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The Environmental Impact of Pollution Prevention, Sustainable Energy Generation, and Other Sustainable Development Strategies Implemented by the Food Manufacturing Sector

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CHAPTER MENU

22.1 Introduction

The US food manufacturing industry is a diverse sector representing $217 billion in value added (about 10% of all manufacturing value added) in 2016 and supporting approximately 1.5 million jobs. This chapter characterizes chemical release and other waste management quantities as well as pollution prevention activities reported by the food manufacturing industry in the United States (US) over the 2007–2017 timeframe.[1] Analysis of information available from federal databases such as the US Environmental Protection Agency's (EPA's) Toxics Release Inventory (TRI) and industry reports reveal the corresponding environmental impacts, and identify opportunities for continued progress. Throughout this chapter several terms are used that may not be familiar to the reader. These terms are defined below.

> A 'TRI chemical' is a chemical that is included on the Toxics Release Inventory (TRI) list of chemicals, as established under Section 313(d)(2) of the *Emergency Planning and Community Right-to-Know Act*. Chemicals included on the TRI list are those that as a result of continuous, or frequently recurring releases are known to cause or can reasonably be anticipated to cause (1) significant adverse acute human health effects at concentration levels reasonably likely to exist beyond facility site boundaries; (2) cancer or teratogenic

1 At the time of the analysis and writing of this chapter, the 2017 reporting year was the year for which the most recent TRI data were available.

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effects or serious or irreversible reproductive dysfunctions, neurological disorders, heritable genetic mutations, or other chronic health effects; or (3) a significant adverse effect on the environment of sufficient seriousness to warrant reporting due to the chemical's toxicity, its toxicity and persistence in the environment, or its toxicity and tendency to bioaccumulate in the environment.

A 'TRI-reported chemical' refers to chemicals on the TRI list of chemicals for which facilities in the US have submitted reports to the US Environmental Protection Agency (EPA) TRI Program indicating releases to the environment or otherwise managed as waste.

'TRI-reported chemical waste' or 'TRI-reported waste' refers to the quantity of the TRI chemical(s) contained in waste and reported to EPA by facilities as released to the environment or otherwise managed as waste, such as through recycling, treatment, or combustion for energy recovery.

Beyond TRI-reported chemical waste management, this chapter also reviews data and literature on a range of pollution prevention and sustainability strategies in the industry such as those related to water conservation, improving energy efficiency and material use. This chapter does not discuss, in detail, the environmental impacts from resource extraction or depletion such as water consumption or energy consumption.

22.2 Overview of the Food Manufacturing Industry

The food manufacturing industry sector consists of any facility that produces foods or food ingredients, from slaughterhouses to bakeries. The industry applies many different industrial processes, varying from preparation (e.g. slaughtering, milling) to processing (e.g. cooking, freezing, fermenting) to packaging. The industry, as discussed in this chapter, consists of facilities classified under the North American Industry Classification System (NAICS) code 311 (Food Manufacturing). The sector consists of nine subsectors: Animal Food; Grain/Oilseed Milling; Sugar and Confectionery; Fruit and Vegetable; Dairy; Meats; Seafood; Bakeries and Tortilla; and Other Food, as described in Table 22.1 (US Census Bureau n.d.-a).[2] The shortened descriptions in Table 22.1 are used throughout the rest of this chapter.

Depending on the subsector and processes involved, TRI-reported chemicals may be manufactured, processed, or otherwise used when manufacturing food products. Some of these chemicals are released into the environment. It is difficult to generalize chemicals used in industrial processes across the entire industry because each subsector has unique processes and techniques. For example, many processes require or produce chemicals during disinfection, cleaning, and waste management, and may also produce large amounts of wastewater. Additionally, most preservation processes have high energy requirements in order to ensure safety of the food product. As a result, combusting fuel for energy leads to releases of TRI chemicals and greenhouse gases (GHGs). Refrigerants are another important class of chemicals for many subsectors in food manufacturing due to the need to prevent microbial growth. As another example, many chemical additives are used for processes including preservation, nutrition supplements, flavouring, and colouring.

2 Although the food manufacturing industry is also known as the food processing industry, the name for NAICS code 311 is food manufacturing and is used throughout this chapter (US Census Bureau n.d.).

Table 22.1 Food manufacturing (NAICS[a]) 311) subsectors.

NAICS	NAICS description	Shortened description	Activities included
3111	Animal food manufacturing	Animal food	Dog, cat, and other animal food manufacturing
3112	Grain and oilseed milling	Grain/oilseed milling	Flour and rice milling; malt manufacturing; soybean and other oilseed processing; fats and oils refining; breakfast cereal manufacturing
3113	Sugar and confectionery product manufacturing	Sugar and confectionery	Sugar manufacturing; chocolate manufacturing; other confectionery manufacturing
3114	Fruit and vegetable preserving and specialty food manufacturing	Fruit and vegetable	Frozen fruit, juice, and vegetable manufacturing; fruit and vegetable canning, pickling, and drying
3115	Dairy product manufacturing	Dairy	Milk, butter, cheese, and ice cream manufacturing
3116	Animal slaughtering and processing	Meats	Animal slaughtering; meat processing; meat byproduct processing
3117	Seafood product preparation and packaging	Seafood	Seafood and seafood products manufacturing
3118	Bakeries and tortilla manufacturing	Bakeries and tortilla	Retail and commercial bakeries; frozen pastries manufacturing, cookie and cracker manufacturing; pasta and dough manufacturing, tortilla manufacturing
3119	Other food manufacturing	Other food	Nuts, peanut butter, coffee and tea, flavouring syrup, prepared sauce, spice and extract, and other miscellaneous food manufacturing

a) North American Industry Classification System.

The food manufacturing industry as discussed in this chapter does not include the following (which are not covered by TRI reporting requirements):

- agriculture (NAICS 111),
- livestock (NAICS 112),
- fishing (NAICS 114),
- support activities for agriculture (NAICS 115),
- supermarkets (NAICS 44-45),
- food warehousing and storage (NAICS 4931), or
- food service such as restaurants (NAICS 722).

It also does not include beverage and tobacco product manufacturing (NAICS 312), although food, beverage, and tobacco manufacturing are frequently combined in other analyses and datasets. Researchers may want to consider these related activities in follow up analyses.

According to recent Statistics of US Businesses (SUSB) data (US Census Bureau 2018), in 2015 there were 26 819 food manufacturing establishments in the US, making up 9% of all manufacturing establishments. During the same year, these establishments employed 1.5 million people, which made up 13% of all employment in all manufacturing industries. Almost half of these establishments employ fewer than 10 full-time employees. Of those food manufacturing establishments with 10 or more employees, 33% were in the Bakeries and Tortilla subsector, which includes retail bakeries. Figure 22.1 presents the number of establishments with 10 or more employees by subsector, representing a total of 13 113 establishments (49% of the total food establishments) during 2015. Establishments in food manufacturing with at least 10 full-time employees (or the equivalent in hours) meet the industry and employment criteria for TRI reporting, and may be required to report to TRI depending on the quantities of TRI chemicals they manufacture, process, or otherwise use annually at the establishment. Of these 13 113 food manufacturing establishments, a relatively small number of facilities (1595) met the TRI reporting requirements during 2015, as evidenced by the fact that each of these facilities submitted at least one TRI reporting form for the 2015 reporting year (RY).

Value added is a measure of the contribution of the industry to the Nation's Gross Domestic Product and is published annually by the US Census Bureau. The Census Bureau derives the value added by subtracting the cost of materials, supplies, containers, fuel, purchased electricity, and contract work from the value of products manufactured plus receipts for services rendered.

As food manufacturing operations have used technological innovations to improve on economies of scale and achieve higher productivity with lower costs, greater industry competition and lower prices have favoured larger companies and resulted in even larger food operations for farms, processing plants, and retailers (Shields 2010). In 2007, the top four companies in the food manufacturing industry held 15% of the market share, while in certain subsectors the market share of the top four firms was much larger, such as soybean processing (80%) and non-poultry slaughterhouses (60%) (US Census Bureau 2011). Vertical integration, where the parts of the supply chain are under a common owner, has also increased, especially in the poultry industry (Martinez 1999). For example, a vertically integrated poultry company may own the feed mill, the breeding stock, the hatchery, and the processing plant, giving them control over the quality and quantity of their supply chain's production. Over a third of the top 50 global food manufacturing companies are headquartered in the US, and American companies such as Tyson Foods, Archer Daniels Midland (ADM), and Kraft are among the largest (Food Engineering 2014).

22.2.1 Production and Economic Trends

Although food manufacturing in the US comprises a significant portion of shipments from all manufacturing industries, due to the necessity and, therewith, inflexible nature of food products as essential commodities, the industry is less impacted by fluctuating economic conditions (US Department of Commerce 2008). In the global recession during 2008–2009, the large impacts felt by many other components of the economy were not as significant in the food manufacturing industry (Ramde 2010). In this analysis, trends in the sector's production levels were based on the annual 'value added' to the overall economy. The annual value added was used as proxy for annual production output. The results are presented in Figure 22.2. Total value added for food manufacturing was $217 billion in 2016, or about 10% of the total value added for all manufacturing industries. As shown in Figure 22.2, estimates of the value added from the food manufacturing subsectors (Bureau of Economic Analysis 2018a, 2018b; US Census Bureau n.d.-b) indicate that the annual value added remained relatively stable over the timeframe, which includes the global recession. Similarly, evaluation of the Federal Reserve Board's production index for food manufacturing (2017), as shown in Figure 22.3, also indicates that this industry was less affected by the recession than other industries and has even expanded in recent years.

