

Food Scrap Recycling:

A Primer for Understanding Large-Scale Food Scrap Recycling Technologies for Urban Areas



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Cover Photos

Photos courtesy of The Peninsula Compost Group
Wilmington Organic Recycling Center
Screening and Pre-Processing Area within the Receiving Building

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In 2010 and 2011, representatives from the City of Bridgeport, Connecticut and Providence, Rhode Island engaged in several in-person meetings and conference calls with EPA to help identify the needs and factors for each community to consider when implementing food scrap recycling. We received considerable support developing and reviewing this document from the following organizations; the Environment Council of Rhode Island, Southside Community Land Trust, Bridgeport Regional Business Council, BGreen 2020 Sustainability Plan, City of Bridgeport, Greater Bridgeport Community Enterprises, Connecticut Department of Energy and Environmental Protection, Rhode Island Department of Environmental Management, Rhode Island Resource Recovery Corporation, University of Connecticut and, BioCycle Magazine.

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Executive Summary

Benefits such as reduced waste disposal and creation of nutrient-rich compost for landscaping and gardening have led to an increased interest in implementing large-scale food scrap recycling processes. However, identifying the ideal recycling method for a community can be a challenging process due to the complex nature of the decision factors involved and the capabilities of the available composting technologies. Each community is unique and as such, each must go through a thorough decision making process to select the most appropriate technology and location for recycling compostable items.

This guide provides an overview of three technologies which could be used to recycle food residuals (or scraps)— aerobic windrow composting, in-vessel aerobic composting and anaerobic digestion—and highlights key considerations for municipalities interested in implementing large scale food scrap recycling in their communities. It is intended to provide municipal officials, non-profits and community stakeholders the tools and information necessary to begin the decision making process for selecting the food scrap recycling technology that best meets the needs of their municipality. See Figure 1 for a list of the key considerations discussed in this guide.

One of the key considerations discussed in this guide is the importance of balancing cost against the complexity of the

technology. In general, there is a progression of increased costs and operating complexity for food scrap recycling technologies. As cost and complexity increase, so do the capabilities of the technologies.

In developing this guide, the capabilities, benefits and costs of the different food scrap recycling technologies were reviewed to gain a better understanding of the challenges and opportunities associated with each food scrap recycling technology. The chart below highlights a comparison summary developed as part of the guide. The information presented in the table assumes a facility processing 40,000 tons per year of organic materials.

Key Evaluation Factors	
✓	Land Area
✓	Quality of Life (odor, noise, visual, traffic)
✓	Environmental Concerns (land contamination, air/water quality)
✓	Regulatory Requirements
✓	Public Acceptability
✓	Public Health
✓	Operational Issues (waste composition, transport and traffic, utility and energy needs, energy generation, residual processing, water needs, wastewater treatment, flood control)
✓	Economics (tipping fees use of product, collection and transportation of food scraps, construction and operation of processing facility)

Figure 1 - Sampling of Key Considerations for Selecting the Appropriate Food Scrap Recycling Technology

Table 1: Comparison of Organic Food Scrap Recycling Technologies

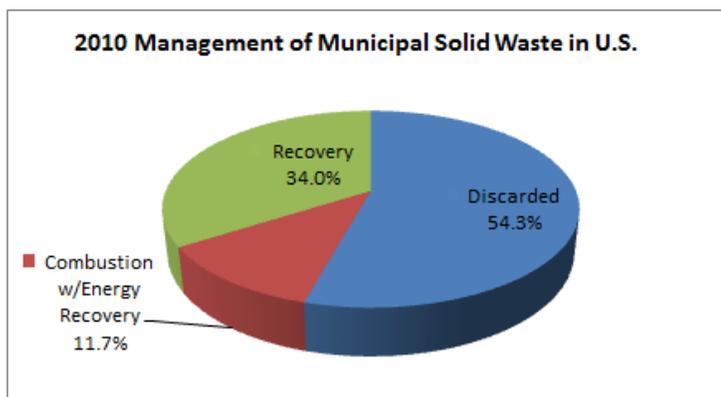
Issue	Aerobic Processes			Anaerobic Digestion
	Turned Windrows	Static Aerated Windrows	In-vessel	
Land Area Requirements	8 to 13 acres	6 to 10 acres	3 to 6 acres. Does not include land for composting.	3 to 6 acres. Does not include land for composting.
Waste Streams	Yard trimmings and food scraps plus bulking agent such as paper, sawdust, wood chips. Food scrap volume will be limited by the mixture of waste streams to achieve control parameters. A 2-to-1 ratio of bulking agents to food scraps is reported in the literature		Yard trimmings and food scraps plus bulking agent such as paper, sawdust, wood chips. Can typically process higher ratios of food scraps than windrows	Can process high moisture contents
Technology	Low complexity with greatest operation experience	Moderate complexity with good operating experience	Greater complexity with good operating experience	Greatest complexity requiring a qualified operator to manage the digestion process
Costs	Lower capital costs, higher labor costs) \$15/ton to \$40/ton	\$25/ton to \$60/ton	(Higher capital cost, lower labor cost) \$80/ton to \$110/ton	(Higher capital cost, lower labor cost) \$110/ton to \$150/ton

While this document does not cover issues related to the collection of food scraps and the use of compost products, it provides municipalities a good basis for beginning the discussion with their communities and helping all involved to become informed as to the options for better managing this organic resource.

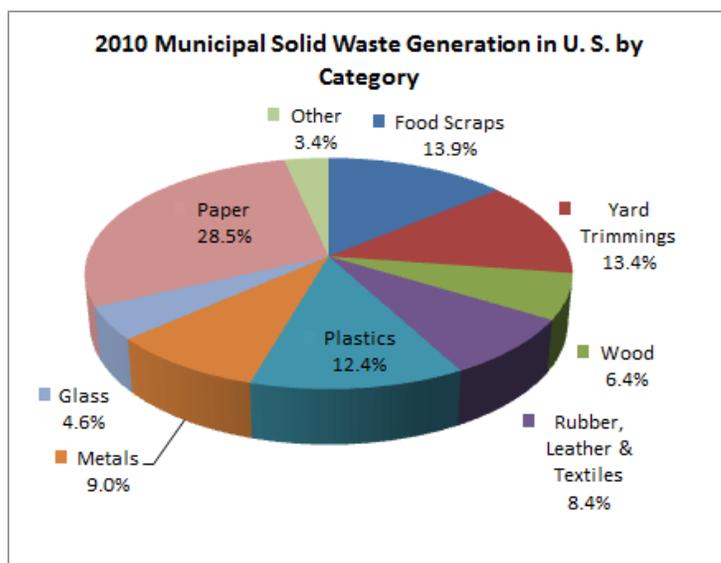
This guide was developed as part of a project supported by the U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) Innovation Program to provide technical assistance to the Cities of Providence, Rhode Island and Bridgeport, Connecticut in the evaluation of options for diversion of food scraps through composting and siting of composting facilities.

Background

In 2010, 250 million tons of municipal solid waste (i.e., garbage or refuse generated by households, commercial establishments or institutional facilities) was generated in the United States. Of this, 11.7 percent was incinerated (often with energy recovery), 54.3 percent was discarded and 34.0 percent was recovered¹ through recycling.² Organic materials, which include food scraps, yard trimmings, wood waste and paper and paperboard products, are the largest component of municipal solid waste and comprise almost two-thirds of the nation's waste stream. Paper and paperboard account for 28.5 percent of the waste stream at 71.3 million tons per year, with 62.5 percent recovered in 2010.



Yard trimmings account for 13.4 percent of the waste stream at 33.4 million tons per year, with 57.5 percent recovered in 2010, which is a dramatic increase from the 12 percent recovery rate in 1990. Accompanying the surge in yard trimming recovery is a composting industry that has grown from less than 1,000 facilities in 1988 to over 2280 in 2010.³ Once dominated by public-sector operations, the composting industry has become increasingly entrepreneurial and private-sector-driven, led by firms that add value to compost products



through processing and marketing. Bulk retail compost produced from yard waste sells for between \$15.00 and \$32.00 per cubic yard in the United States.⁴

¹ Recovery rates vary by type of wastes.

² U.S. EPA. "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2009." EPA-530-F-010-012. December 2010. <http://www.epa.gov/wastes/nonhaz/municipal/pubs/msw2009-fs.pdf>.

³ Van Haaren, Rob; Themelis, Nickolas; Goldstein, Nora. "The State of Garbage in America." *BioCycle*. October 2010. <http://www.jgpress.com/archives/free/002191.html>.

⁴ *Compost News*. August 2011. <http://www.compostingnews.com>.

Food scraps account for 13.9 percent of the waste stream at 34.8 million tons per year, with less than 2.8 percent recovered in 2010. Food scraps are the largest discarded material category in the U.S. municipal waste stream.⁵

For example, in Rhode Island, land disposal is the most common method used for managing solid waste. Almost all of the state's municipal solid waste is disposed of in the Central Landfill in the Town of Johnston, which is operated by the Rhode Island Resource Recovery Corporation (RIRRC). The only exception to this is the Town of Tiverton, which operates its own landfill. Municipal solid waste diversion rates (e.g., waste prevention, recycling, reuse, composting) vary greatly by community, with an overall statewide diversion rate of 21.5 percent. The recycling rate for commercial waste brought to the Central Landfill is less than 3 percent⁶ though this does not reflect commercial waste disposed out of state. The combined landfill disposal is roughly one million tons per year of municipal and commercial solid waste including material used for alternative daily cover along with wood and compost material used for erosion control.⁷

Yard and leaf waste in Rhode Island is a mandated recyclable and there are a number of composting facilities in operation that accept this green waste. According to the Rhode Island Department of Environmental Management, 13 facilities reported a combined 120,513 tons of yard and leaf waste received and 73,246 tons removed in 2004, and 105,082 tons of yard and leaf waste received and 94,193 tons removed in 2006. In 2009, Rhode Island municipalities generated 32,617 tons of leaf and yard waste and of that, delivered 29,548 tons to RIRRC for composting at their own municipal site or at another facility. With the increased interest in composting green waste, RIRRC's capacity to process and store leaf and yard waste is becoming constrained.

In Connecticut, one landfill and six resource recovery or waste-to-energy facilities accept municipal solid waste. The vast majority of municipal solid waste, about 2.2 million tons, is managed in the state's six resource recovery facilities, which generate electricity as a by-product.⁸⁹ In 2009, an estimated 3.2 million tons of municipal solid waste were generated in Connecticut, with 69 percent of the total (2.2 million tons) disposed in the state.¹⁰ Using reported data, the FY2009 average statewide municipal solid waste recycling and composting rate was estimated to be about 24.4 percent (776,380 tons) and an estimated additional 5 percent was recycled but not reported. The rate has remained relatively constant

⁵ U.S. EPA. "Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2009." EPA-530-F-010-012. December 2010. <http://www.epa.gov/wastes/nonhaz/municipal/pubs/msw2009-fs.pdf>.

⁶ Rhode Island Comprehensive Solid Waste Management Plan adopted for the period of April 12, 2007 through April 12, 2012 by the Rhode Island Resource Recovery Corporation.

⁷ According to the Rhode Island Department of Environmental Management, during the year 2006, two landfills operated in Rhode Island, Central Landfill and Tiverton Landfill. The total calculated tons of material landfilled in 2006 was 1,597,559 tons. This figure includes 361,169 tons of alternative daily cover and 51,662 tons of compost and wood products used for erosion control (Rhode Island Department of Environmental Management Office of Waste Management. 2006. Annual Solid Waste Report Summary. www.dem.ri.gov/programs/benviron/waste/topicsol.htm). In 2009, the two landfills in the state received 928,568 tons of material, including alternative daily cover and wood and compost material used for erosion control.

