Long-Term Disposal Alternatives Analysis

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Cumberland County Solid Waste

Cumberland County, North Carolina

January 28, 2022

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Contents

Tables

Figures

1 Introduction

The Cumberland County (or the County) Solid Waste Department manages waste from residential and commercial customers within the County. As of 2021 a total of 61,520 households are currently serviced by this program. The department is comprised of multiple facilities operating in various capacities. The Ann Street Landfill serves as the primary disposal center for most of the waste collected. The Wilkes Road Compost Facility collects and processes large amounts of organic waste. There are 16 container sites spread out around the County that homeowners can use to conveniently drop off and sort their waste products. A household hazardous waste building located on Wilkes Road is also used to collect and safely manage hazardous waste from homeowners.

The Ann Street Landfill provides solid waste disposal for municipal solid waste (MSW) and construction and demolition debris (C&D) generated within the County. The landfill site covers approximately 355 acres and has been operating for over 40 years with a current 30-year franchise agreement with City of Fayetteville that expires in 2038. Waste disposal is primarily provided within the lined Subtitle D Landfill and the unlined C&D landfill.

The Wilkes Road Composting Facility is situated on 51 acres and accepts land clearing debris, yard waste, clean wood, and wooden pallets. The facility is comprised of a stockpile and processing area, a stockpile for screened overs, an area for screened fines curing and public pickup, and an equipment storage area. The composting facility utilizes much of the available area on the site and is permitted to store up to 31,500 CY of materials.

Based on existing waste generation rates and the consumption of landfill airspace, the County anticipates the two landfills will both reach capacity in approximately 10 years. Cumberland County is investigating landfill expansion options to manage solid waste and C&D waste before the landfills reach capacity. The County also desires to evaluate other alternatives, such as viable waste reduction technologies to reduce the amount of waste going to the landfill.

The goal of this analysis is to summarize the technical viability and commercial readiness of waste reduction technologies, and to assess whether any of these technologies may provide feasible alternatives to landfill disposal if implemented into the County's current solid waste program. This analysis also considers the need for inter-municipal partnerships with other communities that may be necessary to aggregate the quantities of waste needed to sustain some of these technologies, as economy of scale is an important factor when considering waste reduction technologies. The estimated ranges of costs provided herein are based on HDR's recent experience and industry knowledge working with similar technologies on both public and private sector projects.

In 2021, the County disposed of approximately 138,000 tons of MSW and 57,000 tons of C&D at the Ann Street Landfill site and over 36,000 tons of yard waste at the Wilkes Road Composting facility. A projection of annual waste material received over the next 30 years based on a 0.5 percent population growth and current waste disposal practices is provided in Figure 1.1.

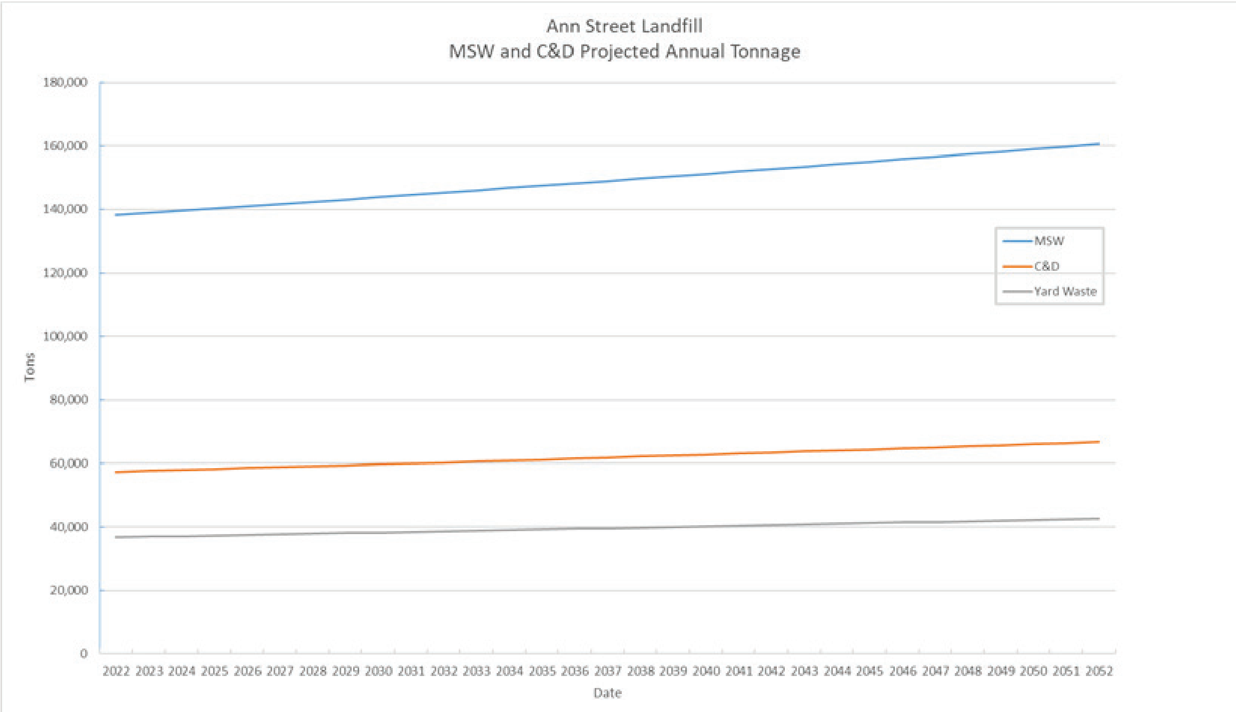

Figure 1.1 Annual Tonnage Projections

The most preferred strategy in the waste management hierarchy is waste reduction as seen in Figure 2.1 Waste reduction can include reusing or donating items, reducing packaging and buying in bulk, redesigning products and packaging, and reducing the toxicity. Many communities in the United States have implemented various solid waste programs to reduce the volume of waste going to landfills.

Figure 2.1 USEPA Waste Management Hierarchy

- Food Waste Reduction Programs
  - Food waste reduction programs donate edible food to people in need and have become popular over the last few years. There are several smartphone apps that allow users to purchase surplus food at discounted rates from restaurants or supermarkets.
- Fix-It/Repair Clinics
  - Fix-it or repair clinics can help reduce quantities of waste by refurbishing or repairing items that would otherwise be disposed. Many people lack the knowledge to make small repairs to items such as clothing, small household items, bikes etc., that would allow an item to continue to be used.
- Reuse/Donation Centers
  - Reuse and donation centers can help reduce quantities of waste entering the landfill. There are several donation centers within Cumberland County such as the Re-Store Warehouse, 2nd Chance Thrift Shop, The Salvation Army, and Goodwill Industries. In addition, the Ann Street Landfill currently collects electronics and shredded paper. Incorporating donation drop off options at the landfill site or convenience sites in conjunction with local organizations could have a positive impact on reducing the volume of waste entering the landfill.
- Materials Exchange Events
  - A material exchange network and/or partnerships with existing organizations that collect gently used materials such as arts and crafts, clothing, school and office supplies, C&D waste, used bicycles, sports equipment, tools etc. could be explored. This option would focus more on larger scale diversion of items, potentially from the commercial sector, rather than on household materials.

- The County could also consider supporting reuse events that allow residents to obtain gently used materials for reuse (e.g., furniture, toys) in a convenient, yet structured way so that the events do not contribute to uncleanliness, litter, or illegal dumping. The events could include garage sales or giveaway events in common areas. Many municipalities promote once or twice-yearly events, generally held in the spring or fall.

- Sharing Libraries
  - Sharing items that are used infrequently, such as bikes, tools, and kitchen appliances are becoming more prevalent in many communities. The County could develop partnerships with existing organizations to provide these opportunities to residents.

2.1 Benefits

Incorporating different waste reduction programs into the community could help to divert waste from landfills. In addition, waste reduction programs could help to reduce waste hauling costs; however, may not reduce the volume of waste sent to the landfill. Waste reduction puts an increased emphasis on purchasing and management of waste. Reduction programs can encourage recycling in addition to buying less. Waste reduction programs drive awareness of waste generation and can lead to impacts on the remainder of the hierarchy including recycling participation.

2.2 Challenges

Waste reduction programs can be difficult to implement and won't have a positive influence on the solid waste system without significant participation from residents. To successfully implement different waste reduction programs in Cumberland County, ongoing education and outreach is necessary. The education and outreach needed can vary from simply updating website information to hiring additional staff to lead the effort. Reduction efforts can also be difficult to measure and document.

Waste reduction programs impact can be challenging to measure without elaborate tracking systems. Waste reduction activities may have a measurable reduction of 1 percent or less; however, the waste reduction programs recommended will support waste diversion in the system as a whole.

2.3 Cost

Education and outreach for the waste reduction programs is necessary to ensure residents understand the programs that have been implemented and the importance of participating in these programs to ensure they are effective. Education and outreach for each of these waste reduction programs can range between $50,000 to $100,000 if the programs are standalone. There can be efficiencies gained by providing education on multiple programs.

Table 2.1 shows the estimated cost to adopt each waste reduction program. Full time employee (FTE) average annual income is $47,000 in Cumberland County, North Carolina according to

United States Census Data[1]. HDR assumed an additional 30 percent of the average FTE salary to be attributed to benefits; therefore, an FTE employee including benefits totals $61,000.