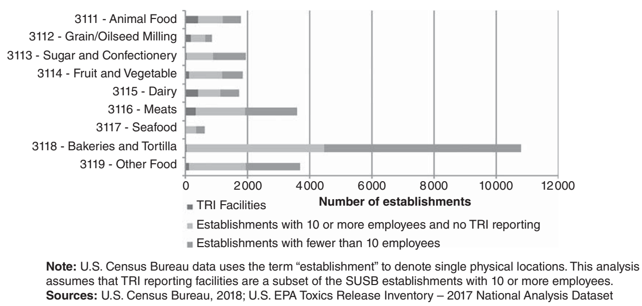
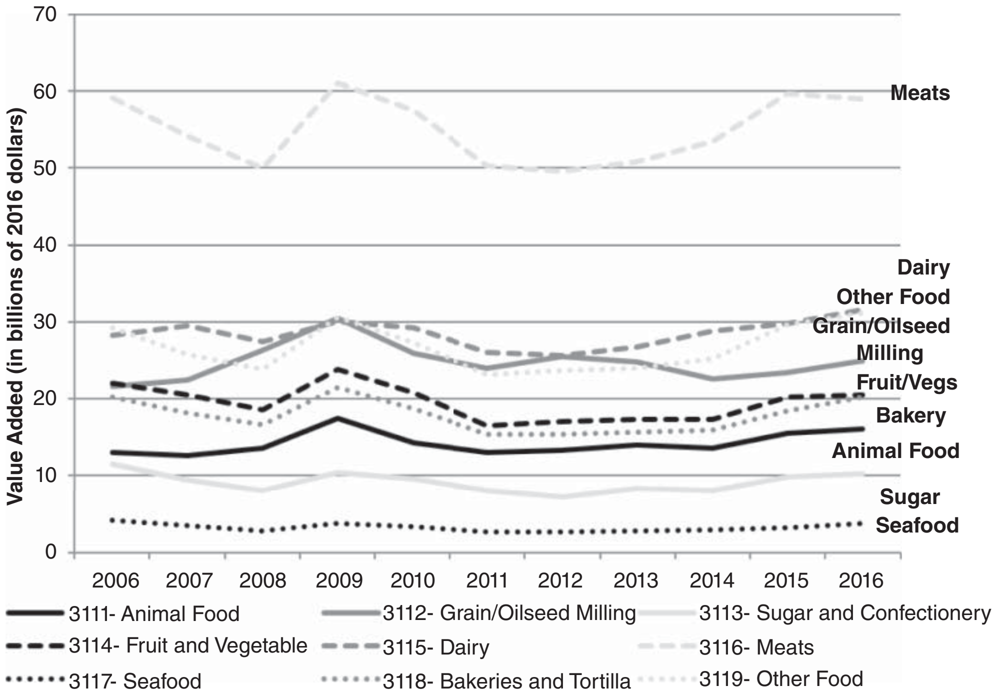
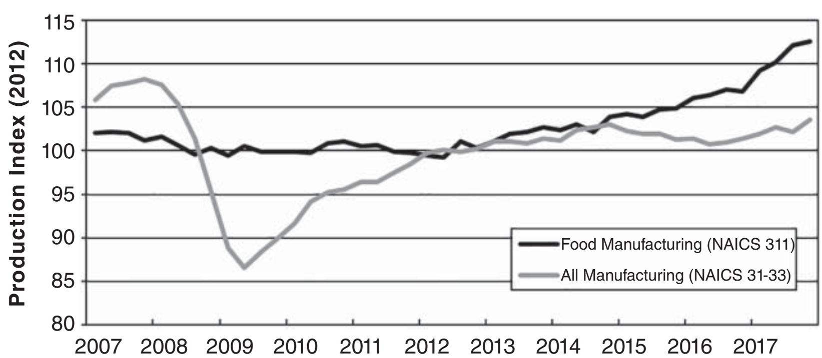


Figure 22.1 Food manufacturing subsectors by TRI reporting status and number of employees, 2015. Note: US Census Bureau data uses the term 'establishment' to denote single physical locations. This analysis assumes that TRI reporting facilities are a subset of the SUSB establishments with 10 or more employees. Sources: US Census Bureau 2018; US EPA Toxics Release Inventory – 2017 National Analysis Dataset.



Note: Value added data is only provided as an aggregated value for food, beverage, and tobacco manufacturing together, so the distribution by subsector of Product Shipments Value from the Annual Survey of Manufacturers was used as a proxy for how to break down value added by subsector as shown in the figure. Data was not available for 2017.
Sources: U.S. Census Annual Survey of Manufacturers, 2006-2016; Bureau of Economic Analysis, 2018a

Figure 22.2 Annual value added by the food manufacturing industry, 2006–2016. Note: Value added data is only provided as an aggregated value for food, beverage, and tobacco manufacturing together, so the distribution by subsector of Product Shipments Value from the Annual Survey of Manufacturers was used as a proxy for how to break down value added by subsector as shown in the figure. Data was not available for 2017. Sources: US Census Annual Survey of Manufacturers, 2006–2016; Bureau of Economic Analysis 2018a.



Source: Federal Reserve Board of Governors, 2007-2017

Figure 22.3 Food manufacturing production index – seasonally adjusted, 2007–2017. Source: Federal Reserve Board of Governors, 2007–2017.

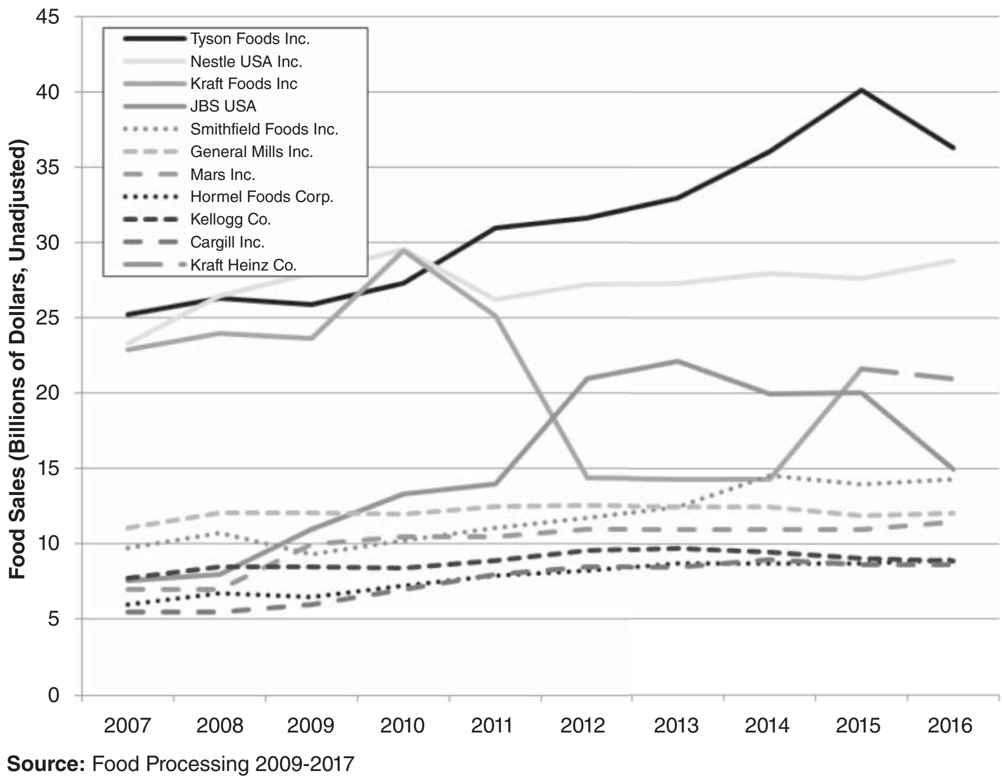


Figure 22.4 Top 10 US and Canadian food manufacturers by food sales, 2007–2016. Source: Food Processing, 2009–2017.

22.2.2 Key Players

Food sales from 2007 to 2016 for the 10 largest US and Canadian food manufacturing companies in 2016 are shown in Figure 22.4. Many of these companies produce a variety of foods and brands and frequently undergo corporate reorganization, restructuring, buyouts, and mergers. For example, the large dip in food sales from Kraft Foods Inc. in 2012 is the result of the reorganization of the company into the separate entities of Kraft Foods and Mondelez International (Food Processing 2018), followed by a merger of Kraft Foods with Heinz in 2015 to form the Kraft Heinz Company. Note that some parent companies may own facilities which are not included in the food manufacturing industry. For example, Nestle USA Inc. also manufactures bottled water and metal can products in addition to food products. The sales figures included in Figure 22.4 represent food sales of the top 10 US and Canadian food manufacturers rather than total sales.

22.3 Chemicals and Chemical Wastes in the Food Manufacturing Industry

Food manufacturing involves processing raw food products, such as produce, grains, meats, and dairy, into more complex and portable products that can be preserved until purchase and used by consumers. In order to create and process these types of food products, various industrial chemicals and chemical processes are required. Chemicals used may include solvents (e.g. *n*-hexane), mineral acids (e.g. nitric acid), artificial additives or preservatives, disinfectants, and refrigerants. Moreover, chemicals may be formed during the food manufacturing processes (e.g. formation of nitrate compounds during wastewater treatment processes when nitric acid is neutralized with alkali), or during activities that support the manufacture of foods (e.g. combustion of fuels for energy, and the resultant creation of GHGs)

22.3.1 Greenhouse Gas Emissions

In regard to the food manufacturing industry, the GHG emissions reported to the EPA's Greenhouse Gas Reporting Program (GHGRP) are mostly generated by the stationary combustion of fuels in order to power manufacturing operations. These are characterized as direct emissions since the GHGs are emitted directly from the facility following combustion of a fuel. Direct emissions reported from the food manufacturing industry for 2017 totalled 28.1 million metric tons of CO2-equivalent (MMCO2-eq) from 336 facilities (US EPA 2018a). More than two-thirds (19.5 MMCO2-eq from 98 facilities) of the emissions were from the Grain/Oilseed Milling subsector, with additional sizable contributions from the Meats (2.9 MMCO2-eq from 99 facilities) and Fruit and Vegetable (2.3 MMCO2-eq from 60 facilities) subsectors.

