Final Report
Project 100057803

Municipal Solid Waste (MSW) Value-Recovery Technology Assessment

Solid Waste Authority of Central Ohio

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1.0 Project Objectives

The mission of the Solid Waste Authority of Central Ohio (SWACO) is to improve the community's solid waste stream through effective reduction, recycling, and disposal. In support of this mission, SWACO is interested in assessing technology options that have the potential to reduce the approximately 1 million tons per year of Municipal Solid Waste (MSW) that enters the landfill, while optimizing the potential for central Ohio's valuable waste assets.

Battelle proposed a phased study to develop a strategic technology roadmap specific to SWACO's existing requirements, challenges, assets, and initiatives. The purpose of the roadmap is to assist SWACO in making informed decisions by vetting technologies and waste diversion strategies for their technical and economic performance and their alignment with SWACO's mission and unique attributes. The development of the roadmap requires collaboration between Battelle and SWACO to identify and document:

1) SWACO's current circumstances and goals and how they may evolve,
2) Technologies and strategies that have been proven to work at best-in-class-landfills and their applicability to SWACO,
3) Conditions for selection of appropriate technologies and strategies for SWACO given its objectives, requirements, and constraints,
4) An outline of associated planning and implementation steps consistent with SWACO's long-term strategy, and
5) Ongoing technical advisory support for the evaluation of specific technology applications and waste management strategies from an independent evaluator such as Battelle.

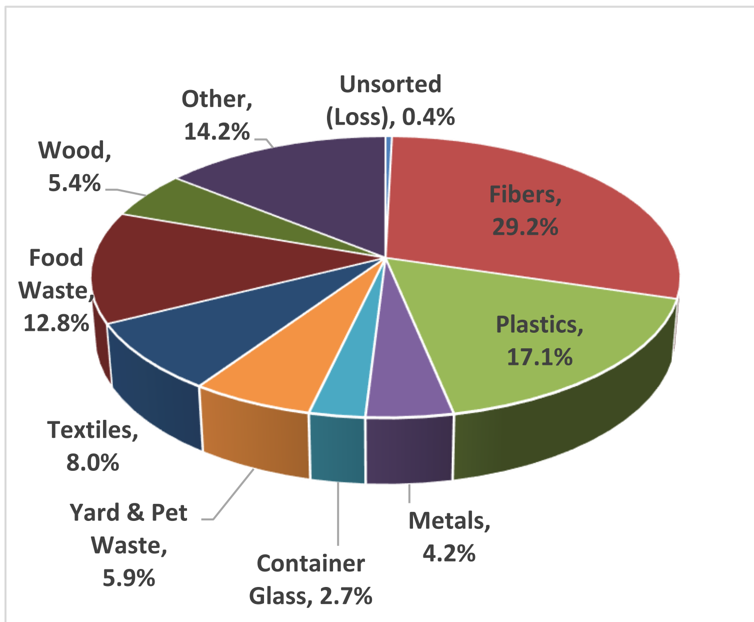
The first phase of the study addresses items 1 and 2 and describes the next steps planned for the continuation of the roadmap development. Accordingly, this report presents the results of the first phase of the strategic technology roadmap development and encompasses documentation of the baseline conditions at SWACO, benchmarking against both traditional and state-of-the-art landfill practices, a preliminary assessment of technology options for value creation from waste resources, and recommendations for further evaluation of technology options that show the potential to meet SWACO's objectives. Further assessment of the technical feasibility, market potential, and economic benefit of priority technology opportunities identified and development of an integrated action plan for implementation of specific technology solutions will be addressed in future program phases.

2.0 SWACO Opportunities

Ohio House Bill 592, passed in 1989, established Solid Waste Districts throughout Ohio to plan for the proper disposal of waste and to develop programming to achieve state-mandated waste reduction and recycling goals. As a result, the Solid Waste Authority of Central Ohio (SWACO) was established by the Franklin County Board of Commissioners and given the authority to adopt rules for the maintenance of the solid waste management district, i.e., Franklin County. The currently established rules include the requirement that any solid waste generated in the District be delivered to a designated solid waste facility, ensuring the flow of Franklin County solid waste to SWACO-managed facilities. The surety of a consistent solid waste supply supports the opportunity for value recovery technology implementation for the approximately 1 million tons of MSW received at the Franklin County Sanitary Landfill every year.