⁸ State of Connecticut Department of Energy & Environmental Protection. "Solid Waste Management Plan Amended 2006." http://www.ct.gov/dep/cwp/view.asp?a=2718&q=325482&depNav_GID=1646%20.

⁹ State of Connecticut Department of Energy & Environmental Protection. "Solid Waste Management Plan Amended 2006." http://www.ct.gov/dep/cwp/view.asp?a=2718&q=325482&depNav_GID=1646%20.

¹⁰ *ibid.*

since 1997. To address rapidly decreasing disposal capacity, the state amended its Solid Waste Management Plan to include a municipal solid waste diversion from disposal (landfill and incineration) target rate of 58 percent by 2024. This goal is consistent with the 2005 Connecticut Climate Change Action Plan recommendation that called for an increase in recycling and source reduction of municipal solid waste to achieve significant greenhouse gas reductions and a state statutory waste generation reduction goal of 40 percent.

In 2010, the Connecticut Department of Energy and Environmental Protection (DEEP) released a Waste Characterization Study¹¹ that analyzed 2009 state municipal solid waste disposal data from four resource recovery facilities and a large municipal transfer station. The municipal solid waste disposal stream was estimated to be comprised of 56 percent residential and 44 percent commercial/industrial waste.

The State of Connecticut requires towns to provide leaf recycling and that leaves are kept separate from other recyclables and garbage. The state has successfully focused efforts on establishing large-scale leaf composting facilities. There are over 100 leaf composting facilities in Connecticut, including 87 municipal, 15 private (non-farm), and five private (on-farm) facilities and 46 brush/clean wood processing facilities. About 268,300 tons of yard trimmings were composted in 2009, plus small quantities of food scraps. In addition, approximately 38,000 tons of organic waste were home composted and/or grass recycled (i.e., leaving clippings on the lawn when mowing) in 2009. The City of Bridgeport reported more than 3,500 tons in 2009 and more than 5,400 tons in 2010 of combined leaf, brush and yard waste recycled.¹²

Food Scraps

The United States generates more than 34 million tons of food scraps each year, accounting for 14 percent of the total municipal solid waste stream. Less than 3 percent of the 34 million tons of food scraps generated in 2010 in the United States was recovered and diverted for some beneficial purpose such as reuse as animal feed, recycling or composting. The remaining food scraps—approximately 33 million tons—were disposed of in landfills or incinerators.

Specifically in Rhode Island, the RIRRC classified 23.2 percent of the entire municipal waste stream as other organics, predominantly food scraps in a 1990 waste characterization study. Assuming food scraps account for 14 percent of the total municipal solid waste stream, consistent with the national average, and 514,811 tons of municipal solid waste

Food scraps account for 14% of the total municipal solid waste stream and now comprise THE LARGEST discarded material category in the United States

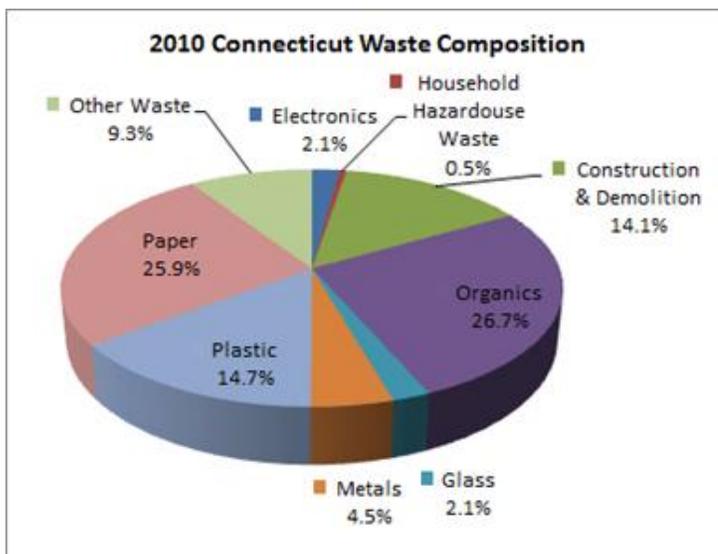
¹¹ State of Connecticut Department of Energy & Environmental Protection. "Connecticut State-wide Solid Waste Composition and Characterization Study, Final Report." May 26, 2010. http://www.ct.gov/dep/lib/dep/waste_management_and_disposal/solid_waste/wastecharstudy/ctcompositioncharstudymay2010.pdf.

¹² As reported by the City of Bridgeport to the CT DEP. For FY2009: Leaves - 1,452.65 tons (5,801.6 cy), Brush - 388.00 tons (2,586 cy), Mixed Yard Waste - 1,706.21 tons (9,749.77 cy). For FY 2010: Leaves - 1,585.9 tons (6,343.6 cy), Brush - 2,194.0 tons (1,462 cy), Mixed Yard Waste - 1,666.4 tons (9,522.28 cy). The conversion factors used for data entry purposes are: Leaves 1 cy = .25 tons; Brush 1 cy = .15 tons; Mixed Yard Waste 1 cy = 350 lbs (175 tons). These estimates do not include additional leaves that may have been composted in-place, or raked into the woods.

were generated in 2009 in Rhode Island, more than 70,000 tons of food scraps are likely placed in landfills in the state annually. In addition, the RIRRC estimates that 80 tons per day are generated by the food industry sector and an additional 74 tons per day are generated by other commercial sectors for a total estimated food scrap commercial tonnage of 56,210 tons a year.¹³ Combining the municipal and commercial sectors, in excess of 120,000 tons per year of municipal and commercial food scraps are disposed in landfills in Rhode Island.

In 2001, Connecticut DEEP initiated a mapping project to identify the opportunities to capture institutional and commercial food scraps.¹⁴ The project identified, quantified and mapped all of the large-scale commercial and institutional locations in Connecticut where potentially recyclable food scraps are generated and matched those sources against the state's transportation network and current composting infrastructure. The research identified over 1,300 food scrap generators in Connecticut comprised of food processors (e.g., bakeries, meat packers, dairies, ice cream manufacturers, pasta factories, and potato chip plants); supermarkets; casinos; military installations; produce terminals; and cafeterias in colleges, hospitals and prisons. The research also identified the following annual food scrap generation in Bridgeport: 10 institutions yielded an estimated 705.2 tons, 10 large groceries yielded 1,557 tons, and a brewery yielded 56.9 tons, for a combined tonnage of 2,319.1 tons of food scraps per year.

According to a 2010 Connecticut Waste Characterization study,¹⁵ organic waste makes up the largest component of both the residential and commercial municipal solid waste streams. The study noted that approximately 26.7 percent (by weight) of statewide municipal solid waste was comprised of organic waste (i.e., food scraps, branches and stumps, pruning and trimmings, leaves and grass, manures, and other organic materials). Food scraps were the most prevalent material, at over 320,000 tons (13.5 percent) per year. Additional material identified that could be available for composting includes compostable paper (8 percent) and untreated construction and



¹³ These estimates were developed using Rhode Island Economic Development Corporation industry data and formulas used by California Department of Resources Recycling and Recovery (CalRecycle) to extrapolate tonnage based on number of employees.

¹⁴ The project was one of the first to use Geographic Information System (GIS) technology to help promote recycling. Called "density mapping," the project visually illustrates all areas in the state where there are concentrations of generators producing similar types of food scraps. By matching these against transportation routes, an entrepreneur, composter, hauler, or waste manager can not only see where food generators are located, but can also use the information to line-up new accounts, select the right collection vehicles, design efficient transportation routes, and choose logical locations to site new organic material recycling facilities. While the readily available food scrap generator mapping data dates back to 2001, it is useful as an indicator, and many of the institutional generators are likely to have similar waste profiles. The 2001 database of food residual generators is currently being updated by US EPA Region 1 to 2011 data.

¹⁵ State of Connecticut Department of Energy & Environmental Protection. "Connecticut State-wide Solid Waste Composition and Characterization Study, Final Report." May 26, 2010. http://www.ct.gov/deep/lib/deep/waste_management_and_disposal/solid_waste/wastecharstudy/ctcompositioncharstudymay2010.pdf.

demolition wood (2.7 percent). Other organic materials—such as old corrugated cardboard and high-grade white office paper found in the municipal solid waste stream—are state mandated recyclables that can be recycled into new paper products and are not included in the above referenced figures.

The 2010 study also analyzed the incoming solid waste at several facilities in Connecticut including the Wheelabrator Bridgeport Resource Recovery Facility, which serves 19 towns and has a maximum capacity of 821,250 tons of solid waste per year. Over the past five years, the facility has incinerated an average of 722,692 tons per year. Based on sampling occurring on two days in February and October 2009, the Wheelabrator Bridgeport facility received 46 percent residential waste and 54 percent commercial waste. Of this, an average of 25 percent was combined organic materials, with food scraps comprising an average of 13.7 percent of the residential waste and 12.7 percent of the commercial waste.

Based on data from the 2010 Connecticut Waste Characterization study, approximately 45,544 tons of the estimated 332,438 tons of annual residential waste burned in the Wheelabrator Bridgeport facility are food scraps. Of the 390,254 tons of commercial waste incinerated in the Wheelabrator Bridgeport facility, an estimated 49,562 tons are food scraps.¹⁶

Food Scrap Collection and Recycling

Recently, there has been an increase in communities exploring food scrap recovery. The 2009 *Best Management Practices in Food Scraps Programs* report¹⁷ identified over 180 communities across the United States with some type of commercial and/or residential food scrap collection and composting program in place.

Food Scrap Collection

The starting point for a food scrap recycling program is collecting organic materials from the generators. As noted above, there are a limited number of food scrap collection programs currently operating in the United States. The implementation of existing programs varies in the following areas: pickup methods (drop-off or curbside), materials accepted, the extent to which different organic materials need to be separated, and targets for different types of organic materials and different generators (e.g., residential, commercial, industrial). Often these programs operate in areas where the economics are less favorable and where tipping fees for municipal solid waste disposal are higher than fees for organic materials.

The success of these collection programs vary depending on a number of factors, including the type of program implemented, the cooperation of residential and commercial generators, the organic material recycling technology employed and the specific goals of the community. In general, most programs are voluntary, but according to the December 2009 issue of *BioCycle Magazine*, the cities of San Francisco and Seattle were the only major U.S. cities that required residential collection of organic materials,

¹⁶ These estimates are based on the average annual tonnage incinerated and the waste stream characterization estimates based on the discrete sampling reported in the 2010 Connecticut Waste Characterization study.

¹⁷ Econservation Institute. *Best Management Practices in Food Scraps Programs*.2010.
http://www.foodscrapsrecovery.com/EPA_FoodWasteReport_EI_Region5_v11_Final.pdf.

including food scraps. Achieving high levels of participation in residential and commercial food scrap collection programs may be difficult. For example, participation in mandated residential and commercial recyclable materials collection programs (e.g., glass and paper), is relatively low in Rhode Island and has not approached the state goals. Fairly recently, the Rhode Island Department of Environmental Management reinstated mandatory recycling reporting for commercial entities with more than 50 employees and has had almost 70 percent compliance in survey response, although a corresponding increase in recycling rates is not yet apparent. Public education, goal setting and financial mechanisms may alter this scenario.

To achieve the cleanest and largest input stream of organic materials for a food scrap recycling facility, it may be necessary to identify larger-scale food scrap generators as initial targets. Toward this end, Connecticut passed legislation in 2011¹⁸ that requires certain large-scale commercial generators of food scraps to participate in an organic materials recycling program once a minimum processing capacity is achieved in the state. The goal of this legislation was to attract developers of food scrap recycling facilities to Connecticut by guaranteeing them feedstock and thereby improving the organic materials recycling infrastructure.

