Metro

Long Term Waste Management Options

Combined Qualitative Analysis And Greenhouse Gas Analysis Of Selected Waste Scenarios

HDR

March
2015

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1.0 Executive Summary

Metro Portland (Metro) has oversight of policies, programs, and facilities in Clackamas, Multnomah, and Washington counties (Tri-County area) and the 25 cities in the Portland region for the management of garbage, also known as municipal solid waste (MSW), which currently results in the disposal of approximately 1.1 million tons of garbage per year in landfills. As part of a long-term strategic planning effort, Metro is exploring a variety of potential technology options to improve the recovery and beneficial use of the garbage after existing waste reduction, reuse and recycling efforts have been implemented.

This Report summarizes a study commissioned to explore technologies that could process Metro's garbage for beneficial uses and for reduced reliance on landfill disposal as the primary waste management methodology. This Report utilizes the results of the Phase 1 Report (October 29, 2013) from this study which described, reviewed, and compared 14 different technology options grouped into four broad categories, namely thermal, biological, chemical, and mechanical techniques. The findings from the Phase 1 Report indicated that some technologies appeared to be less viable than others, mostly due to the relatively low level of demonstrated commercial development with respect to being capable of processing garbage as the feedstock. As a result, the number of possible technology options was reduced to five primary scenarios, two of which can be combined with an optional Materials Recovery Facility, for a total of seven scenarios. The Phase 1 Report findings concluded that some of the technologies considered would require advanced materials recovery, or Advanced Materials Recovery Facilities (AMRFs), as an initial component in the waste management system. AMRFs could recover some commodities (recycling) in addition to preparing the remaining material to be feedstock materials for subsequent processing. The by-products of the AMRF would concentrate the remaining garbage into organic-rich material for biological processes or high energy value material for thermal processes. Consequently, AMRFs are included in most of the waste management system scenarios included in the study.

In prior efforts, the seven remaining technology options were compiled and grouped into a variety of scenario options for review and evaluation. The scenarios included options that matched front-end pre-processing (through mechanical means such as an AMRF) with the actual main process technology (thermal or biological or a combination) and into a market or end destination such as the landfill. At a workshop on January 13, 2014, Metro staff and management along with their consultants reviewed, discussed, and assessed a variety of combined scenarios and selected five (5) scenarios for further consideration based on Metro developed criteria including: protect people's health, protect the environment, get good value for the public's money, keep the commitment to the highest and best use of materials, be adaptable and responsive in managing materials, and be accessible to all residents. These five scenarios for further analysis include:

- **Scenario 1** – Status Quo, which consists of leaving all programs, facilities, and the overall systems that are currently in place as is, and hauling garbage to a landfill for disposal. The Status Quo scenario provides the baseline for all other scenarios in terms of economics, recovery of resources, and environmental impacts.

- **Scenario 1A** – This variation of the Status Quo includes the addition of an AMRF to recover recyclable commodities and reusable materials before disposal.
- **Scenario 2** – This scenario includes a Direct Combustion Facility with energy generation and metals recovery, and a facility for disposal of ash residues, following an initial floor sorting to remove large, bulky, and non-processable materials from feedstock before combustion.
- **Scenario 2A** – This variation of the Direct Combustion Scenario 2 above includes the addition of an AMRF as a preprocessing system placed before the Direct Combustion Unit to recover recyclable commodities and reusable materials, and to remove bulky materials before Direct Combustion. This variation scenario also includes the recovery of plastics that may be marketed to an existing Pyrolysis facility for processing/recovery to crude oil.
- **Scenario 3** – This scenario includes a Gasification/Plasma Arc Gasification Facility with energy generation and metals recovery. There is potential that vitrified ash could have a beneficial use; however, for this study it is being sent to a landfill for disposal. An AMRF is included as a preprocessing system placed before the Gasification/Plasma Arc Gasification Facility to recover recyclable commodities, reusable or marketable materials (including recovery of plastics that may be marketed to an existing Pyrolysis facility) and to remove bulky materials and materials with lower BTU value. This scenario also includes the shredding of the feedstock to enhance the homogeneity of the fuel product for the Gasification/Plasma Arc Gasification Facility;
- **Scenario 4** – This scenario includes an Anaerobic Digestion (dry-type) Facility with initial AMRF preprocessing to separate organic from non-organic materials as best as possible, with non-organics processed to recover recyclable commodities and reusable materials, and to remove bulky materials before the remaining mixture of garbage materials is sent to the Anaerobic Digestion Facility to produce and recover biogas for the energy market. The digestate by-product would likely be sent to a landfill, due to its relatively high quantity of contamination from the garbage feedstock; and
- **Scenario 5** – This scenario includes a combination of an Anaerobic Digestion (dry-type) and RDF/Direct Combustion Facility, with initial AMRF preprocessing to separate organic from non-organic materials as best possible. Non-organics are processed to recover recyclable commodities and reusable materials, and to remove bulky materials, with residuals sent to an RDF/Direct Combustion Facility for energy production. Organic materials are sent to the Anaerobic Digestion Facility to produce and recover biogas for the energy market, with a digestate by-product produced and added back to the RDF, if appropriate with respect to its moisture content and respective energy value (for this study we have assumed that adding the digestate from anaerobic digestion to the RDF is appropriate).

The analyses for these scenarios were done assuming that all 1.1 million tons of garbage would be managed in each scenario. In reality, Metro would not build out one scenario/technology with

the capacity to manage all 1.1 million tons. This method of modeling was used to better illustrate the differences between technologies for managing garbage.

An economic analysis was performed for each of the scenarios. The results are summarized in Table 1 below. The cost estimates are shown as annual costs in 2014 dollars, and include all costs to operate the facility, plus an annualized capital[1] cost payment.

Table 1 – Total Annualized Cost per Scenario

#	Scenario	Total O&M per year* ($ Million)
1	Status Quo – Landfill	$44.79
1A	Status Quo – Landfill with AMRF	$89.13
2	Direct Combustion	$176.65
2A	Direct Combustion with AMRF	$186.27
3	AMRF with Gasification or Plasma Arc Gasification	$232.13
4	AMRF with Anaerobic Digestion	$115.49
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	$190.71

*Includes amortized capital costs.

This report includes environmental analysis of the scenarios for their impact on air quality as measured by the impact on the generation of greenhouse gases. The evaluation of environmental issues is expressed in terms of a life-cycle greenhouse gas (GHG) evaluation, which is explained in further detail in Section 5. The emissions shown for each scenario represent the estimate for net GHG emission, which include gross manufacturing emissions, any increases in carbon stocks, and any avoided utility emissions. The status quo GHG emissions are not shown above as zero because there are emissions associated with manufacturing the materials and disposing of them in a landfill, and emissions avoided by capturing methane produced from the landfill and using it to produce energy, offsetting emissions from fossil fuel consumption.[2] Further detail and discussion on the GHG emissions analysis is provided in Section 5 and Appendix D. The results of the GHG evaluation for 2019 are summarized in Table 2. Negative numbers represent GHG emissions that are avoided, hence the larger the negative value, the more preferable the scenario in terms of its relative impact on air quality as measured by greenhouse gas impacts.

[1] Capital costs were modeled using an amortized annual payment reflecting a 25 year loan at 5 percent interest
[2] WARM Version 13. WARM Background and Overview. June 2014. <http://www.epa.gov/epawaste/conserve/tools/warm/pdfs/Background_Overview.pdf>.

Table 2 – 2019 Life Cycle Greenhouse Gas Evaluation

#	Scenario	GHG Emissions ($MTCO_2e$)
1	Status Quo – Landfill	-63,800
1A	Status Quo – Landfill with AMRF	-509,300
2	Direct Combustion	-31,400
2A	Direct Combustion with AMRF	-518,200
3	AMRF with Gasification or Plasma Arc Gasification	-518,200
4	AMRF with Anaerobic Digestion	-601,500
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	-475,400

2.0 Introduction

This report explores the possible range of opportunities for Metro to utilize the non-recycled portion of garbage as a resource to be transformed into useful products. Technology options exist around the world that convert garbage to energy, fuel and other by-products that may have commercial applications. Metro is considering a set of scenarios which include a variety of potential technology options to manage its items from the garbage stream that cannot be reused, recycled or composted.

2.1 Background

Metro is responsible for solid waste planning and disposal of garbage in the region. As a part of these responsibilities, Metro develops and administers the Regional Solid Waste Management Plan (RSWMP) and is accountable for state-mandated waste reduction goals in the tri-county region, working with its local government and private sector partners to accomplish these goals. Metro oversees the operation of two Metro-owned transfer stations and administers contracts for the transport and disposal of that waste. Metro oversees a system of franchises and licenses to regulate privately owned and operated solid waste facilities that accept waste from the region. Metro also has other duties such as funding closure and monitoring of several inactive landfills located in the region and managing household hazardous waste collection in the region. Metro's current service practice and programs include:

- Waste prevention;
- Residential recycling;
- Commercial recycling;
- Residential and commercial recycling;
- Self-haul disposal;
- Hazardous waste management;
- Public education; and
- Control of illegal dumping.

The following is a list of solid waste facilities that are used (as of the time of this report) by Metro area residences and businesses:

- Thirteen material recovery facilities (MRFs);
- Six licensed yard debris composting facilities;
- Two tire processing facilities;
- Three roofing debris recovery facilities;
- One thermal processing facility, Fuel Processors, Inc.;

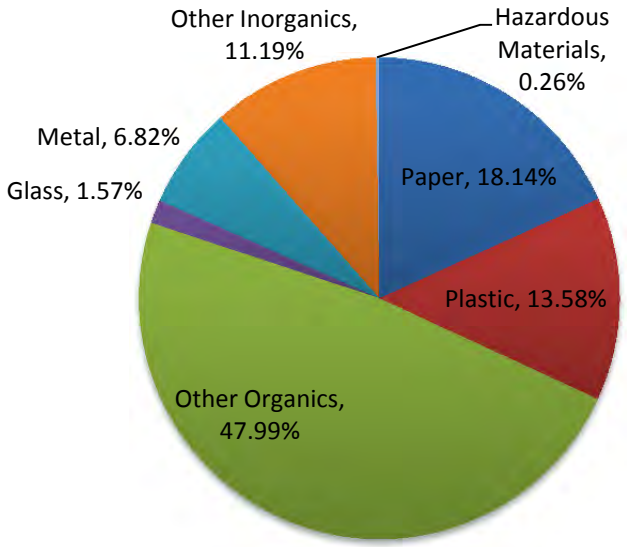
- Two sludge solidification/processors;
- Six transfer stations that include the two Public transfer stations: Metro Central and Metro South (both Metro owned and contractor operated);
- Eight landfills including: Columbia Ridge, Roosevelt Regional, Finely Buttes, Hillsboro, Coffin Butte, Wasco, Cowlitz County and Riverbend landfills; and
- Other facilities such as reload facilities exempt from Metro regulation.

In 2009, approximately 1,098,900 tons from Metro jurisdictions were disposed in various landfills. The composition by major category is shown in Table 3 and illustrated in Figure 1 below. Table 9 below includes more detail of what is included in these major categories.

Table 3 – Metro's 2009 Waste Composition of Major Categories

Component	Percent (%)
Paper	18.14%
Plastic	13.58%
Other Organics	47.99%
Glass	1.57%
Metal	6.82%
Other Inorganics	11.19%
Hazardous Materials	0.26%

Figure 1 - Waste Composition Pie Chart



2.2 Purpose

The purpose of this Report is to provide the combined qualitative and environmental analysis of the five scenarios that were selected by Metro staff and management for further consideration and comparison using Metro's criteria which includes: protecting people's health, protecting the environment, getting good value for the public's money, keeping the commitment to the highest and best use of materials, being adaptable and responsive in managing materials and being accessible to all residents.

This section of the report provides an overview of the qualitative and environmental aspects of these five scenarios selected to represent Metro's Long-Term Waste Management Options apart from the GHG evaluation which is discussed later in this Report. This section provides insights of key attributes of each of the five scenarios on the following key issues:

- Waste recovery and beneficial use capability;
- Energy production potential;
- Relative economics in terms of overall system cost per ton; and
- Environmental impact in terms of greenhouse gas footprint and air and water impacts.

2.3 Overview of Technologies Employed in Scenarios

A prior phase of this study evaluated a broad array of technologies for consideration of possible use in the future long term management of the Metro region's garbage. The prior study identified some technologies that appear to be less attractive than others, mostly due to the level of commercial development with respect to being capable of processing garbage as the feedstock. Some of the technologies identified as commercially viable have limited usefulness to Metro because they only have the capability to receive and process limited sub portions of the Metro feedstock. For example, some of the emerging thermal or thermo-chemical technologies such as pyrolysis-to-oil are designed to process only certain grades of plastics. Consequently, a limited set of technologies was selected for further modeling as consideration in the development of a variety of scenarios.

The following is a brief overview of these technologies. Please see Appendix A for a more detailed discussion of each technology, and Appendix B for illustrative flow diagrams.

Landfills

The use of Landfill as a waste treatment technology is the sanitary burial of the waste consisting of the placement, compaction and daily covering of garbage so as to protect the environment from the wastes. Modern landfill designs have several aspects that serve to protect the environment. These include liner systems, leachate (liquids) management systems, gas collection and landfill gas (LFG) to energy systems, and operational protocols. For modeling purposes, we have assumed the landfill is equipped with a landfill gas to energy (LFGTE) system. The LFGTE system consists of a network of extraction wells installed in waste and connected to an energy producing facility. There are two commonly

used gas-to-energy systems employed at a landfill; either an Internal Combustion (IC) Engine or micro-turbines. These technologies have a relatively high efficiency and low costs and have been in commercial operation on LFG for decades. IC engines are most common of the two and are well-suited for landfill gas-to-energy projects. They are capable of producing between 200 kW to more than 1 MW of electricity per engine. IC engines can be linked together in series to handle larger flows of LFG as gas production increases.

Advanced Material Recovery Facilities (AMRF)

An Advanced Material Recovery Facility is a process that employs a variety of mechanical and manual sorting systems to segregate garbage into discrete commodities, extracting those that have potential resale value for recycling markets. AMRF's can be configured differently depending upon the garbage it processes or the downstream facility which requires a certain feedstock for secondary use. A variety of sorting systems, including manual inspection and removal of large bulky items, followed by mechanical screens to classify the material into uniform sizes for recovery, are used. The process typically includes passing the material 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 to separate materials into size classifications and/or light versus heavier materials. Recovered materials are consolidated and shipped to recycling markets. Residues are shipped as garbage to a landfill or another appropriate waste reduction application.

The recovery effectiveness of these types of facilities varies from 10 percent to 25 percent, although some facilities have reported recovery above these figures. There is a wide range of capacities operating throughout the world. The optimal capacity is between 200 tons per day (tpd) and 1,500 tpd using multiple sort lines and operating additional shifts. AMRFs can have a useful operating life of 20 to 30 years if proper maintenance is provided. Many AMRFs are retrofitted throughout their life with new processing equipment as applicable.

AMRFs are fully developed and used through the U.S. and the world to process garbage (either mixed or commingled) to recover recyclable and reusable materials. They are a well proven technology, although certain 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.

Direct Combustion

Direct combustion of waste, referred to as mass burn combustion, waste-to-energy (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.

Direct combustion technology can be divided into two main types: (a) grate based, waterwall boiler installations; and (b) modular, shop erected combustion units with shop fabricated waste heat recovery boilers. The modular units are typically limited to less than 200 tons per day and are historically used in facilities where the total throughput is under 500 tpd. The larger direct combustion process with waterwall boilers feeds garbage directly into a boiler system with no preprocessing. The garbage is typically pushed onto a grate by a ram connected to hydraulic cylinders. Mass burn plants produce steam and electricity. Economics can be improved if a steam customer with a relatively continuous demand for steam can be identified.

The Marion County Energy-from-Waste facility operated by Covanta is an example of a direct combustion facility. The facility began operation in 1987, serving the solid waste management needs of Marion County, Oregon. The facility processes 550 tpd of municipal solid waste and generates up to 13.1 megawatts of renewable energy sold to Portland General Electric. The facility was the first mass-burn waterwall resource recovery facility combusting municipal solid waste in the U.S. to use dry flue gas scrubbers and fabric filter baghouses to control acid gases and particulates. Large-scale and modular direct combustion technology is used in commercial operations at more than 80 facilities in the U.S., two in Canada, and is the most common waste treatment technology with more than 500 operating in Europe.