Among the 336 facilities in the food manufacturing sector that reported to EPA's GHGRP, 207 also reported to EPA's TRI Program for reporting year (RY) 2017 (US EPA 2018c). Of these, 180 facilities reported a total of 25 million pounds of air releases of TRI chemicals as part of their waste management portfolio. Facilities in the Grain/Oilseed Milling subsector contributed the largest amount of GHG emissions reported to GHGRP, as well as the largest total amount of air releases reported to TRI, primarily as *n*-hexane (17.5 million pounds), hydrochloric acid (0.9 million pounds), and acetaldehyde (0.8 million pounds). Air releases of ammonia from facilities in the Meats subsector (2.0 million pounds) were also notable. In 2017, food manufacturers accounted for 1% of total GHG emissions reported to GHGRP and 7% of total air releases reported to TRI.

22.3.2 Conventional Water Pollutants

Water pollutants discharged by industrial facilities are regulated by EPA's National Pollutant Discharge Elimination System (NPDES) Permit Program by authority under the Clean Water Act. Industrial, municipal, and other facilities must obtain permits before they can discharge pollutants into surface waters. Information on pollutant discharges as required under the NPDES Program is reported to EPA and available via the Discharge Monitoring Report (DMR) Pollutant Loading Tool (US EPA n.d.). Note that there is some overlap between facilities which report to EPA's TRI Program and those that are regulated by EPA's NPDES Program; TRI-reported releases, such as nitrate compounds discharged to surface waters, for example, are also reported to the NPDES Program.

In the food manufacturing industry, biological oxygen demand and solids (both dissolved and suspended) are two of the primary concerns associated with wastewater discharges (UN Industrial Development Organization 2004). Based on DMR classifications via Standard Industrial Classification (SIC) codes that correspond to relevant NAICS codes, facilities in the Meats and Seafood subsectors discharged the largest amounts of total dissolved and suspended solids in wastewater over the nine-year timeframe from 2007 to 2015. The large amounts of solids are likely to be associated with processes inherent to these subsectors, such as euthanization, rendering, and bleeding (UN Industrial Development Organization 2004).

22.3.3 Refrigerants

The Montreal Protocol, an international agreement finalized in 1987 to phase out the consumption and production of ozone-depleting substances, significantly impacted the use of refrigerants in the food manufacturing industry. Prior to the Montreal Protocol, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) were once widely used refrigerants because of their low toxicity and low flammability. At that time, the three most commonly used refrigerants in the food manufacturing industry were R12 (dichlorodifluoromethane, a CFC), R22 (chlorodifluoromethane, an HCFC also known as HCFC-22), and R502 (a mixture of R22 and R115 [chloropentafluoroethane]). Several CFC and HCFC refrigerants are on the TRI list of chemicals, including R12, HCFC-22, and R115 (also called CFC-115).

Use of CFCs have been almost entirely eliminated in the United States, and industry is aiming to phase out use of HCFCs by 2030. Common substitutes for CFCs and HCFCs are hydrofluorocarbon (HFC) mixtures such as R404A (a mixture of pentafluoroethane, 1,1,1-trifluoroethane, and 1,1,1,2-tetrafluoroethane) and R407C (a mixture of difluoromethane, pentafluoroethane, and 1,1,1,2-tetrafluoroethane), neither of which contain TRI-listed chemicals.

Other substitutes for CFCs and HCFCs include ammonia and propane (James and James 2014). Ammonia in particular is becoming the preferred refrigerant for the food manufacturing industry, largely due to its efficiency in large systems, smaller environmental impact relative to other refrigerants, and strong odour that allows for detection of equipment leaks and serves as a warning in case of accidental releases (Food Manufacturing 2015). In addition, CO2 has been used as a substitute refrigerant. However, due to high operating pressure requirements, applications of CO2 refrigeration are currently limited in scale. For example, CO2 is used as a refrigerant in vending machines (Bhatkar, Kriplana, and Awari 2013).

The common refrigerants mentioned in this section are summarized in Table 22.2. As an example of how releases have changed in recent years, air releases for HCFC-22 as reported to EPA's TRI Program have decreased by 84%, from 72 625 lb in 2007 to 11 625 lb in 2017 (US EPA 2018c).

Beyond industrial use within facilities, refrigerants are also necessary in order to properly and safely transport the items to their intended destination. In 2016, the US Food and Drug Administration (FDA) finalized a rule as part of the Food Safety Modernization Act (FSMA) related to the sanitary transportation of human and animal food products that became effective in June 2016 (US FDA 2016). Among other requirements, adequate temperature controls must be maintained for shipments related to food products; this includes a myriad of industry sectors, such as agriculture

Table 22.2 Examples of chemicals used as refrigerants.

Name (Chemical Abstracts Service [CAS] Number)	Alternative names	Type of refrigerant	TRI-listed chemical?
Ammonia [7664-41-7]		Inorganic	Yes
Chlorodifluoromethane [75-45-6]	HCFC22, R22	HCFC	Yes
R404A[a)]	HFC-404A	CFC + HCFC Mixture	No
R407C[b)]	HFC-407C	CFC + HCFC Mixture	No

a) R404A is a mixture of: pentafluoroethane (HFC125; CAS# 354-33-6), 1,1,1-trifluoroethane (HFC143a; CAS# 420-46-2), and 1,1,1,2-tetrafluoroethane (HFC134a; CAS# 811-97-2). None of these substances are on the TRI chemical list.

b) R407C is a mixture of: difluoromethane (HFC32; CAS# 75-10-5), pentafluoroethane (HFC125; CAS# 354-33-6), and 1,1,1,2-tetrafluoroethane (HFC134a; CAS# 811-97-2). None of these substances are on the TRI chemical list.

and grocery retailers, but also includes shipments from food manufacturing facilities. Based on data from the 2012 Commodity Flow Survey (US Census Bureau 2015), the average miles per temperature controlled shipment for food manufacturing facilities was 214 mi. By weight, most of the shipments occurred via truck, and 35% of the shipments were less than 100 mi.

22.3.4 TRI-Reported Chemical Waste Management

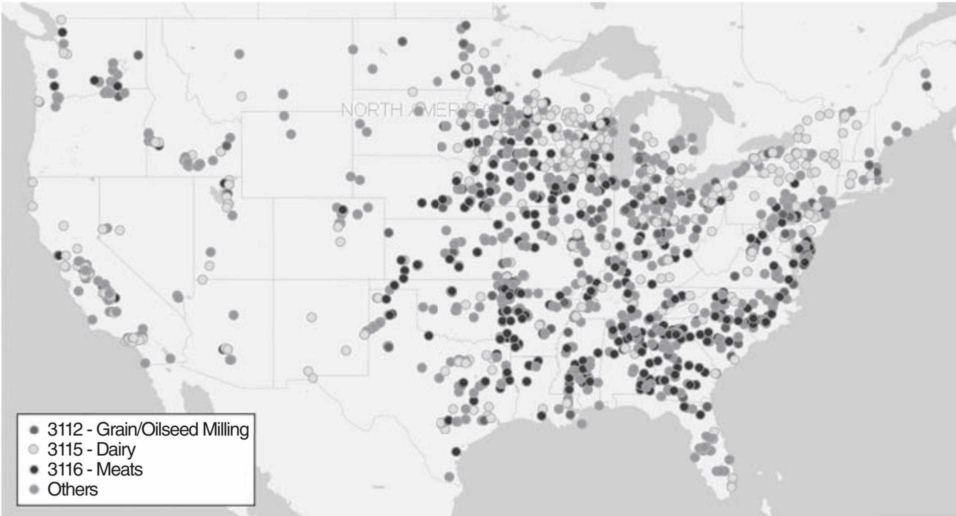
EPA's TRI Program publicly tracks quantities of chemicals included on the TRI chemical list that are released on-site to air, water, and land, transferred off-site to other facilities, or otherwise managed as waste by facilities throughout the United States. Release quantities presented in this chapter include on-site release and disposal, and off-site transfer for further waste management (TRI Form R Sections 5 and 6). Production-related waste management quantities, hereafter referred to simply as 'waste managed', consists of quantities of a TRI chemical released to the environment, as well as recycled, burned for energy recovery, or treated (TRI Form R Sections 8.1–8.7), and excludes any quantity reported as catastrophic or one-time releases (TRI Form R Section 8.8). An overview of TRI's data reporting requirements is available (US EPA 2019b).

For 2017 (the most recent TRI reporting year available at the time of writing), 1585 facilities from the food manufacturing industry reported to the EPA's TRI Program (as illustrated in Figure 22.5) (US EPA 2018c). From 2007 to 2017, the number of food manufacturing facilities reporting to TRI increased by 2%, from 1558 to 1585. Over the same 11-year period, the number of forms for TRI chemicals reported by the food manufacturing industry increased by 7%, from 3478 to 3722. In comparison to the other industry sectors that report to EPA's TRI Program, food manufacturing moved in the opposite direction regarding facilities reporting and forms submitted – across all other industries, both the number of facilities reporting to TRI and the number of forms submitted decreased by approximately 10%. In 2017, food manufacturing accounted for 7% of all facilities, 5% of all waste managed, and 3% of all releases reported to EPA's TRI Program. The food manufacturing industry ranked sixth in waste managed quantities in 2017, after the following industries: chemical manufacturing, primary metals, petroleum, paper manufacturing, and metal mining. In terms of TRI-reported release quantities, food manufacturing was the seventh largest industry contributor to overall TRI-reported release quantities, but was the largest contributor (36%) to the quantities of releases of TRI chemicals (the majority of which was nitrate compounds) to surface waters (Figure 22.5).

A summary of the food manufacturing industry's TRI reporting is included in Table 22.3 and is discussed in more detail throughout the remainder of this chapter. The table also includes the number of facilities reporting source reduction activities. The subsectors with low releases (e.g. Animal Food) tend to have low rates of source reduction reporting. Subsectors that report larger quantities of releases and other waste management quantities (e.g. Dairy) tend to have higher source reduction reporting rates, as there may be more known opportunities to implement source reduction. The type and amount of TRI-reported chemicals handled also depends on the specific subsector and is discussed in the next section.

