation factor of pounds per meal requires two underlying data points: meals per student per year and total students. The number of total students used is the same value as described above as the extrapolation basis for Method 1. To calculate the total number of meals per student, EPA used data released from the National School Lunch Program (NSLP), which reports the total number of students enrolled in the program and the number of meals served per year.[91] The result is an average of 163 meals per student per year. The multiplication of the number of students and meals per student per year yields an extrapolation basis of approximately 9.14 billion meals per year.

Table 46 summarizes the food waste generation estimates associated with Methods 1 and 2. As shown, Method 1 results in an annual generation estimate that is roughly a factor of three lower than the estimate developed via Method 2. EPA's methodology uses a simple average across all the studies applied, i.e., each study has equal weight in the average.

[90] Total K-12 enrollment is estimated as the sum of public and private school enrollment. Specifically, NCES table 203.10 reports total public school enrollment of 50.3 million in 2014, and NCES table 205.10 reports total private school enrollment as 10.3% of total enrollment in 2015. We divide the total public school enrollment by one minus the percentage of students enrolled in private schools (89.7 percent), for a result of 56.1 million total students

[91] Data from the NSLP for FY2017 includes 30.0 million students, or approximately 60% of the total public school enrollment, accessed at: https://catalog.data.gov/dataset/national-school-lunch-assistance-program-participation-and-meals-served-data.

TABLE 46. K-12 SCHOOLS FOOD WASTE GENERATION ESTIMATE

METHOD	PARAMETER	ESTIMATE	UNITS
Method 1	Average Generation Factor	22.0	Lbs/student/year
	Basis for Extrapolation	56,085,576	Students
	Annual Generation Quantity	616,576	Tons/year
	Number of studies (N) with original generation factors	3	Number
Method 2	Average Generation Factor	0.43	Lbs/meal
	Basis for Extrapolation	9,144,080,193	Meals/year
	Annual Generation Quantity	1,981,844	Tons/year
	Number of studies (N) with original generation factors	2	Number
AVERAGE GENERATION ESTIMATE		**1,162,683**	**Tons/year**

EPA's estimate of food waste generated from K-12 schools in 2016 is approximately 1.2 million tons.

Key Assumptions and Limitations

The studies applied in the recommended methods are limited in number and scope, and therefore may not be representative of food waste generation at K-12 schools nationwide. Specifically, food waste generation may be higher for younger students compared to older students, and higher in public school settings compared to private schools.[92] To the extent that the generation factors used to develop the average national estimates fail to capture the true underlying distribution of these characteristics in U.S. K-12 institutions, the total quantity of food waste estimated may be biased.

6.2.6 Food Banks

Unspoiled excess food can be collected and redistributed to those in need through food pantries, food banks and other food rescue programs. To the extent that this excess food is not able to be successfully distributed, food banks themselves are also (minor) generators of food waste.

EPA's literature search identified a total of ten studies examining food waste generated from the food bank sector. Many of these studies, however, are not directly useful to methods development because they lack quantitative information on management rates and/or apply management rates from earlier studies.

Therefore, EPA's estimation method is primarily based on a dataset from Feeding America, a U.S.-based nonprofit food rescue organization with a nationwide network of more than 200 food banks. Feeding America secures food from corporate manufacturers, retailers, and produce suppliers nationwide; stores

[92] The results in the Technical Appendix for NRDC (2017) and Wilkie et al. (2015) show large differences in generation rates per student depending on the age of the student and the school setting (public or private).

excess food temporarily in warehouses; and then distributes the excess food to families and individuals through food assistance agencies such as youth or senior centers, shelters, and food pantries.

The Feeding America dataset details food rescue data from 2014 for 203 food banks. Feeding America provided data for food banks of various sizes in all 50 states. As a result, it likely captures the inherent excess food management variation associated with diverse excess food donation, demand, and operations management practices.

The Feeding America data provide the total quantity of food received from donation as well as the quantity of donated food that is disposed of due to spoilage, expiration, or other quality and safety considerations. EPA used the Feeding America data to estimate the quantity of food waste generated from food banks. Using the reported tonnage of food received that is ultimately disposed of by the food banks, EPA calculated food waste generated per food bank establishment and multiplied this metric by the total number of food banks nationwide to arrive at an estimate of food waste generated from food banks. EPA estimates that each food bank generates about 299 tons of food waste per year. Table 47 summarizes EPA's food waste generation methodology for food banks.

TABLE 47. FOOD BANKS FOOD WASTE GENERATION ESTIMATE

SCOPE	PARAMETER	QUANTITY	SOURCE
Feeding America	Excess food received that is disposed of (tons)	60,787	Feeding America, 2014
	Number of Feeding America locations providing excess food data	203	Feeding America, 2014
	Food waste generated per food bank (tons/food bank)	299	Calculated
National	Total number of food banks nationwide	1,263	Hoovers, 2017
	Total quantity of food waste generated by the food donation sector (tons)	**378,198**	Extrapolation calculation

EPA's estimate of food waste generated from food banks in 2016 is 378,198 tons.[93]

Key Assumptions and Limitations

EPA's estimate relies on several assumptions:

- Feeding America accurately reported the quantity of excess food donated and food waste generated.[94]

[93] While EPA's estimates for almost all sectors are based on 2016 data, data for 2016 for this sector was not available at the time of analysis, so these estimates rely on data from 2014 and 2017. However, EPA does not expect the data to vary too much year to year, and therefore this estimate is likely representative of 2016.