Gasification

Gasification is a technology that thermally converts waste (in particular the carbon-based material) into a synthesis gas or “syngas” composed primarily of carbon monoxide and hydrogen. This syngas can be used as a fuel to generate electricity directly in a combustion turbine or engine, or more likely fired in a heat recovery steam generator (HRSG) to create steam that can be used to generate electricity via steam condensing turbine. In theory the syngas could also be further refined and used as a chemical building block in the synthesis of gasoline, diesel fuel, for generation of hydrogen, or other chemical feedstock gases. However, in general this process has not been developed using municipal wastes as a feedstock at commercial levels in the U.S.

The first facilities employing gasification were attempted several decades ago in the U.S. and in Europe. However, the technology was not developed to a commercial-scale. Japan has several operating commercial-scale gasification facilities that typically receive industrial sourced feedstock materials. Some facilities in Japan claim to process at least some garbage as a portion of their feedstock source, typically blended with industrial waste materials.

Plastics to Oil Using Pyrolysis

Pyrolysis is an emerging process that employs heating low grade plastics (typically film plastics and plastics which are not recyclable) in an oxygen-deficient environment to produce a combustible gaseous or liquid product and a carbon-rich solid residue. The gas or

liquid derived from the process can be refined and used as fuel in an internal combustion engine. Other possible uses for the gas or liquid by-products include fuel to power a gas turbine or, with further refinement, chemical production. Generally, pyrolysis occurs at a lower temperature than gasification, although the basic processes are similar. Also, plastics to oil systems assert that they can convert recovered plastics into oil which can be further refined by a third party into gasoline, diesel, and other industrial fuel or converted to a fuel directly within the system.

Although the use of pyrolysis was ruled out because it is not commercial for the processing of garbage, there are promising demonstration technology facilities processing high energy waste streams derived from garbage. Specifically, the Agilyx facility located in the Portland area is developing a pyrolysis-to-oil facility to process low grade/non recyclable plastics. Several other vendors have pilot scale or research and development (R&D) facilities in operation. The Enerkem facility nearing completion in Edmonton, Canada, has demonstrated the use of pyrolysis by processing used railroad ties and anticipates demonstrating its technology for processing residues of garbage in 2015.

Anaerobic Digestion

Anaerobic digestion is the process of biologically decomposing organic materials such as leaves, grass or food waste in a controlled oxygen-deficient environment. Bacteria consume the biologically available portion of the organic material and produce a biogas that consists mainly of methane (CH_4), water vapor, and carbon dioxide (CO_2). The biogas can be used as a fuel for boilers as a replacement for natural gas. Alternatively, the biogas can be used as fuel in an internal combustion engine or in a gas turbine to produce electricity. The biogas can also be refined to compressed natural gas (CNG), or pipeline quality natural gas. The biogas refinement process consists of the removal of moisture, carbon dioxide and trace gases (nitrogen, etc.).

There has been a recent increase in the use of anaerobic digestion technologies at commercial-scale plants in North America. Two facilities that process commercial organics and/or co-collected green/food wastes using a dry digestion technology and operating in the 100 to 300 tpd range have been recently developed in the San Francisco, California, area. Three facilities that process pre-consumer source separated organics (SSO) using a high-solids mixed tank digestion process and operating in the 50 to 100 tpd range have been constructed in the Sacramento, California, area. Two facilities that process post consumer SSO are operating in the Greater Toronto Area: the Dufferin Organic Processing Facility in Toronto and the CCI Energy Facility in Newmarket, Canada.

Refuse Derived Fuel (RDF)

An RDF processing system is a combined mechanical/thermal system that processes garbage using shredding, screening, air classifying and pelletizing or compressing the materials to produce a high energy solid fuel product, somewhat comparable to coal. The fuel product can then be used for on-site combustion to produce energy and heat, or can be

transported off-site to be used as a coal or biomass replacement in industries such as cement manufacturing. Some RDF facilities that process the fuel on-site can be classified as a “shred and burn” style or be co-located with a direct combustion type facility. These RDF facilities typically screen and shred the material as opposed to producing a pellet or other solid type of fuel. RDF plants with onsite combustion systems use the fuel directly, typically in a combustion process to produce steam and electricity. Economics can be improved if a steam customer with a relatively continuous demand for steam can be identified.

RDF technology is a commercially proven technology that is used at a number of plants in the U.S., Europe and Asia (generally larger plants with capacities greater than 1,500 tpd). Example plants include: the Dongara facility in York Region in Canada, Ames, IA; Southeastern Public Service Authority, VA; French Island, WI; Mid-Connecticut; Honolulu, HI; and West Palm Beach, FL.

3.0 Description of Scenarios

Five (5) scenarios with two variations were developed to represent a spectrum of waste management options that reflect varying degrees of processing capabilities including various types of preprocessing technologies configured specifically for main processing technologies (such as biological or thermal technologies) which are designed to provide differing methods of beneficially using the waste materials. The analyses for these scenarios were prepared assuming all 1.1 million tons of garbage would be managed in each scenario. In reality, Metro would not build out one scenario/technology with the capacity to manage all 1.1 million tons. This method of modeling the entire Metro garbage stream was used to better illustrate the differences between technologies for each of the scenarios.

The five (5) combined scenarios and two variations were selected to include variations on the potential impacts of these scenarios as follows:

- **Scenario 1 and 1A –** The Status Quo (Scenario 1) consists of leaving all programs, facilities, and the overall systems that are **currently** in place as is, and hauling garbage to a landfill for disposal. Scenario 1A was created as a variation to the Status Quo scenario, and includes the addition of an AMRF to recover recyclable commodities and reusable materials before disposal.

- **Scenario 2 and 2A** – Scenario 2 consists of an initial floor sorting to remove large, bulky, and non-processable materials from feedstock before going to a Direct Combustion Facility with combustion. Scenario 2A was created as a variation to Scenario 2, and includes the addition of an AMRF to recover recyclable commodities, reusable materials, and remove bulky materials before sending materials to the Direct Combustion process; this includes augmented recovery of plastics that may be marketed to an existing or future Pyrolysis facility for processing/recovery to crude oil.

- **Scenario 3** – This scenario consists of modeling a Gasification and/or Plasma Arc Gasification Facility for energy generation and metals recovery using an AMRF as a preprocessing system. The AMRF is modeled as the pre-processing facility to prepare the materials to meet the size and homogeneity required by the gasification system, in addition to providing an opportunity to recover recyclable commodities, reusable or marketable materials, and plastics. The AMRF would also function to remove bulky materials and screen out lower BTU materials before shredding the material to make a feedstock for the Gasification Facility. Some forms of gasification employ high temperatures, which results in a glassy or 'vitrified' type of ash; however, doing so typically requires higher internal, or parasitic, energy use. For simplicity, the gasification process modeled in Scenario 3 is assumed to produce an ash that is managed similarly to the management of ash produced by an incinerator or energy-from-waste facility. No vitrified ash is assumed to be generated. This model reflects the conservative assumption that the ash is disposed of in a landfill.

- **Scenario 4** – This scenario consists of modeling an Anaerobic Digestion (dry-type) Facility with initial AMRF preprocessing to separate organic from non-organic materials as best as possible, with non-organics processed to recover recyclable commodities and reusable materials, and the remaining mixture of garbage materials sent to the Anaerobic Digestion Facility to produce and recover biogas for the energy market. The digestate by-product is sent to a landfill, due to its relatively high quantity of contamination from the garbage feedstock.

- **Scenario 5** – This scenario consists of modeling an Anaerobic Digestion (dry-type) Facility with initial AMRF preprocessing to separate organic from non-organic materials as best possible. Non-organics are processed to recover recyclable commodities, reusable materials, and remove bulky materials, with residuals sent to an RDF/Direct Combustion Facility for energy production. Organic materials are sent to the Anaerobic Digestion Facility to produce and recover biogas for the energy market, creating a digestate by-product that is added back to the RDF with the assumption that its moisture content and respective energy value are appropriate.

3.1 Technology Modeling Basis for Scenarios

A design basis was developed for each scenario to define which facilities were included and determine appropriate tonnage to the facilities and the number of facilities required. The tonnage allocations for the design basis are shown in Table 5 (see page 14), along with the by-products produced from each facility type that go to the landfill for disposal. Information for each facility type is detailed below:

- **Landfill** – The landfill is modeled to reflect a modern sanitary landfill equipped with a landfill gas collection field to extract the landfill gas generated within the landfill and a gas to electricity power generation facility to beneficially use the majority of the landfill gas generated. The quantity of material disposed varies according to each of the scenarios. Table 4 below illustrates the estimated quantity of material disposed for each of the scenarios.

Table 4 – Tons to Landfill Disposal by Scenario

		2019	2038
#	**Scenario**	**Final Disposal in Landfill (tons/year)**	**Final Disposal in Landfill (tons/year)**
1	Status Quo – Landfill	1,139,369	1,361,501
1A	Status Quo – Landfill with AMRF	907,097	1,063,167
2	Direct Combustion	319,656	382,442
2A	Direct Combustion with AMRF	272,492	319,411
3	AMRF with Gasification or Plasma Arc Gasification	187,245	220,039
4	AMRF with Anaerobic Digestion	737,947	908,657
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	259,398	313,577

- **AMRF** – The AMRFs modeled in the scenarios vary in terms of their performance to reflect the appropriate feedstock that is produced for the primary treatment in each of the scenarios. The AMRFs were modeled to process the same incoming tonnage, so each facility was assumed to have a 750 tpd capacity. Five facilities are required, with 92 percent availability and 66 personnel (although for Scenarios 2A and 3 an additional seven staff were needed to recover plastics for off-site processing at a pyrolysis facility). Figure B.1 in Appendix B contains a flow diagram and more detail about the AMRF process.
- **Direct Combustion** – Direct Combustion is modeled as a modern mass burn type waste to energy facility equipped with a modern steam powered electrical generation system, ash processing and recovery for metals, and a modern emission control system. Direct Combustion is considered in Scenarios 2 and 2A. Both scenarios assumed that each facility was sized at 1,000 tpd capacity, 90 percent availability and 40 personnel. However, for Scenario 2, four facilities were required, whereas in Scenario 2A with an AMRF, three facilities were required. Figure B.2 in Appendix B contains a flow diagram and more detail about the Direct Combustion process.
- **Gasification** – Gasification is modeled as a modern fluidized bed gasification facility which co-fires the product gases for steam powered electrical power generation, an ash recovery system and a modern emission control system. Gasification is considered in Scenario 3. This scenario assumed that the facility was sized at 1,000 tpd capacity. Three facilities were required, with 85 percent availability and 45 personnel. The lower availability reflects an allowance for additional facility maintenance as observed in gasification facilities currently operating. Figure B.3 in Appendix B contains a flow diagram and more detail about the Gasification process.
- **Anaerobic Digestion** – Anaerobic digestion is modeled as a dry bunker type, batch digestion facility equipped with a biogas to electricity power generation system. Anaerobic digestion is considered in Scenarios 4 and 5. Both scenarios assumed that each facility was sized at 300 tpd capacity, with 93 percent availability and eight personnel. However, Scenario 4 assumes that most of the waste is digested. Therefore nine facilities were required, whereas in Scenario 5, only the digestible materials are sent to anaerobic digestion and only two facilities are required. The rationale for the Anaerobic Digestion Facilities in Scenario 4 to digest a high percentage of waste was to illustrate the environmental and financial affects of attempting to digest the entire waste stream, as opposed to only the digestible materials in Scenario 5. For Scenario 5, the remainder of the waste separated at the AMRF is assumed to be sent to an off-site RDF/Direct Combustion Facility. Figure B.4 in Appendix B contains a flow diagram and more detail about the Anaerobic Digestion process.
- **Refuse Derived Fuel/Direct Combustion** – RDF/Direct Combustion is modeled as a fluidized bed incineration facility which is equipped with a steam powered electrical generation facility, ash recovery and a modern emission control system. RDF/Direct Combustion is considered in Scenario 5. This scenario assumed that a combined

RDF/Direct Combustion facility would be used to process the non-digestible garbage residue from the AMRF. Each RDF/Direct Combustion facility was sized at 1,000 tpd capacity, with 90 percent availability and 40 personnel. Four facilities were required. Figure B.5 in Appendix B contains a flow diagram and more detail about the RDF process.

Table 5 – Assumed Design Basis Comparison (2019)

			Landfill	AMRF or Floor Sort	Direct Combustion		Gasification		Anaerobic Digestion		RDF/Direct Combustion		
#	**Scenario**	**2019 Input (tons/year)**	**Direct to Landfill (tons/year)**	**Recovered Recyclables (tons/year)**	**Material Converted to Energy (tons/year)**	**Ash Produced from Direct Combustion (tons/year)**	**Material Converted to Energy (tons/year)**	**Ash and Non-Processable Material Produced from Gasification (tons/year)**	**Material Converted to Energy (tons/year)**	**Digestate Produced from Anaerobic Digestion (tons/year)**	**Material Converted to Energy (tons/year)**	**Ash Produced from RDF/Direct Combustion (tons/year)**	**To Non-Metro Pyrolysis Plant (tons/year)**
1	Status Quo – Landfill	1,139,369	1,139,369										
1A	Status Quo – Landfill with AMRF	1,139,369	907,097	**232,272**									
2	Direct Combustion	1,139,369	16,750	**21,142**	**798,570**	302,906 To Landfill							
2A	Direct Combustion with AMRF	1,139,369	16,750	**238,645**	**596,730**	255,741 To Landfill							**31,501**
3	AMRF with Gasification or Plasma Arc Gasification	1,139,369	16,750	**238,645**			**681,977**	170,494 To Landfill					**31,501**
4	AMRF with Anaerobic Digestion	1,139,369	19,325	**232,272**					**169,150**	718,622 To Landfill			
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	1,139,369	19,325	**232,272**					**87,527**	To RDF Process	**560,171**	240,073 To Landfill	

1. For Scenario 2, all tons would be hauled to the Direct Combustion Facilities, but a floor sort would separate out materials unsuitable for combustion upon arrival. These materials would be recycled or sent to the landfill.

Note: Tons are shown in bold are recovered or consumed in energy production.

4.0 Technical Analysis of Selected Scenarios

The basis of the analysis for each of the five (5) selected scenarios used qualitative and quantitative criteria, as well as the estimated life-cycle GHG evaluation addressed in Section 5 below. The Report provides the analysis and comparison of the following key factors:

- Waste recovery capability
- Energy production potential
- Water usage
- Truck/transportation requirement
- Relative economics in terms of overall cost to the system per year

4.1 Waste Recovery Capability

The amount of waste recovered for beneficial uses was calculated for each scenario, and the resulting recovery percentage can be seen in Table 6. All tons are modeled as being sent directly to landfill in Scenario 1. In Scenario 1A, by adding an AMRF, approximately 20 percent of the garbage in 2019 is estimated to be recovered. In Scenario 2, Direct Combustion Facilities convert the garbage to energy, producing ash as a by-product. This results in approximately 72 percent (by weight) of the garbage in 2019 being converted to energy. The Scenario 2 result of 72 percent of tons to beneficial use reflects no recyclables being recovered, due to the fact that all of the waste is incinerated and all ash is disposed of in a landfill. In Scenario 2A, an AMRF is added to the Direct Combustion Facilities and the estimated beneficial use increases to 76 percent, which includes 24 percent as recovered materials from the AMRF and the remaining 52 percent as waste converted to energy by incineration. The resulting ash is disposed of in a landfill. In Scenario 3, a Gasification Facility is used in conjunction with an AMRF to recover approximately 84 percent of garbage to beneficial uses. This increase is attributed to a higher temperature conversion of the garbage, resulting in less ash being produced for landfill disposal. In Scenario 4, material is initially sorted at an AMRF, and then any material not sent directly to the landfill or recovered as recyclable is sent though Anaerobic Digestion with an assumed 35 percent converted to energy,[3] and a large portion (as digestate) needing to be disposed in the landfill. In Scenario 5, only the digestible materials are sent to the Anaerobic Digestion Facility resulting in approximately 15% conversion (representing 169,150 tons per year) to energy from the anaerobic digestion process. The remainder of the waste separated at the AMRF is assumed to be sent to an RDF/Direct Combustion Facility where the residues are converted to energy production from the combined RDF/Combustion Facility. Scenario 5 results in a combined estimated 77 percent of tons being recovered for beneficial uses.