For example, SWACO has previously explored partnership opportunities to support the objectives of increasing the life of the Franklin County landfill, recovering economic value from the waste stream, and meeting the health, safety and welfare needs of the community. Proposed concepts have included a materials recovery facility for processing of mixed MSW received at the landfill, along with an integrated industrial and business park adjacent to the landfill. An integrated business park has the potential to take advantage of the Franklin County waste stream to provide recyclable materials for sale and to also supply biogas, biomass and waste-to-energy processes.

To address state waste reduction and recycling goals SWACO has the ability to establish programs to promote source separation, recycling and composting. SWACO's programs include education and outreach, helping to establish best practice for curbside recycling and free recycling drop-off locations across Franklin County. The co-mingled recyclables collected throughout Central Ohio are taken to a Materials Recovery Facility (MRF) where they are sorted, baled and sold to manufacturers. SWACO also supports companies that compost yard waste received from Franklin County residents. SWACO has established public-private partnerships to support increased recovery and recycling of materials. SWACO recently partnered with Kurtz Brothers, Inc. and Quasar Energy Group to construct a 1MW anaerobic digestion renewable energy facility in Columbus, operated by the Quasar Energy Group. The facility processes 25,000 wet tons per year of biosolids from the City of Columbus, regional food waste, and FOG (fats, oils, and grease), generating 3,600 gasoline gallon equivalents each day.



In 2014, SWACO generated approximately 1,450,000 tons of MSW. Of that, approximately 475,000 tons, or more than 30% of central Ohio's MSW, was recycled and composted as a result of these efforts. The remaining 975,000 tons was landfilled. According to a residential/commercial waste composition study conducted by GT Environmental in 2013 (Figure 1), there is still a large amount of recyclable material entering the landfill. Based on projections from this study, approximately 284,700 tons of cardboard and paper, 166,725 tons of plastics, 40,950 tons of metals, and 26,325 tons of glass were delivered to the Franklin County Sanitary Landfill in 2013. Additionally, a large amount of organics were received at the landfill that could alternatively be composted or sent to an anaerobic digester: 57,525 tons of yard & pet waste, 124,800 tons of food waste, and 52,650 tons of wood. The waste category descriptions are provided in Appendix A.

SWACO is currently evaluating its programs to identify opportunities to divert more materials through recycling /composting. An understanding of the waste received at the landfill provides useful information in targeting source reduction programs and selecting viable value recovery technologies for the remaining waste stream. For example, less than 5% of the waste stream received at the landfill in the 2014 Annual District Report was from industrial sources, which indicates that SWACO may want to place more emphasis on residential and commercial waste diversion programs.

3.0 Municipal Solid Waste Handling Practices

According to the US Environmental Protection Agency (EPA), MSW, otherwise known as trash or garbage, consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food waste, newspapers, appliances, and batteries from homes, schools, hospitals, and businesses. Not included are materials that also may be disposed of in landfills but are not generally considered MSW, such as construction and demolition (C&D) materials, municipal wastewater treatment sludges, and non-hazardous industrial wastes (EPA, 2014).

Across the entire United States, a reasonable estimate for generated MSW is that 30% is recycled/composted, 10% is sent to waste-to-energy (WTE) facilities, and 60% ends up in landfills (Shin, 2014; EPA, 2014). In Ohio, where there are no WTE facilities, the 2011 Earth Engineering Center (EEC) study determined that 71.7% of the MSW generated in Ohio was disposed of in a landfill, which equates to approximately 9 million tons of MSW (Shin, 2014).

The US EPA has developed a hierarchy of strategies for disposing of MSW that are the most environmentally sound. The hierarchy, shown in Figure 2, emphasizes reducing, reusing, and recycling the majority of wastes.

Figure 2. Hierarchy of Waste Management (EPA, 2013)

Source/waste reduction occurs when the amount of MSW is reduced or materials are reused rather than discarded, meaning the material never enters the waste stream (EPA, 2013). The second component of the EPA's waste management hierarchy is recycling, including off-site (or community) composting. Materials like glass, metal, plastics, and paper can be collected and separated in a Materials Recovery Facility (MRF), and then sent to facilities that can process them into new materials or products. After recycling/composting, energy can be recovered from the waste materials and converted into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas (LFG) recovery. These process options are often referred to as waste-to-energy (WTE) technologies. The final, least desirable option for treating MSW is MSW disposal in a landfill with no type of methane capture.