In addition to food scrap collection programs, edible food scraps in many communities are donated to the needy, while inedible food scraps are blended into compost or reprocessed into animal feed. In some areas, composting operations are working with high-volume commercial and institutional food producers to recover their food scraps, saving these firms significant disposal costs.

Food Scrap Management

EPA and the U.S. Department of Agriculture recommend the following hierarchy to reduce food scrap generation and disposal:

- Source Reduction – Reduce the amount of food scraps being generated
- Feed People – Donate excess to food banks, soup kitchens and shelters
- Feed Animals – Provide food scraps to farmers
- Industrial Uses – Provide fats for rendering; oil for fuel; food discards for animal feed production; or anaerobic digestion combined with soil amendment production or composting of the residuals

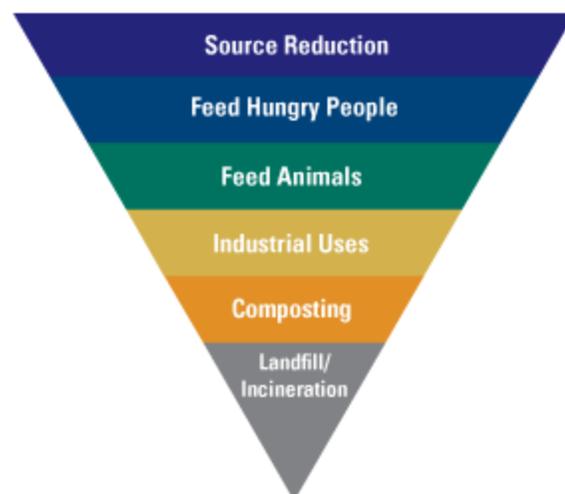


Figure 2 - Food Recovery Hierarchy

Image courtesy of EPA

¹⁸ Substitute Senate Bill No. 1116, Public Act No. 11-217, An Act Concerning The Recycling Of Organic Materials By Certain Food Wholesalers, Manufacturers, Supermarkets And Conference Centers. <http://www.cga.ct.gov/2011/ACT/Pa/pdf/2011PA-00217-R00SB-01116-PA.pdf>.

- Composting – Recycle food scraps into a nutrient rich soil amendment
- Landfill/Incineration¹⁹

As can be seen in Figure 3, the ideal options for addressing food scraps are related to reduction and reuse of the food scraps followed by composting. Diverting food scraps from landfills and incinerators conserves limited landfill space and can help reduce greenhouse gas emissions. In landfills, the digestion of food scraps and other organic waste materials produces methane, a greenhouse gas that is a significant contributor to climate change. Landfills, accounting for more than 17 percent of methane emissions in 2009, are the major source of human-related methane emissions in the United States.²⁰ While many, but not all, landfills now capture their methane, it is more efficient to remove the organic sources of methane in landfills through source separation and alternative processing of organic waste materials using composting and anaerobic digestion technologies. Composting allows for the beneficial reuse of the nutrients through production of soil amendment products and through some treatment processes, can efficiently capture methane to produce clean energy as well.

A significant challenge to developing food scrap recycling efforts can be the incremental costs associated with collecting and processing food scraps separately from the municipal solid waste stream. These costs are attributed to the separation of the food scraps from other trash at the residence or commercial facility, the use of separate containers for food scrap collection, separate pickup of the food scraps for delivery to the food scrap recycling facility, and construction and operating costs of the recycling facility. Adding an additional fee for collecting and processing food scraps along with higher tipping fees for trash as compared to organic materials is the ideal situation. Other types of collection programs such as unit based pricing, Pay as You Throw (PAYT) programs or other variable rate programs also can be used to address the additional cost of food scrap and other organic materials collection programs. In some cases, food scrap collection programs can operate successfully where food scrap tipping fees are higher than landfill tipping fees, but this requires strong political support to overcome the economic issues.²¹

In fiscal year 2010, Rhode Island municipalities paid a base rate of \$32 per ton for municipal solid waste delivered to the Central Landfill. The base municipal tipping fee of \$32 has not increased since 1992. If the municipality exceeds their municipal solid waste cap, then they are charged at the Central Landfill's lowest commercial contract rate. The commercial tipping fees range greatly within and outside of Rhode Island. However, it has been noted that the lowest current commercial tipping fee at the RIRRC facilities is \$54 per ton. In addition to municipal solid waste tipping fees in Rhode Island, a \$25 per ton municipal tipping fee is charged for leaf and yard waste when total tonnage received from a community exceeds an allotted cap. Prior to reaching this tonnage cap, there is no tipping fee for leaf and yard waste disposal. In 2010, a policy went into effect that allowed communities that reach their cap to trade with other communities; however, 11 municipalities still went over the cap by a total of 9,000 tons.

¹⁹ <http://www.epa.gov/osw/conservation/materials/organics/food/fd-gener.htm>

²⁰ <http://www.epa.gov/outreach/sources.html>

²¹ Econservation Institute. *Best Management Practices in Food Waste Composting*. December 2010. <http://www.foodscrapsrecovery.com/research.html>

In Connecticut, according to the 2006 Solid Waste Management Plan, tipping fees for municipal solid waste range from \$57 to \$70 a ton. The municipal tipping fee at the Wheelabrator Bridgeport facility was \$69 a ton in 2005.²² Specific costs associated with commercial tipping in Connecticut were not readily available; however, at the Wheelabrator Bridgeport facility, commercial tipping fees average about \$50 per ton, but vary greatly depending on the hauler and amount of trash delivered.²³

²² State Solid Waste Management Plan: Amended 2006. State of Connecticut, Department of Environmental Protection (p.44).

²³ Conversation notes relayed via personal communication from CT DEEP, Monday, March 7, 2011.

Overview of Approaches for Large-Scale Food Scrap Recycling

Recycling food scraps provides not only a significant opportunity for reducing the amount of food scraps disposed in landfills or incinerators, but can produce a natural soil amendment or provide a potential valuable source of energy. Composting is an aerobic decomposition process in which organic materials such as food scraps, leaves, grass trimmings, and paper break down in the presence of oxygen, creating a humus that can be used as a soil amendment. Composting can be accomplished in a variety of ways and a compost system can range in size from a household bucket, to a backyard barrel or pile, to acres of compost rows, to enclosed systems. In addition to composting, anaerobic digestion processes can break down food scraps in the absence of oxygen to produce methane, a valuable energy source when captured, and a digestate that can be further processed through aerobic decomposition to produce compost. Digestate is a thick sludge with moisture content as high as 80 percent. Two case studies are presented later in this document describing the processes and experiences for two anaerobic digestion food scrap recycling systems.

Did You Know That Compost Can:

- Suppress plant diseases and pests
- Reduce or eliminate the need for chemical fertilizers
- Promote higher yields of agricultural crops
- Increase moisture retention, water infiltration, and organic matter and sequester carbon in soil when used as a soil amendment
- Facilitate reforestation, wetlands restoration, and habitat revitalization efforts by amending contaminated, compacted, and marginal soils
- Remove solids, oil, grease, and heavy metals from stormwater runoff

There are a wide variety of technologies for processing food scraps that utilize either aerobic decomposition or anaerobic digestion processes. These processes can be categorized into three basic groups:

- **Windrow Composting** – a controlled aerobic decomposition process by piling organic materials in long rows (i.e., windrows) and introducing oxygen by either turning or forcing air through the windrows.
- **In-vessel Aerobic Composting** – a controlled aerobic decomposition process that uses a combination of rotating drums, silos or tunnels to mix and aerate the materials and windrows or other form of composting to cure the materials.
- **In-vessel Anaerobic Digestion** – an anaerobic digestion process using a combination of airtight vessels designed to capture gases for conversion to energy and windrows or other form of composting to cure the digestate and create compost.

Generally, there is a progression of increased costs and operating complexity from turned windrows, to covered forced aeration windrows, to in-vessel aerobic composting, to anaerobic digesters. As cost and complexity increase, so do the capabilities and benefits of the technologies. These increased capabilities and benefits include: 1) the ability to process more organic material with higher concentrations of food scrap; 2) uses a smaller land area; 3) odor control; and 4) ability to handle more diverse organic

materials. This chapter provides a brief overview of each of these groups of technologies. Table 1 found on page 27, provides a side-by-side comparison of the different technologies mentioned above.

There are over 180 commercial and residential food scrap collection and recycling programs across the United States.²⁴ The details of the programs vary depending on the resources and specific needs of the individual communities; however, almost all of these existing programs rely on a windrow-based composting system (see description of windrow-based composting later in this chapter). Further, the implementation of food scrap recycling programs presents a number of challenges to communities, including the separation and collection of food scraps, selection of a technology or a method for processing the food scraps, and the location of the recycling facility. The selection of an appropriate technology and location for recycling food scraps and other organic materials will depend on a number of factors including:

- Concerns related to odor and other aesthetic issues (e.g., appearance of the facility) and health and nuisance-related concerns (e.g., birds, insects, and vermin), primarily due to proximity to populated areas;
- Environmental concerns such as greenhouse gas and other air emissions, leachate control, stormwater runoff control, pathogen reduction, water consumption and energy consumption;
- Location of the facility with respect to the sources of the organic materials to minimize the travel distance for vehicles collecting the organic materials and traffic in the neighborhood of the facility;
- Type, quantity and mixture of organic materials required to optimize the composting process;
- Land requirements to meet capacity and residence time requirements and buffer zone requirements for the selected composting process;
- Local, state and federal regulatory requirements; and
- Economics of the approach including capital costs, operating costs, tipping fees, energy recovery, marketability and income from the sale of compost.

In general, the composting process involves a number of components:

- **Receiving** – Organic materials are received at the facility, weighed and stockpiled prior to processing. The receiving area can be an open area, partially enclosed area or fully enclosed area such as a building. Enclosed receiving areas can be equipped with a ventilation system to control odors by directing odor and other gases from the waste materials through a filtering system. Some organic materials such as food scraps are generally not stockpiled for any length of time and are typically incorporated into the composting process within a short period of time. In some, permitting requirements may limit the length of time these materials can be stockpiled.

²⁴ Econservation Institute. *Best Management Practices in Food Scraps Programs*.2010. http://www.foodscrapsrecovery.com/EPA_FoodWasteReport_EI_Region5_v11_Final.pdf.

- **Pre-processing** – Organic materials are screened to remove large materials (e.g., branches) and non-organic materials (e.g., plastic bags). Various types of organic materials (e.g., food scraps, yard trimmings, soiled paper) are mixed and shredded to create a material that meets the proper control parameters. The types of organic materials and mixtures that can be processed and the amount of shredding required will depend on the recycling process or technology used. In addition, separation of organic materials for recycling at the collection point or source may be needed to minimize the amount of non-organic materials incompatible with the food scrap recycling process being used.



Photos courtesy of The Peninsula Compost Group

***Wilmington Organic Recycling Center –
Screening and Pre-Processing Area within the Receiving Building***

- **Processing** – Pre-processed organic materials are placed in piles or introduced into process vessels where the aerobic or anaerobic processes will occur.
- **Post-processing** – Processed organic materials are screened to remove non-organic materials that may not have been removed during pre-processing and large particles remaining after processing to create fine-grade compost for distribution or sale. In some cases, additional curing time or processing may be needed. For anaerobic digestion, the solid or semi-solid material or digestate that remains at the completion of the anaerobic digestion process will typically need to be processed further to develop compost. For the aerobic in-vessel process, additional curing may be needed to develop the compost.
- **Odor management** - Odor is one of the primary concerns when handling materials that are capable of decaying. Odors can be an issue during the receiving and processing of organic materials and during the active composting phase of the process. Odor and other emission controls may be used during receiving, pre-processing and processing to divert air flow from these areas to bio-filters or other treatment systems.
- **Water treatment** – Stormwater and leachate management can also be a significant concern. Control systems, such as impoundments, treatment systems or direct connections to sanitary sewer lines may be needed to meet regulatory requirements.