Table 2.1 Costs for Solid Waste Reduction Programs

Program	Cost (Low)	Cost (High)	Description
Food Waste Reduction Program	$90,275	$180,550	A 0.25 FTE or 0.5 FTE may be needed to establish a food waste reduction program for the County ($40,275 to $80,550 per year) $50,000 to $100,000 for promotional and educational (P&E) material such as flyers, web support, outreach.
Fix-It/Repair Clinics	$92,675	$183,150	A 0.25 FTE or 0.5 FTE to administer program and support through P&E ($40,275 to $80,550 per year) P&E material such as flyers, web support, outreach ($50,000 to $100,000). Facility rentals to hold the clinics is estimated at $200/event. Assume 1 event per month ($2,400/year). Assume volunteers lead clinics.
Reuse/Donation Centers	$90,275	$180,550	A 0.25 FTE or 0.5 FTE to administer program and support through P&E ($40,275 to $80,550 per year) P&E material such as flyers, web support, outreach ($50,000 to $100,000). Assume County develops reuse center(s) located at one or more container sites. No additional cost to operate.
Materials Exchange Events	$90,275	$180,550	A 0.25 FTE or 0.5 FTE to administer program and support through P&E ($40,275 to $80,550 per year) P&E material such as flyers, web support, outreach ($50,000 to $100,000). Assume on-line network established, no physical location required.

[1] https://www.census.gov/quickfacts/cumberlandcountynorthcarolina

Program	Cost (Low)	Cost (High)	Description
Sharing Libraries	$90,275	$180,550	A 0.25 FTE or 0.5 FTE to administer program and support through P&E ($40,275 to $80,550 per year) P&E material such as flyers, web support, outreach ($50,000 to $100,000). Assume at least two sharing libraries are developed by the County. Assume located in an existing public library or other County owned public building. Assume materials are obtained by donation. Assume operated and maintained by County staff. No additional added cost.

3 Recovery of Resources from Solid Waste

According to the EPA, 292.4 million tons of MSW was generated in 2018 in the United States. Of the waste generated in 2018, approximately 48 percent was recyclable materials (paper, metal, glass, and plastic) and approximately 40 percent was organic material (food, yard trimming, and wood) . Programs to recover resources, such as organics, recyclables, C&D waste, metals, etc. can have a positive impact, reduction, on the amount of waste sent to a landfill.

Cumberland County currently generates 150,000 tons of residential MSW per year, 200,000 tons of commercial waste per year and 70,000 tons of C&D waste per year. Residential waste is disposed at the Ann Street Landfill. Most commercial waste is not managed by the County and is disposed of at Sampson County landfill. A majority of the C&D waste is disposed of at Ann Street C&D landfill and a smaller portion is disposed of at Sampson County landfill.

Residential and commercial recyclables, organics, and other resources can be recovered from the solid waste stream through programs targeting a specific material. Due to the high volume of commercial waste generated in Cumberland County, a large percentage of this material could be diverted from the landfill if commercial businesses targeted and separated cardboard, some organics (specifically food waste), scrap metal, or other material to be recycled. A certain percentage of recyclable materials in the residential waste could also be recovered and diverted from landfills, but the type and quantity of these recyclable materials will depend on which entity collects the waste.

Currently Cumberland County operates 17 container sites for homeowners to drop off household garbage, yard debris, cardboard, recyclable containers such as glass bottles and jars, plastic bottles, and aluminum cans, metals, textiles, electronics, televisions, magazines, newspapers, office paper, white goods, cooking oils, tires, and vehicle batteries. These container sites, as identified in Figure 3.1 are essential to the County's solid waste system and could also be utilized to accept additional material such as C&D waste.

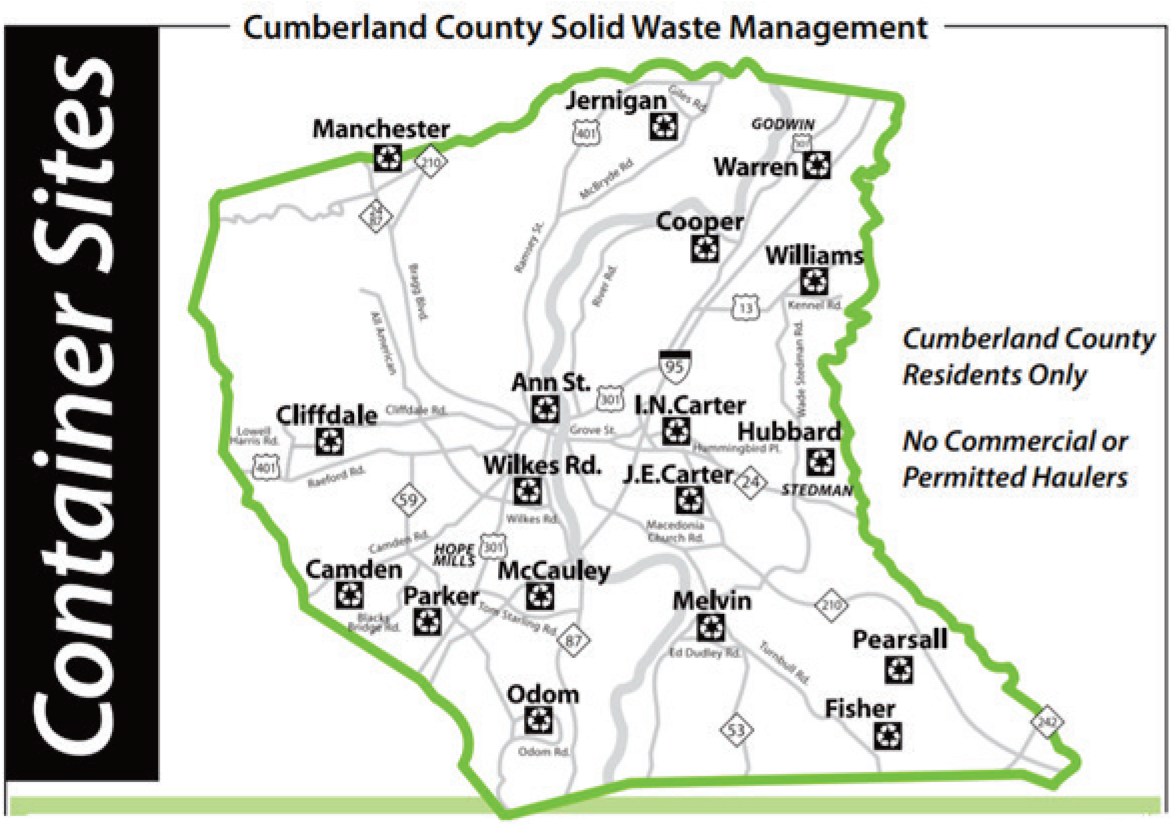

Figure 3.1 Cumberland County Container Sites

3.1 Benefits

Targeting commercial volumes of recoverable or recyclable materials could potentially remove a high volume of material from landfill. Recovering materials like scrap metal can also be an source of revenue for a business. Recovering materials from solid waste could help to reduce waste hauling costs; however, may not have a major impact on the volume of waste sent to the Ann Street Landfill.

3.2 Challenges

Programs currently in place to collect residential and commercial waste and recyclables may need to be altered to be able to target certain materials. Incorporation of food waste or greater emphasis on organics reduction would likely strain operations at Wilkes Road which is already at or near its operational capacity and it is likely that an alternate composting facility would need to be sited and either County owned and operated, County owned and privately operated, or privately owned and operated. In either case, capital investment would be required. In addition, the waste reduction programs recommended are not likely to have a major impact on the solid waste system; however, they would support waste diversion and could drive waste diversion activities in the system as a whole.

3.3 Cost

The cost for this option varies significantly depending on the program chosen to implement. Regardless of the program and material(s) chosen to divert, education and outreach is essential for success. Education and outreach for introducing a new material accepted at the container sites or specifically targeting a material in the commercial stream to recycle can range between $50,000 to $100,000. In addition, the cost for a location to manage materials would also need to be considered.

If additional food waste or greater emphasis on organics reduction occurs, current capacity will not be adequate at the Wilkes Road Facility. The cost for siting a new organics processing facility could range from $10 million to $15 million depending on the type of technology (aerated static pile or turned windrow). The operation and maintenance costs for a new organics processing facility that can process 38,000 to 46,000 tons per year (TPY) could range from $1.4 million to $2.7 million. The cost per ton processed ranges from $60 to $90 per TPD over 20 years which is inclusive of land acquisition, facility costs, and processing equipment, and 4 percent interest rate.

4 Mixed Waste Processing of Solid Waste

4.1 Material Recovery Facility

Cumberland County and the City of Fayetteville currently send their recyclables, commingled and fiber, to Pratt Industries in Fayetteville, NC. A new or additional material recovery facility (MRF) in Cumberland County is not recommended at this time, as the existing local infrastructure is effectively managing the recyclable materials collected.

4.2 Mixed Waste Processing Facility

Mixed waste processing of solid waste is the separation of recyclables and divertible materials from residual waste for landfilling or another appropriate waste processing application. A mixed waste processing facility (MWPF), sometimes referred to as a “dirty” MRF or advanced materials recovery system, accepts and processes mixed MSW and recovers recyclable materials and sometimes organics through a series of mechanical separation and recovery systems. MWPFs generally yield a much lower recovery rate and lower quality of recovered recyclables due to the nature of the feedstock when compared to conventional MRFs; however, they can provide additional landfill diversion compared to single or dual stream recycling, especially if organic materials can be recovered.