4.0 Benchmarking Study

State-of-the-art (SOTA) landfill practices aim to reduce the amount of waste entering a landfill through waste diversion, such as recycling, composting, or waste-to-energy conversion on or near a landfill site. SOTA landfills usually consist of a combination of a clean or dirty MRF, yard waste composting and/or anaerobic digestion, and a waste-to-energy facility (mass burn combustion, gasification, etc.). A few examples provided by the Solid Waste Association of North America (SWANA) website (www.swana.org) are described below:

- 2011 Gold Award for Integrated Solid Waste Management Systems (ISWMS): *Lee County, Florida*, includes a single stream MRF, vegetative waste processing facility, and waste-to-energy facility (mass burn combustion system) with metal recovery facility.
- 2012 Gold Award for ISWMS: *Sacramento County, California*, implements a three bin collection system; one for refuse, one for green waste, and one for recyclable materials. Both the recyclable and green collection are sent to outside vendors, where the green waste is used to generate power. Their fleet of collection vehicles also runs on liquefied natural gas and the landfill has a gas collection system. Overall, Sacramento has a diversion rate of 71%.
- 2013 Gold Award for ISWMS: *City of San Jose, California*, implements an 80,000 square foot processing center capable of sorting 420,000 tons of mixed wet and dry materials every year. It includes a large-scale MRF, composting operations, landfill, and hauling operations yard. There are four different incoming waste sorting lines associated with the MRF, so that the waste streams do not contaminate the other, thus increasing the value of the recovered material. The facility uses a KompofermPlus Dry Fermentation Anaerobic Digestion Facility to convert biomass into biogas and compost.
- 2015 Gold Award for ISWMS: *Montgomery County, Maryland*, converted its fleet from diesel to compressed natural gas. The ISWMS consists of transfer stations with rail access, MRF, yard waste composting facility, and waste-to-energy facility (combustion system). The rail connecting transfer station and waste-to-energy facility save about one million truck miles per year.

Many of the remaining SOTA landfills follow the same technology architecture: clean or dirty MRF, green waste composting or anaerobic digestion facilities, followed by a waste-to-energy facility. The cost of operating WTE facilities is offset by revenue generated through sale of electricity. As a result, these WTE facilities are most attractive in locations where either the cost of electricity and/or tipping fees for landfill disposal are high. Analysis in upcoming phases of this research will help to determine the conditions and feasibility of these applications in Central Ohio. The referenced SOTA facilities do not necessarily list the waste stream composition entering each site or how economical each facility is to operate. Overall, many of the SOTA landfills are owned and operated by the counties in which they reside.

4.1 Description of Material Recovery Facilities

In the EPA's waste management hierarchy, recycling follows source reduction and reuse. MRFs are an important first step in the recycling process to sort and prepare recyclable materials for alternative uses. There are four main types of MRFs, each of which depends on the source material streams:

- *Source separated* – Incoming recyclables have been presorted at the point of collection, so only minimal processing is required. The main purpose is to remove residual contaminants and prepare materials for market.
- *Dual stream* – Recovered materials are received in two streams, typically fiber (newspaper, magazines, mixed paper, cardboard, etc.) and commingled containers (plastic, glass, and metal). Separation of the materials is accomplished by a combination of automated equipment and manual sorting.

- *Single stream* – Recovered materials are received in a single stream, with fiber and commingled containers combined. The first stage of processing typically utilizes equipment that separates the material into two streams (fiber and containers), which are further sorted using equipment similar to that used in dual stream MRFs.
- *Mixed waste* – MSW is processed using various technologies to separate mixed recyclable materials from the waste stream. Recyclable materials are then processed using equipment similar to a single stream MRF. Some facilities process the entire waste stream, while others target commercial waste or loads rich in recyclables.

Advancements in automated processing equipment have resulted in the conversion of many source separated and dual stream MRFs into single stream MRFs and have led to improvements in the performance of mixed waste MRFs or “dirty MRFs”. As communities strive to achieve waste diversion rates of 50% or higher, they are recognizing the critical role one or more of these types of facilities will play in their overall waste management system (Kessler Consulting Inc., 2009). As a result, the presence of single-stream MRFs in operation in the U.S. grew from less than 10 in 1995 to 200 in 2009 (Abramowitz, 2011).