22.3.5 Trends in TRI-Reported Chemical Waste Management

Between 2007 and 2017, total TRI-reported chemical waste managed by the food manufacturing industry increased by 45%. Most of the increase in waste managed came from the Grain/Oilseed Milling subsector, where increased on-site recycling of *n*-hexane (from 571 million pounds in 2007 to 828 million pounds in 2017) was the key driver. However, a majority of the quantities reported



Note: This map does not display any food manufacturing facilities located in Alaska, Hawaii or any of the U.S. territories that filed TRI reports for the 2017 reporting year.

Figure 22.5 Food manufacturing facilities that reported to the TRI program for 2017. Note: This map does not display any food manufacturing facilities located in Alaska, Hawaii or any of the US territories that filed TRI reports for the 2017 reporting year.

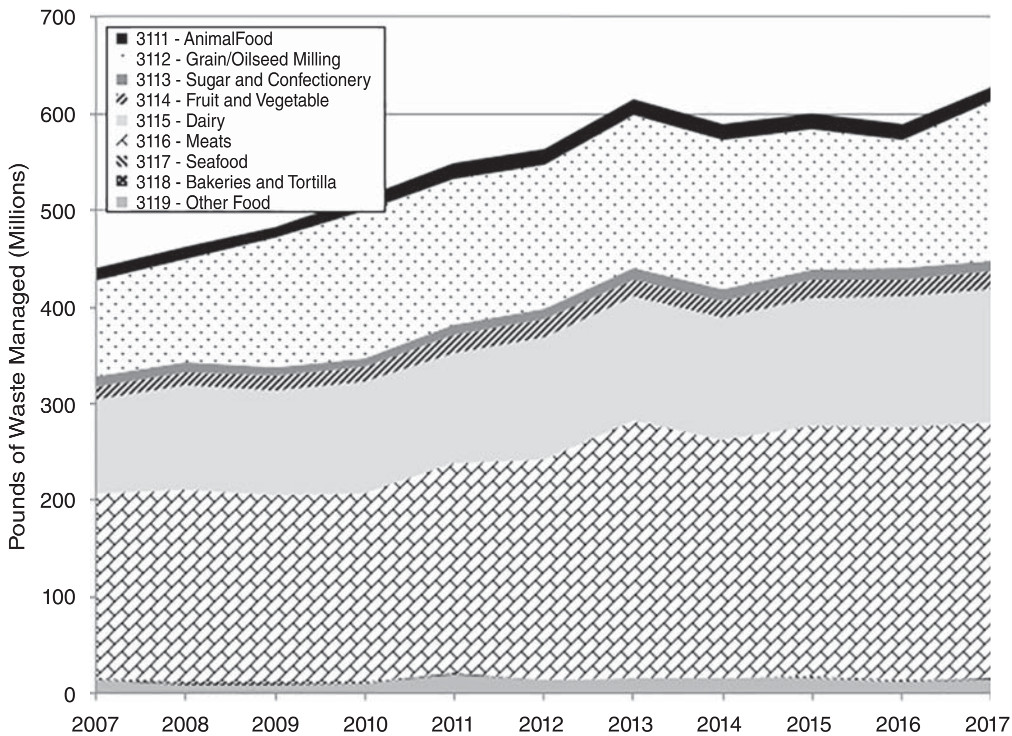
Table 22.3 TRI reporting overview for food manufacturing, 2017.

Sector	Number of facilities	Facilities reporting source reduction	Total waste managed		Releases	
			Pounds	% of sector total	Pounds	% of sector total
311 – Food manufacturing (all subsectors)	1585	101	1 450 898 040	100%	127 297 917	100%
3111 – Animal food	406	5	15 491 786	1%	857 944	1%
3112 – Grain/oilseed milling	167	10	987 494 050	68%	34 381 923	27%
3113 – Sugar and confectionery	34	4	10 844 734	1%	7 305 541	6%
3114 – Fruit and vegetable	92	7	17 984 115	1%	8 680 693	7%
3115 – Dairy	416	28	137 929 752	10%	8 611 508	7%
3116 – Meats	334	33	265 179 184	18%	64 839 756	51%
3117 – Seafood	8	0	402 778	<1%	145 472	<1%
3118 – Bakeries and Tortilla	23	2	1 145 543	<1%	766 862	1%
3119 – Other food	107	12	14 426 099	1%	1 708 218	1%

Note: One facility in the Grain/Oilseed Milling subsector reported that 822 million pounds of *n*-hexane were recycled on-site. EPA's TRI Program contacted the facility about this quantity in previous years, and the facility claimed previous values in this range were valid.
Source: US EPA Toxics Release Inventory – 2017 National Analysis Dataset.

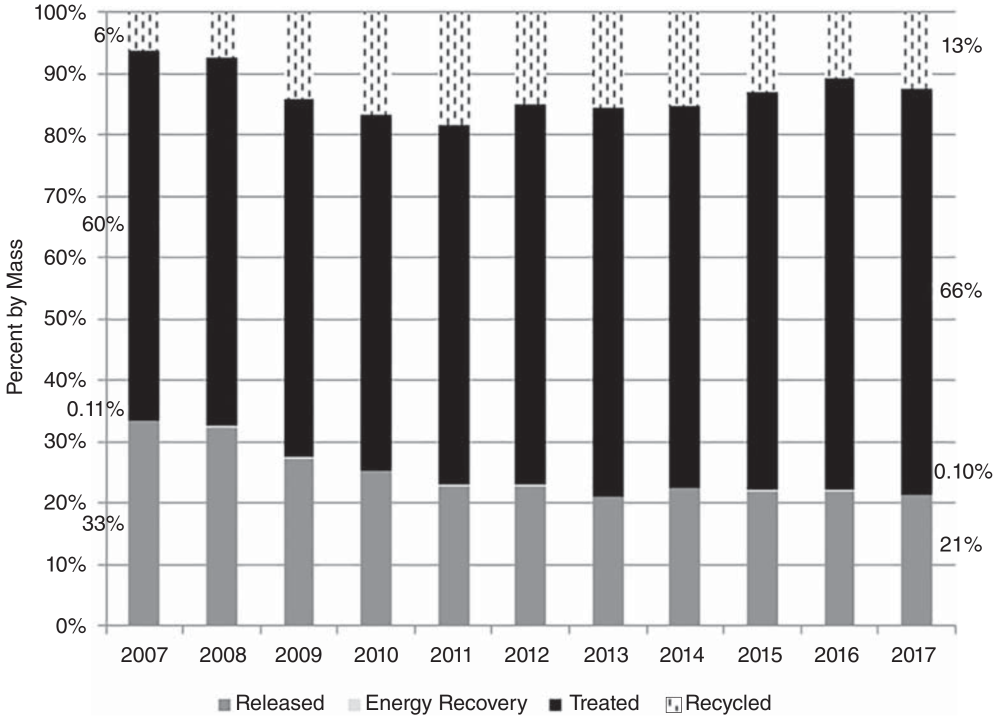
are from *n*-hexane recycled at a single soybean processing facility; this facility reported more than half of all wastes managed in the food manufacturing industry in recent years. When the quantities of *n*-hexane and methanol that were recycled by this facility are removed from the aggregate, as illustrated in Figure 22.6, total waste managed by the food manufacturing industry increased by 43%. Even without that single facility, the overall trend in waste management is similar, and facilities in the Grain/Oilseed Milling subsector reported increases of 66 million pounds of waste managed across this time period. Facilities in a few other subsectors, such as Meats, Dairy, and Fruit and Vegetable, also reported increases in the quantities of TRI chemicals managed as waste.

As shown in Figure 22.7, the primary waste management method for TRI chemicals in the food manufacturing industry is treatment; 60% of waste reported was treated in 2007, increasing to 66% in 2017. Note that one soybean processing facility was removed from these analyses due to its overwhelming impact on the results. It predominantly recycles both *n*-hexane and methanol, which are used in the vegetable oil extraction process. Interesting and encouraging TRI-reported waste management trends that are readily apparent in Figure 22.7 include the shift towards treatment and recycling of wastes, and the corresponding shift away from releasing TRI chemicals. Figure 22.8 illustrates the 10 chemicals for which the largest aggregated quantities of waste managed were reported to EPA's TRI Program over the 2007–2017 timeframe.



Note: This figure does not include one soybean processing facility in the Grain/Oilseed Milling subsector.
Source: U.S. EPA Toxics Release Inventory – 2017 National Analysis Dataset

Figure 22.6 Food manufacturing waste managed by subsector, 2007–2017. Note: This figure does not include one soybean processing facility in the Grain/Oilseed Milling subsector. Source: US EPA Toxics Release Inventory – 2017 National Analysis Dataset.

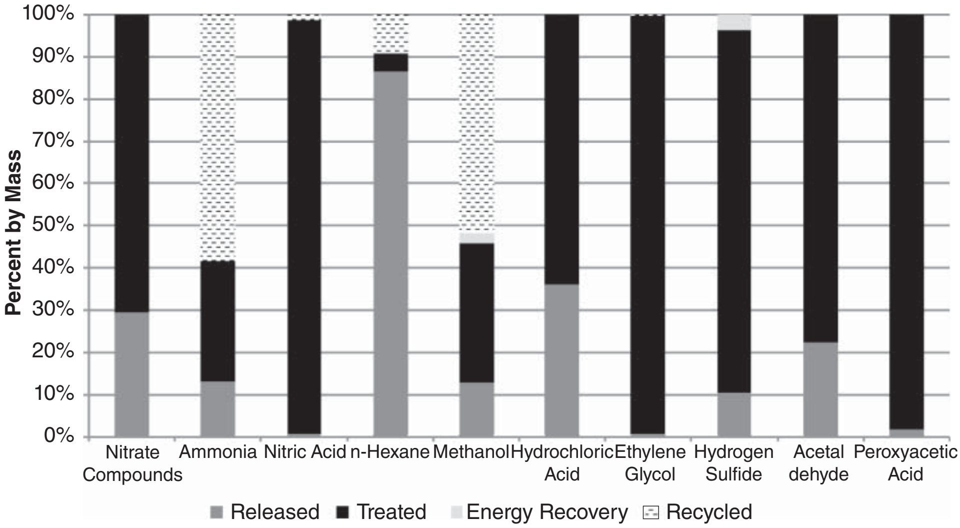


Notes: 1) Less than 0.2% of TRI chemical waste was used for energy recovery each year, therefore it is barely visible in this figure. 2) These results do not include one soybean processing facility in the Grain/Oilseed Milling subsector.
Source: U.S. EPA Toxics Release Inventory – 2017 National Analysis Dataset

Figure 22.7 Food manufacturing waste management methods, 2007–2017. Notes: (i) Less than 0.2% of TRI chemical waste was used for energy recovery each year, therefore it is barely visible in this figure. (ii) These results do not include one soybean processing facility in the Grain/Oilseed Milling subsector. Source: US EPA Toxics Release Inventory – 2017 National Analysis Dataset.