As Metro anticipates the implementation of additional diversion programs and policies, the composition of waste varies from the commencement of the modeling in 2019 to the end of

[3] The 35 percent recovery using Anaerobic Digestion reflects the quantity of recoverable organics and subsequent anaerobic conversion to biogas based on the available quantity of organics in the garbage and the results of the San Jose Dry Fermentation Anaerobic Digester provided by Zero Waste Energy Development Company.

the model in 2038. As a consequence, the projected diversion rate varies slightly over time. Table 6 below illustrates the projected diversion of each scenario in 2019.

Table 6 – Beneficial Use Comparison per Scenario for 2019

#	Scenario	Final Disposal in Landfill (tons/year)	Recovered Recyclables (tons/year)	Material Converted to Energy (tons/year)	Projected Material to Beneficial Use (%)
1	Status Quo – Landfill	1,139,369			0%
1A	Status Quo – Landfill with AMRF	907,097	232,272		20%
2	Direct Combustion	319,656	21,142	798,570	72%
2A	Direct Combustion with AMRF	272,492	270,147	596,730	76%
3	AMRF with Gasification or Plasma Arc Gasification	187,245	270,147	681,977	84%
4	AMRF with Anaerobic Digestion	737,947	232,272	169,150	35%
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	259,398	232,272	647,699	77%

4.2 Energy Generation

The energy production for all facilities by scenario was estimated and is summarized in Table 7. In Scenarios 1 and 1A, energy is produced from the LFGTE system, and in Scenario 4, energy is produced from both the LFGTE to energy system and from biogas generated by the anaerobic digestion system. For the remaining scenarios, the amount of waste sent to the landfill is so small that any energy production from landfill gas is assumed to be negligible. In Scenario 1A, because some of the waste is diverted to recycling markets, the amount of megawatt-hours per year (MWh/year) is slightly less than the amount produced in Scenario 1. In Scenario 2, with the exception of bulky waste materials and recyclables, all of the waste is fed to Direct Combustion Facilities for energy production. In Scenario 2A, a smaller portion of the waste is fed to Direct Combustion Facilities, after recovering recyclables to market (including non-recyclable film plastics being diverted to a plastics pyrolysis plant) and sending inappropriate feedstock material to the landfill. In Scenario 3, after recovering recyclables (including non-recyclable film plastics being diverted to a plastics pyrolysis plant) to market, and sending inappropriate feedstock material to the landfill, the remainder is fed to Gasification Facilities. In Scenario 4, after recovering recyclables to market and sending inappropriate feedstock to the landfill, the remainder is fed into Anaerobic Digestion Facilities for energy production. The residue, or digestate, is disposed of in a landfill due to its relatively high concentration of contaminants, resulting in additional production of landfill gas to energy. This scenario does not include the recovery of film plastics for pyrolysis in order to provide a scenario in which no thermal technologies are included. This allows a contrast to the environmental aspects of a non-thermal based waste solution. In Scenario 5, after recovering recyclables to market and inappropriate feedstock to

the landfill, the remainder is divided into two waste streams. Organic rich materials separated by the AMRF are fed into Anaerobic Digestion Facilities for energy production, and the remainder of the material is fed to RDF/Direct Combustion Facilities for energy production. Scenario 5 also does not include the recovery and pyrolysis of film plastics in order to illustrate the contrasting energy and environmental aspects of Scenarios 2A and 3, which include this feature. Table 7 below provides a summary of the quantities of energy produced per scenario.

Table 7 – Estimated Energy Produced Comparison

#	Scenario	Net Energy Produced (MWh/year)						Total Net Energy Produced (MWh/year)
		Landfill	AMRF	Direct Combustion	Gasification	Anaerobic Digestion	RDF/Direct Combustion	
1	Status Quo – Landfilling	1,640						1,640
1A	Status Quo – Landfilling with AMRF	1,384						1,384
2	Direct Combustion			642,750				642,750
2A	Direct Combustion with AMRF			497,663				497,663
3	AMRF with Gasification or Plasma Arc Gasification				507,288			507,288
4	AMRF with Anaerobic Digestion	942				74,100		75,042
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion					32,900	466,763	499,663

4.3 Estimated Cost

An economic analysis was conducted for all facilities to develop a system wide cost for each scenario as shown in Table 8. It should be noted that all economic figures were assumed in 2014 dollars; no escalation from this current year dollars to 2019 or 2038 dollars was assumed. In all scenarios, a capital cost was estimated, including costs for site improvements and buildings, stationary equipment, rolling stock, spare parts, an environmental impact study, planning, permits, design, construction administration and a start-up and acceptance period of one (1) month. All capital costs were annualized on a levelized basis over a 25 year period with an assumed 5 percent interest rate and a cost of bond issuance of 5 percent. In addition, for all scenarios, an annual operations and maintenance (O&M) cost was estimated. The O&M cost includes costs for labor, rolling stock, stationary equipment maintenance and replacement, utilities, fuel, general and

administrative, legal and accounting, contractor overhead, and insurance, as well as the annualized capital cost over a 25 year period.

For facilities that recover recyclable commodities, an average net revenue $25 per ton of recovered commodity was used to calculate potential revenues for sales of recyclables to the market. For those facilities that generate power, revenues for electrical sales were estimated at $0.08 per kWh. For all facilities except the landfill, a 15 percent contingency was used for both capital and annual O&M costs.

Additional economic assumptions for each facility type are detailed below:

- **Landfill** – In all scenarios for waste requiring disposal, it was assumed that the disposal tipping fee would be the current Columbia Ridge Landfill fee of $22.79. For transportation to the landfill a distance of 300 miles was assumed for the round-trip. For transportation to all facilities discussed below, a distance of 100 miles round-trip to the facilities was assumed, leaving a round trip from the facilities to the landfill at 200 miles round-trip. The costs for transportation were calculated by assuming the time it takes to make the trip at an average speed of 55 miles per hour, an average on site time of one-half an hour, a cost of $95 per hour and an average load capacity of 34 tons which, for modeling purposes, is somewhat similar but higher than the current contracted cost Metro pays Walsh Trucking Inc., but consistent with other aspects of the model in terms of transportation related issues.
- **AMRF** – The AMRF costs reflect capital and operations cost for the construction of five facilities to be constructed to pre-process the waste residuals to a level needed for each of the downstream primary treatment facilities (direct combustion, gasification, anaerobic digestion, or RDF). The operational costs reflect a dual operations shift staffing level with the third shift dedicated to routine maintenance. In Scenarios 2A and 3, an additional seven sorters were included to recover additional plastic materials to send to an off-site non-Metro pyrolysis plant operator.
- **Direct Combustion** – The direct combustion costs reflect the cost for four direct combustion facilities in Scenario 2 and three facilities in Scenario 2A to be constructed and operated. The direct combustion facilities were modeled at 1,000 tpd throughput capacity and include a modern emissions control system in addition to ash processing for metals removal.
- **Gasification** - The gasification facility model reflects the cost for three gasification facilities in scenario 3 to be constructed and operated. The gasification facilities were modeled at 1,000 tpd throughput capacity and include a modern emissions control system in addition to ash processing for metals removal. Both the lower availability figure and higher contingency were used for gasification to reflect overcoming the unknowns in terms of increased risk in constructing and operating the first of these facilities in the United States. No revenues were assumed for the aggregate produced from the vitrified ash as markets will need to be developed.

- **Anaerobic Digestion** – The anaerobic digestion facility model reflects the cost of nine dry fermentation facilities in scenario 4 and two facilities in scenario 5 to be constructed and operated. The anaerobic digestion facilities were modeled at 300 tpd throughput capacity and include a biogas to electricity system equipped with modern emissions controls. Digestate from the anaerobic digestion systems are modeled to be disposed in the landfill.
- **RDF/Direct Combustion** – The RDF/direct combustion costs reflect the cost for two RDF/direct combustions facilities in scenario 5 to be constructed and operated. The RDF/direct combustion facilities were modeled at 1,000 tpd throughput capacity and include a modern emissions control system in addition to ash processing for metals removal.

Comparing the annual operating costs of the scenarios shows that the base case for transport and disposal to the landfill has an estimated cost of approximately $45 million per year, which is the lowest cost of all the scenarios modeled.

The addition of the AMRF to the landfill base case (scenario 1A) recovers approximately 20 percent of waste prior to landfill. However, the annual cost of Scenario 1A is $89M per year, approximately double the cost of landfill disposal alone, taking into account the added costs of the AMRF and adjusting for revenues from the recycled materials. Of this cost, approximately $31M is for landfill disposal, and $51M is for all 5 AMRFs. The remaining costs are from hauling.

Developing Direct Combustion Facilities without the benefit of an AMRF as modeled in Scenario 2 has an estimated annual cost of $177M. Of this cost, approximately $11M is for landfill disposal, and $159M is for all 4 Direct Combustion Facilities. The remaining costs are from hauling.

Adding an AMRF to the Direct Combustion Facilities as modeled in Scenario 2A has a higher annual cost of $186M. Of this cost, approximately $9M is for landfill disposal, $51M is for all 5 AMRFs, and $119M is for all 3 Direct Combustion Facilities. The remaining costs are from hauling.

Utilizing Gasification Facilities with AMRF as modeled in Scenario 3 has an annual cost of $232M. Of this cost, approximately $6M is for landfill disposal, $51M is for all 5 AMRFs, and $168M is for all 3 Gasification Facilities. The remaining costs are from hauling.

Utilizing Anaerobic Digestion Facilities with AMRF as modeled in Scenario 4 has a cost of $115M per year. Of this cost, approximately $25M is for landfill disposal, $51M is for all 5 AMRFs, and $32M is for all 9 Anaerobic Digestion Facilities. The remaining costs are from hauling.

Utilizing Anaerobic Digestion Facilities with AMRF and the remainder processed at RDF/Direct Combustion Facilities as modeled in Scenario 5 has an annual cost of $191M. Of this cost, approximately $9M is for landfill disposal, $51M is for all 5 AMRFs, $119M is for

all 3 RDF/Direct Combustion Facilities, and just over $5M is for both Anaerobic Digestion Facilities. The remaining costs are from hauling.

These values are shown in Table 8 below. The capital cost is shown to illustrate the amount of capital investment required to provide the infrastructure for each of the scenarios. The annual cost shown reflects the amortized capital cost plus the operating and maintenance costs.

Table 8 – Annualized Capital and O&M Cost Comparison

#	Scenario	Capital Cost ($ Millions)	Total Annualized cost (Amortized capital plus O&M) per Year* ($ Million)
1	Status Quo – Landfill	$0	$44.79
1A	Status Quo – Landfill with AMRF	$28	$89.13
2	Direct Combustion	$494	$176.65
2A	Direct Combustion with AMRF	$522	$186.27
3	AMRF with Gasification or Plasma Arc Gasification	$708	$232.13
4	AMRF with Anaerobic Digestion	$62	$115.49
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	$556	$190.71

*Includes amortized capital costs.

5.0 Greenhouse Gas and Renewable Energy Standards

5.1 Oregon Greenhouse Gas Emission Standards

Oregon has adopted several state policies to evaluate and reduce greenhouse gas emissions. In 1992, a benchmark was adopted as the basis for efforts to hold the state's emissions to 1990 levels. In 2007, the Oregon Legislature adopted ORS 468A.205, which set the following goals:

- By 2010, stop the growth of and begin reduction of GHG emissions;
- By 2020, reduce GHG levels to 10 percent below 1990 levels; and
- By 2050, reduce GHG levels to at least 75 percent below 1990 levels.[4]

Also in 2007, House Bill 3543 established the Oregon Global Warming Commission, to be supported by state agencies. The responsibilities of this commission include making recommendations to meet the GHG reduction goals, examining cap and trade systems, developing an educational strategy on global warming issues, and tracking global warming impacts on Oregon and other issues. House Bill 3543 also established the Oregon Climate Research Institute in the Oregon University System.[5]

The report "Oregon's Greenhouse Gas Emissions Through 2010: In-Boundary, Consumption-Based and Expanded Transportation Sector Inventories," was published in 2013 as a joint effort of Oregon Departments of Energy (ODOE), Environmental Quality (ODEQ), and Transportation (ODOT). It detailed the following three methods of inventorying GHG emissions for Oregon:

1. In-boundary emissions, which include emissions that occur within Oregon's borders and emissions associated with the use of electricity within Oregon's borders;
2. Consumption-based emissions, which include the global emissions associated with goods and services, including energy, consumed in Oregon; and
3. Expanded transportation sector emissions, which include emissions associated with fuel use by ground and commercial vehicle travel, freight movement of in-bound goods by all other modes of transportation (heavy trucks, railroads, ships, airplanes, and pipelines), and air passenger travel by Oregonians.

The report quantifies GHG emissions using the three methods of inventories, identifies emissions that are counted by more than one method (overlap), and then calculates a total overall emission profile for Oregon.

[4] Oregon Department of Environmental Quality, Oregon Department of Energy, and Oregon Department of Transportation. "Oregon's Greenhouse Gas Emissions Through 2010: In-Boundary, Consumption-Based and Expanded Transportation Sector Inventories." July 18, 2013.
[5] Oregon Department of Energy. "House Bill 3543: Global Warming Actions." <http://www.oregon.gov/ENERGY/GBLWRM/Pages/HB3543.aspx>.

5.2 European Union Greenhouse Gas Emission Standards

The European Union (EU) compiles GHG inventories on an annual basis as part of its participation in the United Nations Framework Convention on Climate Change (UNFCCC) and the EU-15 submission under the Kyoto Protocol. National GHG inventories are compiled from reports by the EU Member States of the EU-15 and the EU-28, the European Commission Directorate-General Climate Action, the European Environment Agency and its European Topic Centre on Air Pollution and Climate Change Mitigation, Eurostat, and the Joint Research Centre. Monitoring and reporting standards are determined by the Regulation (EU) 525/2013, which includes required monitoring, reporting, reviewing and verifying of GHG emissions and other information.[6]

In April 2009, the EU adopted the Climate and Energy Package, with the stated goal of limiting the rise in global average temperature to no more than 2 degrees (Celsius) above pre-industrial levels. In order to accomplish this, the EU committed to reducing GHG emissions by 20% from 1990 levels by 2020.[7] They are on track to meet or exceed this goal.

A study performed for the European Commission Directorate-General found that the greatest reduction in GHG emissions was achieved by source segregation of garbage, with paper, metals, textiles, and plastics sent to recycling, and putrescible garbage sent to composting or anaerobic digestion. The study considered that incineration (and similarly combustion, pyrolysis and gasification) causes the production of fossil-derived carbon dioxide from the combustion of plastics and some textiles, as well as emissions of nitrous oxide. The amount of emissions reduced by incineration, and how much this offsets the emissions created, is dependent on if electricity and heat are recovered, and what energy source is displaced by recovering the energy from the incinerator.[8]

However, the study examined garbage management only from the perspective of greenhouse gas emissions. It did not take into account other environmental, social, or economic considerations. The cost of disposing of garbage in a landfill in Europe continues to increase as landfill capacities are reduced and expansion is limited by available land, strict environmental standards, and the resulting increasing costs. Incineration and other energy from waste facilities have become common throughout Europe, as those types of technologies have established themselves as successful at treating large amounts of waste and reducing the overall footprint that waste disposal requires.

[6] European Environment Agency. “Annual European Union greenhouse gas inventory 1990–2012 and inventory report 2014.” September 2014.
[7] Ibid
[8] AEA Technology. “Waste Management Options and Climate Change.” July 2001.

5.3 USEPA Greenhouse Gas Emission Standards

The United States Environmental Protection Agency (USEPA) is required to use renewable energy and green power according to the following federal statutes:

- Energy Policy Act of 2005, which directs the federal government to increase its renewable energy use to offset a minimum of 3 percent of its energy consumption in FY 2007 through 2009, 5 percent in FY 2010 through 2012, and 7.5 percent by FY 2013.
- Executive Order (EO) 13423, "Strengthening Federal Environmental, Energy and Transportation Management," which mandates that a minimum of half of the green power usage requirements be met with energy from new renewable sources.
- Energy Independence and Security Act of 2007 (EISA), Section 523, which requires solar hot water equipment to be used to meet at least 30 percent of the hot water demand in federal buildings or major renovations, as long as it is life cycle cost-effective.
- EO 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," which directs federal agencies to consider increasing agency renewable energy use and onsite renewable energy projects when the agency is setting its targets for GHG emission reductions.