4.2 Description of Organic Waste Processing Operations

Yard trimmings and food residuals make up almost a quarter of the U.S. municipal solid waste stream, making the identification of environmentally friendly and economic organic waste processes an important component of a total waste management strategy. While organic waste processing solutions are easily implemented for source-separated materials, the organic content of MSW can also be diverted to these facilities through use of a single stream or “dirty MRF”. Notably, all of the SOTA landfill examples described above include both a MRF and a complementary organic waste processing solution.

For organic wastes, the EPA points to composting as a preferred waste management practice following source reduction and reuse. Through composting, yard waste and other source-separated organic wastes can be recycled into mulch and compost. Anaerobic digestion (AD) presents an additional organic waste processing solution that falls into the energy recovery category for waste management. Organic material processed by digester systems may include animal manure, organics separated from mixed MSW, food scraps, food production residuals, agricultural residues, wastewater solids, or some combination of the former.

In AD systems, the controlled decomposition of the biodegradable waste by microbes yields two primary products: biogas and digestate. The biogas can be used to create energy in the form of electricity, heat or vehicle fuel, while the digestate may be used in byproducts such as soil amendments, fertilizers, and even as a feedstock for plastics and chemicals (USDA, 2014).

Because of the variety of applications for AD systems, there are several benefits that can be realized through effective use of the technology (EPA, 2015):

- Nutrient management alternatives
- Soil improvement opportunities
- Methane emissions reduction
- Production of renewable energy, and
- Diversion of organic wastes from less preferred disposal options.

Depending on the source of organic waste and the objective for the AD installation, i.e., waste processing or energy generation, different types of AD systems can be selected or combined. While older systems were typically designed to process one feedstock, new systems are usually designed for co-digestion to enhance biogas production. For example, the Merchant Digester in Columbus, OH accepts municipal wastewater biosolids, food and beverage wastes, and fats, oil and greases (FOG) as its feedstocks. The facility produces biogas for conversion to compressed natural gas (CNG) and electricity, while the digestate effluent is applied locally as fertilizer.

In 2015, the EPA estimated that there were 247 AD systems located at commercial livestock farms, and almost 100 facilities for processing of food-based materials (EPA, 2015). The economic feasibility of these and future systems is dependent upon regional conditions, including the characteristics and volume of feedstock waste streams, local energy and waste disposal costs, the marketability of any co-products, and the existence of environmental incentives.

4.3 Description of Waste-to-Energy Facilities

Waste to Energy (WTE) processes are implemented for value conversion from MSW following waste diversion and recycling/composting. In the United States and Europe, anaerobic digestion facilities are growing more common as a greener approach for handling of compostable material. For the remaining non-recyclable materials, mass burn facilities are employed in the United States, particularly in population dense areas where landfill capacity is limited and tipping fees and power costs are high, such as the Northeast US. In Canada and Asia, the use of gasification technologies is growing, similarly due to environmental and economic incentives. Detailed WTE technology descriptions are provided in Appendix B.

There are currently 80 WTE/Refuse Derived Fuel (RDF) facilities in operation in the United States. The product of WTE facilities is either electricity for sale to the grid and/or steam which is exported to closely located end users. The majority of the facilities (61) employ mass burn technology, which allows the MSW to be combusted without pre-processing. A smaller fraction (13) utilize the RDF technology, which requires pre-processed MSW (removal of metals and shredding of materials), which is then combusted. Finally, there are 7 modular facilities, which are similar to mass burn but are typically smaller, pre-fabricated units that are portable (Michaels, 2014).

The WTE facilities range in size from a few hundred to several thousand tons of MSW processed each day. Almost half of the WTE facilities are publicly owned, while the remaining facilities are mostly owned by either Covanta Energy or Wheelabrator Technologies. Most of the WTE facilities were constructed in the late 1980s and early 1990s. Since 2010, 5 new WTE facilities have been constructed. Four of the five facilities operate mass burn technologies, while the fifth facility employs a gasification technology, CLEERGAS.