[94] Note that available data from the literature and other sources support Feeding America's quantity of food waste generated. Based on Feeding America's data, 3% of food received is disposed of due to spoilage. This percentage aligns with reported food waste generated from other sources. Email correspondence with Food for Free, a Boston-based food rescue organization noted that 2.4% of all received food is disposed of due to spoilage and FoodLink, a Rochester-based food rescue organization noted that approximately 6% of all received food is disposed of (Source: http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1797430).

- The data reported by Feeding America capture a representative sample of the food donation universe and comparable in size to other food banks; forming a reasonable basis for extrapolation.
- The quantity of direct local, informal donations (e.g., food donated directly to a local food bank) is negligible in comparison to the quantity of food managed by Feeding America and food banks nationwide.
- Any packaging included in the excess food tonnage reported by Feeding America is significantly lower in comparison to the overall quantity of excess food managed and is therefore negligible.

6.3 Appendix C: Detailed Generation and Management Estimates of Excess Food and Food Waste

Table 48 contains estimates of the amount of food waste and excess food generated by each sector, and the amount managed by each management pathway, per sector.

TABLE 48. GENERATION AND MANAGEMENT ESTIMATES OF EXCESS FOOD/FOOD WASTE BY SECTOR (2016)

	EXCESS FOOD AND FOOD WASTE MANAGED BY SECTOR (TONS)																
MANAGEMENT PATHWAY	MANUFACTURING/ PROCESSING	RESIDENTIAL	RETAIL	WHOLESALE	HOTELS	RESTAURANTS/ FOOD SERVICES	SPORTS VENUES	HOSPITALS	NURSING HOMES	MILITARY INSTALLATIONS	OFFICE BUILDINGS	CORRECTIONAL FACILITIES	COLLEGES & UNIVERSITIES	K-12 SCHOOLS	FOOD BANKS	INTERMEDIATE AMOUNT MANAGED[1]	TOTAL MANAGED BY EACH PATHWAY[2]
Food Donation	3,017,788	-	2,082,097	935,691	-	3,017,788	-	-	-	-	-	-	-	-	-	9,053,365[1]	**8,675,167**
Animal Feed	18,642,450	-	1,243,416	558,789	-	3,054	-	-	-	-	-	-	-	-	-	20,447,709	**20,447,709**
Codigestion/ Anaerobic Digestion	5,377,238	-	1,218,209	547,461	155,275	2,354,142	5,309	40,199	64,943	8,216	558,154	61,747	86,088	162,059	52,715	10,639,041[1]	**10,691,756[2]**
Composting/ Aerobic Processes	819,205	702,209	684,923	307,803	37,907	164,811	1,296	9,814	15,855	2,006	136,262	15,074	21,017	39,564	11,427	2,957,746[1]	**2,969,173[2]**
Bio-based Materials/ Biochemical Processing	328,042	-	382,005	171,673	-	1,269,399	-	-	-	-	-	-	-	-	-	2,151,119	**2,151,119**

	EXCESS FOOD AND FOOD WASTE MANAGED BY SECTOR (TONS)																
MANAGEMENT PATHWAY	MANUFACTURING/ PROCESSING	RESIDENTIAL	RETAIL	WHOLESALE	HOTELS	RESTAURANTS/ FOOD SERVICES	SPORTS VENUES	HOSPITALS	NURSING HOMES	MILITARY INSTALLATIONS	OFFICE BUILDINGS	CORRECTIONAL FACILITIES	COLLEGES & UNIVERSITIES	K-12 SCHOOLS	FOOD BANKS	INTERMEDIATE AMOUNT MANAGED[1]	TOTAL MANAGED BY EACH PATHWAY [2]
Land Application	8,214,481	-	178,047	80,014	-	-	-	-	-	-	-	-	-	-	-	8,472,542	**8,472,542**
Sewer/ Wastewater Treatment	-	3,685,299	-	-	-	-	-	-	-	-	-	-	-	-	-	3,685,299	**3,685,299**
Landfill	1,234,043	16,422,413	2,660,396	1,195,578	742,087	8,202,954	25,372	192,116	310,376	39,265	2,667,512	295,102	411,431	774,510	252,463	35,173,154[1]	**35,425,617[2]**
Controlled Combustion	180,048	3,758,740	232,905	104,667	178,741	1,874,385	6,111	46,273	74,758	9,458	642,503	71,079	99,098	186,550	61,593	7,465,317[1]	**7,526,909[2]**
Total Food Waste & Excess Food	**37,813,294**	**24,568,660**	**8,681,999**	**3,901,677**	**1,114,011**	**16,886,535**	**38,088**	**288,401**	**465,932**	**58,944**	**4,004,430**	**443,002**	**617,634**	**1,162,683**	**378,198**	**100,045,291**	**100,045,291**
Percent of Total	37.8%	24.6%	8.7%	3.9%	1.1%	16.9%	0.0%	0.3%	0.5%	0.1%	4.0%	0.4%	0.6%	1.2%	n/a		

Note:

[1] Although 9,053,365 tons of excess food are donated to food banks, food banks are not able to distribute all the food that is donated to them due to spoilage, expiration, or other reasons. Therefore, approximately 378,198 tons of the 9,053,365 tons ends up being managed as food waste via codigestion/anaerobic digestion, composting/aerobic processes, landfill, and controlled combustion. In the Intermediate Amount Managed column, the estimates of food waste do not yet distribute the 378,198 tons to those four pathways.

[2] Although 9,053,365 tons of excess food are donated to food banks, food banks are not able to distribute all the food that is donated to them due to spoilage, expiration, or other reasons. Therefore, approximately 378,198 tons of the 9,053,365 tons ends up being managed as food waste via codigestion/anaerobic digestion, composting/aerobic processes, landfill, and controlled combustion. In the Total Managed by Each Pathway column, the estimates of food waste generated by food banks are included in the management pathway estimates for those four pathways.