- **Storage** – Compost may need to be stored at the facility prior to delivery or sale.

The configuration and size of a composting facility will vary based on the technology employed at the facility and local requirements. A comparison of the technologies is presented in Table 4. The information presented in the table assumes a facility processing 40,000 tons per year of organic materials.



Photo courtesy of The Peninsula Compost Group

Wilmington Organic Recycling Center – Bio-Filter to Control Odors

Aerobic Decomposition

Aerobic decomposition is the break-down of organic materials by microorganisms in the presence of oxygen under controlled conditions. Aerobic decomposition relies on a number of parameters that control the efficiency of the composting process. These control parameters include the concentration of oxygen, the ratio of carbon to nitrogen, the moisture content, the size of the pieces of organic material and the temperature.

Table 2 - Aerobic Decomposition Control Parameters

Parameter	Value
Oxygen Concentration	5%
Carbon-to-Nitrogen Ratio	Range from 20:1 to 40:1
Moisture Content	Range from 40% to 60%
Particle Size	Range from 1/8 inch to 2 inches diameter
Temperature	Greater than 50°F with peak temperatures greater than 130°F to destroy pathogens, weeds, fly larvae

The aerobic decomposition process occurs in two phases. The active decomposition phase requires higher amounts of oxygen and higher temperatures to reduce biodegradable volatile solids. This phase requires frequent monitoring of the control parameters and adjustments to the oxygen and moisture content to maintain optimum conditions for composting. This phase also has the greatest potential for producing odors.

As the active decomposition slows, temperatures will gradually drop until the pile reaches ambient air temperatures. Once the temperature in the organic material reaches ambient air temperature, the curing phase begins. This phase is characterized by lower temperature and reduced oxygen uptake. There is also a lower potential for odors to occur during this phase. The curing phase can last two to four weeks. After the curing phase is complete, the compost becomes relatively stable and easy to handle.

The volume of food scraps that can be processed is limited by the ability to achieve the optimum control parameter requirements in the organic materials processed. Food scraps are high in moisture content and low in physical structure making it difficult to create stable piles and allow oxygen to move through the pile. In addition, high concentrations of food scraps in the mixture can lower the carbon-to-nitrogen ratio and create anaerobic conditions with resulting odor problems. As a result, the processing of food scraps using aerobic decomposition requires a mixture of organic waste materials (e.g., food scraps, yard trimmings, soiled paper, wood chips) to achieve the optimum control parameters. These various types of organic materials are mixed to create the proper carbon-to-nitrogen ratio, add bulk to increase the stability of the pile, and increase porosity to allow greater air flow through the material during the decomposition process. The ratio of food scraps to bulking agent will vary depending on the composition of the food scraps and the type of bulking agent used; however, a mix of two parts bulking agent to one part food scraps appears to be common. A reliable source of bulk organic materials must be available in addition to the food scraps in order for the process to be effective. These mixing strategies for food scraps are important to the success of aerobic composting.

There are three basic approaches typically used for aerobic decomposition: turned windrow, static forced aerated windrow and in-vessel.

Windrow Composting Systems

Windrow composting systems are the least costly composting technology but require large land areas to accommodate the windrows and buffer zones. In addition, these systems typically can handle only small amounts of food scraps mixed with soiled paper, yard trimmings or other bulk organic materials without significant impacts on the decomposition process. The amount of food scraps that can be added depends on a number of factors including:

- The correct ratio of carbon and nitrogen to encourage efficient decomposition;
- The appropriate particle size to maintain sufficient porosity in the windrow to allow proper air flow; and
- Proper bulk to maintain stability of the pile.

Windrow composting systems involve piling organic materials in long rows referred to as windrows that can be six to 10 feet high, 12 to 20 feet wide, and hundreds of feet long. The windrows are typically placed on paved or low-permeability soil surfaces to minimize the infiltration of leachate from the windrows to groundwater. Aisles are also needed between piles to allow for equipment to place and maintain the windrows. The height, width and shape of the windrows will vary depending on the organic



Photo courtesy of The Peninsula Compost Group
Wilmington Organic Recycling Center

materials processed and the approach used for managing them. Windrows can be covered or uncovered depending on the technology or method selected. During the active decomposition phase, the windrows can be either turned or aerated to maintain oxygen content and porosity in the piles.

Turned windrows are the least complex of the windrow technologies. The turned windrows are typically uncovered piles that are periodically mechanically turned to improve porosity and oxygen content, mix in or reduce moisture, and redistribute cooler and hotter portions of the windrow to maintain an aerobic decomposition process. Surface water runoff from rainfall and excess water applied for moisture control generally need to be managed (e.g., surface impoundments) to meet local water quality regulations. Odors and volatile emissions can also be an issue for turned windrows, particularly if control parameters are not maintained within optimum ranges. Odor control is essentially limited to maintaining proper aeration and moisture content in the windrows. Rainfall can come in contact with the organic materials in turned windrows resulting in potential contamination, including adding nutrients from surface water runoff from the facility. Excessive rainfall can affect the efficiency of the active decomposition phase in turned windrows by increasing the moisture content in the windrows beyond the control parameters. Runoff controls typically are required to manage surface water prior to discharge from the facility. Additional control parameters for the turned windrows include pile size and turning frequency. Depending on the control parameters maintained in the windrows, active composting time for an uncovered, turned windrow can range from eight to 16 weeks. It is important to note that turned windrows can be placed in buildings or under cover to address odor, rainfall and surface runoff issues; however, the use of buildings or other structures as cover may be limited by the size and number of windrows required for a facility.

Static forced aerated windrows are a more complex windrow technology, but can typically process larger volumes of food scraps than turned windrows. Static forced aerated windrows are covered or uncovered piles in which the oxygen concentration is maintained by blowing or pulling air through the windrow using a blower and aeration tubes. Water is added as needed to maintain moisture content.

Odors and volatile emissions can be less of an issue for static forced aerated windrows if exhaust air from the ventilation system is captured and treated. Some best management practices suggest covering the pile with a wood chip blanket to control odors. Several vendors also market covered aerated static pile systems that utilize a fabric cover over the windrow to manage odors. These piles are built, covered with an engineered fabric and then treated with forced aeration.

Surface water runoff and excessive moisture due to rainfall are typically less of an issue for covered static forced aerated windrows than turned windrows or uncovered static forced aerated windrows due to the cover. Drainage systems, however, are typically needed to manage the leachate from the windrows regardless of whether they are covered or uncovered.



Photo Courtesy of The Peninsula Compost Group

Wilmington Organic Recycling Center – Covered Windrows

Rainfall may have limited contact with the organic materials in the windrow due to the cover; however, this increases the volume of surface water runoff from the facility that may need to be managed.

An additional control parameter for static forced aerated windrows is the ventilation rate for air flow. Depending on the control parameters maintained in the windrow, active composting time for a static forced aerated windrow can range from four to 10 weeks. It is important to note that static forced aerated windrows can be uncovered. In this case, issues related to odor control, rainfall and surface water runoff will be similar to those discussed for uncovered turned windrows.

During the curing phase, the windrows are uncovered and the remaining organic materials continue to slowly decompose. Forced aeration systems may continue to operate or the piles could be mechanically turned during this phase. The curing phase can last for three to six weeks and after it is complete, the compost is screened. Materials removed during the post-process screening may need to be disposed of in a landfill or other disposal facility.

In-vessel Aerobic Composting Systems

In-vessel aerobic composting systems are more costly than windrow systems, but offer greater management of the control parameters, better odor control, better aeration, shorter processing time, and require less land area than windrow systems. The process involves placing organic materials in a vessel or reactor in batches or continuously fed using front-end loaders, loading conveyors and/or loading hoppers. Vertical vessels (e.g., silos) allow larger quantities of organic materials to be processed in smaller land areas. Organic materials are typically fed into the top of the vessel and removed from the bottom. Horizontal vessels (e.g., rotating drums, containers, or enclosed tunnels or channels) require a larger land area than silo systems, but an in-vessel system will require less overall land area to process similar volumes of material than windrow systems due to the lower retention time required. The size of the vessels will vary depending on the type and the volume of organic materials to be processed.

During the active composting phase, the organic materials are aerated either by forcing air through the vessel or by mechanically agitating the material. Agitated systems (e.g., rotary drums, agitated beds, augers) break up the organic materials providing microorganisms with better access to the nutrients needed for digestion. Liquid is added as needed to maintain the moisture content in the organic materials. This phase requires frequent monitoring of the control parameters and adjustments to the oxygen and moisture content to maintain optimum conditions for composting. Common, in-vessel aerobic composting systems include:

- Horizontal rotary drums that continuously mix, aerate and move the organic materials. Drums can range from 4 to 12 feet in diameter and 50 to 175 feet in length.
- Enclosed containers that use fans to force aerate the organic materials without internal agitation. Container capacity can range from 20 to 110 cubic yards.

- Long channels with concrete walls that contain agitated beds with air forced through the underside of the beds. These systems are typically operated as continuous systems with organic materials fed into the channels at one end, and the agitation process moving the material to the other end for removal as finished compost. Channel lengths typically range from 200 to 300 feet.

Because the in-vessel systems are fully enclosed systems, rainfall does not come in contact with the organic materials. However, surface water runoff from the facility may still need to be managed. Leachate generated during the composting process can be reused to add moisture content to the organic materials or managed appropriately (e.g., treated or discharged to a sanitary sewer). Odors and volatile emissions are controlled by recirculating air through the vessel and/or diverting air from the vessel through a treatment process. Depending on the type of vessel, aeration and control parameters maintained in the vessel, active composting time can range from one to four weeks.

During the curing phase, which can last for three to six weeks, the processed organic material can be cured in the composting vessel, moved to a separate vessel, or placed in open or aerated static piles. After the curing phase is complete, the compost is screened. Materials removed during screening may need to be disposed of in a landfill or other disposal facility.

Anaerobic Digestion

Anaerobic digestion is a naturally occurring biochemical process where microorganisms break down organic material in a low or no-oxygen environment. The digestion process takes place in a heated, sealed vessel or container. The heat can be generated using an external energy source such as natural gas from a commercial tap or methane generated from the anaerobic digestion process. Anaerobic digestion relies on a number of control parameters within the vessel or container that control the efficiency of the digestion process. These control parameters include the ratio of carbon to nitrogen, the moisture content, the pH level, the size of the organic material pieces, the temperature, and the amount of volatile organic solids in the organic materials being processed (i.e., organic loading rate).

Table 3 - Anaerobic Digestion Control Parameters

Parameter	Value
Carbon-to-Nitrogen Ratio	Range from 20:1 to 40:1
Moisture Content	Range from 75% to 90%
pH	Range from 5.5 to 8.5
Particle Size	Range from 1/8 inch to 2 inches diameter
Temperature	Greater than 85°F with peak temperatures greater than 130°F depending on the process
Organic Loading Rate	0.48 to 1.6 kg/m ³

Anaerobic digestion technology has been widely employed in Europe to manage organic materials but has had limited use in the United States. Its use and continued growth in Europe is due to a number of factors including:

- Landfill directives adopted by the European Union requiring processing of organic materials before disposal;²⁵
- Energy-generating potential of anaerobic processes to help offset the high electricity costs in Europe;
- High, feed-in tariffs paid for electricity generated from biogas; and
- Substantial subsidies offered for collection and processing.