Treatment is the principal waste management method for TRI chemicals in food manufacturing. The manufacture, processing or otherwise use (and the waste management methods chosen for them) are largely associated with specific subsectors:

- *Nitrate compounds* are manufactured as a result of nitrification during aerobic biological treatment of ammonia in wastewater. They are also manufactured when nitric acid, used for cleaning and sanitation, is treated (neutralized) prior to wastewater discharge. For nitrate compounds, the biggest contributors of waste managed quantities specific to food manufacturing facilities are releases and treatment by the Dairy and Meats subsectors. Management of nitrate compounds in wastewater are regulated under environmental laws such as the Clean Water Act.
- *Ammonia* is often used to sanitize food manufacturing equipment and may also be formed by mineralization of organic nitrogen-containing waste. Releases and treatment of ammonia are largely dominated by the Meats subsector. However, more than half of ammonia waste is managed through recycling, and mostly reported by Grain/Oilseed Milling facilities, where ammonia is used during pre-treatment in the wet corn milling process to improve yields. Recycling of ammonia has increased within the Grain/Oilseed Milling subsector, from 9 million pounds recycled in 2007 to 57 million pounds recycled in 2017. Note that ammonia may also be used in



Notes: 1) The 10 chemicals shown had the highest aggregated quantities of waste managed reported to TRI by the food manufacturing industry over the period 2007 - 2017. 2) Hydrogen sulfide reporting began in 2012. 3) This figure does not include one soybean processing facility in the Grain/Oilseed Milling subsector.
Source: U.S. EPA Toxics Release Inventory – 2017 National Analysis Dataset

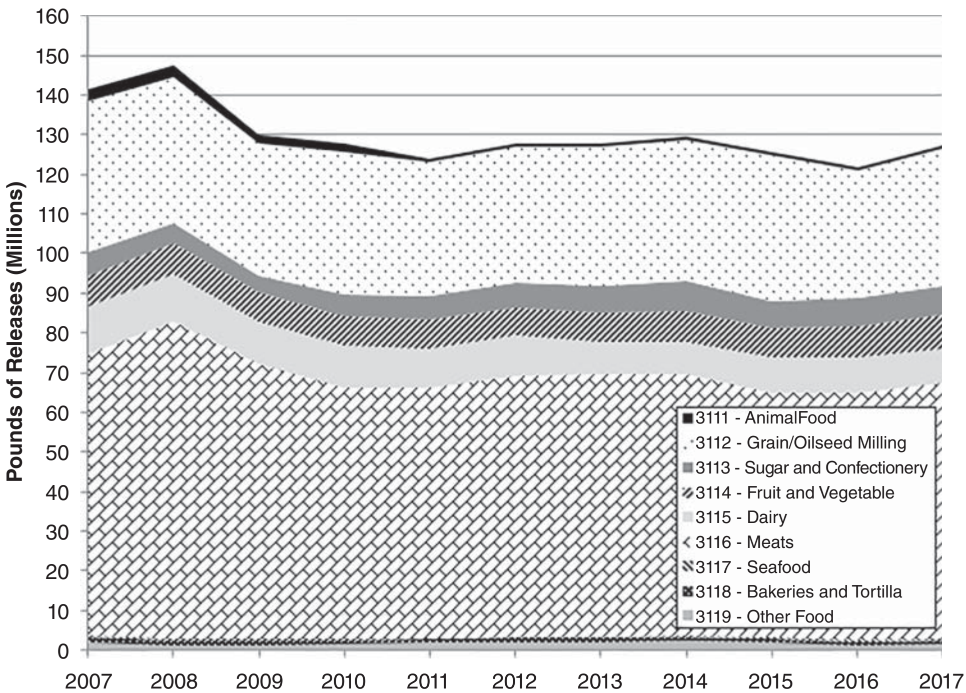
Figure 22.8 Waste management methods for top food manufacturing chemicals during 2007–2017. Notes: (i) The 10 chemicals shown had the highest aggregated quantities of waste managed reported to TRI by the food manufacturing industry over the period 2007–2017. (ii) Hydrogen sulfide reporting began in 2012. (iii) This figure does not include one soybean processing facility in the Grain/Oilseed Milling subsector. Source: US EPA Toxics Release Inventory – 2017 National Analysis Dataset.

refrigeration systems, as discussed previously in Section 22.3.3, but only the quantity used to recharge the system in a given year is reportable to TRI (not the total quantity used for refrigeration). In many cases, this quantity may be below the 10 000 lb. otherwise use threshold for TRI reporting.

- *n-Hexane* is used within the Grain/Oilseed Milling subsector to extract and process a variety of oils from raw agricultural commodities. Most of the *n*-hexane waste reported to EPA's TRI Program from the food manufacturing industry is reported by this subsector, with other reports from the Other Food subsectors including Spice and Extract Manufacturing as well as Flavouring Syrup and Concentrate Manufacturing. As a volatile chemical, *n*-hexane releases are almost entirely to air. TRI reporting forms also indicate a small number of facilities treat *n*-hexane waste through methods such as using absorbers and flaring.

22.3.5.1 Trends in Releases

Figure 22.9 shows total release quantities of TRI chemicals from the food manufacturing industry by subsector and includes quantities released on-site to air, water, and land as well as transferred to an off-site location for disposal. From 2007 to 2017, releases decreased by 10%. Figure 22.9 presents total releases across the 11-year time period from each subsector. These graphs indicate that the quantities of TRI chemicals released largely depend on the subsector. For example, the largest quantity of releases are from the Meats subsector, which are often in the form of nitrate compounds formed in wastewater and are subsequently discharged to surface water. Facilities in the



Source: U.S. EPA Toxics Release Inventory – 2017 National Analysis Dataset

Figure 22.9 Food manufacturing releases by subsector for 2007 through 2017. Source: US EPA Toxics Release Inventory – 2017 National Analysis Dataset.

Grain/Oilseed Milling subsector are responsible for the second greatest quantities of TRI chemicals released to the environment; these releases are often in the form of volatile chemicals such as *n*-hexane, which are released to air. Note that the single soybean processing facility removed from analyses in the previous section on waste managed is not removed from the releases analyses in this or subsequent sections, as it does not have a significant influence on the results.

Facilities in the food manufacturing industry have reported releases for 108 TRI chemicals listed individually or in chemical categories (e.g. nitrate compounds). Nitrate compounds, *n*-hexane, and ammonia accounted for the majority of the quantities of TRI chemicals reported by the food manufacturing industry. These are the same as the top chemicals based on quantities of chemical waste managed. From 2007 to 2017, the top 10 chemicals in terms of quantities released have remained fairly constant, and the following seven chemicals have remained at the top of the list: nitrate compounds, *n*-hexane, ammonia, hydrochloric acid, barium and barium compounds, methanol, and acetaldehyde. The quantities of releases for top chemicals, other than nitrate compounds, have remained relatively constant since 2007; nitrate compound releases decreased by 11% over this time period, though release quantities of nitrate compounds are still large enough for this class of substances to remain at the top of the list.

The three chemicals released in the largest quantities in 2017 for each subsector are shown in Table 22.4. Nitrate compounds ranks in the top three chemicals for every subsector except Bakeries and Tortilla. Ammonia ranks in the top three chemicals for every subsector except Grain/Oilseed Milling.

Table 22.4 The three chemicals released in the largest quantities by food manufacturing subsector, 2017.

Subsector	Top chemicals released
Animal food	Nitrate compounds, ammonia, zinc compounds
Grain/oilseed milling	*n*-Hexane, nitrate compounds, barium compounds
Sugar and confectionery	Ammonia, methanol, nitrate compounds
Fruit and vegetable	Nitrate compounds, ammonia, methanol
Dairy	Nitrate compounds, toluene, ammonia
Meats	Nitrate compounds, ammonia, sodium nitrite
Seafood	Ammonia, nitrate compounds, formaldehyde
Bakeries and tortilla	Ammonia, sulfuryl fluoride, sulfuric acid
Other food	Methanol, nitrate compounds, ammonia

22.3.5.2 Summary of TRI Reporting

The number of facilities within the food manufacturing industry that report to EPA's TRI Program has not changed considerably over the last 11 years. In 2017, the industry accounted for 7% of all facilities, 5% of all TRI chemical quantities managed as waste, and 3% of all release quantities reported to EPA's TRI Program. Based on releases in 2017, the sector was the seventh largest contributor to TRI release quantities reported among all sectors (as defined by three-digit NAICS code) and fourth largest among manufacturing industries, after chemical manufacturing, primary metals, and paper manufacturing.

TRI-reported chemical waste managed in the food manufacturing industry is largely driven by the Grain/Oilseed Milling, Dairy, and Meats subsectors and has increased over the past 11 years. Overall, releases from the food manufacturing industry have decreased by 10% over the same time period, but specific chemical trends are dependent on the subsector and closely tied to the processes involved in that subsector. For example, most releases came from the Meats subsector, which were largely in the form of surface water discharges of nitrate compounds (authorized under the National Pollutant Discharge Elimination System program) due to the organic content of wastewaters resulting from harvesting (i.e. processes such as euthanizing, bleeding, and rendering). Similarly, many of the parent companies whose facilities therein report the largest quantities of TRI chemical releases in aggregate are involved in either the Grain/Oilseed Milling or Meats subsectors.[3] Geographically, the largest quantities of chemicals released are reported from southern and midwestern states, and driven largely by facilities in the Meats and Grain/Oilseed Milling subsectors.