MWPFs can sort and recover many types of recyclable materials using optical sorters, eddy currents, magnets, and pneumatic sorters as well as traditional picking lines. The MWPF process begins with mixed solid waste from residential and/or commercial collection vehicles being off-loaded onto a tipping floor. Materials are first sorted on the floor using manual labor and mobile equipment to remove larger or bulky items such as appliances, dimensional wood, metal, or large pieces of plastics that might interrupt or damage operations of the advanced processing systems.

Materials are then processed through multi-stage screens to separate fiber (cardboard, newspaper, and mixed paper), plastic, metal and glass containers, and small contaminants. This is usually accomplished through the use of mechanical, optical, or pneumatic screening equipment and/or labor to separate materials into size classifications and/or light versus heavier materials. Fiber is usually sorted optically, or hand sorted off elevated conveyor platforms into commodities and dropped into bunkers below. Containers are processed through ferrous magnets, optical sorters, robotic sorters, hand sorters, and eddy current separators. The small contaminant stream (dirt, rocks, broken glass and ceramics, bottle caps, etc.) may be further processed by optical/pneumatic sorting, magnets and eddy current separators to recover metals, fiber, and a glass-rich stream.

Sorted material is moved from bunkers and baled (fiber, plastic, metal) or loaded directly into roll-off trucks (glass). The remaining material is shipped to a local landfill or another appropriate waste processing/conversion facility. The typical purpose of this type of MWPF is to remove recyclable and organic material from MSW prior to landfilling or for pre-processing prior to an advanced conversion technology or other technologies such as engineered fuel production (also known as refuse derived fuel (RDF), waste-to-energy (WTE), composting, or anaerobic digestion (AD). Traditional “dirty” MRFs typically recover from 10 to 25 percent of the recyclable waste stream. There are claims that an advanced MWPF can achieve up to 50 percent recovery rate. However, diversion rates above 50 percent can only be achieved if the facility diverts both recyclable and other organic and non-recyclable materials such as food waste, leaf and yard waste and C&D debris.

There is a wide range of capacities for MWPF operating throughout the world. Typical capacity is between 200 tons per day (TPD) and 1,500 TPD using multiple sort lines and operating additional shifts. MWPFs can have a useful operating life of 20 to 30 years if proper maintenance is provided. Many MWPFs will be retrofitted throughout their lifespan to replace equipment that wears out; to provide new processing equipment in response to changing waste stream composition; to adapt to commodity market fluctuations; or to meet downstream recovery and/or feedstock specifications. Figure 4.1 shows a photo of a MWPF in California.

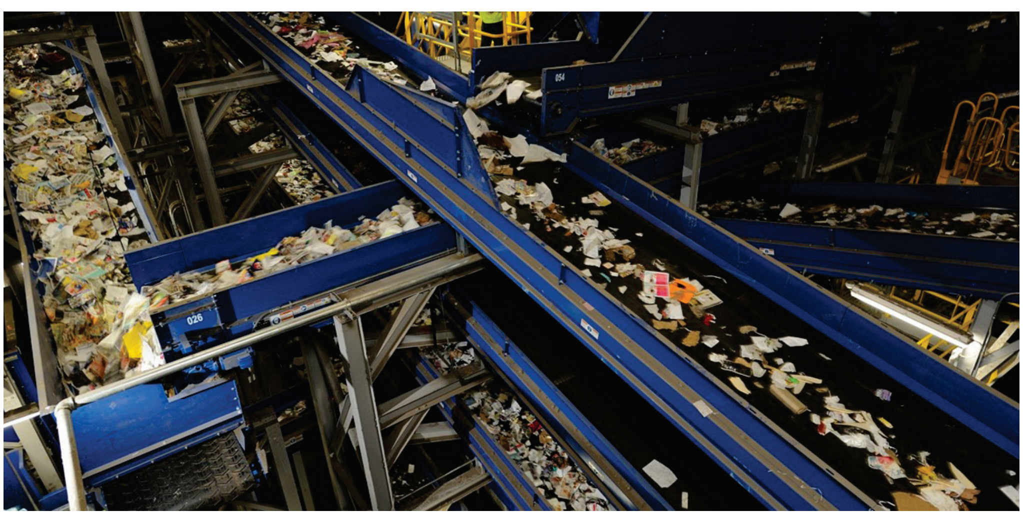

Figure 4.1 Newby Island Resource Recovery Park, California

4.2.1 Benefits

MWPFs are fully developed and used throughout the United States and the world to process MSW (either mixed or commingled) to recover recyclable and divertible materials. This technology has the ability to process a wide range of MSW materials and yield potentially high recyclable and recovery rates. MWPFs are a well proven technology, and various mechanical, pneumatic, and optical processes are updated continually. This technology is being used more and more as a pre-processing step in preparing feedstock for thermal, biological, and chemical processes. A local benefit is the creation of construction jobs over the 1 to 2-year construction period and approximately 20 to 60 permanent jobs, depending on the size and complexity of the facility.

To help combat low public participation rates of traditional recycling programs and minimize collection costs, such as collection of curbside source-separated recyclables and source separated organics, some communities are turning to MWPFs to either capture additional recyclables or as a pre-sorting operation prior to more advanced conversion technologies.

4.2.2 Challenges

The economics of MWPFs are dependent largely on fluctuations in the commodity market and local waste stream. An end use that is consistent and long-term must be established for the products. Environmental impacts of MWPFs, similar to other waste management facilities, must be mitigated such as noise, dust, and odor. The most common issue is that the available equipment is not able to extract recyclables from the MSW waste stream and provide a clean enough product for the recycling industries end-users. MWPFs typically have higher capital and operating costs than landfilling in the United States; however, other benefits such as increased landfill diversion and reduced greenhouse gas impacts should be considered.

4.2.3 Cost

MWPF’s require about two 50 tons per hour lines to be economically viable. Assuming each line operates for 16 hours a day with 8 hours of downtime for maintenance, a MWPF with 90 percent availability processes about 525,600 tons a year or about 1,500 TPD. A 1,500 TPD MWPF has an estimated capital cost of $50 million or approximately $33,000 per ton of daily design capacity. Over a 30-year life, this equates to $3.05 per TPD; or over a 20-year life, this equates to $4.56 per TPD .

Operations and maintenance (O&M) costs consist primarily of labor, equipment maintenance, and disposal costs for residue. A survey conducted in 2019-2020 concluded that the average processing costs for MWPFs were $112/ton and the average processing costs for source separated MRFs were $60/ton. O&M costs typical decrease on a per ton basis as facility throughput increases. In a 2020 survey, it was noted that MWPFs received approximately $42/ton for their recyclables and source separated MRFs received approximately $53/ton.

A total cost per ton for a 30-year MWPF is estimated to be about $115/ton. Present day dollars were not escalated over time and did not include any annual interest rates.

5 Recovery of Heat, Fuel or Electricity

5.1 Gasification

Gasification is a process that transforms a carbon-based material, such as MSW or biomass, into recoverable by-products and energy under high temperatures and moderate to high pressure without combustion. Gasification converts the solid and liquid organic waste materials into a gas and smaller amounts of solid and liquid by-products through an exothermic chemical reaction. The gasification process differs from traditional combustion due to the low amounts of oxygen needed to generate the high temperatures and convert the waste materials.

The gas generated from this process can be treated to generate a synthesis gas (or "syngas") that can be used as a fuel to generate electricity directly in a combustion turbine or internal combustion engine, or further treated and processed to be used as a chemical building block in the synthesis of liquid biofuels. A common commercial application for gasification processes that use mixed MSW as a feedstock involves firing the syngas produced directly in a heat recovery steam generator to produce steam. The steam generated can be used directly or passed through a steam condensing turbine to generate electricity. Figure 5.1 shows the gasification process.

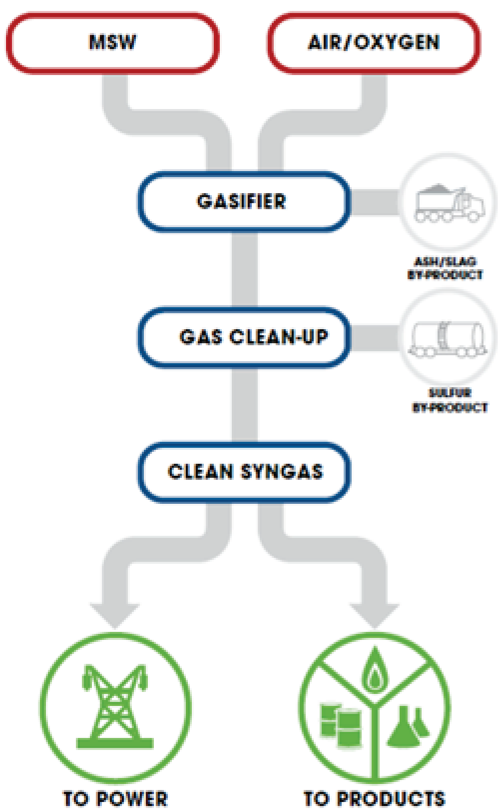

Figure 5.1 The Gasification Process

There are a wide variety of technology designs that can be defined as gasification, including bubbling fluid bed and circulating fluid bed gasifiers, upflow and downflow gasifiers, among others. These different types of gasifiers can vary widely by arrangement and the type of materials they can process but all still operate under similar thermochemical principles. In addition, many gasification technologies are sensitive to the type, composition and even the size of the materials the technology can process. The feedstock for many gasification technologies must be prepared from the mixed or “raw” incoming MSW through shredding and pre-sorting to pull out bulky materials and other inorganic materials, such as dirt, glass/grit, and metals that may cause operating issues in the gasification unit. Therefore, these technologies are often coupled to an advanced front-end separation and size reduction, which results in lower fuel yields (less fuel per ton of MSW input) when compared to other technologies.