Through this market growth, anaerobic digestion technology has continued to evolve, and processing capacity has continued to grow. For example, the average dry batch anaerobic digestion system installed in 2009 in Northern Europe is capable of digesting 24,600 tons per year.²⁶

In the United States, application of anaerobic digestion technology has been largely growing in the agricultural sector. Across the country, 176 anaerobic digester systems for livestock manure were operating in the United States by the end of 2011.²⁷ Some of these farm anaerobic digesters also received and processed food scraps, as well as fats, oils and grease. There are also a few examples of food scrap anaerobic digesters that are already in operation or slated to come online. A number of large communities in the United States have undertaken feasibility studies evaluating the application of anaerobic digestion for organic materials associated with municipal waste. One of the attractions of anaerobic digesters in particular is the ability for cities to use the biogas (e.g., methane) generated during the anaerobic digestion to produce energy (e.g., electricity, heat, natural gas) and help reach renewable energy targets. A report issued by New York City on new and emerging technologies²⁸ for municipal solid waste found that anaerobic digestion and biogas energy generation technologies were less costly on a commercial scale than the current export practices for organic materials. The analysis concluded that anaerobic digesters offered better environmental performance than waste-to-energy facilities, lower air-pollutant emissions, increased beneficial use of waste, and reduced reliance on landfills. A number of other U.S. communities, including Palo Alto, Los Angeles, Santa Barbara County, and Alameda, California; Linden Hills, Minnesota; and Seattle, Washington, have examined anaerobic digester technologies.

Anaerobic digestion processes can be either high or low temperature processes. The low temperature process, mesophilic digestion, maintains a temperature in the vessel in the range of 85°F to 95°F. This

²⁵ In 1999, the EC adopted the Landfill Directive (Council Directive 99/31/EC) that became enforceable in 2001. It required the biodegradable portion of municipal solid waste to be reduced by 25% of that disposed in 1995 within five years, 50% within eight years, and 65% within 15 years.

²⁶ Spencer, Robert. "High Solids Anaerobic Digestion of Source Separated Organics." *BioCycle*. August 2010, Vol. 51, No. 8, p. 46. <http://www.igpress.com/archives/free/002137.html>.

²⁷ U.S. EPA. "U.S. Anaerobic Digester Status: A 2011 Snapshot." http://www.epa.gov/agstar/documents/2011_digester_update.pdf.

²⁸ New York City Economic Development Corporation and New York City Department of Sanitation. *Evaluation of New and Emerging Solid Waste Management Technologies*. September 16, 2004. www.nyc.gov/html/dsny/downloads/pdf/swmp_implement/otherinit/wmtech/phase1.pdf.

process can tolerate greater changes in the control parameters, but requires larger tanks, produces smaller quantities of biogas, and requires additional treatment to effectively remove pathogens and other contaminants. The high temperature process, thermophilic digestion, maintains a temperature in the vessel of 130°F or greater. This process allows higher loading rates, produces greater quantities of biogas, and achieves a higher rate of pathogen and other contaminant destruction without additional treatment. The thermophilic digestion process is also more sensitive to changes in the environment, and in most cases, a heating mechanism is needed to maintain the digester at the desired temperature.



Image courtesy of BIOFerm™ Energy Systems

Figure 3 – Dry Fermentation Facility

Anaerobic digestion processes can also be wet (low solid content) or dry (high solid content) processes. The wet process increases moisture to reduce the total solids content to 10 percent or less. This process, common for treatment of sewage effluent, results in lower organic volatile solids that reduce the energy value of the biogas. The dry process uses less moisture and higher total solids in the range of 20 percent to 40 percent. This process results in higher organic volatile solids and higher energy value, but may be less effective in the removal of contaminants. The resident time for wet processes can range from 14 to 30 days, while the resident time for dry processes can vary between two to six weeks. The time depends on the anaerobic technology used and a number of parameters including the size of the digester, loading rate, removal rate of the digestate, temperature in the digester, volatile solids content, and desired degree of digestion. The moisture content of food scraps ranges from 60 percent to as high as 90 percent. Depending on the process selected and the content of the food scraps, moisture may need to be added to the organic material (e.g., for wet processes) or a bulking agent (e.g., yard trimmings) may need to be added to decrease the moisture content (e.g., dry processes). Recirculated liquid from the dewatering of the digestate is often used to increase moisture content and to create or enhance the growth of bacteria for the digestion process.

Anaerobic digestion processes can also be single-stage systems that involve no pre-treatment or multistage systems that involve some form of pre-treatment prior to placement in the digester. Multistage systems can be more efficient than the single-stage systems since they provide increased volatile organic solids, which results in greater production of biogas, but also results in additional costs for pre-treatment.

An organic residual or digestate is produced by the anaerobic digestion process, which is dewatered using a screw press, a belt press, a centrifuge or other separating technology. The resulting dewatering liquid can be recycled back into the process, treated and discharged, discharged to a sanitary sewer, or potentially used as a liquid fertilizer. In many cases, a storage tank may be needed to store the dewatering liquid prior to recirculation into the process or transporting off-site. The quality and chemical composition of the dewatering liquid may impact the use or disposal method, requiring aeration and/or filtration before recirculating it back into the process or discharging it. Odor can be an issue with the digestate, and processing of the digestate may need to be conducted in a building or enclosed space to allow for containment and treatment of the air. After further drying and processing, the remaining solids can be further processed to create compost using windrows or other aerobic decomposition approaches.

One of the primary by-products of the anaerobic digestion process is biogas composed of methane gas (60 to 70 percent), carbon dioxide (30 to 40 percent), small percentages of hydrogen sulfide, water vapor, oxygen and trace amounts of hydrocarbons. The biogas can be captured and treated by removing water vapor and other trace contaminants. The resulting product can be used to generate electricity or heat, or sold as pipeline-grade gas or vehicle fuel. Any excess gas can be stored in spherical, high-pressure tanks or similar vessels.



Combined heat and power generation unit



Heat only biogas boiler



Biogas upgrade to natural gas

Photos courtesy of BIOFerm™ Energy Systems

A study supported by EPA Region 9 found that anaerobic digestion of food scraps has approximately three times the methane production potential by volume of municipal wastewater solids. The study found that the methane production potential of biosolids from wastewater sludge was 120 cubic meters (m³) of gas per ton compared to food scraps at around 367 m³ of gas per ton. Anaerobic digestion of 100

tons of food scraps per day, five days a week, can provide sufficient power for approximately 1,000 homes.²⁹ Food scraps are also more readily digestible than wastewater sludge, requiring a shorter residence time to process the waste. The shorter residence time means that food scraps can be processed in smaller digesters than municipal solids, resulting in lower capital costs. Additionally, a digester can accept a larger amount of food scraps at one time than wastewater solids without adverse impacts. It is estimated that if 50 percent of the food scraps generated each year in the United States were processed in an anaerobic digester, enough electricity could be generated to power more than 2,500,000 homes annually.³⁰

Design considerations for anaerobic digestion facilities include:

- **Capacity** – Volume of organic materials to be processed.
- **Orientation** – The horizontal or vertical orientation of the process vessels. It will depend on the process used, space requirements and other operating considerations.
- **Organic materials** – Could include food scraps, unmarketable food products, food manufacturing residuals and yard trimmings.
- **Pretreatment** – Depending on the purity of the organic materials, non-organic materials such as metal, glass, plastic and larger objects such as branches, may need to be removed or reduced in size via shredding, pulping, crushing or other similar processing. This will provide greater surface area and reduce retention time. Organic materials may also need to be mixed with water or digestate dewatering liquid to increase the moisture content of the material prior to processing.
- **Digesters** – The technology to be employed including batch or continuous processing, wet or dry processing, or single- or multiple-stage digesters.
- **Solids Content** – The use of a wet or dry digestion process.
- **Mixing** – Flow of the organic material through the digester impacts how quickly the material is digested.

²⁹ www.epa.gov/region9/waste/features/foodtoenergy/food-waste.html

³⁰ <http://www.epa.gov/region9/organics/coeat/index.html>

Table 4 - Comparison of Food Scrap Recycling Technologies

Issue	Aerobic Processes			Anaerobic Digestion
	Turned Windrows	Static Aerated Windrows	In-vessel	
Land Area Requirements ³¹	8 to 13 acres	6 to 10 acres	3 to 6 acres. Does not include land for composting.	3 to 6 acres. Does not include land for composting.
Waste Streams ³²	Yard trimmings and food scrap plus bulking agent. Food scrap volume will be limited by the mixture of waste streams to achieve control parameters.	Yard trimmings and food scrap plus bulking agent. Food scrap volume will be limited by the mixture of waste streams to achieve control parameters.	Yard trimmings and food scrap plus bulking agent. Food scrap volume will be limited by the mixture of waste streams to achieve control parameters. Typically processes higher food scrap ratios than windrows.	Organic material need high moisture content (>80%). Water or digestate dewatering liquid can be used to increase moisture content.
Typical Labor Requirements ³³	Site manager, heavy equipment operators, laborers, and maintenance personnel (10-16). Plant manager / operator with a clear understanding of biological systems and processes is necessary.	Site manager, heavy equipment operators, laborers, maintenance personnel, and instrument/computer operators (10-16). Plant manager/operator with a clear understanding of biological systems and processes is necessary.	Heavy equipment operators, laborers, maintenance personnel, and instrumentation/computer operators. Plant manager / operator with a clear understanding of technical biological systems and processes is necessary (requires lower level of manpower to operate process).	Heavy equipment operators, laborers, process operators, maintenance personnel, and instrumentation/computer operators (requires the lowest level of manpower to operate process). Plant manager or operator with a clear understanding of biological systems and processes is necessary.
Food Scrap	30% to 40% of organic materials	30% to 40% of organic materials	30% to 40% of organic materials	>50% of organic materials
Processing Time	8 to 16 weeks	4 to 10 weeks	1 to 4 weeks	2 to 4 weeks

³¹ Assumes a facility processing 40,000 tons of organic waste materials per year. This does not include buffer zones that may be required by state or local regulations or as a result of public input. Land estimates for in-vessel aerobic processes and anaerobic digestion do not include digestate curing requirements to create compost or other soil enhancement. The curing process type (e.g., aerobic decomposition or pelletizing) will govern the required land amount. In addition, set-back requirements may also impact the size of the land required.

³² A 2-to-1 ratio of bulking agents (e.g., paper, sawdust, wood chips) to food scraps is reported in the literature for all three aerobic processes.

³³ Additional staff or consultants are needed to manage end use and market the compost for all technologies.

Issue	Aerobic Processes			Anaerobic Digestion
	Turned Windrows	Static Aerated Windrows	In-vessel	
Curing Time	3 to 6 weeks	3 to 6 weeks	3 to 6 weeks	3 to 6 weeks
End Product	Compost	Compost	Compost	Electricity (biogas from digester) Digestate Liquids (liquid fertilizer) Digestate Solids (further processing can result in compost)
By-Products	Surface-water runoff, volatile emissions, screening materials	Leachate from windrows, stormwater runoff, volatile emissions, screening materials	Leachate from digestion process, volatile emissions	Liquid digestate (if required to be disposed rather than reused)
Costs³⁴	\$15/ton to \$40/ton (lower capital costs, higher labor costs)	\$25/ton to \$60/ton	\$80/ton to \$110/ton (higher capital costs, lower labor costs)	\$110/ton to \$150/ton (higher capital costs, lower labor costs)
Odor Control	Capture and treat odor during receiving and pre-processing. Maintain control parameters during composting.	Capture and treat odor during receiving, pre-processing and composting.	Capture and treat odor during receiving, pre-processing and composting.	Capture and treat odor during receiving, pre-processing and digestate dewatering.
Birds, Insect, and Vermin	Issue in receiving, pre-processing and composting areas	Issue in receiving, pre-processing and composting areas	Issue in receiving and pre-processing areas	Issue in receiving and pre-processing areas
Technology	Low complexity with greatest operation experience	Moderate complexity with good operating experience	Greater complexity with good operating experience	Greatest complexity requiring a qualified operator with extensive experience in operating water treatment technologies, to manage the digestion process

³⁴ Center for a Competitive Waste Industry. *Beyond Recycling – Composting Food Scraps and Soiled Paper*. January 2010. http://beyondrecycling.org/pdf_files/FinalReport.pdf

Key Considerations

There are many different technologies and approaches available to implement food scrap recycling. The appropriate technology or process for a particular community or facility will depend on many factors ranging from the source of the material, the technology used to process the material, and the by-products generated by the process. In many cases, it may be appropriate to engage a technical consultant or issue a request for information or qualifications to support the evaluation of the recycling technologies. Summarized below are key considerations for evaluating food scrap processing technologies.