22.4 Pollution Prevention in Food Manufacturing

The prevention of pollution in food manufacturing constitutes a major factor of industrial efficiency, and tackling it answers both economic and environmental goals.

22.4.1 Sustainability Trends in Food Manufacturing

This section discusses the activities, research, and developments that are believed to have contributed to the food industry's reduction in TRI chemicals entering the environment. These

3 As will be discussed in Section 22.4, there are many opportunities for recycling organic materials produced in the harvest process, including through animal rendering. Organic materials that would otherwise be wasted can be processed into a broad range of useful products, which serves to enhance sustainability in the sector.

methods and technologies are compared to TRI-reported (implemented) source reduction activities (Section 22.4.5) to assess their effectiveness and to provide insights as to where additional source reduction activities could be implemented.

Pollution prevention is an essential component of sustainable manufacturing practices. In the US the Pollution Prevention Act of 1990 established a national policy that pollution should be prevented or reduced at source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner. This hierarchy is illustrated in Figure 22.10 While not mentioned in the Pollution Prevention Act of 1990, energy recovery is a preferred practice over treatment and disposal, and hence, is included in the hierarchy illustrated in Figure 22.10.[4]

As established by the Act, source reduction is more desirable than waste management or pollution control. Source reduction refers to practices that reduce hazardous substances from being released into the environment prior to recycling, or treatment. These practices include equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control (Pollution Prevention Act 1990).

Along with source reduction, further sustainability gains are achieved by implementing preferred waste management practices such as recycling and treatment. Pollution prevention and other waste management practices in food manufacturing discussed in this section include:

- **process and technology modifications** implemented to reduce energy consumption and the amount of raw materials used;
- **recycling** of food packaging and organic waste to reduce environmental impacts after the useful life of a material; and
- **wastewater treatment** to destroy TRI chemicals (except for TRI chemicals that are metals or metal compounds).

22.4.1.1 Corporate Sustainability Reports

Corporate sustainability reports provide an overview of sustainability goals, efforts, and accomplishments for some of the largest food manufacturing companies and may include progress

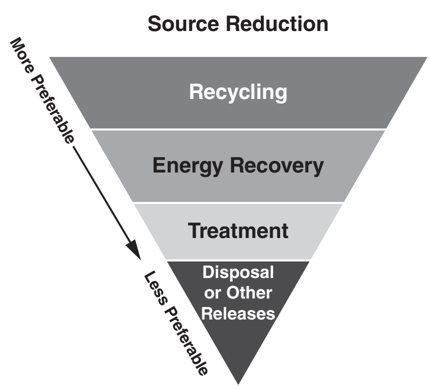


Figure 22.10 Waste management hierarchy.

4 Prior to reporting year 1991, incineration for destruction or energy recovery were not distinguished on the TRI reporting Form R. Beginning with reporting year 1991, the TRI Form R was revised to accommodate the TRI-related mandates of the Pollution Prevention Act. The revisions included a separate section for reporting incineration on-site for energy recovery (Section 8.2) and quantities sent off-site for incineration for energy recovery (Section 8.3).

in reducing CO_2 emissions, water use, energy use, and/or waste generation. Several companies highlight recent innovations in pollution prevention and other improved environmental practices, such as implementing anaerobic wastewater treatment systems that produce biogas and using it to offset their natural gas consumption (Hilmar Cheese Company 2015). Additionally, they provide specific examples of sustainability achievements such as: Cargill's 38 worldwide sites that utilize energy-saving combined heat and power (CHP) systems (Cargill 2015); ADM's sweetener facility that eliminated landfill waste by directing wastewater to local beekeepers and other waste to an energy recovery plant (ADM 2014); and Tyson Food's reduction of almost 1 million pounds of packaging through design modifications (Tyson Foods, Inc. 2015).

22.4.1.2 Eco-Efficiency

In a recent study of sustainability across many manufacturing sectors (Egilmez et al. 2013), sectors were ranked by an *eco-efficiency score*, a measure of environmental performance against economic output. The score accounts for GHG emissions, energy use, hazardous waste, TRI releases, and water use as input categories in comparison to total economic output. The higher the score, the more eco-efficient a sector is said to be. Food manufacturing (NAICS 311) ranked among the highest in *eco-efficiency score* at 100%[5] indicating that the industry is efficiently producing economic output based on the environmental performance indicators included in the model. However, the authors of the study note that this is largely due to the significant economic output of the industry despite its large environmental footprint.

In contrast, when on-site food manufacturing is considered along with its off-site supply chain (including extraction and processing of raw materials), the industry's upstream supply chain is responsible for 81.7% of TRI releases and 97.3% of hazardous waste generation associated with food manufacturing and its inputs. In other words, the production of materials used by the industry to manufacture foods generates significantly more pollution than food manufacturing alone and has a larger environmental impact. Some of the highest-contributing supply chain sectors include: other basic organic chemical manufacturing, petroleum refineries, and plastics material and resin manufacturing (Egilmez et al. 2013).

The following section describes the food manufacturing industry's progress towards reducing TRI chemical waste managed including releases.

22.4.2 Process and Technology Modifications

22.4.2.1 Energy Efficiency

Historically, the food manufacturing industry has been slow to research or adopt new energy-saving technologies. This is due to low profit margins, the need to comply with federal safety and sanitation standards, and competition within the industry that hinders collaboration. As a result, the industry relies on innovations from within the chemical and biotechnology sectors, which are adopted later without the high cost of research and development (Lung et al. 2006). Examples of processes first developed in the chemical and biotechnology sectors and later adopted for use in food manufacturing include oil seed extraction and wet corn milling.

Due to barriers to innovation, government programs may incentivize improvements. For example, the Energy Star Program recognizes facilities with the best energy performance in the food manufacturing industry through an energy performance indicator (Boyd 2011). Energy Star certification is awarded to plants ranking in the top 25% for energy efficiency nationwide. Many

5 Eco-efficiency scores are a comparison of environmental impacts and economic output relative to other manufacturing sectors. A score of 100% does not mean that the industry cannot improve upon its eco-efficiency.

large food manufacturing companies, such as General Mills and Cargill, are Energy Star partners (ENERGY STAR n.d.). Energy Star also produced reports containing recommendations for energy-efficiency measures for the Fruits and Vegetables and Bakeries and Tortilla subsectors, providing detailed technical direction, associated cost-savings, and payback times. Some specific recommendations include:

- for the Fruits and Vegetables subsector – adopting technologies in efficient steam production, CHP generation, piping insulation, and reuse of produce washing water;
- for the Bakeries and Tortilla subsector – placing ovens in well-ventilated areas away from processes that require cooler environments, using radio frequency ovens, and reducing the need to open freezer doors (Masanet et al. 2008).

Improving energy efficiency reduces the quantity of fuels burned to produce energy and therefore reduces the quantities of TRI chemicals formed as by-products of combustion or that are contained in the fuel and released to the environment during combustion. If energy is generated during combustion of fossil fuels on-site at a facility, and practices that improve energy efficiencies are implemented by the facility, the corresponding reductions in the releases of TRI chemicals during energy production will likely be reflected in the facility's TRI reporting.

In order to help facilities realize the many possible energy efficiency improvement options, the US Department of Energy's Advanced Manufacturing Office sponsors the development of emerging green technologies to help industry invest in broadly-applicable manufacturing processes that reduce energy consumption and improve efficiency (US DOE 2016). For many facilities in the food manufacturing industry, their processes involve food preservation, which historically requires thermal treatments such as cooking, pasteurization, and drying. These processes account for approximately half of the sector's energy use. To incentivize energy reduction in the sector, the Advanced Manufacturing Office sponsored the development of green technologies, including energy-efficient blanching, pulsed electric field pasteurization, radio frequency drying, and evaporator fan controls for refrigerated storage, all of which provide additional benefits such as reduced wastewater and improved product quality. For some of these technologies, high up-front capital cost may be a barrier to implementation (Lung et al. 2006).

22.4.2.2 Chemical Substitutes

Switching to safer chemicals (i.e. chemicals not included on the TRI list of toxic chemicals) where feasible allows facilities to decrease the generation of wastes that contain TRI chemicals. For example, oilseed processing plants commonly use *n*-hexane (a TRI chemical) for oil extraction, and efforts are underway to find a less toxic (i.e. non-TRI chemical) alternative. Recent laboratory research has identified alternative green extraction methods, such as supercritical CO_2 (a technique used for many years to decaffeinate coffee beans and extract soluble hops), but these methods are expensive to implement on a larger scale, and have not yet replaced *n*-hexane extraction in the industry (Jokic et al. 2012). But, as discussed in Section 22.4.5.3 of this chapter, facilities also face many barriers to source reduction, particularly a lack of adequate substitutes or concerns about product quality.

Food packaging is another research focus area looking into chemical substitutes. Increasingly, biodegradable and compostable materials are being developed for food packaging. For example, polylactic acid, a biodegradable polymer derived from lactic acid, is used in wraps for bakery and confectionery products (Shin and Selke 2014). Several EPA Green Chemistry award nominations have focused on the opportunities to replace conventional food packaging materials with more sustainable options, such as compostable food packaging or eliminating bisphenol A (a TRI-listed chemical) from the interior coatings of aluminium cans (US EPA 2016a).

Chemical substitutes in the food manufacturing industry may also be driven by external forces. For example, one of the largest importers of US poultry is Russia. However, in 2010, the country announced that it was lowering the acceptable level of chlorine residuals on imported poultry. Chlorine was the primary disinfectant used on US poultry products at the time, and the announcement effectively banned US imports of poultry to Russia. In response, the two countries brokered an agreement to allow for the use of alternative disinfectants, such as peroxyacetic acid, that are considered to be acceptable and less toxic than chlorine (Bottemiller 2010). Since 2007, peroxyacetic acid waste managed by the poultry processing subsector (NAICS 311615) has continually increased, while chlorine waste managed has decreased.