However, since fiscal year (FY) 2006, EPA has purchased enough green power to offset all of the Agency's estimated annual electricity consumption, voluntarily exceeding its renewable energy consumption requirements.[9]

The USEPA also has several voluntary programs that promote renewable energy on a national level. The Green Power Partnership (GPP) supports procurement of green power by organizations such as companies, universities, and local, state, and federal government agencies. It does this by providing expert advice, technical support, tools, and other resources to reduce the environmental impacts associated with conventional electricity use. The Landfill Methane Outreach Program (LMOP) promotes the use of landfill gas as a renewable, green energy source. AgSTAR (jointly sponsored by EPA, the U.S. Department of Agriculture, and the U.S. Department of Energy) promotes the use of methane (biogas) recovery technologies to reduce methane emissions and produce renewable energy from livestock waste management operations. The RE–Powering America's Lands program promotes and provides resources for renewable energy development on current and formerly contaminated land and mining sites.[10]

[9] USEPA. "Federal Renewable Energy and Green Power Requirements." <http://www.epa.gov/oaintrnt/greenpower/requirements.htm>. Last updated October 24, 2012.
[10] USEPA. "EPA Programs Supporting Renewable Energy." <http://www.epa.gov/statelocalclimate/state/topics/renewable.html.> Last updated August 13, 2014.

6.0 Greenhouse Gas Analysis of Selected Scenarios

A GHG emissions model was prepared comparing the seven scenarios evaluated for projected garbage disposal in the Metro region in 2019 and in 2038. The USEPA WAste Reduction Model (WARM), Version 13, was used to evaluate GHG emissions from landfill operations versus combustion, composting, and recycling operations. There are limitations to the model, and results should be seen as illustrative of overall GHG reduction potential. One such limitation is that the model does not offer anaerobic digestion as an alternative to disposal. Separate calculations were done to estimate the GHG reduction that would result from using the biogas generated by anaerobic digestion as an alternative energy source. Similarly, WARM does not include pyrolysis or gasification. Gasification was assumed to produce similar energy quantities and similar emissions, and was modeled using the combustion option in WARM. Pyrolysis was not included in the modeling, as that processing option contains many unknowns and would require many assumptions, the result would be rendered impractical to use in the planning process. For this reason, scenarios containing pyrolysis as process were modeled with only the tons going to a landfill, combustion, or gasification process.

6.1 WARM

WARM was created by the USEPA as a tool to help managers and policy makers understand and compare the emissions and offsets resulting from different materials management options (e.g., landfill disposal, composting, etc.) for materials commonly found in the waste stream. Only anthropogenic emissions are considered as GHG emissions in WARM. Biogenic emissions are considered to be carbon that was originally removed from the atmosphere through natural processes, like photosynthesis, and would eventually return to the atmosphere through a natural degradation process. Anthropogenic emissions are emissions resulting from human activities and subject to human control, which are considered disruptive to the naturally occurring carbon cycles and balance. The emissions resulting from burning fossil fuels (i.e., petroleum based materials such a plastics) are considered to be anthropogenic because the emissions would not have been released without human intervention.[11]

Although the GHG emissions results of WARM are presented as occurring in two discrete years (2019 and 2038), the results actually indicate the full life-cycle benefits of each waste management alternative, which may accrue over the long-term.[12] The emissions shown for each scenario in WARM represent the estimate for net GHG emission, which include gross manufacturing emissions, any increases in carbon stocks, and any avoided utility emissions. No scenario results in zero emissions, as there are emissions associated with manufacturing the materials modeled and then processing them for reuse, conversion, or disposal.[13]

[11] USEPA, 2012. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), available at http://www.epa.gov/climatechange/waste/SWMGHGreport.html.
[12] USEPA. WAste Reduction Model (WARM), Version 13.
[13] WARM Version 13. WARM Background and Overview. June 2014. <http://www.epa.gov/epawaste/conserve/tools/warm/pdfs/Background_Overview.pdf>.

6.2 WARM General Assumptions

The Columbia Ridge Landfill is located in an area receiving approximately 9 inches of rain per year. For the purposes of modeling landfill gas generation, the "dry" designation in WARM (receiving less than 20 inches of precipitation annually) was chosen for the modeling. Since landfill disposal creates an anaerobic environment that generates methane (CH_4) that would not have been generated without human intervention, WARM counts this as anthropogenic GHG emissions. Columbia Ridge Landfill recovers the landfill gas for energy, which reduces the GHG emissions associated with disposing of waste in a landfill. The WARM analysis assumes that the landfill has a landfill gas recovery system with typical operating efficiency (Years 0-1: 0 percent; Years 2-4: 50 percent; Years 5-14: 75 percent; Years 15 to 1 year before final cover: 82.5 percent; Final cover: 90 percent).[14] Carbon dioxide (CO_2) in the landfill gas, as well as that produced by combusting landfill gas to produce energy, is not counted, as it is considered biogenic. WARM takes into account that recovering landfill gas for energy offsets emissions that would have been produced if that energy was generated with fossil fuels. WARM also assumes a level of biogenic carbon storage, as well as emissions produced by landfill operating equipment.

For recycling, WARM estimates GHG impacts from the point where the material is collected for recycling (in these scenarios, the AMRF) to the point where the material has been manufactured into a new product. These emissions include those generated by collecting, transporting, processing, and recycling the material or manufacturing the new product. There is also a "recycled input credit" assumed for offsetting the upstream GHG emissions created when producing products from an equivalent amount of virgin material.[15]

The collection of garbage from the community and delivery to the regional transfer stations were not part of this study. WARM allows input of the distances from the curb to the landfill, combustor, MRF, and composting facility. For the WARM inputs, the location of the "curb" is assumed to be the geographical center of the Metro region. As described previously, round-trip transportation to the landfill from Metro was assumed to be a distance of 300 miles. For transportation to all other facilities discussed in the scenarios, a distance of 100 miles round-trip from Metro to the facilities was assumed, leaving an assumed round trip from the facilities to the landfill of 200 miles round-trip.

Scenarios 1A, 2A, 3, 4 and 5 include the recovery of 50 percent of Yard Trimmings. Recovered Yard Trimmings are assumed to be sent to a biomass energy production facility. Therefore, recovered tons of Yard Trimmings were input to WARM as going to combustion.

The composition of garbage used for the Metro design basis has some variation between 2019 and 2038. Most notably, the 2019 garbage is assumed to contain 18 percent food waste, while 2038 is assumed to contain 12.8 percent food waste. This reflects the modeling assumption that Metro will implement waste diversion programs (e.g., organics collection), resulting in fewer food waste, compostable non-recyclable paper, and plastic bottles in the 2038 waste stream. This

[14] USEPA. WAste Reduction Model (WARM), Version 13
[15] http://www.epa.gov/climatechange/wycd/waste/SWMGHGreport.html

causes a net effect of increasing percentages of all other materials that are not predicted to have increased diversion.

The 2019 design basis for Scenarios 2A and 3 assumes that 31,501 tons of plastic film are recovered and sent to a pyrolysis facility in the Metro area. Pyrolysis is not a waste management option in WARM. Consequently, there is insufficient information available to use as a basis to evaluate the GHG impacts for the pyrolysis process. Therefore, these tons of recovered plastic were removed from the WARM input quantities for both Scenarios 2A and 3, resulting in 1,107,867 tons modeled in WARM for these two scenarios in 2019. The 2038 design basis for Scenarios 2A and 3 assumes 40,047 tons are sent to a pyrolysis facility, resulting in only 1,321,453.6 tons modeled in WARM.

Avoided electricity production-related emissions in the landfill and combustion pathways were estimated by WARM based on the national average mix of electric generation (i.e., fossil, nuclear, hydro, etc.), as there is no modeling option specific to Oregon.

Anaerobic digestion is also not a waste management option in WARM, but is part of the design basis for Scenarios 4 and 5. Separate calculations were used to estimate the emissions avoided by processing waste using anaerobic digestion. All biogas produced by anaerobic digestion is assumed to be captured (i.e., no GHG emissions are assumed for this pathway) and used to generate electricity. The Metro design basis assumes that the 9 anaerobic digester facilities in Scenario 4 will yield approximately 74,100 MWh total per year by using the produced biogas to power an internal combustion engine operating at 35 percent overall electrical efficiency, with 95 percent engine availability. The 2 anaerobic digester facilities in Scenario 5 are assumed to yield approximately 32,900 MWh total per year. Using this power will avoid the GHG emissions that would have been created using an equivalent amount of power from delivered electricity. Power that is generated but used on-site for operation of the anaerobic digestion facility is not counted in the power generation number. The Emissions & Generation Resource Integrated Database (eGRID) U.S. annual non-baseload CO_2 output emission rate was used to convert the estimated kilowatt-hours into units of avoided CO_2e emissions.[16]

The tons of material processed by anaerobic digestion were not input to WARM for Scenarios 4 and 5. Instead, the digestate was input as disposed in a landfill in Scenario 4 and as Combustion in Scenario 5.

Appendix C shows the waste composition and design basis by scenario. The WARM inputs were chosen to resemble these arrangements as closely as possible. In some cases, there were not WARM material classifications that match the material classification from the Metro design basis. In these cases, a WARM category that approximated the design basis material was chosen.

Gasification and RDF technologies are also not options for waste management modeling in WARM. For modeling purposes, it is assumed that the emissions from these pathways closely

[16] EPA (2014) eGRID, U.S. annual non-baseload CO2 output emission rate, year 2010 data. U.S. Environmental Protection Agency, Washington, DC. <http://www.epa.gov/cleanenergy/energy-resources/refs.html>.

resemble those of combustion. All tons shown processed as gasification or RDF in the Metro design basis are modeled to be the same as having been processed as combustion in WARM.

Table 9 shows the material classifications used in the design basis for the Metro scenarios and the corresponding WARM material classifications that were used in the modeling. It also shows the material flow to different waste management processes to illustrate how WARM was used to approximate the design basis processes. All modeling assumptions and the full WARM results are included in Appendix D.

Table 9 – Waste Composition and Material Flow for Metro Design Basis and WARM

Metro Design Basis Material Classification	WARM Material Classification	2019 Tons	2038 Tons	Scenario 1		Scenario 1A		Scenario 2		Scenario 2A		Scenario 3[1]		Scenario 4[2]		Scenario 5[2,3]	
				Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM
TOTAL PAPER																	
Cardboard	Corrugated Containers	40,653.9	51,683.0	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Office paper	Office Paper	8,887.8	11,299.0	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
Newspaper and magazines	Magazines/Third-class Mail	17,166.2	21,823.3	LF	LF	R+LF	R+LF	CB	CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Mixed paper	Mixed Paper (general)	21,602.4	32,888.8	LF	LF	R+LF	R+LF	CB	CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Other compostable nonrecycl. paper	Mixed Paper (general)	70,773.4	79,262.0	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
Other non-compostable nonrecycl. paper	Mixed Paper (general)	35,798.6	45,510.5	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
TOTAL PLASTIC																	
Plastic bottles	PET	7,154.6	7,746.7	LF	LF	R+LF	R+LF	CB	CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+RDF	R+NM/CB
Other rigid plastics	Mixed Plastics	64,945.8	83,487.5	LF	LF	R+LF	R+LF	CB	CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+RDF	R+NM/CB
Plastic film - recyclable	Mixed Plastics	21,245.8	27,009.6	LF	LF	R+LF	R+LF	CB	CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Plastic film - non-recyclable	LDPE	52,502.2	66,745.7	LF	LF	LF	LF	CB	CB	PY+CB[4]	CB[4]	PY+G[4]	NM+CB[4]	AD/LF	NM/LF	AD/RDF	NM/CB
Mixed plastic / materials	Mixed Plastics	10,579.9	13,450.2	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	RDF	NM/CB
OTHER ORGANICS																	
Yard Debris	Yard Trimmings	25,121.3	31,936.6	LF	LF	R+LF	CB+LF[5]	CB	CB	R+CB	CB[5]	R+G	CB[5]	R+AD/LF	CB+NM/LF[5]	R+AD/RDF	NM/CB[5]
Clean wood	Dimensional Lumber	47,779.6	60,741.9	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Painted & treated lumber	Wood Flooring	16,805.3	21,364.4	LF	LF	LF	LF	LF+CB	LF+CB	LF+CB	LF+CB	LF+G	LF+CB	LF+AD/LF	NM/LF	LF+AD/RDF	LF+NM/CB
Mixed wood / materials	Dimensional Lumber	56,184.5	71,427.0	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Food waste	Food Waste (non-meat)	204,804.1	174,658.7	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
Rubber	Tires	6,550.7	8,327.9	LF	LF	R+LF	R+LF	CB	CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Disposable diapers	Mixed MSW	38,226.0	48,596.5	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
Carpet/pad	Carpet	28,460.4	36,181.5	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Textiles	Carpet	46,923.5	59,979.0	LF	LF	R+LF	R+LF	CB	CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Other misc. organics	Mixed Organics	61,169.6	80,423.2	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB

Table 9 – Waste Composition and Material Flow for Metro Design Basis and WARM (Continued)

Metro Design Basis Material Classification	WARM Material Classification	2019 Tons	2038 Tons	Scenario 1		Scenario 1A		Scenario 2		Scenario 2A		Scenario 3[1]		Scenario 4[2]		Scenario 5[2,3]	
				Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM	Metro	WARM
GLASS																	
Deposit Beverage Glass	Glass	2,803.4	3,563.9	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
Window and other glass	Glass	16,011.9	20,355.8	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
METAL																	
Aluminum	Aluminum Cans	4,205.5	5,346.5	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Ferrous metals	Steel Cans	29,694.3	37,750.1	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Mixed Metals	Mixed Metals	26,028.3	33,089.6	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
Computers, brown goods, small appliances.	Personal Computers	16,753.0	22,600.2	LF	LF	R+LF	R+LF	R+CB	R+CB	R+CB	R+CB	R+G	R+CB	R+AD/LF	R+NM/LF	R+AD/RDF	R+NM/CB
OTHER INORGANICS																	
Rock, concrete, brick	Concrete	12,142.6	15,436.8	LF	LF	LF	LF	LF+CB[6]	LF[6]	LF+CB[6]	LF[6]	LF+G[6]	LF[6]	LF+AD/LF	NM/LF	LF+AD/RDF[6]	NM/LF[6]
Soil, sand, dirt	Concrete	16,581.6	21,080.1	LF	LF	LF	LF	CB[6]	LF[6]	CB[6]	LF[6]	G[6]	LF[6]	AD/LF	NM/LF	AD/RDF[6]	NM/LF[6]
Gypsum wallboard	Drywall	36,358.3	46,222.0	LF	LF	R+LF	R+LF	CB[6]	LF[6]	R+CB[6]	R+LF[6]	R+G[6]	R+LF[6]	R+AD/LF	R+NM/LF	R+AD/RDF[6]	R+NM/LF[6]
Other miscellaneous inorganics	Asphalt Concrete	68,581.8	87,187.6	LF	LF	LF	LF	CB[6]	LF[6]	CB[6]	LF[6]	G[6]	LF[6]	AD/LF	NM/LF	AD/RDF[6]	NM/LF[6]
BULKY MATERIALS	10% Tires, 90% Mixed MSW	18,930.2	24,065.9	LF	LF	LF	LF	LF+CB	LF+CB	LF+CB	LF+CB	LF+G	LF+CB	LF+AD/LF	NM/LF	LF+AD/RDF	LF+NM/CB
MEDICAL WASTES	Mixed MSW	5,422.5	6,893.6	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
HAZARDOUS MATERIALS	Mixed MSW	2,519.6	3,365.9	LF	LF	LF	LF	CB	CB	CB	CB	G	CB	AD/LF	NM/LF	AD/RDF	NM/CB
Total Material Modeled (2019 tons)				1,139,368.6		1,139,368.6		1,139,368.6		1,107,867.3		1,107,867.3		975,445.3		1,051,841.1	
Total Material Modeled (2038 tons)				1,361,501.0		1,361,501.0		1,361,501.0		1,321,453.6		1,321,453.6		1,206,990.4		1,286,265.4	

1. Gasification is not available as a modeling option in WARM. All tons going to gasification in the Metro design basis are modeled as going to combustion in WARM.
2. Anaerobic Digestion is not available as a modeling option in WARM. The WARM model includes the management of the digestate (i.e., the digestate was input as either being sent to landfill or to combustion), but does not include management of the tons of material that are converted to biogas during the anaerobic digestion process.
3. Refuse Derived Fuel (RDF) is not available as a modeling option in WARM. All tons going to RDF in the Metro design basis are modeled as going to combustion in WARM.
4. Pyrolysis is not available as a modeling option in WARM. The 31,501 tons of plastic film sent to pyrolysis in the Metro design basis in 2019 (40,047 tons in 2038) were not modeled in WARM, due to many unknown variables that would affect estimating emissions.
5. Yard Trimmings recovered at the AMRF in the Metro design basis are assumed to be sent to a biomass facility and are modeled as going to combustion in WARM.
6. These inorganics are assumed to not volatilize during combustion, gasification, anaerobic digestion, or as RDF. All tons are assumed to end up in the landfill after processing.