Land Area

How much land will be needed for the receipt, storage and processing of the organic materials? The type of technology as well as community issues will drive the location and amount of land needed to process organic materials. In addition to the land requirements for the technology (e.g., aerobic or anaerobic processes), land requirements for storage and pre-treatment of organic materials, post-processing of residues, wastewater treatment, and administrative and maintenance facilities should also be considered. Proximity to neighboring properties or populated areas could also significantly affect the location and size of land.

Quality of Life

Are there issues that will affect the location and community acceptance of the facility? Some of the most significant issues raised by communities and neighbors surrounding a facility are those that can impact their quality of life, such as increased traffic and odors. Successful operating facilities have found ways to mitigate these issues through design, operation and siting.

- **Odor** can occur from the handling of organic materials as well as from the ammonia, volatile amines, hydrogen sulfide, volatile organic compounds, and other byproducts of the degradation process. In many cases, odors are controlled by conducting material receipt, pre-treatment and post-processing activities within buildings or other enclosed areas. This solution contains the air indoors where it can be treated to eliminate odors before it is released from the building.
- **Traffic** can be intrusive or have detracting effects especially in residential or commercial areas. Buffer areas may be needed to separate residential or commercial areas from the operating portions of the facility.

Key Evaluation Factors

- ✓ **Land Area**
- ✓ **Quality of Life (odor, noise, visual, traffic)**
- ✓ **Environmental Concerns (land contamination, air/water quality)**
- ✓ **Regulatory Requirements**
- ✓ **Public Acceptability**
- ✓ **Public Health**
- ✓ **Operational Issues (waste composition, transport and traffic, utility and energy needs, energy generation, residual processing, water needs, wastewater treatment, flood control)**
- ✓ **Economics (tipping fees use of product, collection and transportation of food scraps, construction and operation of processing facility)**

- **Excessive Noise** from trucks, equipment (e.g., loaders) and construction and operation of the facility could impact the surrounding community. Permit conditions about hours of active operation can be put into place to reduce the effects.
- **Negative Aesthetics** may become eyesores for the surrounding community (e.g., weeds and litter control). This could result in the need for fencing or landscaping to enhance the appearance of the facility as well as weed and litter control activities to contain organic materials within the facility boundaries.

Environmental Concerns

What environmental concerns will need to be addressed during the design, construction and operation of the facility? Air, water and waste management issues can have a significant impact on the design, construction and operation of an organic materials processing facility. Permitting requirements will vary based on federal, state and local requirements; however, permits will typically be required for the construction and operation of the facility.

Environmental Condition of the Site

Are there environmental conditions that need to be addressed on the property being considered for the facility? In some cases, it may be desirable to locate an organic materials processing facility on a brownfield or current industrial property. In these cases, environmental site assessments may be appropriate to identify environmental conditions on the property, understand potential liability and responsibilities for the environmental condition, and establish appropriate liability protections. Environmental cleanup may be needed in order to construct or operate the facility. In addition, other measures (e.g., dust control) may need to be taken to protect workers or neighbors from potential exposures to contaminated materials during construction activities. It is important to note that cleanup activities can be incorporated into the design and construction of the processing facility to minimize impacts on the construction of the facility and overall costs of cleanup.

Air Quality

Are there air emissions that will result from the facility operation? Air quality issues will vary depending on the type of technology used for food scrap processing. However, at least one or more air quality issues will need to be addressed during the construction and operation of the facility. These include:

- **Gas emissions** such as methane, nitrogen oxide, non-methane organic compounds (greenhouse gases) and hydrogen sulfide (scrubbed before emission) can be released from processing equipment. In some cases, a processing or co-generation facility may be used to collect and use the resulting biogas as a fuel or to produce energy for the facility operation. In cases of co-generation or other biogas processing systems, emergency flares may be needed to deal with biogas during periods when the biogas processing system is not operating.
- **Dust emissions** from the facility can become an issue during construction and operation from truck traffic and other equipment used on the facility. This can be addressed by using pavement

in areas where there will be extensive truck traffic during the operation of the facility. Other control measures include wheel washing and use of water spraying to reduce dust.

- **Vehicle emissions** can be released from facility vehicles and equipment engines. Consideration should be given to low-emission vehicles or alternative fuels for vehicles and equipment operating on the facility.

Water Quality (Surface and Ground Water)

Are there water discharges that will result from the facility operation? Water quality issues will vary depending on the type of technology used for organic material processing. However, at least one or more water quality issues may affect ground water and/or surface water at or near the processing facility and will need to be addressed during construction and operation. These include:

- Discharges of leachate and surface water runoff that contacts digester feedstock such as:
 - Stormwater from feedstock handling and storage facilities,
 - Water from equipment wash down and feedstock wetting,
 - Discharges to sanitary sewer, and
 - Leaking delivery vehicles.
- Discharges from ponds used for retention of storm or process water will need to comply with applicable water discharge requirements.

Regulatory Requirements

What regulatory requirements need to be considered during the design, construction and operation of the facility? Federal, state and/or local regulatory requirements will need to be considered. When considering regulatory and permitting processes, it is critical to work at the local level as well as with state regulators. Typical permits and regulatory requirements that may be encountered during construction and operation include:

- Solid waste management requirements and permits,
- Water quality requirements and permits,
- NPDES construction stormwater requirements and permits,
- Stormwater pollution prevention plan requirements,
- Waste/water discharge requirements,
- Air permits,
- Local zoning requirements,
- Local construction/building permits,
- Grading and erosion control requirements,
- Composting regulations and permits, and

- Waste transfer processing requirements.

Operational Issues

The selection of the process technology and the location of the facility will be impacted by a number of operational issues discussed below.

Feedstock Composition

What is the composition of the feedstock to be processed? The quality and composition of the feedstock will govern the extent of pre-processing required and impacts on the process. Consideration should be given to the source of the feedstock (e.g., residential, commercial or industrial) when evaluating a technology and the extent of pre-treatment required. For example, residential organic materials can include greater amounts of non-organic materials (e.g., packaging materials) than commercial or industrial organic materials. In addition, some processing may require the addition of bulking agents or liquids to provide the proper composition for processing. Processing technology should be selected based on its efficiency in processing the type of organic materials to be received at the facility and the amount of pre-treatment required to process the materials. The efficiency of the processing (e.g., anaerobic digestion) will directly affect the quality and quantity of gas produced. To achieve the necessary input stream for a food scrap recycling facility, it may be necessary to identify large-scale (i.e., commercial, institutional or industrial) food scrap generators as initial targets.

Transport and Traffic

What area will be serviced by the facility and what route will transport vehicles use to access the facility? Truck routes and transport distances will be important considerations from both a community and an economic perspective. The location of the facility and proximity to truck routes will be important not only for community issues, but for accessibility to the facility by transport vehicles. Proximity to the feedstock source minimizes travel time to the facility resulting in lower transportation costs, air emissions and fuel costs.

Utility and Energy Needs

What are the utility and energy needs for the facility? The energy needs for processing will vary based on the technology used. Energy used in biogas processing in addition to the energy requirements of the facility affect the amount of energy available for sale. Biogas generated by the anaerobic digestion process can be used to generate heat or energy to offset energy needs for the facility. Electricity generation for the local electric grid, or pipeline-grade gas for insertion into a pipeline, will require accessibility to the appropriate utility infrastructure.

Energy Generation

Is energy generation going to be an integral part of the facility processing and what approach will be taken for energy generation? The quality of gas (e.g., methane content) is directly related to the quality of the feedstock and the operation of the process technology. Energy generation can take a number of forms including:

- Electric and heat co-generation for on-site use,
- Electric generation onto local grid, and
- Pipeline-grade gas generation into local pipeline.

Residual Processing

How are residuals (e.g., digestate) from an anaerobic digester going to be handled? In most cases, the process residuals will require additional curing or processing in order to obtain a product (e.g., compost) that can be beneficially used or sold. The type of product to be produced will govern the amount of additional curing and the operational and land requirements for this processing. For example, to produce commercial-grade compost from an anaerobic digestate would require an aerobic decomposition process to achieve a quality product. The decision to do additional treatment on the facility property will affect the size requirements for the property and other considerations resulting from the additional processing. There may be an option for moving the residuals to an off-site composting facility for processing.

Water Needs

Will water be needed for the process technology? Depending on the process technology used, water may be needed to achieve the required moisture content of the organic materials prior to processing or for dust control. The quantity of water needed may be an issue in rural areas where access to a public water supply is not available. In areas where a public water supply is available, the cost of water may also be an issue. The need to drill a well may involve additional permitting and operating requirements. At a minimum, a water supply will be needed for employees on the facility.

Wastewater Treatment

How much wastewater, if any, will be generated and how will it be handled? Wastewater can be the result of leachate or runoff associated with the storage, handling and pre-treatment of the organic materials. In addition, depending on the technology used, wastewater may be generated by the process technology. Many technologies store and reuse this wastewater in the process. If wastewater is generated that cannot be reused by the process, it may need to be treated on-site prior to discharge from the facility.

Flood Control

Is the facility located in a flood zone or an area prone to flooding? The facility should be located, designed and constructed to minimize or eliminate the risk of flooding, if practical.

Public Acceptability

What are the public concerns or issues associated with a processing facility? Concerns of neighbors and surrounding communities may include odor, truck traffic and health issues. Location and design considerations can address many potential public concerns. Community buy-in from town leaders and residents will be a significant consideration in the siting and operation of a proposed food scraps

recycling facility. Community engagement through involvement in the planning and selection processes, education and dissemination of information are important mechanisms for obtaining this buy-in.

Public Health

What actions can be taken to avoid or minimize pests and other vermin on the facility and the surrounding area? Pests and vermin can proliferate at or near the facility. To avoid potential health risks to facility personnel and the local community, site cleanliness, regular self-inspections and routine pest control are ways to avoid pest and vermin infestation.

Economics

What are the economics for the processing facility? As one of the larger categories of unrecovered solid waste, food scrap recycling can help alleviate landfill capacity and expansion pressures. The economics and logistics of food scrap recycling present some challenges, and broad public education, policy, and possibly regulation may be necessary to motivate the market.

Collection and Transportation of Food Scraps

How will food scraps be collected and transported to the recycling facility? In order for a food scrap recycling program to be successful, requiring, encouraging or incentivizing residential and commercial municipal solid waste generators to separate organic materials from the rest of the waste stream is essential. Separation of food scraps from other organic materials at the source (source separation) may improve the economics of the food recycling process by minimizing the amount of pre-processing needed at the processing facility. In addition, costs of these programs include containers to store the food scraps and separate vehicles or modified vehicles to transport them. See the *Best Management Practices in Food Scraps Programs* report³⁵ for additional information on food scrap recycling programs.

Construction and Operation of the Processing Facility

What are the potential construction and operating costs for the various technologies and facilities under consideration? Construction and operating costs can be significant. As discussed in Chapter 4 with the Dufferin and Disco facilities in Toronto, costs of construction for large-scale waste processing facilities can range from \$800 to \$900 per design ton³⁶ and approximately \$70 per ton to operate. Operating costs should also consider costs to cure or further handle and process the digestate from an anaerobic digester.