22.4.3 Recycling

While strictly speaking it is not considered pollution prevention and thus not the focus of this chapter, recycling continues to play a crucial role in achieving sustainability in the food manufacturing industry both during the manufacturing process and for using food waste. The following text is not meant to be comprehensive but instead provides examples of recycling practices in food manufacturing.

22.4.3.1 Packaging

Almost all food manufacturing facilities are involved in some form of food packaging, either for transportation to another facility or distribution to consumers. Common materials used in food packaging are paper, paperboard, glass, aluminium, and plastic. In the food manufacturing industry, paper is the most recycled material, and plastics are the least recycled (Shin and Selke 2014). Because of risk of contamination, facilities often cannot use recycled paper or plastic for their packaging. The US Food and Drug Administration (FDA) evaluates all recycled plastic on a case-by-case basis and requires food packaging manufacturers to submit a description of the recycled plastic they wish to use, as well as the results of testing to ensure that they removed all contaminants (US FDA 2015).

22.4.3.2 Food Waste

Excess unsaleable food may be donated to those in need and is considered the best alternative after source reduction measures, as explained in EPA's food waste hierarchy shown in Figure 22.11 (US EPA 2019a). As shown in a survey conducted by the Food Waste Reduction Alliance, medium-sized manufacturers are donating food at higher rates than large and small manufacturers, and food donation is being considered as an investment area by over half of the survey respondents (Food Waste Reduction Alliance 2016). Nonetheless, large amounts of organic waste are generated in the food manufacturing industry, and many of these materials may be recycled. According to the survey responses, two types of recycling – land application (60%) and animal feed (34%) – dominated the downstream uses of food waste based on pounds diverted away from landfills (Food Waste Reduction Alliance 2016). The survey results also noted that the most commonly cited barrier to donating or recycling food wastes were transportation constraints.

Specific examples of food waste reutilization and the creation of value-added products is observable in various subsectors. In the Seafood subsector, skin, bone, and fin can be reused as fish meal and fertilizer. Research is also focused on reusing shellfish waste for production of chitin, which is used in several industries, especially textile, cosmetic, and pharmaceutical manufacturing. Fruit and vegetable waste is a source of pectin, which is used in processing jams, jellies, pastries, and confectioneries, and increasingly in pharmaceuticals and cosmetics as well. Other examples are using beet waste as a source of red food colouring and using collagen byproducts from the Meats subsector in leather production (Kosseva 2009).

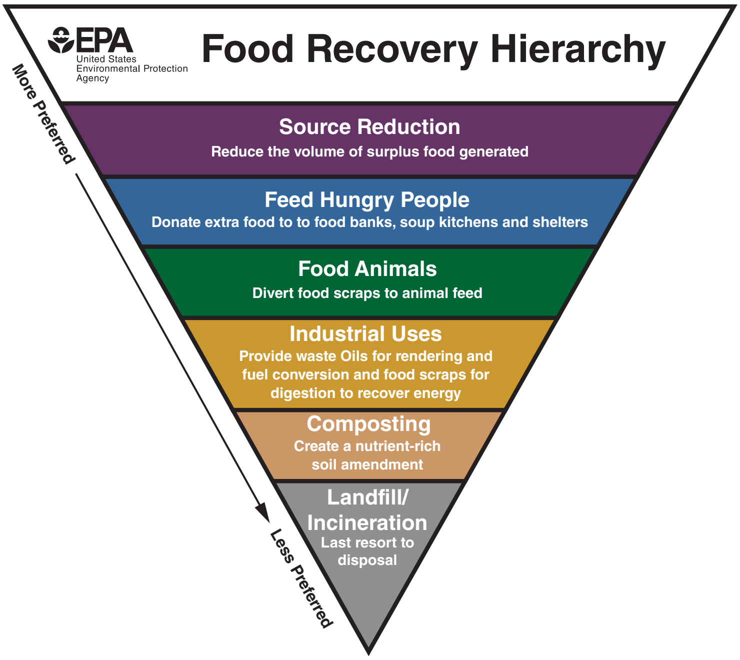


Figure 22.11 Food recovery hierarchy.

Moreover, according to a report from the National Renderers Association, every year the rendering industry recycles approximately 59 billion pounds of perishable material generated by the livestock and poultry meat/poultry processing, food processing, supermarket and restaurant industries. These materials are then rendered into ingredients for soaps, paints, cosmetics, explosives, toothpaste, pharmaceuticals, leather, textiles, and lubricants (National Renderers Association, Inc. n.d.).

22.4.3.3 Energy Recovery

While energy recovery from combustion of TRI chemical wastes is not typical among large food manufacturers (less than 0.2% of TRI chemical waste was used for energy recovery each year from 2007 to 2017, as shown in Figure 22.7), there is potential for energy recovery from food wastes at these facilities, as evidenced by the municipal solid waste stream where approximately 19% of food waste is combusted for energy recovery (US EPA 2018b). There are also case studies which focus on adopting large-scale energy recovery systems to use municipal food waste as a source for renewable energy generation such as a pilot facility at the East Bay Municipal Utility District, which converts food waste into electric power (East Bay Municipal Utility District n.d.). These energy recovery technologies could represent an alternative for companies seeking to increase value from the food waste and divert it from entering the waste stream to less preferred food recovery practices such as composting, incineration, and landfill disposal.

22.4.4 Wastewater Treatment

Food manufacturing uses a significant amount of water in processing operations (e.g. heating) and for cleaning and sanitation where water use is essential in protecting people from foodborne illnesses. Consequently, the sector generates considerable wastewater. Researchers have investigated if a portion of this wastewater can be reused. However, high levels of organic compounds and bacterial contaminants lead to low rates of wastewater recycling (Visvanathan and Asano 2009). Pressure-driven membrane separation techniques, such as ultrafiltration and reverse osmosis, use permeable membranes to separate and remove dissolved solids and microbes. These processes are already used for reusing wastewater across the food manufacturing industry, including in the fish, poultry, and soybean subsectors (Vourch et al. 2008). Membrane bioreactor technology combines biological treatment with membrane filtration and potentially allows significant reuse of wastewater in food manufacturing plants. However, membrane bioreactor systems are expensive and require a lot of energy to operate (Cicek 2003). Finally, as seen in the corporate sustainability reports, many facilities are using their organic waste to offset their fuel use by producing natural biogas during treatment of wastewater. This process takes advantage of anaerobic bacterial activity that converts organic waste to methane gas and carbon dioxide (CO_2) (Hall and Howe 2012).

Any wastewater that is discharged from facilities must be treated in some manner before release. Some facilities are transitioning away from the use of traditional disinfectants such as chlorine and using alternative technologies for treating wastewater, such as installing ultraviolet (UV) treatment systems. In addition to reducing the chlorine releases reported to TRI by switching to UV treatment, facilities may also reduce the amount of total chlorine residuals reported to EPA's NPDES Program (see Section 22.3.2).

Some food manufacturing facilities are also able to adapt their wastewater treatment plants to collect and handle residual food wastes. For example, a sweet potato processing plant uses anaerobic digestion to generate biogas from its wastewater treatment operations, and was designed to treat both the wastewater stream as well as leftover sweet potato peels (Food Waste Reduction Alliance 2014). The facility is able to offset about 20% of its annual energy demands and divert approximately 10 000 tons of food waste from landfills per year.

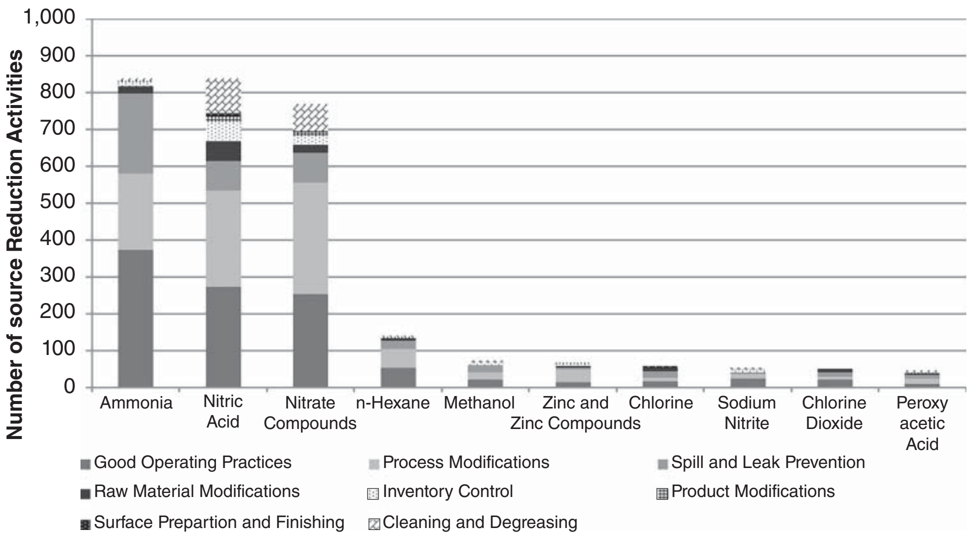
22.4.5 Pollution Prevention Activities Reported to TRI

As discussed earlier, quantities of TRI chemicals released by the food manufacturing industry as reported to EPA's TRI Program have decreased between 2007 and 2017, while the amount of waste managed has increased (though there is some variation within subsectors). This section identifies chemicals targeted for pollution prevention and the types of activities implemented to reduce TRI chemical waste quantities. Additionally, it describes the food manufacturing industry's overall progress towards reducing TRI chemical waste managed quantities, including their release.