NOTE: LF=Landfill; R=Recover/Recycle; CB=Combustion; PY=Pyrolysis; G=Gasification; AD=Anaerobic Digester; RDF=Refuse Derived Fuel; NM=Not Modeled in WARM

6.3 Scenarios

Scenario 1 – Entire Disposal Stream to Landfill

Scenario 1 is based on disposing of the entire Metro disposal stream at a landfill. This assumes that all tons are transported from Metro and disposed at the Columbia Ridge Landfill.

Scenario 1A – AMRF with Residuals to Landfill

Scenario 1A incorporates an advanced material recovery facility (AMRF) processing the entire waste stream to remove recyclable and compostable materials accounting for 20.4 percent of the garbage in 2019 and 21.9 percent of the garbage in 2038. The model assumes all AMRF residuals are transported and disposed of at the landfill as subject to the same assumptions and parameters as Scenario 1.

Scenario 2 – Direct Combustion after Hand Recovery of Certain Materials

Scenario 2 considers hand sorting on the tipping floor to separate recyclable cardboard, wood, carpet, metals and brown goods amounting to 1.9 percent of incoming waste in 2019 (2 percent in 2038). Hand sorting is also assumed to separate out waste that should not or cannot be burned, such as painted or treated wood; rock, concrete or brick; and bulky materials such as mattresses and appliances, amounting to 1.5 percent of incoming waste in 2019 (1.6 percent in 2038). This unsuitable material is sent directly to the landfill. The remaining waste is sent to a direct combustion facility.

Scenario 2A – AMRF, Film Plastics Pyrolysis, & Residuals Direct Combustion

Scenario 2A features hand sorting of bulky materials as in Scenario 2, followed by AMRF as in Scenario 1A, but with augmented recovery of plastics including non-recyclable film plastics that are sent to a pyrolysis facility to produce a crude oil substitute. The AMRF residuals are sent to direct combustion. The 31,501 tons sent to pyrolysis in 2019 (40,047 tons in 2038) are not modeled in WARM or modeled with separate calculations, due to the many unknown variables associated with pyrolysis.

Scenario 3 – AMRF, Film Plastics Pyrolysis, & Residuals Gasification

Scenario 3 has the same material flows as Scenario 2A, except AMRF residuals are processed at a gasification and synthetic gas combustion facility instead of through direct combustion. However, for WARM modeling purposes, gasification is assumed to have a similar GHG emissions profile as the emissions profile for combustion in WARM. As in Scenario 2A, the 31,501 tons sent to pyrolysis in 2019 (40,047 in 2038) are not modeled in WARM or modeled with separate calculations.

Scenario 4 – AMRF, Residues to Dry Anaerobic Digestion & Digestate to Landfill

Scenario 4 includes an AMRF to process the garbage stream for recycling, with AMRF residues processed by a dry Anaerobic Digestion facility. Digestate from the anaerobic

digestion process is sent to landfill. The high level of contamination that is expected in the digestate makes it unsuitable for composting into a marketable soil amendment.

Because the anaerobic digestion process is designed to process digestible organic materials, large/bulky waste items are extracted in the pre-processing system of the AMRF in Scenario 4. The model assumes that these bulky wastes, plus other waste sent directly to landfill in Scenario 4, are greater than in previous scenarios; they account for 1.7 percent, or 19,325 tons in 2019 (1.8 percent or 24,568 tons in 2038), of material delivered to the AMRF. AMRF recovery of recyclables is the same as under Scenario 1A. However, in Scenario 4, the beneficial use of the waste occurs by sending AMRF processing residues to dry Anaerobic Digestion Facilities. At each of the 9 Anaerobic Digestion Facilities, a portion of the biodegradable materials in the AMRF residues are converted to biogas consisting of mainly biogenic carbon dioxide and methane. The methane is used to generate electricity in internal combustion engines operating at 35 percent overall electrical efficiency, with 95 percent engine availability.

The net electricity generated from the anaerobic digestion methane amounts to 74,100 MWh per year in 2019 and 73,938 MWh per year in 2038. Using this power will avoid 51,096 metric tons of carbon dioxide equivalent ($MTCO_2E$) GHG emissions in 2019 and 50,984 $MTCO_2E$ GHG emissions in 2038 that would have been created using an equivalent amount of power from utility-produced electricity. The reason for the decrease in electricity produced (and associated GHG emissions) between the two years is due to the reduction of food waste in the material stream. These negative GHG emissions (reductions) from anaerobic digestion are combined with the GHG emissions of recycling material recovered in the AMRF and disposing of the digestate in a landfill, as modeled in WARM.

Scenario 5 – AMRF, AMRF Organics to Dry Anaerobic Digestion with Digestate + AMRF Residuals to a Combined Refuse Derived Fuel/Direct Combustion Facility

Scenario 5 includes the use of an AMRF to process the garbage stream for recycling and composting, with AMRF organics processed by dry Anaerobic Digestion) Facilities. Digestate from the anaerobic digestion process, as well as AMRF non-organic residues, are sent to RDF/direct combustion facility.

Bypass bulky waste plus other waste sent directly to landfill in Scenario 5 is the same as in Scenario 4, accounting for 1.7 percent, or 19,325 tons in 2019 (1.8 percent or 24,568 tons in 2038), of material delivered to the AMRF. AMRF recovery of recyclables is the same as under Scenarios 1A and 4. At the Anaerobic Digestion Facilities, a portion of the biodegradable materials in the AMRF residues are converted to biogas consisting of mainly biogenic carbon dioxide and methane. The methane is used to generate electricity in internal combustion engines operating at 35 percent overall electrical efficiency, with 95 percent engine availability.

The net electricity generated from the anaerobic digestion methane amounts to 32,900 MWh per year in 2019 and 30,588 MWh per year in 2038. Using this power will avoid 22,686

$MTCO_2E$ GHG emissions in 2019 and 21,092 $MTCO_2E$ GHG emissions in 2038 that would have been created using an equivalent amount of power from utility-produced electricity.

For WARM modeling purposes, the RDF/direct combustion facility is assumed to have a similar GHG emissions profile as the emissions profile for combustion used in Scenarios 2, 2A, and 3.

The negative GHG emissions (reductions) from anaerobic digestion are combined with the GHG emissions of recycling material recovered in the AMRF, combustion of waste and digestate as RDF, and disposing of the unsuitable material in a landfill , as modeled in WARM.

6.4 Results

Table 10 shows a summary of the emissions results for each scenario in 2019. Negative numbers represent GHG emissions that are avoided. Consequently, the greater negative value represents a more preferable scenario. Comparing Scenarios 1 and 2 to their counterparts with AMRFs, it is evident that recovering materials for recycling markets avoids more GHG emissions over the material's lifecycles than would be avoided by disposal with LFGTE or with combustion. Scenario 2A results in slightly less GHG emissions than Scenario 5, due to the assumed power production from combustion versus anaerobic digestion. When compared to landfilling, combustion results in a greater GHG reduction than anaerobic digestion for yard debris and a much greater GHG reduction for paper materials. Anaerobic Digestion results in the greatest greenhouse gas reduction for food waste. Because the waste stream contains more yard debris and paper materials than food waste, Scenario 2A is able to offset more GHG emissions through power generation than Scenario 5.

Table 10 – Estimated Greenhouse Gas Emissions in 2019

#	Scenario	Yearly GHG Emissions (MTCO2e)
1	Status Quo – Landfill	-63,800
1A	Status Quo – Landfill with AMRF	-509,300
2	Direct Combustion	-31,400
2A	Direct Combustion with an AMRF	-518,200
3	AMRF with Gasification or Plasma Arc Gasification	-518,200
4	AMRF with Anaerobic Digestion	-601,500
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	-475,400

Table 11 shows a summary of the emissions results for each scenario in 2038. The variance in GHG emission reductions is reflected by a change in the garbage composition the future, as described in Section 6.2. The models were constructed using the 2009/2010 Waste Composition Study and population growth projections of increases in the waste generation quantities to reflect corresponding increases in population and commercial activity in the region. The model includes an increase of total materials quantities from 2009 to 2019 of 8.726% and an increase from 2009 to 2038 of 38.223%. As a consequence, the overall quantity of material

produced in the Metro region and necessitating management increases over time. The increased quantity of material modeled in the WARM reflects increases in GHG emissions in the Status Quo Scenario 1. Similarly, GHG reductions modeled in 2038 reflect larger reductions in GHG emissions due to the offsets each of scenarios provide, as compared to the increased scenario 1 GHG emission in the same year.

As mentioned previously, the most dramatic difference is the decrease of food waste in the garbage, which results in fewer emissions offsets from anaerobic digestion and lower fugitive emissions from landfilled garbage.

Table 11 – Estimated Greenhouse Gas Emissions in 2038

#	Scenario	Yearly GHG Emissions (MTCO2e)
1	Status Quo – Landfill	-105,500
1A	Status Quo – Landfill with AMRF	-682,200
2	Direct Combustion	-28,300
2A	Direct Combustion with an AMRF	-656,000
3	AMRF with Gasification or Plasma Arc Gasification	-656,000
4	AMRF with Anaerobic Digestion	-766,300
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	-598,000

One item of note with both the 2019 and the 2038 waste characterization is that the status quo of Scenario 1 actually results in a greater GHG emissions reduction than Scenario 2. The WARM results take into account N_2O emissions and the non-biogenic CO_2 emissions produced from combusting materials in garbage. These emissions are not produced when those same materials are sequestered in a landfill. Without the AMRF to recover select materials before combustion, the landfill is the preferable management method in terms of GHG emission avoidance.

7.0 Scenario comparison

This section compares the scenarios by considering the criteria developed by Metro's Roadmap for Long Term Waste Management, including: protect the environment, get good value for the public's money, keep the commitment to the highest and best use of materials and be adaptable and responsive in managing materials. Table 12 below illustrates graphically the relative level of favorability for each of these criteria. The Metro Roadmap goals include two other criteria ('Protect Public's Health' and 'Accessibility for all of Metro Residents') which were not modeled at this time. Protecting the Public Health and Accessibility for all of Metro residents was not evaluated at this time because they both require site specific analysis based on the locations of the selected facilities, which are not defined at this time. Scenarios which most favorably comply with the criteria are illustrated as a full red circle. Scenarios which comply with the criteria least favorably are illustrated as a full black circle.

Table 12 was developed as follows:

- 'Protect the Environment' reflects the results of the GHG emission estimates for 2019, illustrated in Table 10.
- 'Good Value for Public's Money' reflects the rankings of the Annualized Capital and O&M Costs illustrated in Table 8.
- 'Highest and Best Use of Materials' reflects the respective ranking of the combined ranking of the beneficial use of materials and the net power produced per year illustrated in Tables 6 and 7.
- 'Adaptable and Responsive in Managing Materials' reflects HDR's and Metro staff's perspective of the relative capability of each of the scenarios to meet this criterion.
- 'Remaining within the System' reflects HDR's perspective of the relative capability of each of the scenarios to meet these criteria.

Table 12 – Evaluation Using Metro Criteria

Scenario	Description	Criteria: Protect the Environment	Criteria: Good Value for Public's Money	Criteria: Highest and Best Use of Materials	Criteria: Adaptable and Responsive in Managing Materials
1	Status Quo – Landfills	○	◉	◡	◠
1A	Status Quo – Landfills with AMRF as variance	◠	◠	◡	◠
2	Direct Combustion	○	○	○	○
2A	Direct Combustion with an AMRF as a variance	◠	○	◠	○
3	AMRF with Gasification or Plasma Arc Gasification	◠	◡	◠	◡
4	AMRF with Anaerobic Digestion	◉	○	○	◡
5	AMRF with Anaerobic Digestion and RDF/Direct Combustion	◠	◡	◉	○

Legend

● **Least favorable. May not meet Metro needs**

◡ **Unfavorable**

○ **Neutral**

◠ **Favorable**

◉ **Most favorable**

Appendix A

Phase 1 Report:
Description of Technology Options
(HDR, 2013)

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PHASE 1 - DESCRIPTION OF TECHNOLOGY OPTIONS

Development of Metro's Long-Term Options for Solid Waste Management

Metro

October 29, 2013

HDR

Phase 1 – Description of Technology Options

Long Term Disposal Options

Metro Portland

October 29, 2013

2365 Iron Point Road, Suite 300
Folsom, CA 95630

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1.0 Executive Summary

Metro Portland (Metro) has oversight of policies, programs and facilities in Clackamas, Multnomah and Washington counties (Tri-County area) and the 25 cities in the Portland region for the management of municipal solid waste (MSW) which currently results in the disposal of approximately 1.1 million tons per year in landfills. As part of a long term strategic planning effort, Metro is exploring a variety of potential technology options to improve the recovery and beneficial use of the MSW non-recovered discards.

This study is the first phase of a study commissioned to explore technologies that could process Metro's MSW non-recovered discards for beneficial uses of these materials and for reduced reliance on landfill disposal as the primary waste management methodology. The study describes reviews and compares 14 different technology options grouped into four broad categories, namely thermal, biological, chemical and mechanical techniques. These technologies treat this waste material in different ways, resulting in different recovery amounts, potential energy generation amounts, by-product types, environmental benefits and local economic benefits. These technologies also vary in type, characteristics and quantity of the waste stream they can accommodate. The technologies also vary with respect to their current stage of development, capacity and costs. Although they have been described, analyzed and compared, all technologies are presented for review and selection of those that best fit with the goals and needs of Metro in a subsequent evaluation.

From review and evaluation of the technologies included in this report the findings indicate that some technologies appear to be less attractive than others, mostly due to the level of commercial development with respect to being capable of processing MSW as the feedstock. The technologies which are the least developed and therefore recommended for removal of further consideration include:

- Pyrolysis;
- Hydrolysis;
- Catalytic and Thermal Depolymerization; and
- Autoclaving.

Our findings also conclude that some of the technologies considered have limitations with respect to the types of feedstock they can process. For example biological technologies such as anaerobic digestion and composting can only affect the organic portion of the non-recyclable discards. As such we find that while some technologies are not suited to process the entire spectrum of Metro's waste discards, the use of Materials Recovery Facilities in the waste management system raises the possibility to develop feedstock materials which are subsets of MSW. For example, assuming Materials Recovery Facilities are included in the waste management system, we find Pyrolysis of plastics is recommended.

In the next phase of the commissioned study, Metro will be provided with a comparative analysis and screening of the various technology options identified for further review in this phase of the study, and then to compile the more attractive options into groupings (scenarios) to inform and obtain public comment, for Metro Council consideration.

2.0 Introduction

There may be opportunities for Metro to use municipal solid waste (MSW) as a resource that can be transformed into useful products. Technology options exist around the world that convert MSW to energy, fuel and other by-products that may have commercial applications. Metro Portland (Metro) is considering potential technology options to manage their non-recovered discards from the MSW stream.

2.1 Background

As an elected regional government, one of Metro's responsibilities is to serve the solid waste management and recycling needs of more than 1.5 million residents in Clackamas, Multnomah and Washington counties (TRI-County area) and the 25 cities in the Portland region. To meet this responsibility, Metro has been granted authority under state law to regulate or operate solid waste disposal and recovery facilities. By state statute, the regulation of collection services is limited to cities and counties.

Metro is responsible for solid waste planning and disposal in the region. As a part of these responsibilities, Metro develops and administers the Regional Solid Waste Management Plan (RSWMP). Metro is accountable for state-mandated waste reduction goals in the tri-county region, and works with its local government and private sector partners to accomplish these goals. Metro provides funding assistance to local governments for waste reduction programs, and operates household hazardous waste prevention and collection programs in the region. Metro oversees the operation of two Metro-owned transfer stations and administers contracts for the transport and disposal of that waste. Metro also oversees a system of franchises and licenses to regulate privately owned and operated solid waste facilities that accept waste from the region. Finally, Metro plays a role in closure and monitoring of several inactive landfills located in the region.