Tipping Fees

What are the tipping fees for existing municipal solid waste handling and anticipated fees for the recycling facility? Overall, solid waste tipping fee rate increases may help to stimulate recycling and food scrap recycling efforts. As garbage tip fees increase, recycling and composting, which usually have lower tip fees, become more attractive. Future savings by reducing landfill needs should also be considered.

³⁵ Econservation Institute. *Best Management Practices in Food Scraps Programs*.2010. http://www.foodscrapsrecovery.com/EPA_FoodWasteReport_EI_Region5_v11_Final.pdf.

³⁶ Based on an estimated construction cost of \$65,000,000 for a 75,000 ton per year design processing rate for the Toronto Disco facility currently under construction.

Use of Products

What products will be generated and how will they be used? Depending on the technology used, biogas, a liquid and/or solid digestate or compost will be generated from the process. The use or sale of the products will be impacted by the strength and volatility of the markets for these products. An evaluation of the end products from the process should be conducted. Some of the potential uses include fuel for electrical generation from the biogas; and compost to be used to improve the soil to suppress plant diseases and pests, reduce or eliminate the need for chemical fertilizers, promote higher yields of agricultural crops and increase moisture retention, water infiltration, and organic matter and sequester carbon in soil when used as a soil amendment.

Anaerobic Digestion Case Studies

In North America, anaerobic digestion is commonly used in wastewater treatment plants to treat sewage sludge to reduce biological and chemical oxygen demands and in farming communities to treat manure and control odor. There are very few municipal-scale anaerobic digestion facilities to treat food scrap and only a few pilot-scale operations in the United States. As a result, there is very limited information available on the costs and economics for the construction and operation of these types of facilities. In addition, a variety of technologies for anaerobic digestion exists, with varying capability and applicability for municipal waste processing.

Two facilities were identified to provide information on the application of anaerobic digestion for processing food scraps on a municipal scale. The first facility is the Dufferin Organic Processing Facility located in Toronto, Ontario. It uses a wet digestion continuous flow process and is currently processing approximately 40,000 tons per year of source-separated organic materials collected primarily from residential households. The second facility recently began operating at the University of Wisconsin in Oshkosh, Wisconsin. This facility uses a dry digestion batch process and is designed to process 8,000 tons per year of source separated organic materials.

Dufferin Organic Processing Facility

The Dufferin Organic Processing Facility is owned by the City of Toronto and began operations in 2002. The facility occupies approximately 2.5 acres of land with approximately 24,000 ft² of buildings in a densely populated urban area. Neighboring properties are within 328 feet of the facility. It was designed and constructed by CCI BioEnergy (CCI), as a pilot plant on an existing waste management facility to process 25,000 tons per year of residential household organic materials.

The facility quickly moved from a pilot plant to a full-scale operation and is currently processing, on average, 40,000 tons per year of organic materials. Toronto's Green Bin program provides curbside organic materials collection from 500,000 households and 20,000 businesses. The combined businesses and households provide a large amount of source separated organic materials to the facility. The facility is currently undergoing an upgrade to double the design capacity of the facility to a capacity of between 50,000 and 60,000 tons per year to accommodate the current and anticipated increased throughput and to install a biogas utilization system. The original facility did not have a biogas utilization system. CCI is the operator of the facility. In addition, a second facility (the Disco Road Organic Processing Facility facility) is being constructed with a design capacity of 75,000 tons per year and a biogas utilization system.



Photo courtesy of City of Toronto, Ontario, Canada: Solid Waste Management Services

Dufferin Organic Processing Facility

Operation

Ten employees operate the facility 24 hours per day, seven days per week, but the facility only receives organic wastes on weekdays. Organic materials processed by the facility consist of approximately 75 percent residential and 25 percent commercial organic materials. Trucks containing organic materials are received in an enclosed, atmosphere-controlled building to control odors. The trucks enter the building through an air-lock and deposit the material in a receiving area. The building is partitioned on the inside to control air flow and extraction. Enclosures are installed around equipment that could release odors, and air is extracted from the enclosure. Negative air pressure is maintained in the building and around equipment, and extracted air is directed to bio-filters.

The facility utilizes an anaerobic digestion technology known as "The BTA® Process" which was developed in Europe and is licensed exclusively by CCI in the United States and Canada. Prior to entering the digestion tanks, the material is pre-processed to remove inorganic material and other contaminants. It is important that the material be free of inorganic materials prior to the digestion process to maintain the efficiency of the process and minimize the wear and tear and maintenance on the process equipment. It was noted by CCI that while protocols for separation of organic materials by the households are in place, residential materials typically contain 85 to 90 percent organic materials with the remainder being inorganic materials such plastic and glass. Commercial (e.g., supermarkets, fast food restaurants, and institutional cafeterias) waste materials typically are cleaner, but still can contain some inorganic materials (e.g., packaging, plastic or metal strapping).

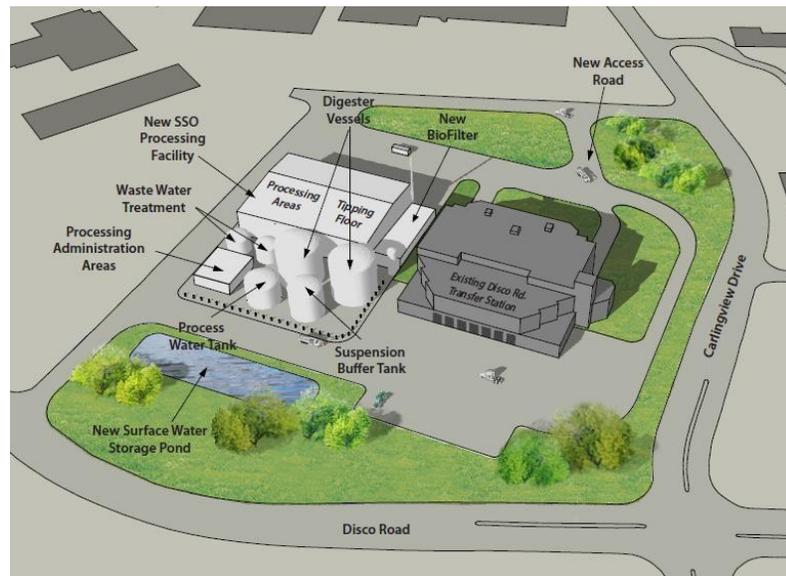


Photo courtesy of City of Toronto, Ontario, Canada: Solid Waste Management Services

Figure 4 - Disco Road Organic Processing Facility Under Construction

Preprocessing involves the introduction of the organic material to a hydropulper that uses the hydraulic friction of water to de-fiber the organic materials (e.g., separate the cotton from the plastic shell of a diaper). During this pretreatment process, materials are separated into a light fraction (e.g., plastic) and a heavy fraction (e.g., stones, sand, glass, metals, and bones). The light fraction rises to the top and is removed by a rake in the hydropulper, and the heavy fraction drops to the bottom of the hydropulper. The remaining material is a pulp that is pumped to a grit removal

system to remove the fine grit material (e.g., sand, glass shards, and plastic pieces). Residual solids (e.g., light and heavy fraction inorganic materials removed during preprocessing) are disposed of in a landfill. Residual water is discharged to the sanitary sewer. The clean pulp is pumped to the digester and is continuously mixed within the digester during the digestion process. The digester is designed for a 20-day retention time; however, retention time in the digester ranges between 11 and 19 days due to the need to process higher throughputs.

The output of the digester is a digester solid or digestate and a biogas. The digestate requires additional treatment such as aerobic decomposition to create useable compost. The digestate is transported to a third party for curing and production of high-quality commercial compost. Biogas from the digester is flared.

Economics

Specific costs for the construction and operation of the Dufferin facility were not available. However, CCI provided information on the potential range of costs based on recent cost information. In general, the construction cost of a new facility can range from \$500 to \$1,000 per ton of organic material processed with the lower end of the range typical for smaller private facilities (e.g., food processing facility) and the higher end more typical for larger municipal facilities. CCI noted that the higher costs for municipal facilities are typically driven by community issues and more conservative approaches taken by municipalities in the design and construction of the facilities. CCI is currently constructing a new facility for the City of Toronto referred to as the Disco facility. The Disco facility is designed to process 75,000 tons per year and estimated to cost \$65 million to construct. Interestingly, CCI stated that the anaerobic digestion process accounts for 10 to 25 percent of the total construction costs. The remainder of the construction costs is associated with the land; buildings; air and wastewater treatment; and mechanical, electrical, and engineering expenses.

Operating costs for organic waste processing facilities can range from \$50 to \$75 per ton of organic waste processed. Operating costs for the Dufferin facility is approximately \$70 per ton. These costs can vary depending on residual waste disposal and treatment costs, hours of operation and other operating requirements. The two largest components of the operating costs are labor and solid and liquid waste disposal. Operating costs can be offset by revenue derived from gas production and compost sales. Revenue from biogas production at the Disco facility is projected to be approximately \$30 per ton with estimated operating costs around \$70 per ton.

CCI estimates that one ton of source-separated organic materials processed can generate approximately 270 kilowatt hours of power assuming 65 percent methane content in the biogas and 35 percent efficiency of the co-generation engine. This would result in approximately 1.1 megawatts of power being generated annually for 40,000 tons per year of organic materials processed. CCI also estimates that one ton of source-separated organic materials processed can generate approximately 2,650 ft³ of pipeline-grade gas assuming 65 percent methane content in the biogas. This would

result in approximately 106 million ft³ of pipeline-grade gas generated annually for 40,000 tons per year of organic materials processed. Where biogas is used to produce energy, CCI estimates that 30 to 40 percent of the energy produced would be needed to meet the energy requirements for the facility. The revenue value of the power or gas will depend on the local energy costs and accessibility to the distribution system.

Other Considerations

The operation of the Dufferin facility over the past nine years provides several lessons for future facilities. First, odors can be successfully contained, controlled and treated resolving a major roadblock in the siting of a facility. Second, the absence of micro-nutrients (e.g., cobalt, iron, nickel and sulfide) in the feedstock can be limiting, and operation of the facility should focus on both macro and micro-nutrients required for the anaerobic digestion process. The feedstock should be periodically analyzed for the appropriate nutrients. The presence of adequate nutrients will minimize digester upsets. Third, the anaerobic digestion process is adaptable to different operating strategies; however, there is a tradeoff between throughput and biogas. Higher throughputs with shorter retention times can result in lower biogas production. In general, CCI noted that retention times ranging between 11 and 19 days will provide the ideal biogas production. Finally, the source-separated organic materials processed by the Dufferin facility resulted in good quality biogas suitable for co-generation with methane percentages around 60 percent.

Construction of a facility similar to the Dufferin facility would typically require three to five acres of land for the organic waste processing facility and up to 15 additional acres if aerobic decomposition were to be conducted on the site to cure the digestate (e.g., create compost). Less land would be required for curing if the digestate were to be pelletized. However, the pelletizing process would add additional construction and operating costs.

The construction of the Dufferin facility did not encounter any significant opposition or permitting issues since it was originally constructed as a pilot plant. The Disco facility, on the other hand, involved numerous public consultations, environmental assessments, odor abatement assurances, dust studies, noise studies, bird studies, vermin studies and appropriate mitigation plans before the permit was issued. Five locations were originally proposed and evaluated before the Disco site was selected. It took six years to obtain final approval for the construction of the facility.