- Palm Beach Renewable Energy Facility #2, West Palm Beach, FL
- Honolulu Resource Recovery Venture – H-Power, Kapolei, HI
- Olmsted Waste-to-Energy Facility, Rochester, MN
- Pope/Douglas Waste-to-Energy Facility, Alexandria, MN
- Walter B. Hall Resource Recovery Facility (CLEERGAS - gasification), Tulsa, OK

4.4 Considerations for Application at SWACO

The overall objective of this study is to assist SWACO in developing and executing a strategic technology action plan that will achieve the SWACO objectives of diverting waste from the landfill while creating value for the citizens of Central Ohio. As demonstrated by the SOTA landfills discussed previously, the preferred approach is a combination of a MRF, composting and one or more waste-to-energy technologies.

Based on the waste composition arriving at the Franklin County Sanitary Landfill, both recyclable and compostable materials are currently entering the landfill. In 2014, approximately 518,700 tons of the material (cardboard, paper, plastic, metals, and glass) that entered the landfill may be able to be recovered through MRF operations. Should the quality of those materials be sufficient for recycling, this would equate to a 53% reduction in the total waste entering the landfill. In addition, programs may be considered to divert the food and pet waste received at the landfill to anaerobic digester and compost facilities. The waste types and volumes diverted should be evaluated in future studies against the capacity of any existing facilities.

For the remaining waste mix at the landfill, WTE technologies may be applied. The best three options for WTE conversion at the Franklin County Sanitary Landfill are combustion, gasification, and plasma gasification, as the selected WTE technology must be robust enough to handle a changing feedstock with reduced paper, plastics and biomass. In addition, combustion and gasification technologies have been more widely demonstrated at commercial scale in WTE applications. By comparison, pyrolysis is known to have difficulty with accepting a mixed feed stream and has not yet been demonstrated at the commercial scale for mixed MSW.

Table 1: Comparison of WTE Technologies

Technology	Advantages	Disadvantages
Combustion	• Low Maintenance • No waste sorting required • Most common WTE technology • RDF (refuse-derived fuel) version is more efficient	• High fuel demand • Feed water required • Steam infrastructure required • Necessary to control air emissions • Need to pre-process/shred MSW for use with RDF
Gasification	• Power generation • Low to no fuel demand • Minimal air emissions	• Waste sorting and pre-processing • High maintenance and complexity • Limited installations • Works best with a uniform and select feedstock (plastics, biomass, industrial waste) • Most large scale operations are in Japan, not prevalent elsewhere
Plasma Gasification	• High burn temperature reduces the need for waste sorting • Low air emissions • Can handle hazardous waste	• High cost operating cost • Not net energy positive, i.e., fuel consumption exceeds energy generation • Limited commercial applications
Pyrolysis	• Power generation • Low to no fuel demand • Creation of liquid distillate products	• Technology still being developed for MSW • Waste Sorting and Pre-processing required • Requires waste post-processing

In SOTA landfills, traditional waste management systems, recycling, and alternative processing options are converging (USDA, 2015). This creates opportunity for the most efficient use of SWACO's waste resources through the development of a total waste management strategy that takes into account the characteristics of the waste mix received at the Franklin County Sanitary Landfill and the local economic conditions. Single waste streams or byproducts from the primary waste management technologies selected has the potential to create new industry in the region. The co-location of these processes in an Ecological Industrial Park would enhance the efficiency for use of these byproducts and result in more comprehensive solutions for disposition of the County's waste stream.

5.0 Recommendations for Next Steps

Overall, there are many options available to SWACO to help reduce the MSW entering the landfill and to create affiliated economic opportunities for the local community. Although the amount of waste recycled in the central Ohio region is comparable to the national average at ~30%, there is still opportunity for SWACO to encourage increased recycling and waste reduction through programming, community outreach and education, and the addition or expansion of existing recycling and composting programs. Thus, SWACO should continue to emphasize recycling to the community as a priority. In addition, enhanced composting efforts should also be considered.

An additional key task recommended includes further research into opportunities for implementation of SOTA waste management practices at or near the Franklin County Sanitary Landfill. This research will consider material recovery, organic processing and WTE options in light of both SWACO's objectives and the specific conditions in and around Franklin County. Accordingly, assessment of the technical feasibility, market potential, economic benefit, and the community acceptance for specific technology solutions will be performed in the next phases of this study. Other considerations specific to the Franklin County region include the impacts or synergies of the existing and future recycling-based industry in central Ohio. In addition, regional commercial and industrial activities will be evaluated to identify other synergistic opportunities for additional revenue generation through the optimal utilization of SWACO's waste resources.