The cities and counties are responsible for designing and administering waste reduction programs for their jurisdictions. These activities must comply with state laws, including the Opportunity to Recycle Act, the Oregon Recycling Act and the Metro RSWMP. Local governments are also responsible for regulating and managing solid waste and recycling collection services within their jurisdictional boundaries (including setting franchise boundaries), and reviewing collection rates and service standards. Within the Metro region, private haulers that are permitted or franchised by their respective jurisdictions provide garbage and recycling collection services and have the liberty to select where they will take their collected waste, however waste generated in the Metro region must be delivered to a "Designated Facility" or the hauler must have a "Non-System" license. The two Metro transfer stations as well as other transfer stations are used by these companies for delivery of the waste materials, however some do haul these materials directly to a landfill.

Metro's current service practice and programs include:

- Waste prevention;
- Residential recycling;
- Commercial recycling;
- Residential and commercial recycling;
- Self-haul disposal;
- Hazardous waste management;
- Public education; and
- Control of illegal dumping.

Within Metro's jurisdiction we understand the following solid waste facilities exist at the time of this report:

- 13 material recovery facilities (MRFs);
- Six licensed yard debris composting facilities;
- Two tire processing facilities;
- Three roofing debris recovery facilities;
- One thermal processing facility, Fuel Processors, Inc.;
- Two sludge solidification/processors;
- Six transfer stations that include the two Public transfer stations: Metro Central and Metro South (both Metro owned and operated facilities);
- Eight landfills including: Columbia Ridge, Roosevelt Regional, Finely Buttes, Hillsboro, Coffin Butte, Wasco, Weyerhaeuser and Riverbend landfills; and
- Other facilities such as reload facilities exempt from Metro regulation.

In 2009 approximately 1,098,900 tons were disposed. The composition by major category is shown in **Table 1**.

Table 1 - Metro's 2009 Waste Composition

Component	Percent (%)
Paper	18.14%
Plastic	13.58%
Other Organics	47.99%
Glass	1.57%
Metal	6.82%
Other Inorganics	11.19%
Hazardous Materials	0.26%

2.2 Purpose

The purpose of this report is to define and describe the array of technology options available, and to qualitatively assess each technology's applicability to the Metro waste stream. The report contains some technical terminology to describe the options as well as their technical basis such as air pollution control equipment and other specific equipment and operating conditions. Since this report will later serve as background for a more detailed evaluation, quantitative analysis, and final comparison, the technical terminology was included. The technology options evaluated for applicability with Metro's waste stream are listed below by main technology class:

- **Thermal Technologies**
  - Direct Combustion (traditional waste-to-energy)
  - Gasification
  - Plasma Arc Gasification
  - Pyrolysis

- **Biological Technologies**
  - Aerobic Composting
  - Anaerobic Digestion with biogas production for electricity or fuel generation
  - Mechanical Biological Treatment (MBT)

- **Chemical Technologies**
  - Hydrolysis
  - Catalytic and Thermal Depolymerization
  - Waste-to-Fuel Technologies

- **Mechanical Technologies**
  - Autoclave/Steam Classification
  - Advanced Materials Recovery
  - Refused Derived Fuel (RDF) Production

- **Landfill**
  - With Landfill-Gas-to Energy

A general description and qualitative summary for each technology option is included, as well as a summary comparison of the technologies. The summary comparison included the following:

- The current stage of development of the technology;
- The extent to which the technology is capable of processing a feedstock similar to Metro's non-recovered discards;

- The minimum and maximum amount of non-recovered discards that the technology can process and the approximate range of the optimal throughput capacity;
- The potential type of products produced by the technology;
- The approximate range of useful operating life;
- Typical or commonly cited environmental benefits and drawbacks of the technology; and
- The potential for local economic benefit (e.g., job creation, correlation to other industrial uses/synergy).

The information on technology options and the technical considerations associated with each option was gathered by HDR from a number of sources, including:

- HDR's in-house project and library files compiled from a number of similar recent projects and studies;
- Technology Vendor supplied information; and
- Data and information available in the literature.

3.0 Technical Descriptions

3.1 Thermal Technologies

Thermal technologies are designed to either combust, gasify or pyrolyze the carbonaceous combustible materials in MSW feedstocks to use the caloric energy contained in the waste to produce an energy product. Thermal processes which produce electrical power directly do so by transforming the waste exothermically using combustion of the feedstock or the gas produced. Usually thermal processes which produce fuels (gasification, plasma arc gasification and pyrolysis) subsequently use the fuel by combusting the fuel for its heating value. In either case, the combustion of the waste or of the fuel produces certain types of constituent air emissions at certain levels depending on the technology. In theory the emissions from the use of a fuel product are lower than direct combustion of the waste, however modern emission control systems can reduce emissions from both types of technologies below emission standards. Thermal technologies can yield gases such as CO_2, water vapor, particulate matter, NOx, SOx, and some products of incomplete combustion during the combustion process. New thermal technologies are expected to utilize modern air pollution control (APC) devices for emissions clean-up which include many new advances in air emissions control. The array of APC equipment available for use in minimizing air emissions are quite diverse and include: selective catalytic reduction (SCR), selective non-catalytic reduction (SNCR) for NOx emissions reduction; spray dryer absorbers (SDA), scrubbers for acid gas reduction; activated carbon injection (CI) for mercury and dioxins reduction; and a fabric filter baghouse (FB) for particulate and heavy metals removal.

3.1.1 Direct Combustion

Direct combustion of waste, referred to as waste-to-energy (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. **Figure 1** shows an example of an approximate 1,000 tons per day (tpd) Direct Combustion facility, the Mullverwertung Rugenberger Damm (MVR) in Hamburg, Germany.

There are several types of boilers used in direct combustion technologies; the most popular include: 1) mass burn with a grate system, 2) stoker-fired and 3) fluidized bed. Mass burn technology has been the standard for many years as it does not require much if any front-end processing. The MVR facility referenced above uses a mass burn technology. Both the stoker-fired and fluidized bed systems require pre-processing of the waste and operate with prepared refused derived fuel (RDF), which is discussed late in this report.

Mass Burn combustion technology can be divided into two main types: (a) grate based, waterwall boiler installations; and (b) modular, shop erected combustion units with shop

Figure 1 - Aerial View of Mullverwertung Rugenberger Damm (MVR) WTE Facility in Hamburg, Germany

*Mullverwertung Rugenberger Damm (MVR) Facility in Hamburg, Germany

fabricated waste heat recovery boilers. The modular units are typically limited to less than 200 tpd and are historically used in facilities where the total throughput is under 500 tpd.

The larger Mass Burn Combustion processes with waterwall boilers are sized at 500 tpd up to a 1,000 tpd or more. MSW is fed directly into a boiler system with little to no pre-processing other than the removal of large bulky items such as furniture and white goods. If pre-processing is used, the materials from the processing could be reused, recycled or landfilled and could be used as landfill cover material in some cases. The MSW is typically pushed onto a grate by a ram connected to hydraulic cylinders. Air is admitted under the grates, into the bed of material, and additional air is supplied above the grates. The resulting flue gases pass through the boiler and the heat energy is recovered in the boiler tubes to generate steam. This creates three streams of material: Steam, Flue Gases and Ash.

In the smaller modular mass burn systems, MSW is fed into a refractory lined combustor where the waste is combusted on refractory lined hearths, or within a refractory lined oscillating combustor. Typically there is no heat recovery in the refractory combustors, but rather, the flue gases exit the combustors and enter a heat recovery steam generator, or waste heat boiler, where steam is generated by the heat in the flue gas, resulting again in steam, flue gas, and ash.

- **Steam** - The steam can be sold directly to an end-user such as a manufacturing facility or district heating loop, or sent to a turbine generator and converted into electrical power, or a combination of these uses.

- **Flue Gases** – As discussed a hot flue gas is produced that yields gases such as CO_2, water vapor, particulate matter, NOx, SOx, and some products of incomplete combustion during the combustion process.

- **Ash** - An ash residue made up of two components, fly ash and bottom ash is generated from combustion. Ferrous metals can be recovered from the ash. Most all Direct Combustion facilities in the U.S. combine the fly and bottom ash to achieve the requirements to be classified as a nonhazardous material to be landfilled in Class III landfills, usually in a monofill at the landfill. If the ash materials are not combined, the elevated levels of leachable metals in the fly ash alone may case the fly as to be considered hazardous and require landfilling in a Class I landfill. In some states, the material is used as daily cover and for other landfill uses. Some demonstration projects have shown that at least the bottom ash can be screened for use as an aggregate and used as roadbed subgrade material, formed into artificial reefs, used for mine capping, or employed for other uses. However, large-scale commercial end uses for the ash have not occurred in North America. In Europe, bottom ash is kept separate from fly ash due to the European Union regulations that stipulate fly ash be stabilized using a product such as Portland cement with certain limitations as to its use, or disposed of in deep mines. Canada also separates its ash and uses certain products to stabilize the fly ash. The bottom ash is typically used as aggregate or disposed as a nonhazardous material in landfills.

Direct Combustion technologies, such as the mass burn technology used at the Marion County WTE Facility, have been used in the United States since the mid-1970s, and continue to be implemented around the world. With many facilities currently operating 25 to 40 years, direct combustion is the most widely demonstrated and commercially viable of the thermal conversion technologies available. Since the mid-1970's the Direct Combustion industry has made much advancement to improve efficiency through new boiler designs and equipment upgrades and reduction in emissions through modern Air Pollution Control equipment and operational techniques. Large-scale and modular combustion technology are used in commercial operations at more than 80 facilities in the U.S., six (6) in Canada (including a new facility that is currently under construction outside of Toronto, Ontario), and more than 500 in Europe, as well as several in Asia.

Benefits of this technology are the production of local energy and potential uses of the by-products of ferrous metals and ash as landfill cover or as an aggregate in the construction industry. In addition, direct combustion technologies are flexible enough to handle a variety of feedstocks including Metro's with little to no pre-processing requirements. Development of the technology can create a number of construction jobs over the one to three years of

construction and 40 to 80 permanent jobs over the life of the project. In addition, although the technology recycles and re-uses water on-site, it also requires a moderate use of water.

3.1.2 Gasification

Gasification has been used for over two hundred years starting with “coal gas” in the 1790’s used for factory lighting. In the 1970’s to present-day, gasification of various types of biomass was, once again, used to power vehicles and some stationary internal combustion engines. Gasification is the conversion of carbonaceous material in the MSW feedstock into a raw gas that is called producer gas that contains principally carbon monoxide, hydrogen, methane, and other light hydrocarbons, as well as CO_2 and N_2 depending on the specific process. Synthesis gas (syngas) is primarily CO and H_2 and can be derived from producer gas through appropriate cleaning and reforming processes. The relative concentration of syngas components depends upon the composition of the feedstock and process operating conditions (autothermal, allothermal, air, oxygen, or steam injection, temperature, pressure, etc.). Syngas can be used as a fuel to generate electricity directly in a combustion turbine, or more likely fired in a heat recovery steam generator (HRSG) to create steam that can be used to generate electricity through a steam condensing turbine as in the Direct Combustion technology described above. The syngas generated can also theoretically be used as a chemical building block in the synthesis of liquid fuels, such as diesel. **Figure 2** shows an example of a 550 tpd Gasification facility in Tokyo, Japan (Tokyo Recycle Power Plant (TRP)) which processes a mixture of waste, including mostly plastics and papers containing a relatively high Btu value, collected specifically for this facility.

There are a wide variety of technology designs that can be defined as gasification. The feedstock for most gasification technologies must be prepared from the incoming MSW through shredding and pre-sorting to pull out bulky materials, and household hazardous waste as well as recyclables and materials such as dirt, glass/grit, and metals to prevent these materials from forming slag and causing potential operating issues.

In the Gasification process, the MSW feedstock reacts in the gasifier with steam and sometimes air or oxygen at high temperatures and pressures in a reduced, oxygen-starved environment. Gasification technology generally involves higher operating temperatures than Direct Combustion. The low to mid British Thermal Unit (BTU) syngas content can be combusted in a boiler, gas turbine, or engine or used in chemical refining. Of these alternatives, boiler combustion is the most common, but the efficiency can be improved if the gas can be processed in an engine or gas turbine, particularly if the waste heat is then used to generate steam and additional electricity in a combined cycle facility. If the gasification facility is sited near an industrial gas user, the syngas produced can be used to supplement the gas used in the industrial processes.

Figure 2 - 550 TPD High Btu Waste Gasification Plant in Tokyo, Japan

*HDR Photo of TRP Gasification Plant in Tokyo, Japan

Gasification facilities are expected to have similar air emissions issues as Direct Combustion facilities although vendors of this technology claim that many emission constituents will be lower in concentration than for Direct Combustion. Units that heat the feedstock in an oxygen-deficient environment would produce less NOx. Mercury would be expected to be largely driven off with the gas and would have to be dealt with from the exhaust of the gas combustion device. Other metals would likely remain with the char/ash. If the syngas is conditioned for use elsewhere, the conditioning equipment will need to address acid gases, mercury, tars and particulates.

Japan has several commercial-scale gasification facilities, some of which have been operating almost two decades. These facilities are known to process 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. Gasification facilities in Japan typically utilize feedstocks with high energy content, such as industrial wastes, to help sustain the process. In addition, waste tipping fees in Japan are much higher than the U.S. and can be in excess of $250/ton, which allows those systems to

operate commercially. Also most Japanese gasification plants are scheduled for at lease 3 months of planned shutdown per year to conduct thorough maintenance. In Japan, one goal of the process is to generate a vitrified ash product that is claimed to have an application for use as an aggregate in the construction industry to limit the amount of material having to be diverted to scarce Japanese landfills. However, until this material is laboratory tested for its constituents and markets are developed for the product, we would expect this material to be landfilled in the U.S similar to the mixture of ash products from existing WTE facilities.

Thermal gasification of MSW in the United States has been limited to demonstration or pilot scale operations, and has had limited operational history. Metro's MSW could be used as feedstock, however it may need to be supplemented with shredded tires or other high BTU materials such as plastics to garner the input BTU needed.

Although there are a number of demonstration or pilot-scale facilities gasifying MSW feedstocks in the U.S. they are constrained in attempting to scale-up to commercial operations. This is partially due to economics, because of the low sales price for electricity and lower tipping fees experienced in the U.S. It is also due to the ability to clean-up, homogenize and achieve a higher BTU-content feedstock. In addition, we understand 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. Facilities that have been built on a larger scale, such as the Covanta Energy facility in Oklahoma are using a variation of gasification, which is essentially a two-stage combustion process, where materials are gasified in the first chamber and the gas is immediately combusted in the second chamber with no actual syngas being produced externally for use. This technology is closer to Direct Combustion technology.

Gasification operators assert one of the benefits of gasification is that very high diversion levels (above 90%) can be achieved because the slag is not leachable. Other benefits include the production of energy and potential uses of the by-products of ferrous metals and ash as landfill cover or as an aggregate in the construction industry. Local benefits include the creation of construction jobs over the one to three years of construction and 25 to 75 permanent jobs over the life of the project. Theoretically the emissions should be lower than that from Direct Combustion and the vendors of this technology claim this is true. However, to date, actual emissions from operating facilities have been difficult to obtain or difficult to translate.

In addition, the technology may only process a specific subset of waste materials (not just MSW as reviewed in this document) such as wood waste, tires, carpet, scrap plastic, or other waste streams.

3.1.3 Plasma Arc Gasification

Plasma Arc Gasification is considered a subset of thermal gasification. Although plasma arc melting technology has been in operation in the metal industry since the late 19th century

and later Plasma Arc Gasification (PAG) has been used for a range of industrial and disposal applications (such as, the gasification of hazardous waste, auto shredder, and other types of homogeneous wastes, mostly overseas). It has only been within the last 10 to 15 years that this technology has been applied to the MSW feed stock at demonstration and pilot-scale levels. **Figure 3** shows an example of the approximate 100 tpd Plasco Energy Company's Trail Road Facility in Ottawa, Canada.

Plasma arc technology uses carbon electrodes to produce a very-high-temperature arc ranging between 5,000 to 12,000 degrees Fairenheit that "vaporizes" the feedstock. 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 synthesis gas or syngas is generated that could be suitable to be combusted and the heat recovered in a HRSG, or the syngas can be cleaned with its temperature reduced and combusted directly in an internal combustion engine or gas turbine to produce electricity and/or thermal energy (i.e. steam, hot water). The inorganic fractions (glass, metals, etc.) of the MSW stream are melted to form a liquid slag material which when cooled and hardened encapsulates toxic metals. Recyclable and contaminated materials can be recovered through a pre-processing system. Metals may be recovered from both feedstock pre-processing and from post-processing the slag material.