Once the expansion of the Dufferin facility is complete and the Disco facility is in operation, the City of Toronto is anticipating that it could increase the amount of source-separated organics processed to 150,000 to 180,000 tons per year. Of that amount, 110,000 to 135,000 tons per year will be processed in city facilities and 15,000 to 70,000 tons per year will be processed in third-party facilities. In addition, it is anticipated that approximately 480 million ft³ per year of biogas will be generated and processed at the Dufferin and Disco facilities resulting in approximately 275 million

ft³ per year of pipeline-grade gas that will be inserted into a natural gas pipeline system and extracted at city-owned facilities for use in city buildings and city compressed-natural-gas vehicles.³⁷

The University of Wisconsin Oshkosh

The University of Wisconsin (UW) Oshkosh recently completed construction on a commercial-scale dry fermentation anaerobic digester with heat and power generation capabilities. The facility is located adjacent to the Campus Services Center and across the street from a wastewater treatment facility. It occupies less than one acre of land with approximately 19,000 square feet of buildings. The UW Oshkosh facility is designed to process 8,000 tons of organic materials per year. The feedstock will be composed of approximately 4,000 tons of agricultural wastes per year and 2,000 tons of source-separated organic materials—including food scrap—per year. The feedstock is anticipated to come primarily from campus and community sources with some portion provided by other area sources such as school districts, communities, and food processing plants. The facility began operation in October 2011.



Photo courtesy of University of Wisconsin Oshkosh
***University of Wisconsin at Oshkosh Dry Fermentation
Anaerobic Digester***

Operation

The UW Oshkosh facility utilizes a dry fermentation anaerobic digestion process supplied by BIOFerm™ Energy Systems. This is the first plant of this type constructed in the United States. It is a batch system that loads on a 28-day cycle. The plant is automated and controlled by a supervisory control and data acquisition system that can be remotely monitored.

There are four, 65 feet long by 23 feet wide by 13 feet tall concrete fermentation chambers at this facility. Because this is a batch process, agricultural and source-separated organic materials will be stored in an atmosphere-controlled enclosed area until they are introduced into the fermentation chamber. Prior to placement in the chamber, the agricultural and source-separated organic materials will be mixed to achieve the planned composition. The mixed material will then be placed in a fermentation chamber. Negative air pressure will be maintained in the enclosed areas, and extracted air will be directed to a bio-filter.

Once the chamber is filled, it is sealed by air and gas-tight doors with pneumatic locking mechanisms. The material stays stationary within the chamber while a percolate solution that contains the methanogenic bacteria is sprayed over the material from piping with spray nozzles installed in the ceiling of the chamber. Biogas from the pile is vented from the chamber to flexible

³⁷ Van Opstal, Brian. "City of Toronto Case Study in the Anaerobic Digestion of Source Separated Organic Material." California Organics Recycling Council. November 17, 2009.

biogas storage bags located above the fermentation chambers. Residual percolate and other accumulated moisture in the chamber is collected in drains in the floor of the chamber and circulated to the percolate storage tank. The percolate storage tank is a concrete tank located outside of the chamber that provides an anaerobic environment for the bacteria in the percolate. Biogas is also collected from the percolate storage tank. Biogas is continuously fed from the gas bag to a 370-kilowatt biogas combined heat and power co-generation system supplied by 2G-CENERGY. Biogas can also be directed to an emergency flare if there are operating problems with the co-generation system. After 28 days, the volume of material will have been reduced by approximately 40 percent and this digestate will be removed from the chamber and transported to a local composting facility to produce commercial grade compost. Each week one of the four fermentation chambers will be emptied and new organic materials will be placed in the chamber.

Economics

The facility is a collaborative effort between UW Oshkosh and the University of Wisconsin Oshkosh Foundation, which purchased the land. It is partially funded with a \$232,587 grant from Wisconsin Focus on Energy and a \$500,000 grant from the Department of Energy. The cost to construct the facility is approximately \$3.7 million. The facility is expected to produce 490 kilowatts of thermal energy and 370 kilowatts of electricity per year that will be utilized by the UW Oshkosh campus. In addition, it is anticipated that biogas generated from the wastewater treatment plant during the summer months, which is currently flared, will be diverted to the co-generation system. The facility is anticipated to initially produce up to 5 percent—and eventually up to 10 percent—of the campus' electricity and heating needs. Within seven to 10 years, the facility is expected to pay for itself.

BIOFerm™ Energy Systems has indicated that the facility is automated and is not a labor-intensive operation. The facility will be staffed by a facility manager plus a part-time person to load and unload the chambers. It is estimated that one person working 20 hours per week will be required to load and unload the chambers. Operating costs will also be offset by heat and electricity derived from the co-generation system and use of compost produced from the digestate on campus. UW Oshkosh is also building a laboratory to test feedstock and plans to use this facility for research and development. As a result, students and researchers will also likely be involved in the operation, maintenance and monitoring of the digester process.

Other Considerations

There were no significant problems with obtaining permits and approvals for the facility, although the approval process took some time due to the unfamiliar technology. In addition to normal construction permits and approvals, the facility required a solid waste permit, air permits for the co-generation system and the emergency flare, and a conditional-use permit to construct and operate a renewable energy plant.

Observations

Over the past 20 years, the implementation of separation and recycling programs for paper, plastics and glass has resulted in significant reductions in the volume of these materials being discarded, leaving food scrap as the largest discarded material category in the U.S. municipal waste streams. As landfill capacity continues to decrease, many municipalities are looking to food scrap recycling programs as a means to further reduce the volume of municipal solid waste discarded.

Food scrap recycling programs present a number of challenges, starting with the collection of food scraps from residential and commercial generators, to the technologies for separating and processing the food scraps. The programs also provide a number of benefits including the production of compost and the capture of methane to produce energy. Collection programs can vary and their success will depend on the type of program implemented, the cooperation of residential and commercial generators, and the specific goals of the community. Food scrap recycling technologies generally rely on either aerobic or anaerobic digestion processes. The appropriate technology or process for a particular community or facility will depend on many factors, ranging from the feedstock source, the technology used to process the waste material and the by-products generated from the process.

In the northeast, aerobic decomposition technologies are commonly used to compost grass clippings, leaves and other yard trimmings. Processing of food scrap is very limited in these composting operations due in part to the lack of separation programs for food scrap, proximity of the compost site to neighbors, change in best management practices and siting requirements for adding food scraps, as well as limitations on the amount of food scrap that can be processed in these composting facilities. Anaerobic digestion processes are commonly used in wastewater treatment plants to treat sewage sludge to reduce biological and chemical oxygen demands and in farming communities to treat manure and control odor. There are very few municipal-scale anaerobic digestion facilities for processing food scraps and only a few pilot-scale operations in the United States. As a result, there is very limited information available on operational issues, costs and economics for the construction and operation of these types of facilities for processing food scraps.

Food scrap recycling programs using anaerobic digestion technology are being widely employed in Europe to manage food scraps and other organic materials. With the market growth in Europe, anaerobic technology continues to evolve and the processing capacity continues to grow. This growth in technologies in Europe offers significant opportunity for processing food scrap in the United States. In addition, as food scrap collection programs continue to evolve, the experience and knowledge gained from these programs will help shape successful food scrap recycling programs in the future.

Resources

BioCycle Magazine. <http://www.jgpress.com/biocycle.htm>.

California Department of Resources, Recycling, and Recovery. *Statewide Anaerobic Digester Facilities for the Treatment of Municipal Organic Solid Waste*. February 2011. <http://www.calrecycle.ca.gov/swfacilities/Compostables/AnaerobicDig/DPEIR.pdf>.

California Integrated Waste Management Board. *How Anaerobic Digestion Fits Current Board Regulatory Structure*. September 2009. <http://www.calrecycle.ca.gov/publications/Organics/2009021.pdf>.

Center for a Competitive Waste Industry. *Beyond Recycling – Composting Food Scraps and Soiled Paper*. January 2010. http://beyondrecycling.org/pdf_files/FinalReport.pdf.

Econservation Institute. *Best Management Practices in Food Scraps Programs*. 2010. http://www.foodscrapsrecovery.com/EPA_FoodWasteReport_EI_Region5_v11_Final.pdf.

Levis, J.W.; Barlaz, M.A.; Themelis, N.J.; & Ulloa, P. "Assessment of the State of Food Waste Treatment in the United States and Canada." *Waste Management*. 2010. http://www.seas.columbia.edu/earth/wtert/sofos/Food_Waste_Web_Barlaz_Themelis.pdf.

New York City Economic Development Corporation and New York City Department of Sanitation. *Evaluation of New and Emerging Solid Waste Management Technologies*. September 2004. http://www.nyc.gov/html/dsny/downloads/pdf/swmp_implement/otherinit/wmtech/phase1.pdf.

Regenstein, Joe.; Kay, David; Turci, Paul; & Outerbridge, Thomas. *Small to Medium Scale Composting of Food Wastes in New York City*. August 1999. <http://compost.css.cornell.edu/NYCComposting.pdf>.

U.S. EPA. *Biosolids Technology Fact Sheet - In-Vessel Composting of Biosolids*. (EPA 832-F-00-061). September 2000. http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_invessel.pdf.

Glossary

Aerobic Decomposition – the breakdown of organic materials under controlled conditions by microorganisms in the presence of oxygen.

Anaerobic Digestion – the breakdown of organic materials under controlled conditions by microorganisms in the absence of oxygen.

Biogas – a gas comprised primarily methane and carbon dioxide produced by the biological breakdown of organic matter in the absence of oxygen.

Brownfield – a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.³⁸

Compost – a humus rich in nutrients and minerals resulting from aerobic decomposition of organic materials that can be used as a soil amendment.

Composting – a biological process in which organic materials such as food scraps, leaves, grass trimmings and paper are broken down by microorganisms in the presence of oxygen creating a humus rich in nutrients and minerals that can be used as a soil amendment.

Digestate – the solid that remains at the completion of the anaerobic digestion process. The digestate typically requires a composting stage be employed after digestion to break down materials that cannot be broken down by the anaerobic microorganisms.

Dry Anaerobic Digestion – An anaerobic digestion process that requires total solids in the range of 20 to 30 percent.

Feedstock – the raw material used to create a product. For composting, the feedstock is the organic material introduced to the aerobic decomposition or anaerobic digestion processes.

Food Scraps (Food Waste) – any food substance, raw or cooked, which is discarded or intended or required to be discarded. Food wastes are the organic residues generated by the handling, storage, sale, preparation, cooking, and serving of foods.³⁹

In-Vessel Aerobic Composting – a controlled aerobic decomposition process that uses a combination of rotating drums, silos or tunnels to mix and aerate the materials and windrow, or other form of composting, to cure the materials.

In-Vessel Anaerobic Digestion – an anaerobic digestion process using a combination of air-tight vessels designed to capture gasses for conversion to energy, and windrow or other form of composting to cure the digestate and create compost.

Mesophilic Digestion – an anaerobic digestion process that requires moderate temperatures in the range of 85°F to 95°F.

Methanogenic Bacteria – an anaerobic microorganism that grows in the presence of carbon dioxide and produces methane gas.⁴⁰

Municipal Solid Waste – garbage or refuse generated by households, commercial establishments or institutional facilities including durable goods, non-durable goods, containers and packaging, food wastes and yard trimmings, and miscellaneous inorganic waste materials.

³⁸ http://www.epa.gov/brownfields/basic_info.htm

³⁹ <http://www.epa.gov/osw/conserve/materials/organics/food/>

⁴⁰ <http://medical-dictionary.thefreedictionary.com/Methanogenic+bacteria>

Soil Amendment – a material added to soil to improve plant growth and health.

Static Aerated Windrows – an aerobic decomposition process in which oxygen levels are maintained in windrows by forcing air through them with a blower and aeration tubes.

Thermophilic Digestion – an anaerobic digestion process that requires high temperatures of 130°F or greater.

Turned Windrows – an aerobic decomposition process in which oxygen levels are maintained in the windrows by mechanically turning the pile.

Wet Anaerobic Digestion – an anaerobic digestion process that requires total solids content to be 10 percent or less.

Windrow – piles of organic materials in long rows that can be six to 10 feet high, 12 to 20 feet wide, and hundreds of feet long.