Gasification facilities that combust syngas generated from MSW generates many of the same pollutants as traditional combustion processes, like WTE facilities. However, the volume and concentration of these air pollutants should theoretically be lower due to lower oxygen concentrations and higher temperatures. If the syngas generated by a gasification technology is being used for further processing (e.g., as part of a catalytic process to generate a liquid fuel), then additional gas cleaning and conditioning equipment is required to remove impurities and fine particulates. These technologies also produce small amounts of char or ash that can either be re-used or will require landfilling. The quantities of the ash/char produced would be similar or less than traditional WTE technologies (<90 percent by volume and <20 percent by weight). Other metals and inert materials can remain in the char/ash and may be recovered after processing.

The majority of the commercial-scale (i.e., greater than 100 TPD) gasification facilities are located in Europe and more so in Asia (specifically Japan). Some of these facilities have been operating for over 2 decades, but it is very difficult to get reliable operating and cost data for these facilities in HDR’s experience. These facilities are known to process a variety of feedstock materials using units sized from about 100 TPD to 275 TPD which are usually combined in multi-unit configurations when developing a facility to create an overall capacity of 500 TPD or greater. Some gasification facilities in Japan utilize feedstocks with high energy content, such as industrial wastes (e.g., shredded automobile fluff), or a combination of these feedstocks and MSW. The drivers for the use of gasification in Japan are largely related to the lack of available landfill capacity and very stringent emission standards, which favor the use of this technology.

Enerkem Alberta Biofuels located in Edmonton, Alberta, Canada is an example of a facility that uses a form of gasification coupled with a catalytic process to produce a bio-methanol and ethanol from a pre-processed MSW stream. This facility reportedly began commercial operation in 2016, but very little operating data and new information regarding this facility has been reported or published. There are other small and pilot-scale gasification facilities operating in North America that utilize some fraction of a mixed MSW waste stream as a feedstock to the process . Thermal gasification of MSW in the United States has been attempted for many years, but many of these facilities experienced financial difficulties and technical/design issues when scaling-up to commercial operations. Currently, gasification technologies in North America are mostly limited to demonstration or pilot scale operations with limited operational history. This is partially due to economics due to low electricity prices and lower landfill tipping fees in the United States.

In other parts of the world, such as Japan and parts of Europe, waste tipping fees are much higher than the United States (in excess of $250/ton in some cases) due to landfill levees, regulations and even bans that are in place to discourage landfill disposal and helps make gasification and other waste reduction technologies more financially viable. Front-end processing of MSW is costly and difficult and is necessary to achieve a homogenized and higher BTU-content MSW feedstock suitable for some gasification technologies. In addition, many of the gasification facilities are having issues meeting the gas quality and energy content of the syngas in order to allow the engines or other power operating equipment to efficiently produce electricity.

5.1.1 Benefits

Gasification operators assert one of the benefits of gasification is very high conversion levels of the incoming MSW stream through the thermal process (above 90 percent by volume), as well as an added reuse benefit for the slag material generated that is not leachable and can be sold as aggregate to industrial users. In addition, the emissions from gasification technologies are theoretically lower than that of a WTE or direct combustion process. As noted previously, obtaining actual emissions and operation data from operating facilities is difficult to obtain or verify due to the lack of commercial-scale facilities in North America. Other benefits include the production of energy, or a liquid fuel if the syngas produced is further cleaned and passed through a catalytic process (e.g., Fischer-Tropsch). Local benefits include the creation of construction jobs over the 1 to 3-year construction period and 25 to 75 permanent jobs over the life of the project.

5.1.2 Challenges

Although there are some commercial scale facilities in Europe and Asia, there has been limited commercial application using mixed MSW in North America. The technology may only efficiently process a specific subset of waste materials (not mixed MSW as reviewed in this document) with a higher energy content, such as wood waste, tires, carpet, scrap plastic, or other waste streams. Typically, advanced front-end separation and size reduction is required for these technologies. In addition, the challenge to scale up to commercial operations for gasification technologies in the United States has been impacted by economics due to low electricity prices and lower landfill tipping.

5.1.3 Cost

The cost for implementing the gasification process is on the higher end of the options considered here. The front-end processes including source separating into a homogenous product remains one of the most difficult tasks. Preparing MSW for many gasification technologies involves a large amount of mechanical processing, which greatly impact operating costs and can account for as much as 40% of the total plant capital costs.

A 220 TPD gasification plant has an estimated capital cost of $170 million or approximately $773,000 per ton of daily design capacity. Assuming an 85 percent availability, over a 30-year life, this equates to $83 per TPD; or over a 20-year life, this equates to $124 per TPD. Operation and maintenance costs for the 220 TPD plant was estimated at $36/TPD.

A total cost per ton for a 30-year gasification plant is estimated to be about $119/TPD over 30 years (excludes up front processing costs). Present day dollars were not escalated over time and did not include any annual interest rates.

Gasification, in all its forms, tends to be more modular in size and design and have comparable or higher capital costs than a similar size WTE facility. This is especially true when waste requires pre-processing. While they do have lower emissions and generate less ash, if Cumberland County was to consider a thermal technology, these benefits will not likely offset the higher costs of constructing a suitably sized gasification plant.

5.2 Plasma Arc Gasification

Plasma arc gasification is a subset of thermal gasification that uses carbon electrodes to produce a very-high-temperature arc ranging between 5,000 to 12,000 degrees Fahrenheit to convert the feedstock into a syngas and molten slag. The high-energy electric arc that is struck between the two carbon electrodes creates a high temperature ionized gas (or plasma). The intense heat of the plasma breaks the MSW, and the other organic materials fed to the reaction chamber into basic elemental compounds. As the feedstock gasifies, a low-BTU syngas (i.e., approximately 30 percent the heating value of natural gas) is generated that can be suitable for combustion to recover the heat in a boiler. The technology providers claim the high temperatures produce a cleaner and higher quality syngas, which makes it more suitable for internal combustion engines or even gas combustion turbines to produce electricity. The inorganic fractions (glass, metals, etc.) of the MSW stream are melted to form a liquid slag material, which when cooled and hardened encapsulates heavy metals. The ash material forms an inert vitrified or glass-like slag material that may be marketable as a construction aggregate. Metals can also be recovered from both feedstock pre-processing and from the post-processing slag material. Figure 5.2 shows a plasma arc gasification system.

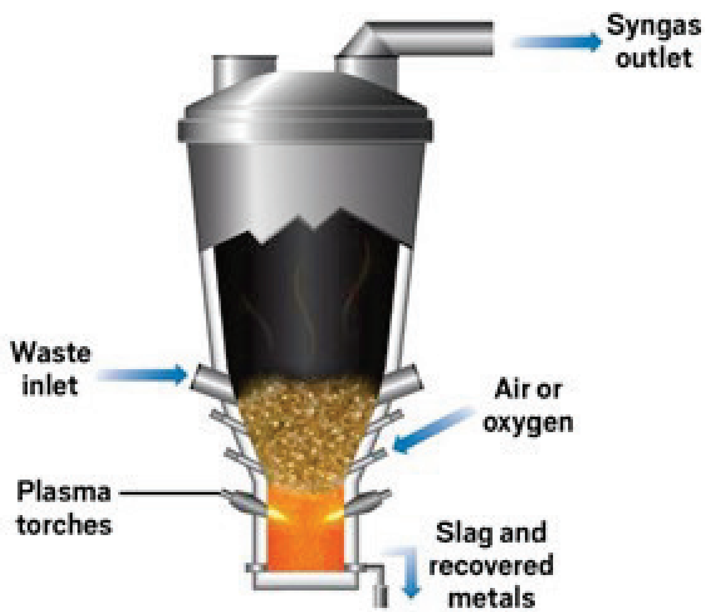

Figure 5.2 Plasma Arc Gasification Diagram

Similar to other gasification processes, the MSW feedstock requires pre-processing to remove bulky waste and other inorganic materials, as well as for size reduction. Vendors of this technology claim efficiencies that are comparable to conventional mass burn technologies (600-700+ kWh/ton (net)). Some vendors are claiming even higher efficiencies (900-1,200 kWh/ton (net)). These higher efficiencies may be feasible if a combined cycle power system is proposed that uses both a steam turbine and a gas combustion turbine. However, the electricity required to generate the plasma arc, as well as the other auxiliary systems required, brings into question whether more electrical power or other energy products can be produced than what is consumed in the process. Although combined cycle power plants using natural gas are commercially proven, using a mixed MSW stream and plasma arc technology has yet to be proven on a continuous operating basis. On a smaller scale, the plasma technology has been employed successfully on cruise ships and most recently on the USS Gerald Ford supercarrier for the United States Navy. However, these examples are on a much smaller scale.