Figure 3 - Photo of the Plasco Energy Plasma Arc Gasification Facility in Ottawa, Ontario

Similar to the Gasification and Pyrolysis processes, the MSW feedstock will need pre-processed to remove the larger, bulky waste and household hazardous waste as well as dirt, glass/grit, and metals to prevent these materials from forming slag and causing potential operating issues. Vendors of this technology claim efficiencies that are higher than Direct Combustion and Gasification technologies. These higher efficiencies may be possible if a combined cycle power system is proposed.

Vendors of this technology claim to achieve lower concentrations of emissions than more conventional technologies, like Direct Combustion. However, APC equipment similar to other thermal technologies would still be required for the clean-up from the combustion of the syngas as these facilities generally have similar air emissions issues as other Gasification, Pyrolysis and Direct Combustion facilities. Mercury and some other more volatile metals are expected be driven off with the gas and would have to be dealt with from the exhaust of the gas combustion device.

Outside the U.S., a large, approximate 1,000 tpd facility is currently under construction in Tees Valley in the United Kingdom. Individual units in Japan and around the world are sized from about 20 tpd to 200 tpd and are sometimes combined in multi-unit configurations when developing a facility to create an overall capacity of 400 tpd or greater. Since MSW Plasma Arc Gasification facilities are somewhat new to the industry, there is little information regarding long-term operating experience.

Although Japan has about 10 to 15 years of operating experience, their facilities have been mainly used for ash melting as described below and in addition they are using mostly industrial waste or MSW with high plastics or BTU's combined with a high tipping fee and they only operate about 9 months per year which makes any data from these facilities difficult to use in facilities for the U.S. that need to produce energy using typical MSW at low costs while operating for much more than 9 months per year. Several facilities operate in Japan, most notably three developed by Hitachi Metals, in Yoshii, Utashinai, and Mihama-Mikata. These facilities are referred to as plasma direct melting reactors. This is significant owing to the desire in Japan to vitrify ash from mass burn waste to energy facilities. Many gasification facilities in Japan accept ash from conventional WTE facilities for vitrification. The facilities are in many cases intended as ash vitrification facilities rather than energy recovery facilities. The benefit of the vitrified ash is to bind potentially hazardous elements thereby rendering the ash inert. In Japan most facilities use this vitrified ash as an aggregate product.

Plasma technology has received considerable attention recently in North America, and there are large-scale projects being planned, including facilities in Saint Lucie County, Florida and Atlantic County, New Jersey. In addition, there are a number of demonstration facilities in North America, including the Plasco Energy Facility in Ottawa, Ontario and the Alter NRG demonstration facility in Madison, Pennsylvania and PyroGenesis Canada, Inc., which also has a demonstration unit (approximately 10 tpd) located on Hurlburt Air Force Base in

Florida. S4 Energy Solutions, a joint venture of Waste Management, Inc. and a subsidiary to InEnTec Inc. has built a small 25 tpd facility at the Columbia Ridge Landfill in Arlington, Oregon. It started accepting waste in late 2011, and has tested to produce a syngas, but is still in the testing stages to successfully process the full 25 tpd and produce the gas products planned. NRG/Adaptive Arc is in the permitting/approvals phase for a facility in Atlantic County, NJ. However, currently no commercial operating facilities using MSW as a feedstock exist in the U.S.

Benefits include a claimed over 95% diversion of waste from landfills, production of energy and potential uses of the by-products of ferrous metals and the slag formed and marketed as aggregate (although no markets currently exist for this product). Another local benefit is the creation of construction jobs over the one to three years of construction and 25 to 60 permanent jobs over the life of the project. In addition, although the technology recycles and re-uses water on-site, it also requires a moderate use of water.

3.1.4 Pyrolysis

Pyrolysis technologies are closely related to gasification and some facilities could fall into either technology category depending on how they are operated. Pyrolysis is defined as the process of heating material to high temperatures (700° to 1500°F) in an oxygen-deficient environment to produce a combustible gas or liquid product and a carbon-rich solid residue. This is similar to what is done to produce coke from coal or charcoal from wood. The feedstock has typically been homogeneous such as coal or biomass however the entire municipal waste stream has been used in some operations with pre- processing to obtain a homogeneous feedstock such as refuse-derived fuel. Some modular combustors use a two-stage combustion process in which the first chamber operates in a low-oxygen environment and the combustion is completed in the second chamber. Similar to gasification, the Pyrolysis process can be designed to optimize the production of gases or liquids. Syngas can be produced and used as fuel in boilers with HRSGs, or in internal combustion units or gas turbines, provided that the gas is adequately cleaned. As discussed, the pyrolysis process is performed in an air- or oxygen-free environment, and therefore the system usually must have a complex design and control system to prevent air or oxygen from intruding into the process, or a provision must be incorporated into the design to purge air from the reaction chamber. However, some pyrolysis processes allow very small amounts of air/oxygen into the system. This allows the feedstock to partially combust to supplement the heating process.

Air emissions from pyrolysis systems are primarily those discharged from combustion of the syngas (and possibly char), for example an internal combustion engine-generator set or a steam boiler. The treatment of syngas produced from pyrolytic processing of MSW for use in energy conversion equipment and emissions control of syngas constituents has little history but is similar to the process of Gasification described above. Facilities using the pyrolytic oil and other products as fuel could have some of the same air emissions issues as Direct Combustion. Less SO_2 might be generated in the gas or oil, because most of the sulfur is

expected to stay with the char. However, if the char is combusted, the sulfur would then be released. Units that heat the feedstock in an oxygen-deficient environment would produce less NOx. Mercury would be expected to be largely driven off with the gas and would have to be dealt with from the exhaust of the gas combustion device. Other metals could remain with the char and could largely be separated from the char prior to combustion with a suitable processing system. These emissions can be controlled using modern air pollution control devices to meet local, state and national regulatory standards.

Pyrolysis systems have had some success with wood waste feedstocks and specific waste components such as shredded used tires, however, not with MSW as a feedstock. Historically, a few large-scale Pyrolysis facilities were built in the U.S. that had mechanical and other problems when processing MSW. Of particular note were large-scale pyrolysis plants built near Baltimore and San Diego. They were scaled up from pilot projects and were never able to function at a commercial level. Several other projects were also completed but none have proved to be economically viable. In Germany, at least one pyrolysis facility using MSW as a feedstock is operating. It was built in the mid-1980s and appears to still be operating today. It is a relatively low capacity facility and has not been replicated on a larger scale. We understand that Australia has been using this technology on wood waste and is attempting to use MSW. A plant in Moscow is being built to demonstrate use of MSW as a feedstock. Agilyx, based in Beaverton, Oregon is currently operating a type of pyrolysis technology that utilizes chemical and thermal processes to heat the plastic waste 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 located in Tigard, Oregon.

Pyrolysis of MSW has had limited operational history and no commercial success to date, therefore there is little information regarding long-term operating experience. As there are not many Pyrolysis units functioning at a high level of capacity using MSW as a feedstock, the industry needs more time developing this technology.

Benefits include a claimed over 90% diversion of waste from landfills, the production of energy and potential uses of the by-products, if marketable. Other local benefits include the creation of construction jobs over the one to three years of construction and a certain amount of permanent jobs over the life of the project. This figure cannot be estimated as the technology requires additional development.

3.2 Biological Technologies

3.2.1 Aerobic Composting

Aerobic Composting has not been successfully used with MSW as a feedstock. Aerobic Composting is usually employed on source separated yard waste. Aerobic Composting can include a number of different processes, however the two most common are aerobic

windrow composting and forced aerated static pile composting. Windrow style composting is usually conducted outdoors, while forced aerated static pile composting is usually employed indoors. However, some forced aerated static pile composting is conducted outdoors in areas that are isolated from odor receptors other outdoor operations use a bag system to contain 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” or by mechanically turning the piles with a machine or forced aeration to improve porosity. 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 composting is 8 to 12 weeks. **Figure 4** shows an example of Aerobic Composting using an outdoor windrow system.

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 can be particularly odorous if the composting pile is allowed to have pockets of anaerobic activity. The aerated composting process refers to any of a number of systems used to biodegrade organic material without physical manipulation during primary composting. The blended mixture is usually placed on perforated piping, providing air circulation for controlled aeration. It may be in windrows, open or covered, or in closed containers (in-vessel). **Figure 5** shows an example of Aerobic Composting using a forced aerated static pile composting technology system.

In most facilities using the aerated compost process a series of perforated pipes draws air down through the windrows to an air collection manifold that runs under the windrows. The compost-air can be 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, air can be injected into the windows; however, this results in dispersing the potentially odorous air and therefore is not recommended.

Aerobic Composting is used by numerous communities in commercial operations throughout the U.S. and the world for composting yard and green wastes; however it is not used for a mixed MSW feedstock. Although windrow composting is the most popular, aerated static pile composting is used quite frequently. Products from Aerobic Composting are compost and mulch. Aerobic Composting has been used at various sizes as low as only a few tons per day to more than 500 tpd. An Aerobic Composting facility of 250 tpd to 400 tpd is usually the norm for capacity.

Figure 4 - Example of a Windrow Aerobic Composting Facility

Benefits include diversion of waste from landfill and the local production of beneficial use compost and mulch which can be used in the community. In addition, local benefits include the creation of construction jobs over the short period of construction and about 2-10 permanent jobs over the life of the project, depending on the size and complexity of the facility. The only drawback is the potential for creating odors, noise and dust. This can be mitigated with proper operations and facility siting.

3.2.2 Anaerobic Digestion (AD)

Anaerobic digestion (AD) is commonly used to treat wastewater; however, it has also been used as a way of treating some portions of the MSW waste stream. These processes were first employed in the 1980's under the term Mechanical Biological Treatment (MBT). A few facilities were developed in the U.S. using these AD and MBT technologies; however, for the most part, these facilities ceased to operate years ago due to a variety of issues. However, evolution of the technology in Europe has been recently re-introduced to North America with the use of Anaerobic Digestion in combination with aerobic composting to bio-stabilize the process residue. AD and MBT are successfully operating in Europe due to landfill ban policies, high tipping fees and high prices paid for energy.

Figure 5 - Example of an Aerobic Composting Facility – Forced Aerated Static Pile

The Anaerobic Digestion 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). Feedstocks for Anaerobic Digestion vary according to the type of technology but in broad terms could 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 might be contained in the digestion feedstock, such as metals, glass, and plastics are undesirable and considered contamination and either must 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 anaerobic digestion. 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.

Anaerobic digestion can be categorized into two types of processes:

- 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 15 and 40 percent solids in a liquid slurry or paste; and

- Low-Solids: typically less than 15 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.

JC-Biomethane has recently begun operations of a 100 tpd wet-type anaerobic digestion facility located in Junction City, Oregon. This facility as shown in **Figure 6** uses a Conventional Stir Tank Reactor (CSTR) design for the digestion. It is planned to accept commercial organics, such as food waste and agricultural residues to produce approximately 1.5 MW of power. The project is still in the early operational phases and will need time to show its full potential.

Bunker-type dry fermentation facilities consist of a series of concrete bunkers equipped with air tight ceilings and doors, as shown in **Figure 7.**

Figure 6 - Photo of JC-Biomethane's Anaerobic Digestion facility in Junction City, Oregon

*Courtesy of Register-Guard News

Figure 7 - Example of Bunker type - Dry Fermentation Process

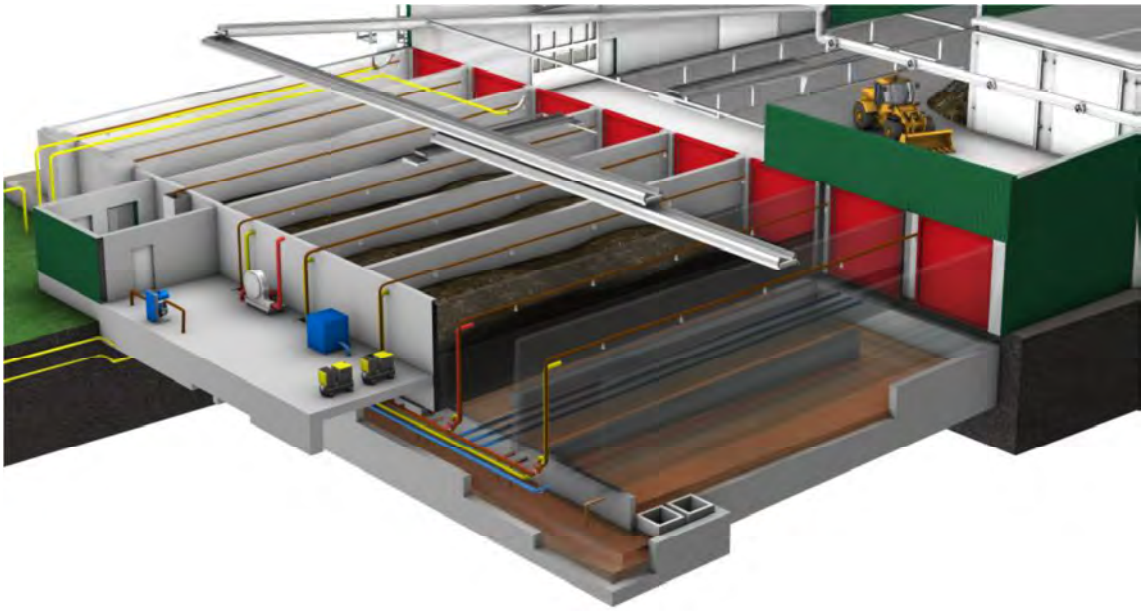

*Illustration courtesy of Kompoferm

The most conventional use of the biogas produced from any Anaerobic Digestion process is using it as a fuel in internal combustion engines and gas turbines to produce electricity. A by-product of the process is a digestate that can be processed into a compost or mulch.

Anaerobic Digestion 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 (SSO), but 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 SSO; the Dufferin Organic Processing Facility and the Newmarket AD Facility. There are a number of smaller facilities in the U.S. operating on either mixed MSW, SSO, or in some cases co-digested with wastewater sludge. Anaerobic Digestion could handle the Metro waste stream including their SSO or their MSW discards. The MSW discards would require pre-processing to remove the larger, bulky waste and other undesirable materials such as glass, metals, and inerts and then shred the materials for size reduction to the specifications of the digester.

Benefits of this technology include diversion of waste from landfill, the production of energy and potential uses of the by-products. In addition, other local benefits include the creation of construction jobs over the year or so of construction and about 10 to 25 permanent jobs over the life of the project, depending on the size and complexity of the facility. The drawbacks include the limitation of the technology to process the limited feedstock appropriate for the technology (organics), as well as the potential for creating odors, noise

and dust. The management of odors, noise and dust can be mitigated with proper operations and facility siting.

3.2.3 Mechanical Biological Treatment (MBT)

Mechanical Biological Treatment (MBT) is a variation on composting and materials recovery that incorporates a two-stage process of mechanical and biological treatments. During the mechanical stage the entire feedstock is sorted to remove recyclables and contaminants and then shredding or grinding takes place for size reduction of the materials prior to the biological stage. The biological stage includes a digestion step in an enclosed vessel which produces a bio-gas that is used to produce energy in addition to heat to dry the feedstock thereby making it ready for processing into a refuse-derived fuel (RDF) product as described below. If no fuel markets are available, the product could be further composted to render the material inert for landfilling.

This technology is designed to process a fully mixed MSW stream and can handle the Metro waste stream. Materials usually derived from the process include marketable metals, glass, and other recyclables. Limited composting is used to break the MSW down and dry the fuel. The order of mechanical separating, shredding, and composting can vary. It is an effective waste-management method and can be built in various sizes. The RDF produced by an MBT process is intended to be converted into energy in some way: fired directly in a boiler; converted to energy via some thermal process (e.g., combustion, gasification, etc.); or selling it to a third party (e.g. Cement Kiln). Consequently, similar to RDF, the MBT process produces a fuel product that depends on the sale of the product for economic viability.

This technology has been used in Europe, including Herhof GmbH facilities in Germany. There are several operating plants in Korea, Spain, Eastern Europe and the UK. More recently, Wrexhan of Greater Manchester has signed an agreement to have a large MBT developed for their area. However there has been no commercial development of MBT in the U.S. using a MSW feedstock.

A benefit is the post-collection separation of feedstocks to divert material from landfill while preparing a feedstock for digestion and thermal consumption. Another benefit is the creation of construction jobs over the construction period and approximately 10 to 50 permanent jobs over the life of the project. The primary drawback is the necessity for the process to rely upon the sale of the fuel product for economic viability. Other operating drawbacks include the potential for creating odors, noise and dust. This can be mitigated with proper operations and facility siting.