Finally, broader strategic planning will help to create a roadmap that leverages other SWACO assets, operations, planning, and programming to create value-adding opportunities from the waste stream. The outcome of the future phases of this study will be a strategic technology action plan that guides SWACO's future state for the benefit of Franklin County residents.

Appendix A: Waste Categories

Major Waste Types	Waste Material Categories	Examples
Fibers	1. OCC – Cardboard	Corrugated cardboard, packing/shipping boxes, paperboard (cereal and soda boxes)
	2. Newspaper	Daily/weekly newspapers (glossy inserts removed)
	3. Office Paper	High grade copy paper, letterhead
	4. Other Mixed Paper	Magazines, glossy paper, brown shopping bags, junk mail, tissues, napkins
Plastics	5. PET #1	PET bottles, trays, tubs, and PET shopping bags
	6. HDPE #2 Natural	Natural HDPE bottles (milk), trays, tubs, and natural HDPE shopping bags
	7. HDPE #2 Colored	Colored HDPE bottles (detergent), trays, tubs, and colored HDPE shopping bags
	8. PVC #3	PVC pipes, tubes, and liners
	9. LDPE #4	LDPE garbage bags, saran wrap, LDPE film plastic
	10. Other Plastics	Plastic #5 Polypropylene (yogurt and other refrigerated food containers), Plastic #6 Polystyrene (disposable food utensils, styrofoam), Plastic #7 (layered or mixed plastics), and unidentifiable plastics
Metals	11. Aluminum Cans	Soda and beer cans
	12. Steel and Tin Cans	Food cans, meal replacement drink cans
	13. Other Ferrous	Steel, stainless steel, wrought iron, pig iron
	14. Other Non-Ferrous	Aluminum, copper, lead, nickel, tin, brass, and precious metals such as gold and silver
Organics	15. Yard/Pet Waste	Leaves, plants, yard trimmings, pet excrement, cat litter
	16. Wood	Treated and untreated lumber, plywood, particle board
	17. Food Waste	Plant based food and non-plant based food
Miscellaneous	18. Container Glass	Clear, brown, green and blue glass bottles and jars in which food products are packaged
	19. Textiles	Clothing, carpet, and bedding
	20. Other	Small sorting residue, diapers, feminine products, biohazard materials/sharps, dirt, rock, electronics, HHW, unrecyclable paper coated with foil or plastic
	21. Unsorted	Material lost during sorting process due to factors such as being adhered to floor, wind

Reference: GT Environmental, 2013

Appendix B: Glossary of Waste-to-Energy Technologies

To extract more value from the remaining MSW stream, a waste-to-energy (WTE) facility/operation is the best solution in reducing the amount of waste entering landfills, while also extracting value from the waste stream. Common WTE technologies are described below:

Anaerobic Digesters
Anaerobic digestion is a biological process where microorganisms break down biodegradable materials in the absence of oxygen. The end products are methane and nutrient rich composting material for crop application. Anaerobic digestion offers a more efficient method of methane capture than current landfill gas capture systems. Source separated organic waste streams, mainly food waste, yard trimmings and soiled paper, are the ideal starting materials for anaerobic digestion. Presorting is necessary to remove as much inert material as possible.

Enzymatic Hydrolysis and Fermentation
Enzymatic hydrolysis is a process in which enzymes are used to break down organic materials (food scraps, paper, cardboard, etc.) into sugars. The resulting products can then be fed to an anaerobic digester or a fermentation unit, where the sugar is converted into ethanol or other chemical products.

Autoclaving
Autoclaving MSW is primarily used as a pre-processing step for other energy conversion technologies such as gasification or pyrolysis. An autoclave uses heat, steam, and pressure to sterilize the waste. It is also able to separate the organic biomass (paper, cardboard, food scraps, etc.) from the inorganic waste (glass, metal, plastic, etc.).