5.2.1 Benefits

This technology claims to achieve lower emissions of criteria pollutants compared to more conventional technologies, like mass burn and RDF processes. However, the gas clean-up technology and/or air pollution control equipment required would be similar to other technologies. The high temperatures generated by the plasma arc technology has made it an attractive option in some parts of the world to process and destroy certain hazardous waste materials, such as asbestos and some liquid wastes.

5.2.2 Challenges

There are some plasma arc gasification units operating around the world that process a variety of feedstocks, but there are currently no commercial-scale continuously operating units in the United States that process MSW. There have been several projects that attempted to apply this technology on a commercial scale in North America and the United Kingdom (U.K.); however, a number of these projects failed to meet both technical and financial hurdles. Several larger-scale projects have failed in North America, including a 600 TPD facility that was planned for Saint Lucie County, Florida and a 110 TPD unit in Ottawa, Canada. In the U.K., AlterNRG teamed with Air Products to build a 1,000 TPD plasma gasifier in Tees Valley Facility in Billingham, England. This facility was designed to be a combined cycle power plant but was plagued by significant technology challenges during start-up due to scale-up issues that ultimately led Air Products to abandon the project after an almost $1 billion USD write-off.

5.2.3 Costs

Plasma-arc gasification has recently experienced several high-profile closures and shut-downs in North America and the U.K. Because plasma-arc has a higher capital cost than a similar size WTE facility and a poor track record using MSW as a feed stream, there is no obvious benefit that a plasma-arc facility has over a traditional WTE technology.

5.3 Pyrolysis

Pyrolysis technologies are closely related to gasification and some facilities can fall into either technology category depending on how they are operated. Pyrolysis is generally defined as the process of heating MSW in an oxygen-free (or reducing) environment (700° to 1,500°F) to produce a combustible gas, a liquid product, and a carbon-rich solid residue or char. This is similar to what is done to produce coke from coal or charcoal from wood. The feedstock that is generally used in pyrolysis is homogeneous, unlike MSW, and typically includes coal, clean biomass, and even waste tires. MSW may be used in some operations after pre-processing to obtain a homogeneous feedstock (similar to refuse-derived fuel).

Similar to gasification technologies, pyrolysis is often proposed as the initial thermal treatment module connected to a series of other systems designed to produce chemicals or other by-products. One recent example is in Kern County, California, a pilot project that is under development by Ways2H, a waste-to-fuel technology that is classified as gasification; however, it uses pyrolysis to generate a gas that can be purified and reformed and used in high temperature fuel cells to generate Hydrogen (H2). For other pyrolysis operations, syngas is produced and used as fuel in boilers with heat recovery steam generators, or in internal combustion units or gas turbines, provided that the syngas is adequately cleaned. Pyrolysis technologies have also been used to convert waste plastics that are not easily recyclable into a bio-crude and fuels. There are a number of pilot projects in North America that are experimenting with processing plastics using pyrolysis, including the Agilyx technology in the Pacific Northwest. Some other examples of vendors that offer the pyrolysis technology include Mitsui; Compact Power; PKA; Thide Environmental; WasteGen UK; International Environmental Solutions (IES); SMUDA Technologies (plastics only); and Utah Valley Energy. The Agilyx process flow diagram can be seen in Figure 5.3.

Figure 5.3 Agilyx Process Flow Diagram

Similar to gasification technologies, the air emissions generated from pyrolysis systems are primarily those created from the combustion of the syngas produced (and possibly char). The cleanup and treatment of syngas produced from pyrolysis of MSW for use in engines or combustion turbines has little long-term operating history in North America. Other pollutants in quantities similar to gasification technologies would be expected as a result of combusting the gas or oil produced from the process. These emissions can be controlled using modern air pollution control devices to meet local, state, and national regulatory standards.

5.3.1 Benefits

Pyrolysis claims 90 percent diversion of waste from landfills, the production of energy and potential uses of the by-products, where marketable. Other local benefits include the creation of construction jobs over the one to three years of construction and a certain number of permanent jobs dependent on the size of the project.

5.3.2 Challenges

Pyrolysis systems have had some historical operating success with woody biomass feedstocks and specific waste components such as shredded used tires; however, there are no known long-term commercial success using MSW as a feedstock in these technologies in the United States

In Oregon, Agilyx is currently operating a type of pyrolysis technology that utilizes chemical and thermal processes to heat plastic wastes and break it down to short-chain hydrocarbons and eventually synthetic crude oil. According to Agilyx, to date, they have converted plastic waste into approximately 360,000 gallons of synthetic crude oil at their production demonstration facility. There have been some commercial-scale pyrolysis facilities in operation in Europe on select waste streams. Vendors claim that the activated carbon by-product from the pyrolysis is marketable, but this has not been demonstrated.

5.3.3 Costs

Little reliable information is available on the capital and operational costs of pyrolysis using MSW as a feed stream. Pyrolysis has higher capital costs than other proven technologies and the long-term reliability of such emerging technologies remains in question. Therefore, there is no obvious benefit that a pyrolysis plant has over another more proven technology.

6 Solid Waste Incineration

6.1 Direct Combustion (or Traditional WTE)

Direct combustion of waste, often referred to as WTE or Energy from Waste (EFW), involves the complete oxidation of a fuel by combustion under controlled conditions. The heat generated from the combustion process is recovered in a boiler to generate steam which can be used directly for heating/industrial purposes or passed through a steam turbine-generator to create electricity. This technology was introduced to the United States in the 1970s after being employed in Europe in the 1950s. Many of the larger facilities that were constructed in the mid-1970s and 1980s make up the over 70 facilities still in operation today.

WTE is the most widely demonstrated and commercially viable of the thermal conversion technologies available with approximately 4,000 installations worldwide. The widespread construction of traditional WTE facilities stopped in the mid-1990s, but several WTE facilities in Minnesota, two in Florida, and one in Hawaii underwent expansions in the last 10 years.

Furthermore, two new greenfield facilities were constructed and began commercial operations in early 2016.

Figure 6.1 shows an example of a modern 500 TPD.

Mass burn combustion technology can be divided into two main types:

- Grate based, waterwall boiler installations
- Modular, shop erected combustion units with shop fabricated waste heat recovery boilers

The modular units are typically limited to less than 200 TPD and were historically used in facilities where the total throughput is under 500 TPD. All direct combustion technologies require advanced air pollution controls to meet the stringent air emission guidelines that these facilities are required to comply with. The most common examples of air pollution control equipment used at traditional WTE facilities, include:

- Selective catalytic reduction or selective non-catalytic reduction for nitrogen oxide emissions reduction;
- Spray dryer absorbers or dry sorbent scrubbers for acid gas;
- Activated carbon injection for mercury and dioxin reductions; and
- Fabric filter baghouse, for particulate and heavy metal removal.

Ferrous and non-ferrous metals are recovered from the bottom ash which can be used as a construction base material, a common end-use for this by-product in Europe. The fly ash from the boiler and flue gas treatment equipment is collected separately and can either be treated or disposed in a landfill.

Mass burn technology is the most widely used technology in North America and around the world, as it does not require advanced front-end processing of the MSW feedstock. The Durham York WTE facility uses a mass burn/inclined grate technology. Both the stoker-fired and fluidized bed systems require pre-processing of the waste and operate with prepared RDF, which is discussed later in this report.

Figure 6.1 Aerial View of Durham York WTE Facility in Clarington, Ontario, Canada

6.1.1 Benefits

WTE is a proven technology, large-scale and modular combustion technology used in commercial operations at more than 70 facilities in the United States, 6 in Canada, and thousands in Europe and Asia combined. Mass burn facilities are a flexible technology in terms of processing variable waste streams. It yields an approximate 90 percent reduction in volume resulting in significant savings in landfill space. This technology is also able to recover metals as an additional revenue stream. Development of the technology can create a number of construction jobs over the 1 to 3 years of construction and 40 to 80 permanent jobs over the life of the project.

6.1.2 Challenges

This technology generally requires a large waste stream to be economically beneficial. The minimal amount of waste needed for a WTE plant to be economically viable is about 500 TPD (~165,000 TPY). It is often controversial to build due to a perception by the public that this technology is not environmentally friendly. Permitting of WTE facilities is typically a multi-year effort. For reference, the West Palm Beach, Florida facility and the Durham York, Ontario Canada facility took approximately 2 to 3 years for permit renewal.

6.1.3 Cost

Table 6.1 summarizes the capital costs of various mass burn technologies. O&M costs are included where reliable information was obtained. Based on the information available the average capital cost to build a modern WTE facility, $358,000,000, is based on the average cost capital cost per ton and the annual O&M costs are approximately $16,800,000.

Table 6.1 WTE Facility Costs

Facility	Waste Throughput (TPD)	Capital Cost	O&M Cost	Capital Cost per TPD	O&M Cost per TPD
Durham York Energy Center, Ontario[2]	480	$284,200,000	$16,800,000	$545,833	$96
Covanta Dublin, Ireland[3]	1,819 Tons	$650,000,000	-	$357,376	-
Palm Beach Renewable Energy Facility 2, West Palm Beach, FL[4]	3,000	$674,000,000	-	$237,333	-
Lee County Waste to Energy Facility, FL	636	$165,000,000	-	$259,434	-
AVERAGE	**1,485**	**$443,000,000**	**$16,800,000**	**$358,000**	**$96**

A cost per ton to determine the feasibility of adding a WTE plant in Cumberland County was estimated to be $119/ton. The assumptions include the capital cost of the facility, the facility's operating years, the design throughput, the fee per kilowatt hour received. Present day dollars were not escalated over time did not include any annual interest rates.