Facilities that are subject to the TRI reporting requirements, such as those within the food manufacturing industry, are required to report any source reduction activities (e.g. process modifications, substitution of raw materials) that were newly implemented at the facility during the year for which they are reporting. Specific data fields exist in the TRI Reporting Form R for these required data elements. For example, in Section 8.10 of Form R, facilities select source reduction activities[6] from a list of coded processes or improvements (US EPA 2019b). In addition, facilities may voluntarily include specific details on their source reduction activities or other environmental management practices, in the form of text, in Section 8.11 of the TRI Form. Including this additional text provides facilities with a unique opportunity to showcase their achievements in preventing pollution to the public and other users of TRI data and information.

For the 2017 reporting year, 101 facilities in the food manufacturing industry reported 167 source reduction activity codes for 23 chemicals and chemical categories. This represents about 6% of the

6 The terms 'source reduction' and 'pollution prevention' are used interchangeably in this chapter. However, in this section, the term 'source reduction' is used in lieu of pollution prevention to be consistent with TRI reporting terminology.



Note: Metals are grouped with their metal compounds.
Source: U.S. EPA Toxics Release Inventory – 2017 National Analysis Dataset

Figure 22.12 Chemicals manufactured, processed or otherwise used in food manufacturing with the greatest number of source reduction activities reported from 2007 to 2017. Note: Metals are grouped with their metal compounds. Source: US EPA Toxics Release Inventory – 2017 National Analysis Dataset.

1585 food manufacturing facilities that reported to EPA's TRI Program for 2017, which is slightly lower than the rate of 7% across all facilities that reported for 2017. 'Good operating practices' was one of the most commonly reported source reduction categories, most often through improved maintenance, record-keeping, or procedures. 'Process modifications' were also frequently reported, most often comprised of optimized reaction conditions or modified equipment, layout, or piping. Figure 22.12 shows that most of the activities were implemented for ammonia, nitric acid, and nitrate compounds, which are also the most commonly reported chemicals.

22.4.5.1 Examples of Source Reduction Activities Reported to EPA's TRI Program

Facilities that report to EPA's TRI Program have the option of describing their source reduction activities in explanatory text. In addition to optional explanatory text, facilities also report specific source reduction activity codes to further characterize the type of source reduction activity implemented within each of the eight categories. Six of these source reduction activity codes are associated with green chemistry practices. Among food manufacturing facilities, the most common green chemistry practice reported is 'W50: Optimized reaction conditions or otherwise increased efficiency of synthesis' and is most commonly reported for nitrate compounds by facilities in the Meats and Sugar and Confectionery subsectors. Other green chemistry practices reported include 'W15: Introduced in-line product quality monitoring or other process analysis system' and 'W43: Substituted a feedstock or reagent chemical with a different chemical'.

22.4.5.2 TRI Pollution Prevention Analysis – Effectiveness of Source Reduction Activities

A study published in 2015 estimated how source reduction activities affect quantities of TRI chemical releases reported by facilities that are subject to the TRI reporting requirements (Ranson et al. 2015). The study used a common economics research technique known as a 'differences-in-differences' analysis. This method estimates how releases of a TRI chemical from a facility change in the years before and after implementing a source reduction project by comparing trends in releases of TRI chemicals targeted by source reduction against trends in releases of TRI chemicals not targeted for source reduction. This comparison helps to control for other factors that affect releases, such as changes in production, economic conditions, and environmental regulations.

Applying this technique to the food manufacturing industry showed that the *average* source reduction project in the industry resulted in a 10% decrease in facility-level TRI releases of the targeted chemical. 'Raw material modifications' and 'product modifications' were found to be the most effective types of source reduction with average decreases in releases of 30% and 23%, respectively. Between 1991 and 2014, source reduction may have reduced cumulative food manufacturing releases reported to EPA's TRI Program by 227–336 million pounds, as calculated by the difference between actual releases and simulated releases with no source reduction.

22.4.5.3 Barriers to Source Reduction

As part of their TRI reporting, facilities have the option of providing explanatory text on barriers that they face in implementing source reduction activities. This information can be used to identify challenges that the food manufacturing industry faces in implementing source reduction.

From 2014 through 2017, 8% of forms (1200 forms) submitted by facilities in the food manufacturing industry included specific barrier text entries. Of these entries, the most commonly reported barrier category was facilities' concerns that source reduction activities would affect product quality. The second most commonly reported barrier category was a lack of substitutes for a specific chemical, and the third most commonly reported barrier category included general concerns such as customer demand. Barriers were primarily reported for nitric acid, nitrate compounds, and ammonia, which are also the chemicals reported most frequently.

The barrier categories reported suggest that some chemicals reported by the food manufacturing industry are integral to the operations and processes, such as the use of nitric acid in cleaning-in-place operations in the Dairy subsector. However, there may still be opportunities for introducing efficiencies in these situations, such as optimizing chemical blends or recovering and reusing cleaning solutions (Solid and Hazardous Waste Education Center 2016). Barriers reported reveal some challenges to source reduction, such as the necessity for sanitation in dairy product manufacturing facilities; however, for some chemicals there is no evidence that source reduction was attempted.

22.4.5.4 Summary of Pollution Prevention Activities Reported to TRI

In the food manufacturing industry, many of the reported source reduction activities are in either the 'good operating practices' or 'process modifications' categories and are most frequently reported for ammonia, nitrate compounds, and nitric acid. For other chemicals with few reported source reduction activities, further research is needed to identify if potential pollution prevention opportunities are available. An analysis of the source reduction activities reported by food manufacturing facilities and releases reported by those facilities suggests that some types of categories, particularly raw material modifications and product modifications, are associated with decreases in reported release quantities of TRI chemicals. The source reduction activity information reported to TRI may be able to provide insight or ideas for facilities that have not yet implemented source reduction activities for particular chemicals or that have additional potential pollution prevention opportunities.

22.5 Perspectives

From 2007 through 2017, overall quantities of TRI chemical wastes managed by the food manufacturing industry as reported to EPA's TRI Program have increased while releases of TRI chemicals have decreased. Trends in chemical releases and waste management are specific to processes within the subsectors included in food manufacturing and can greatly vary by subsector. For example, *n*-hexane is largely associated with soybean processing whereas ammonia and nitrate compounds are often reported by meat and dairy product processing facilities due to the organic content of wastewater.

The TRI chemical waste managed within the industry is not only dominated by a few particular processes, including wet corn milling and meat processing, but also by a few large parent companies due to the economies of scale inherent in the industry and the resulting trend towards mergers. Chemical wastes are also concentrated geographically, with most releases reported to the TRI Program occurring in regions associated with inputs to the food manufacturing industry, primarily southern and midwestern states.

Many companies within the food manufacturing industry include sustainability efforts as part of their corporate reports and highlight progress in reducing GHG emissions, improving energy efficiency, and reducing wastes. A review of the literature identified very little information on research or activities describing chemical substitutes to TRI chemicals in the sector, though there have been successful case studies such as the replacement of chlorine (a TRI chemical) in poultry disinfection systems with the less toxic peroxyacetic acid (also a TRI chemical). Notably, 'no substitutes' is also one of the most common barriers reported to EPA's TRI Program by food manufacturers, indicating that for some chemicals or processes, research into identifying safer chemical substitutes is needed. In other cases, there may not yet be a viable, safer substitute, such as for the use of *n*-hexane in soybean oil extraction, and pollution prevention strategies could focus on identifying alternative substitutes or technologies that obviate the need for TRI chemicals.

The chemicals that facilities most frequently report in the context of source reduction activities are the same chemicals which are also most frequently included in the reported barriers to pollution prevention. These chemicals include nitrate compounds, nitric acid, ammonia, and *n*-hexane. This reporting of both implemented source reduction activities and barriers indicates that there may be opportunities to increase the sector's source reduction activities through information dissemination among facilities in the sector. An analysis of source reduction activities reported to the TRI Program indicates that source reduction can reduce releases by 10% across the food manufacturing industry. Methods for pursuing source reduction that have proven to be effective in the food manufacturing industry include raw material modifications, and process modification. Due to the nature of specific uses of chemicals and associated releases in the food manufacturing industry, pollution prevention activities often need to be both sector- and process-specific.

Companies are seeking synergistic opportunities for reducing food loss and waste including diversion efforts to keep food from being disposed of in a landfill. Such efforts include creation of other value-added products from food wastes, land application, animal feed generation, conversion of food to fuel, and food as an energy recovery source. While energy recovery from combustion of TRI chemical wastes is not as common among food manufacturers (less than 0.2% of TRI chemical waste was used for energy recovery each year from 2007 to 2017), there is a potential for energy recovery from food waste at these facilities, as evidenced by the municipal solid waste stream where approximately 19% of food waste is combusted for energy recovery. Energy recovery technologies documented in case studies could represent an alternative for companies seeking to divert food waste from entering the waste stream who have identified insufficient recycling or industrial use options for optimizing food waste as a resource.

22.5.1 Next Steps

Future efforts to promote pollution prevention activities in this industry sector would have the most impact on subsectors with the larger amounts of waste generation and releases, such as Grain/Oilseed Milling, and Meats. Meat and poultry processing, as well as soybean processing and wet corn milling, are some examples of specific processes where large amounts of TRI chemicals are used and released. These processes may potentially benefit from an increased focus on promoting source reduction activities, depending on the specific chemical and process involved.

A more targeted focus on chemicals involved in upstream or downstream activities (e.g. transportation, distribution, agriculture, and livestock) in the food manufacturing supply chain may also have a larger impact on the overall environmental impact of the industry and warrants additional research. Other efforts related to sustainability include the continued pursuit of more energy efficient operations and elimination of ozone-depleting substances. Resources related to these impact categories, such as energy efficient recommendations for specific subsectors provided by Energy Star, are already available for food manufacturing facilities examining opportunities for pollution prevention.

Disclaimer

The views, statements, opinions, and conclusions expressed in this chapter are entirely those of the authors, and do not necessarily reflect those of the United States Environmental Protection Agency, Abt Associates Incorporated, or the Eastern Research Group, nor does mention of any chemical substance, commercial product, or company constitute an endorsement by these organizations.

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