Combustion
Mass burn and modular facilities are by far the most common types of combustion facilities in the United States. The waste supplied is used as fuel for the facility and may or may not be sorted or processed before it enters the combustion chamber. Mass burn units are designed to burn MSW with excess air in a single combustion chamber. The waste must be agitated to ensure the waste is mixed with the air to allow for complete combustion. Most mass-burn facilities burn MSW on a sloping, moving grate that is vibrated to create waste/air mixing. Modular systems are similar to mass burn facilities; however, they are much smaller, pre-fabricated units and are portable. Refuse derived fuel (RDF) facilities separate the non-combustible portion of the MSW stream from the combustible, and prepare the combustible portion into a form (material is shredded) that can be effectively fired in a boiler, which may or may not be located at the RDF facility.

Energy is created at combustion facilities by converting water to steam using the heat released from burning. The steam is then sent to a turbine generator to produce electricity. The remaining ash is collected and taken to a landfill. The amount of ash generated ranges from 15-25 percent by weight of the MSW processed and from 5-15 percent of the volume of the MSW processed. Generally, MSW combustion residues consist of two types of material: fly ash and bottom ash. Fly ash refers to the fine particles that are removed from the flue gas, and bottom ash is the MSW combustion ash (80-90 percent by weight). The ash can be processed for removal of recyclable scrap metals before being sent to landfills. As a result of combustion, the quantity of MSW sent to the landfill is significantly reduced but not eliminated.

Gasification
Gasification is a process that transforms carbon-based material into energy without burning it. Gasification converts the materials into a gas through a chemical reaction at high temperatures (typically ranging from 1,100 to 1,800 °F) with small amounts of air or oxygen. The material is broken down into simple molecules, primarily a mixture of carbon monoxide, hydrogen, methane, and other lighter hydrocarbons. Pollutants and impurities (trace minerals, particulates, sulfur, mercury and unconverted carbon) can be removed to very low levels using processes common to the chemical and refining

industries. One of the important advantages of gasification is that the syngas can be cleaned of contaminants prior to its use, eliminating many of the types of after-the-fact (post-combustion – mass burn technologies) emission control systems required by incineration plants. The resulting clean “synthesis gas” (syngas) can then be sent to a boiler, internal combustion engine or gas turbine to produce power or further converted into chemicals, fertilizers and transportation fuels (GTC, 2011).

Before gasifying MSW, it is typically shredded or ground into small particles. Metals and glass must be segregated from the waste stream prior to being sent into the gasification process. The ash produced from gasification is different from what is produced from an incinerator. While incinerator ash is considered safe for use as alternative daily cover on landfills, there are concerns with its use in commercial products. In high-temperature gasification, the ash flows from the gasifier in a molten form, where it is quench-cooled, forming a glassy, non-leachable slag that can be used for making cement, roofing shingles, as an asphalt filler or for sandblasting. Some gasifiers are designed to recover melted metals in a separate stream, taking advantage of the ability of gasification technology to enhance recycling (GTC, 2011).

A common challenge for implementation of gasification plants is the cost of the equipment due to the high temperature of the process and the additional syngas cleanup and emissions control steps. In addition, a significant fraction of the energy produced is used in the process to achieve the high temperatures necessary for gasification. This reduces the energy available for sale, further reducing the economic potential of the technology.

Plasma Gasification

Plasma gasification is similar to regular gasification, except a plasma torch/arc is used to generate the heat. Plasma torches/arcs are capable of generating temperatures up to 10,000ºF. The plasma torches/arcs can increase the rate of chemical reactions, which produce mainly carbon monoxide and hydrogen (syngas). Since the feedstocks are converted into their basic elements, even hazardous waste becomes a useful syngas. If present in the waste stream, inorganic materials (metals, tin, glass, etc.) are melted and fused into a glassy-like slag, which is non-hazardous and can be used in applications such as roadbed construction and roofing materials (GTC, 2011).

Pyrolysis

Pyrolysis is the thermo-chemical decomposition of organic material, at elevated temperatures in the absence of oxygen. The process involves the simultaneous change of physical phase and chemical composition, which is irreversible. Pyrolysis occurs at temperatures greater than 750°F (400°C) in order to generate syngas, which can be converted to liquid hydrocarbons such as biodiesel. Byproducts from the process are generally unconverted carbon and/or charcoal and ash. Currently, there are no large-scale commercial applications using pyrolysis for MSW due to the difficulty in creating valuable products with the process when a mixed waste stream is fed to the reactor.

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