Assumptions:

- $358,000,000 Capital cost of facility
- 30 Years of operation
- 1,000 TPD at 90 percent availability
- $0.02/kwh
    - Assume every $0.01/kwh reduces total cost by $6

$36/ton: Pay off debt
$95/ton: O&M (ash disposal, cost of reagents, etc.)
$0.02/kwh: Reduces cost by $12/ton
$119/ton

[2] https://www.durhamyorkwaste.ca/en/education-and-resources/faqs.aspx#How-much-did-the-DYEC-project-cost
[3] Covanta Q4 2016 Earnings Call Final Transcript, Page 11
[4] https://swa.org/Facilities/Facility/Details/Renewable-Energy-Facility-2-11

6.2 Refuse-Derived Fuel Combustion

An RDF processing system prepares MSW by shredding, screening, and removing non-combustible materials prior to thermal conversion. The goal of this technology is to derive a more homogenous fuel (uniform in size, composition, and heating value) that can be used in a more conventional solid-fuel boiler as compared to a mass burn combustion waterwall boiler.

Facilities can range in size from several hundred to more than 3,000 TPD. Pre-processing via an MWPF (as discussed above) is typically one component of an RDF facility to remove metals and other undesirables and prepare the remaining materials for the conversion technology. These facilities can employ multiple shredding stages, large trommel screens or other types of screens for sizing, several stages of magnets, and possibly air separation and eddy current magnets. The product will typically have a nominal particle size of 3 to 4 inches (although the sizing of final product RDF can be controlled for a specific technology), have the grit and metals largely removed, and is ready to market. The RDF process typically results in a fuel yield in the 80-90 percent range (i.e., 80-90 percent of the incoming MSW is converted to RDF). The remaining 10-20 percent of the incoming waste that is not converted to RDF is composed of either recovered ferrous metals (1-5 percent) which can be sold to market, or process residue (15-20 percent) that must be disposed of in a landfill.

In most cases, the fuel is used at the same facility where it is processed, although this does not have to be the case. The RDF is blown or fed into a boiler for semi-suspension firing. Combustion is completed on a traveling grate. Thermal recovery occurs in an integral boiler. The air pollution control equipment arrangement for an RDF facility would be similar to that of a mass-burn combustion system.

Some RDF facilities can be classified as a “shred and burn” style, which shred the material and magnetically remove ferrous metals without removing fines. Fines usually consist of material 2 inches in diameter or smaller that include organic material such as paper, dirt, and food particles as well as inorganics such as glass, plastics, and metals.

There are several examples of RDF plants still operating in the United States, Europe, and Asia that use varying degrees of preprocessing. RDF front-end processing can create challenges for the facility. Explosions can occur in the shredders due to propane tanks or other items that should not be placed in the trash. At a minimum, the primary shredders need to be placed in explosion-resistant bunkers. MSW is very abrasive, which causes wear and tear on all components. All systems are subject to high maintenance costs and require extensive repairs and frequent cleaning to keep the facility online. Normally, processing occurs on one or two shifts with a shift reserved each day for cleaning and maintenance. With proper maintenance, RDF facilities can have a useful operating life of 20 to 30 years. Many RDF facilities are retrofitted throughout their life with new processing equipment as technologies evolve.

When the thermal facility is not co-located with the RDF processing facility, communications and arrangements need to be established and maintained between the two facilities and on-site storage of RDF is important for both facilities.

Many of the existing RDF combustion facilities in the United States (e.g., Miami-Dade, FL; West Palm Beach, FL; Honolulu, HI; Ames, IA; and Rochester, Massachusetts) employ these practices to process the fuel. The Entsorga West Virginia facility processes MSW to separate out recyclables and generate a renewable fuel known as solid recovered fuel to be used as an alternative to fossil fuels and sold to large energy users or co-processing facilities.

6.2.1 Benefits

RDF technology is an established technology that is used at a number of plants in the United States, Europe, and Asia (generally larger plants with capacities greater than 1,500 TPD). There are also a number of commercial-ready technologies that convert the waste stream into a stabilized RDF pellet that can be fired in an existing solid fuel boiler or cement kiln. Similar to WTE, RDF is typically combusted to create energy.

6.2.2 Challenges

A drawback is that RDF facilities have some air emissions directly from the processing (dust) as well as from the combustion of the RDF. Fugitive particulates from the process must be controlled. In addition, other environmental impacts must be mitigated such as noise and odor. Costs for this type of facility are greatly based on the amount of revenues garnered from sale of the RDF product. An economic drawback of RDF is that it produces a solid fuel similar to coal; production of the RDF product presumes a local appetite for a coal-substitute to be economically viable. Markets should be secured prior to building a facility as an RDF facility in the County was tried and failed in the 1990s.

6.2.3 Cost

In 2006, the estimated capital cost for the 1,000 TPD Rock-Tenn Biomass RDF Facility in St. Paul, MN was $140,900,000; estimated annual operation and maintenance costs was about $14,000,000/year.

Recently, WastAway, an RDF technology company, claimed that they could build a 200 TPD RDF facility that produces a pellet that has a British thermal unit content of 8,000-9,000 Btu/pound for about $22,000,000.

Averaging the ton of daily design capacity for the Rock-Tenn Biomass RDF Facility and the WastAway technology, HDR assumed an average $125,550 per ton of daily design capacity. A cost per ton to determine the feasibility of adding an RDF facility in Cumberland County was estimated to be $54/ton. Present day dollars were not escalated over time and did not include any annual interest rates.

Assumptions:

- $75,300,000 Capital cost of facility
- 30 Years of operation
- 600 TPD at 90 percent availability

$14/ton: Pay off debt
$40/ton: O&M
$54/ton

7 Aerobic and Anaerobic Digestion

Cumberland County owns and operates the Wilkes Road Compost Facility which accepts yard wastes such as trees, branches, straw, leaves, hedge clippings, grass, and clean, non-treated wood which is processed into mulch and sold back to the community. Food waste is not accepted or processed at Wilkes Road.

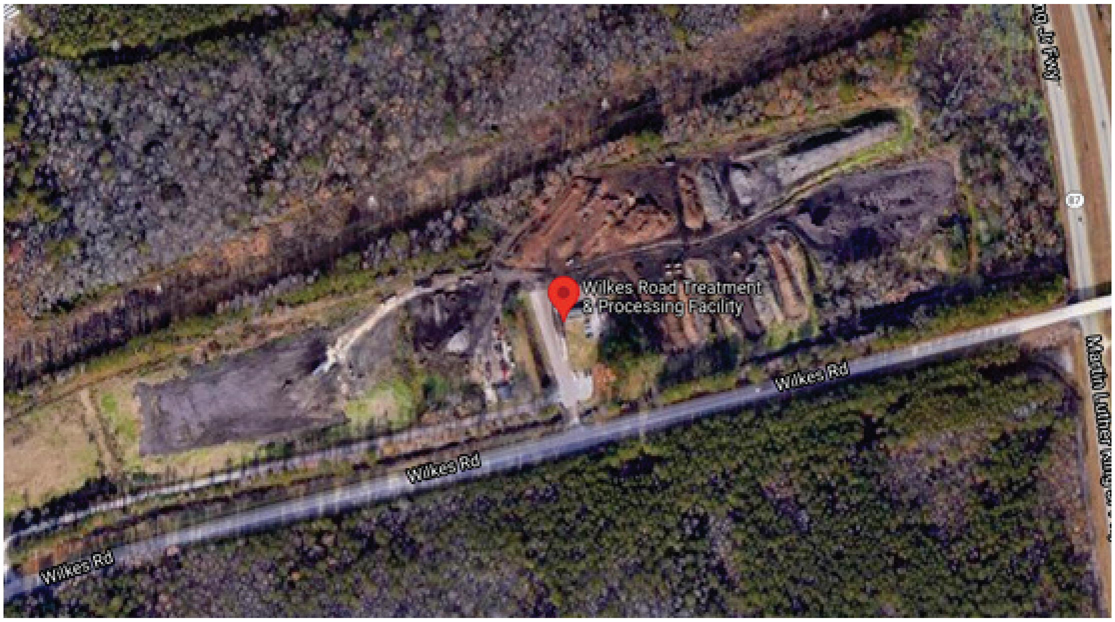

Figure 7.1 Wilkes Road Compost Facility

7.1 Composting

Composting is a naturally occurring, aerobic, biochemical process that breaks down organic material into humus. Composting is the biological degradation of organic material by bacteria in an oxygen rich, moist environment. The process generates heat and carbon dioxide. The process must be managed to keep it within an ideal temperature range to allow bacteria to work most effectively and to sterilize undesirable organisms. Composting technologies can use a building or other structure, or the raw material can be placed outdoors in windrows or piles. The process also requires a way to control the moisture content and periodically turn the material. Generally, composting can be performed in-vessel or in the open-air and is typically used for the “green waste” portions of the waste stream only.

Composting has been successfully used with source separated organics such as food waste, yard waste, and wastewater biosolids. Some facilities are even permitted and designed to accept compostable paper and plastics. Composting can include a number of different processes; however, the two most common are turned windrow composting and forced aerated static pile composting. Windrow style composting is typically conducted outdoors. Aerated static pile composting can occur outdoors or indoors. Some forced aerated static pile composting is conducted outdoors in areas that are isolated from odor receptors or with systems that use a bag system to contain the emissions and odors from the materials.

In windrow composting, the materials (generally green material) are placed in elongated piles called windrows that are aerated naturally through a "chimney effect," mechanically by physically turning the windrows with a machine. Frequent turning of the pile introduces oxygen, accelerates physical degradation of feedstocks and provides an opportunity to adjust the moisture content to the optimum level. This technology can be particularly odorous if food waste is included in the feedstock. The average time required for active aerated composting is 8 to 12 weeks. Figure 7.2 shows an example of composting using an outdoor windrow system.

Figure 7.2 Example of a Windrow Composting Facility

In an enclosed forced aerated static pile composting technology, fresh air is forced into the pile to speed up the process and to ensure that the system remains aerobic. This method is suited to producing large volumes of compost in relatively smaller areas. This technology is also used where the quantity of putrescible material (such as food waste or biosolids) are high. The purpose of using this type of technology is maintain aerobic conditions inside the compost pile and to prevent anaerobic pockets from developing. Anaerobic degradation produces odorous off gasses which is to be avoided. Figure 7.3 shows an example of composting using a forced aerated static pile composting technology system.

Figure 7.3 Example of a Composting Facility - Forced Aerobic Static Pile

Aerated compost processes could employ a negative or positive aeration process. A negative aeration process that draws air down through the windrows to an air collection manifold that runs under the windrows. The compost-air is drawn through the compost using a blower system which then pushes the air through a biofilter that acts as an emission and odor control system. Alternatively, a positive aeration process is when air is injected into the windows; both systems can function satisfactorily if oxygen levels are maintained in appropriate ranges.

Composting is used by numerous communities in commercial operations throughout the United States and the world for composting yard and food waste. Products from composting are compost and mulch. Composting projects are sized as low as only a few TPD to more than 500 TPD. An aerobic composting facility of 250 TPD to 400 TPD is typical.

7.1.1 Benefits

Benefits of composting include diversion of organic wastes from landfill and the local production of compost and mulch which can be used within the community. There are commercially operating plants in parts of Europe and some development in the United States operating on source separated organics or the organic fraction of MSW. Local benefits include the creation of construction jobs over the short period of construction and about 2 to 10 permanent jobs over the life of the project, depending on the size and complexity of the facility.

7.1.2 Challenges

There is a potential for odors and high operating costs if the materials being composted include high quantities of putrescible material and/or high levels of contamination. Windrow composting should be limited to accepting up to 10 percent putrescible (food) waste. Above this level, an aerated system is recommended. The maximum range of putrescible material (food) is up to 40 percent of incoming waste stream.

7.1.3 Cost

A 60,000 TPY Windrow, Aerated Static Pile, Enclosed Channel, and Container/Tunnel Aerobic Composting facility has an estimated capital cost of $5.4M, $10.8M, $21.6M, and $39.6M, respectively. Over a 20-year life, this equates to $4.50 per ton, $9.00 per ton, $18.00 per ton, or $33.00 per ton respectively. Operation and maintenance costs for the 60,000 TPY plant was estimated between $33 to $53 per ton.

A total cost per ton over 20 years for a composting facility is estimated to be about $37.50 to $86.00/ton. Present day dollars were not escalated over time and did not include any annual interest rates. In addition, the cost per ton for composting is about 50 percent less than the cost of truck or rail haul the food waste to a landfill as shown in Table 7.1.

Table 7.1 Composting Cost Comparison to Landfill Haul Costs

Cost/Ton	Composting	Truck	Rail
Low	$37.50	$65	$77
High	$86	$136	$188

7.2 7.2 Anaerobic Digestion

AD is commonly used to treat wastewater biosolids and industrial/agricultural wastewater. AD has also been used to treat the organic fraction of MSW such as food waste and in some types of AD systems, yard waste.

The AD process occurs when organic matter is decomposed using bacteria in the absence of oxygen. By consuming the organic materials, the bacteria produce a biogas (primarily methane and carbon dioxide). Feedstock for AD vary according to the type of technology but in broad terms can include MSW-derived organics, manure, food waste, grass clippings, and for some technologies, yard waste, brush, and wastewater treatment plant biosolids. Biologically inert materials that are present in the digestion feedstock, such as metals, glass, and plastics are undesirable and considered contamination and must either be removed prior to digestion (for wet type systems) or be screened-out during or after digestion (for dry type systems).

There are several factors that influence the design and performance of AD. Some of these factors include the concentration and composition of nutrients in the feedstock, temperature of the digesting mass, and retention time of the material in the reactor, pH, acid concentration, and oxygen level.

The two types of processes used for AD systems are based largely on the nature of the feedstocks:

- Wet systems that require the feedstock to be prepared into liquid slurry and whose process is liquid in a tank or similar type of container. Wet systems can be treated in either of the following levels of solids:
    - High-Solids: between 10 and 40 percent solids in a liquid slurry or paste
    - Low-Solids: typically, less than 10 percent solids

- Dry systems, often referred to as dry fermentation. Unlike wet systems, dry fermentation systems do not prepare or pre-process the feedstock; instead, the feedstock is retained in a stacked pile as a stationary solid, with circulating bacteria rich liquid through the solids to perform the degradation process. Dry systems process the feedstock as a solid, and typically operate as a batch type process in bunkers or garage type containers.

AD is widely used on a commercial-scale for industrial and agricultural wastes, as well as wastewater sludge. AD technology has been applied on a larger scale in Europe on mixed MSW and source separated organics, but until recently there is limited commercial-scale application in North America. The Greater Toronto Area is home to two commercial-scale plants that are designed specifically for processing source separated organics ; the Dufferin Organic Processing Facility and the Disco Road Organics Processing Facility. There are also some full-scale commercial facilities in New York City, Southern California, and Boston.

7.2.1 Benefits

Benefits of this technology include capturing and converting organics to low carbon fuels in addition to diversion of organic waste from landfill and the production of energy and potential uses of the by-products. Commercially operating plants in Europe and the United States convert source separated organics and some on the organic fraction of MSW into a variety of beneficial products. It is possible to retrofit existing wastewater treatment plant digesters to accept the organic fraction of MSW. Local benefits include the creation of construction jobs over the year of construction and 10 to 25 permanent jobs over the life of the project, depending on the size and complexity of the facility.

7.2.2 Challenges

AD requires either a source separated feedstock free of contaminants or a high level of pre-processing to remove inorganics from the MSW stream (metals, glass, inerts) and reduce the size of organics prior to digestion. There is a high residual waste generation (about 40 percent of waste stream) as only the organic fraction of the waste stream can be processed. Successful projects use a limited waste feed stream of source separated organics (food waste from grocery stores and restaurants) and wastewater treatment plant biosolids. There is a potential for high capital and operating costs. There is a potential for creating odors, noise, and dust.

7.2.3 Cost

The cost of AD facilities can vary significantly, and one varying factor is the feedstock used. AD facilities that accept MSW require pre-processing, which is an additional upfront cost. The cost of preprocessing MSW into an organic feedstock can cost about $20 million.

Based on a feasibility study conducted in Oregon, on average, capital costs for a 46,000 TPY facility were estimated to be $43M and capital costs were estimated to be $4M. Over a 30-year life, capital costs are estimated to be $32 per TPD and operating costs are estimated to be $87 per TPD for a total cost of $119 per TPD. The total cost is inclusive of processing costs. Present day dollars were not escalated over time and did not include any annual interest rates. In addition, based on HDR experience, annual capital and operating costs can range from $90 to $115 per ton. In addition, the average cost per ton for AD is similar to the cost of hauling waste via truck and approximately 20 percent less than the cost of hauling waste via rail as shown in Table 7.2.

Some of these costs can be offset by revenues from energy or fuels. The US EPA Renewable Fuel Standard program provides revenues for renewable attributes of fuel depending on its classification generation type, referred to as a renewable identification number. California's Low Carbon Fuel Standard incentivizes the production of renewable transportation fuels by monetizing their relative carbon intensity. Also, economic success of an AD facility sometimes hinges on whether the residue can be processed and sold as a soil amendment or fertilizer product.

Table 7.2 AD Cost Comparison to Landfill Haul Costs

Cost/Ton	AD	Truck	Rail
Low	$90	$65	$77
High	$119	$136	$188

8 Waste to fuel

8.1 Waste-to-Fuel

Waste-to-fuel technologies involve two or more of the technologies highlighted previously, including mechanical pre-processing, thermal conversion technologies, and in some cases a biological technology. Overall, waste-to-fuel technologies typically involve four main steps:

1. Pre-processing and preparation of the feedstock material (e.g., woody biomass, plastics, or MSW)
2. Converting the feedstock to generate a syngas through some thermal conversion process (e.g., gasification or another technology)
3. Cleaning and conditioning the syngas of impurities and other contaminants
4. Passing the syngas through a catalytic process to synthesize a liquid fuel

There are several proposed methodologies to convert MSW into fuels. The first step the majority of MSW-to-fuel technologies requires is use of a process to generate a syngas, typically a thermal conversion process such as gasification, pyrolysis, or plasma arc gasification. The next, and most important step, in this process is to take the syngas produced and clean it to remove impurities (tars, hydrocarbons, contaminants, etc.) that can impact the catalytic process. The next step involves a catalytic process, such as a Fischer-Tropsch (FT) process, that is needed to convert the syngas into a liquid fuel. The FT process is defined as a collection of chemical reactions that use a metal-based catalyst (cobalt, iron, or others) to convert a mixture of carbon monoxide and hydrogen into liquid hydrocarbons. The FT process has been around for almost 100 years, and is most commonly used to convert coal, biomass or even methane into synthetic liquid fuels. The purity of the syngas used can be critical in the success of the FT process, which makes syngas produced from MSW gasification challenging because of the contaminants present in the MSW feedstock and the relatively low ratios of hydrogen (H2) to carbon monoxide (CO). Figure 8.1 shows the FT process.

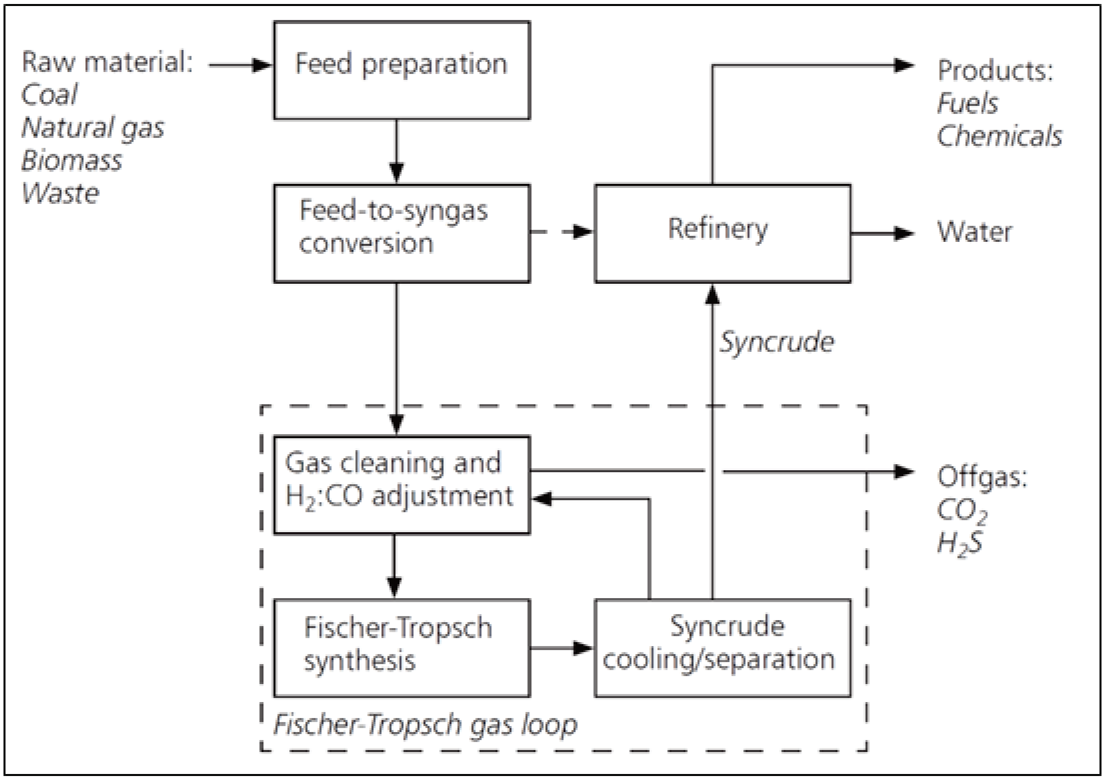

Figure 8.1 Fischer Tropshe Process Diagram

As described, FT is one of the most popular types of a chemical catalytic process used to synthesize syngas into a liquid fuel. Alternative processes include methanol synthesis; mixed alcohol synthesis; or syngas fermentation. Each process features different reaction pressures and temperatures, requires different syngas compositions, and uses different catalysts.

One type of waste-to-fuel technology is the catalytic depolymerization process. During this process, the plastics, synthetic-fiber components, and water in the MSW feedstock react with a catalyst under non-atmospheric pressure and temperatures to produce a crude oil. This crude oil can then be distilled to produce a synthetic gasoline or fuel-grade diesel. There are four major steps in a catalytic depolymerization process: pre-processing, process fluid upgrading, catalytic reaction, and separation and distillation.

This catalytic depolymerization process is somewhat similar to that used at an oil refinery to convert crude oil into usable products. This technology is most effective with processing a waste stream with a high plastic content and may not be suitable for a mixed MSW stream. The need for a high-plastics content feedstock also limits the size of the facility.

Ineos Biofuels developed the Indian River Biofuels Facility, a waste-to-fuel technology facility located in Vero Beach, Florida. This 300 TPD facility (2 units x 150 TPD/each) started operations in late 2012 using woody biomass wastes as a feedstock. In 2016, the facility was shut down to several failed attempts at using a thermal gasification process to generate a syngas that is then passed through a fermentation reactor where biological organisms convert the hydrogen and CO in the syngas directly to ethanol.

8.1.1 Benefits

Benefits include the diversion of organic waste or plastics from landfill and the production of oil that can be used as a fuel product. A local benefit is the creation of construction jobs over the construction period and a certain amount of permanent jobs over the life of the project; however, this figure cannot be estimated as the technology requires additional development.

8.1.2 Challenges

Feedstock preparation, gasification, syngas clean-up and fuel synthesis are commercially viable at some scale using select feedstock materials such as biomass, coal or petroleum-based materials. However, when using MSW as a feedstock, these systems as a whole are still in the development or demonstration stage.

8.1.3 Cost

The Indian River Biofuels Facility cost approximately $130 million. The waste-to-fuel option has a higher capital cost than other proven technologies and the long-term reliability of such emerging technologies remains in question. Therefore, there is no obvious benefit that a waste-to-fuel plant (catalytic depolymerization or hybrid facility) has over other, more cost effective and proven technologies.

9 Summary of Recommendations

HDR researched several different waste reduction technologies for consideration and implementation into the County's current solid waste program. There are several factors identified to determine if a technology is feasible for incorporation into the current system. These include being commercially available and viable, the economics of implementing the technology, and the volume of tons required. The following technologies are recommended for further analysis and Table 9.1 summarizes the costs associated with each technology

1. Waste Reduction Programs
    a. Waste reduction programs are considered low cost in comparison to more advanced technologies and do not require a significant volume to be feasible. This recommendation will not have a significant impact on the volume going to the landfill, it may only have an impact on the hauling costs. Educating residents on different ways to reduce, reuse, and recycle, will have a positive impact on the future of Cumberland County's solid waste system. Awareness of waste reduction can impact actual participation in other areas of waste management such as recycling or diversion.
2. Recovery of Resources from Solid Waste
    a. The recovery of resources from solid waste can help expand Cumberland County's container sites by accepting additional materials such as C&D. In addition, specifically targeting high volume materials to be diverted from the

waste stream can also have a positive effect on the volume of waste entering the landfill. The cost for outreach and education on recovery of resources is low compared to the cost of other advanced technologies and will be beneficial for the solid waste program in the future. In addition, targeting specific materials such as C&D waste can have a positive impact, decrease in volumes, on the amount of waste hauled to the landfill. This option may not have a large impact alone; however, it can be impactful when included with other programs.

3. Mixed Waste Processing Facilities
    a. MWPFs are a viable technology for recovering recyclable and reusable materials from MSW. MWPFs generally require about 1,000 TPD and processing costs are about $110 to $120/ton.
4. Gasification
    a. Gasification of MSW is has limited availability in the United States; however, has been more successful in other countries such as Japan and North America. The economics of landfilling in the United States has made gasification less attractive due to low tipping fees. Other than the gasification of MSW, the gasification of certain waste streams such as plastics or tires may be economically feasible and a possible solution for Cumberland County.
5. Direct Combustion
    a. Direct combustion is another commercially available technology that has been proven successful in the United States for over 30 years. The capital cost for a WTE facility is on the higher side (about $300 million) of the options considered. Facilities accept, on average, 1,000 tons of MSW per day and it costs about $100 to $130/ton to consider the technology viable.
6. Composting
    a. Aerobic composting is a commercially viable technology to remove organics from the waste stream. A new site would need to be acquired for this technology; however, it would increase the amount of organic material diverted from the landfill. Capital costs for an aerobic composting facility can range from $5 million to $40 million and have an operating cost of about $33 to $53 per TPD.
7. Anaerobic Digestion
    a. Anaerobic digestion is a commercially available technology in North America and has been proven to remove organic materials from the waste stream and convert it to electricity or renewable fuels. The total capital and operating costs can vary significantly based on the type of feedstock and pre-processing needed.

Table 9.1 Summary of Technology Costs

Technology	Tons/Year	Cost/Year	Capital Cost ($/TPD)	O&M Cost ($/TPD)	Total Cost ($/TPD)	Amortization (Years)
Waste Reduction Programs	1,380*	$90,275 to $183,150	-	-	-	-
Recovery of Resources from Solid Waste	1,380*	$50,000 to $100,000	-	-	-	-
Mixed Waste Processing Facilities	584,000	-	$3	$112	$115	30
Gasification	80,300	-	$83	$36	$119	30
Direct Combustion*	365,000	-	$45	$65	$110 ($98 w/ electric profit)	30
Composting	60,000	-	$4.5 to $33	$33 to $53	$37.5 to $86	20
Anaerobic Digestion	46,000	-	$32	$87	$119	30

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