3.3 Chemical Technologies

3.3.1 Hydrolysis

There is much interest and development in the area of cellulosic ethanol technology to move from corn based ethanol production to the use of more abundant cellulosic materials. Hydrolysis is part of that development. The Hydrolysis process involves the reaction of the

water and cellulose fractions in a feedstock (e.g., paper, yard waste, etc.) with a strong acid (e.g., sulfuric acid) to produce sugars. In the next process step, these sugars are fermented to produce an organic alcohol. This alcohol is then distilled to produce a fuel-grade ethanol solution which can be burned in energy conversion devices such as heaters and engines.

Hydrolysis is a multi-step process that includes four major steps: Pre-treatment; Hydrolysis; Fermentation; and Distillation. For MSW the pre-treatment step would include separation of the feedstock stream as necessary to remove any inorganic/inert materials (glass, plastic, metal, etc.) from the organic materials (yard waste, paper, etc.). Feedstock materials that are appropriate for hydrolysis/fermentation of the cellulosic components of MSW include wood, green waste and paper. Metro would have to collect and supply a SSO materials feedstock stream for this technology. This process does not handle or convert MSW directly and is best suited for clean source-separated cellulosic waste components. The organic material is shredded to reduce the size and to make the feedstock more homogenous. The hydrolysis step places the shredded organic material into a reactor where it is introduced to the acid catalyst, with the cellulose in the organic material converted into simple sugars as discussed above. The fermentation step utilizes these sugars to be fermented and converted into an organic alcohol. The distillation step takes the organic alcohol and distills it into fuel-grade ethanol. The by-products from this process are carbon dioxide (from the fermentation step), gypsum (from the hydrolysis step) and lignin (non-cellulose material from the hydrolysis step). Since the acid acts only as a catalyst, it can usually be extracted and recycled back into the process.

The process of chemical Hydrolysis is well established for some organic feedstocks, such as in the conversion of wood to paper pulp, but has only been applied to MSW-derived organics on a conceptual basis, or limited to laboratory- or pilot-scale. There has been no widespread commercial application of this technology using MSW as a feedstock in North America or abroad.

Similarly, the environmental risks are not well defined. In addition to the environmental risks of any associated technology, there would be some emissions risks related to methane emissions or issues dealing with potential chemical spills. It is also expected that significant quantities of water and wastewater use would be required.

Benefits include the diversion of organic waste from landfill, the production of a cellulosic ethanol that can be used as a fuel product and the creation of construction jobs over the construction period and a certain amount of permanent jobs over the life of the project. This figure cannot be estimated as the technology requires additional development

3.3.2 Catalytic and Thermal Depolymerization

The depolymerization, or cracking, process converts long-chain hydrocarbon polymers present in some waste materials into intermediate products that can be processed into fuels such as diesel and gasoline. Pressure and heat are used to decompose long-chain

polymers composed of hydrogen, oxygen, and carbon into shorter chains of petroleum-like feedstock. This process is somewhat similar to that used at an oil refinery to convert crude oil into usable products, including the use of distillation to segregate the desired hydrocarbon liquids (such as diesel fuel). The typical feedstocks proposed for depolymerization are plastics, waste oils, grease, and offal (i.e., processed animal soft tissue), although the technology vendors are representing that this technology can theoretically use MSW and biomass as feedstocks. This has not been shown as feasible except at extremely small scale. There are two depolymerization methods that can be used to convert organic materials into fuel: thermal and catalytic.

Thermal Depolymerization

Thermal depolymerization utilizes temperature (temperature ranges from 1,000° to 1,400° Fairenheit) and pressure to crack the large hydrocarbon molecules within the feedstock. Once the hydrocarbon molecules are broken into shorter chains, additional refining steps are required to convert the molecules into oil. The high temperature and additional refining steps in the thermal process require the input of a significant amount of energy, as compared to the catalytic depolymerization approach. The energy balance data for thermal depolymerization of waste-derived organic materials are lacking with regard to commercial scale processing.

Catalytic Depolymerization

The Catalytic Depolymerization process uses lower temperatures (ranging from 500° to 700°F) and lower pressures than thermal depolymerization. In order to achieve adequate product yields and qualities at the lower temperatures and pressures, a catalyst is employed to aid in the process of breaking down or cracking the large molecules efficiently. Zeolite, silica-alumina, and bauxite are common types of catalysts used in the process. In a Catalytic Depolymerization process, the plastics, synthetic-fiber components and water in the 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. The Pre-processing step is where the feedstock is removed of contaminants and is sized. This process typically requires processing to produce a much smaller particle size with less contamination. The next step in the process is preparing this feedstock. The feedstock is mixed with water and a carrier oil (hydraulic oil) to create a sludge-type material. This sludge is sent through a catalytic turbine where the catalytic reaction under high temperature and pressure produces light oil. The light oil is then distilled to separate the synthetic gasoline or diesel oil. This Catalytic Depolymerization process is somewhat similar to that used at an oil refinery to convert crude oil into usable products. This technology is reportedly most effective with processing a waste stream with high plastics 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.

There are no large-scale commercial Depolymerization facilities operating in North America that use a purely mixed MSW stream as a feedstock. There are some facilities in Europe and one in Mexico that utilize this or a similar process to convert waste plastics, waste oils, and other select feedstocks. One vendor claims to have a commercial-scale facility in Spain that has been in operation using MSW since late 2009; however operating data (including feedstock used) could not be obtained. Catalytic Depolymerization has been proposed in some locations for select portions of the waste stream with concentrated plastics content. It might be most effectively applied at a very large plastics manufacturing facility or similar industry that can become the source of the feedstock. Because such arrangements are very rare, limited interest in this technology has developed.

Benefits include the diversion of plastic and oil waste from landfill, the production of an oil or fuel product that can be used as fuel and the creation of construction jobs over the construction period and a certain amount of permanent jobs over the life of the project. This figure cannot be estimated as the technology requires additional development. The drawback is that the environmental risks are not well defined. Catalytic cracking could emit some hydrocarbons from the process. There could also be some other risks resulting from the handling of the catalysts or solvents and related compounds that might be required for the process. Water and wastewater use is also not known.

3.3.3 Waste-to-Fuel Technology

The generation of liquid fuels from wastes is an evolving technology. The use of biomass and organic wastes as a feedstock appears to be advancing in demonstration/pilot projects with a couple projects moving towards commercialization. However, the use of an MSW feedstock is still being tested in laboratories and demonstration/pilot projects.

There are several proposed methodologies to convert MSW into fuels. The first step in the most prevalent MSW-to-fuel technologies requires the use of a process to generate a syngas, typically a thermal conversion process such as gasification. The syngas is then cleaned to remove impurities (tars, hydrocarbons, contaminants, etc.). The next step involves a Fischer-Tropsch (FT) process. The FT process is defined as a collection of chemical reactions that converts a mixture of carbon monoxide and hydrogen into liquid hydrocarbons. It was first developed by Franz Fischer and Hans Tropsch in 1925. The process, a key component of gas to liquids technology to produces a synthetic liquid fuel. The chemical reactions produce a variety of hydrocarbon molecules with the more useful reactions producing alkanes. Most of the alkanes produced tend to be straight-chain, suitable as diesel fuel. Use of the proper catalyst in the FT process is essential to garner the highest quality fuel while not deteriorating the catalyst. In this technical industry there are many forms of catalyst including cobalt and ferrous based. This is the area that syngas from

MSW gasification is having the greatest issues because of the contaminants in the MSW syngas and low of ratios of H_2 to CO.
This FT process is usually followed by a hydro-cracking process. Hydro-cracking is required as part of the FT process to breakup the form of long-chained hydrocarbons. The very long-chained hydrocarbons are waxes, which are solid at room temperature. Therefore, for production of liquid transportation fuels it is usually necessary to crack some of the FT products.

As described, this is one of the most popular types of a chemical catalytic process that is used to synthesize the syngas into a liquid fuel. In addition to the FT synthesis, there is Methanol synthesis; mixed alcohol synthesis; or Syngas fermentation. Each process features different reaction pressures and temperatures, require different syngas compositions, and use different catalysts.

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 mixed waste streams as a feedstock, these systems as a whole are still in the development or demonstration stage. INEOS has constructed the Indian River BioEnergy Center (Centre) in Vero Beach, Florida and expects to be producing cellulosic ethanol at a commercial scale in late 2013. However, this facility will use biomass waste as a feedstock, not MSW in the gasification and fermentation technology. In addition, there is currently a project under construction by Enerkem Alberta Biofuels in Edmonton, Canada that is shown in **Figure 8**. Enerkem states that it will handle up to 100,000 metric tpy of MSW.

Given the emerging status of this technology with MSW, there is minimal information available on this technology. If Metro wishes to use only the biomass portion of their MSW feedstock in this process there is more information available. However, it should be understood that this is a two step process: 1) syngas will need to be generated through gasification or another technology and 2) the syngas will then need to be cleaned and conditioned with the proper chemical catalytic process used to synthesize the syngas into a liquid fuel.

Benefits include the potential production of an ethanol based fuel and the creation of construction jobs over the construction period and a certain amount of permanent jobs over the life of the project. Drawbacks include air emissions impacts associated with the thermal gasification and syngas conditioning process and the potential for only being able to produce fuel from a biomass only feedstock. In addition, there are solid and liquid wastes associated with this technology.

Figure 8 - Example of Enerkem's Waste-to-Fuels Project in Edmonton, Canada

*Picture courtesy of Enerkem (plant under construction as of May 2013)

3.4 Mechanical Technologies

3.4.1 Autoclave/Steam Classification

Autoclaving is classified as a "mechanical" process that uses heat and pressure in a mechanical rotating cylinder to separate the cellulosic material from other portions of the municipal solid waste stream. The basic Autoclave technology has been in use for sterilization of hospital wastes and equipment and other related applications for many years.

Like Anaerobic Digestion, Autoclaving addresses only a portion of the waste stream, namely the cellulose-fiber-containing portion, which is usually 40% to 60% of the total MSW input stream. However, this technology can accept mixed MSW which contains a large organic fraction (just not inerts from a C&D mix) to be used as a "front-end" to many of the other emerging technologies such as Hydrolysis for production of a fuel product, Gasification or Pyrolysis for energy generation, Anaerobic Digestion for energy and compost production, or for fiber recovery for the pulp/paper industry. A trommel screen is usually utilized after Autoclaving to separate out the various mixes of fibrous organic materials produced from Autoclaving and other materials (i.e., fine organics stream, bulky organics stream, and overs, such as inorganic materials, and recyclables such as glass, metals and plastics). If the goal for the Autoclaving technology is recovery for paper production, because the fibers are of such a mixed grade, the main product that can be produced is a lower-grade cardboard.

Autoclaves are large rotating vessels that have steam injected and kept at a certain temperature and pressure over a 2 to 4 hour period to convert the MSW. Autoclaves are currently operating in batch mode accepting from approximately 1 to 25 tons per batch (2-3

hour). **Figure 9** shows a small autoclave unit (~1 ton per batch) used by the Salinas Valley Solid Waste Authority for testing at their Crazy Horse Landfill in Salinas California.

In conclusion, the Autoclave process has the potential for a 40% to 60% reduction in waste volume with the cellulose recovery having the potential to be used as feedstock for:

- Paper production;
- Ethanol production feedstock;
- Compost feedstock; or
- Digester feedstock for methane production.

There are no large-scale commercial Autoclave facilities operating in North America that use a purely mixed MSW stream as a feedstock. All of the demonstration projects have been completed on a fairly small scale (less than 300 tpd) on different feedstocks besides MSW. No known commercial operation exists at this time in the U.S. or elsewhere for processing MSW.

Benefits include the diversion of materials from landfill, the production of a cellulose product valuable for many uses as described above and the creation of construction jobs over the construction period and a certain amount of permanent jobs over the life of the project. This figure cannot be estimated as the technology requires additional development. A drawback is that the environmental risks of Autoclaving are not known and this technology could be used primarily as a front-end system to prepare materials for other processes such as fiber recovery, MRFs and thermal technologies. Water and wastewater use is also not known.

Figure 9 - Example of an Autoclave

*HDR photo of Autoclave Unit, Salinas, California

3.4.2 Advanced Materials Recovery

There are a number of types of materials recovery facilities (MRFs) in operation in the U.S. and around the world. Most can be classified into two groups, 1) those that accept source separated recyclables, sometimes referred to “clean” MRFs, and 2) those that take mixed MSW and process these materials to recover recyclables and reusable materials leaving the residual waste for landfill, or another appropriate waste reduction application, as discussed in this technical memorandum. This section describes the latter technology, a MRF that handles mixed solid waste materials.

The MRF process begins with mixed solid waste from residential and/or commercial collection vehicles being off-loaded onto a tipping floor such as that from Metro’s MSW stream. 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 clog or interrupt operations of the processing system. Loaders or grapples then load a conveyor or surge hopper to convey the material to the sort lines and mechanical equipment for separation. In most cases either a mechanical device or manual labor is used to open bags and containers prior to screening and sorting.

Material is usually 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 to separate materials into size classifications and/or light versus heavier materials. Fiber is usually hand sorted off elevated conveyor platforms into commodities and dropped into bunkers below. Containers are processed through ferrous magnets, eddy-current magnets, air screens and hand sorting. The small contaminant stream (dirt, rocks, broken glass and ceramics, bottle caps, etc.) may be further processed by optical/pneumatic sorting. 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 reduction application. The main purpose of this type of MRF is to remove recyclable material from mixed municipal solid waste. These types of facilities usually recover about 10% to 25% although some facilities have reported recovery above these figures. There is a wide range of capacities operating throughout the world. The optimal capacity is between 200 tpd and 1,500 tpd using multiple sort lines and operating additional shifts. MRFs can have a useful operating life of 20 to 30 years if proper maintenance is provided. Many MRFs are retrofitted throughout their life with new processing equipment as applicable.

MRFs are fully developed and used through the U.S. and the world to process MSW (either mixed or commingled) to recover recyclable and reusable materials. They are a well proven technology, although certain 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.

Benefits include the diversion of recyclables from landfill, preparation of feedstock for thermal, chemical or biological processes and the creation of construction jobs over the one to two year construction period and approximately 20 to 60 permanent jobs, depending on the size and complexity of the project. A drawback is that certain environmental impacts must be mitigated such as noise, dust and odor. In addition, some of the commodities recovered from a MRF of this type may be more contaminated than a “clean” MRF.

3.4.3 Refuse Derived Fuel (RDF) Production

An RDF processing system prepares MSW by using separation, shredding, screening, air classifying and other equipment to produce a fuel product for either on-site thermal processing, off site thermal processing, or use in another conversion technology that requires a prepared feedstock. The goal of this technology is to derive a more homogeneous fuel product that can be used in specified thermal equipment. The fuel goes by various names but generally is categorized as a refuse-derived fuel (RDF).

Non-recovered discards, such as Metro’s, can be processed by this technology. Facilities can range in size from several hundred tons per day to more than 3,000 tons per day. Recycling processes can also be built into an RDF such as in the MRF, metals can usually be sorted and removed by magnets and eddy current separators. An RDF facility strives to develop a consistently sized fuel with a relatively constant heating value for thermal technologies. 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 would 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 be ready to market.

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 two 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. Some RDF facilities have converted to shred and burn through blanking the small holes in trommels. The purpose for this is to reduce the overall amount of residue (fines) landfilled.

There are several examples of RDF plants in the U.S. that use varying degrees of preprocessing and RDF production. RDF front-end processing can create challenges for the facility. Explosions can occur in the shredders, thus requiring, at a minimum, the primary shredders 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. Therefore, processing systems need to be sized larger than the associated thermal equipment, and storage capacity must be provided both for incoming waste and for

RDF to keep the facility running smoothly. 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 applicable.

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. **Figure 10** shows an example of stockpiled RDF at a facility in Rennerod, Germany.

RDF technology is a proven technology that is used at a number of plants in the U.S., Europe and Asia (generally larger plants with capacities greater than 1,500 tons per day). 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 coal-boiler or cement kiln. Some RDF plants within the US include facilities at Ames, IA; Southeastern Public Service Authority, VA; French Island, WI; Mid-Connecticut; Honolulu, HI; and West Palm Beach, FL.

Figure 10 - Example of Stockpiled RDF

*HDR photo of Rennerod, Germany Facility

Benefits include the preparation of the MSW into a feedstock that is acceptable by other processes allowing them to be more effective and efficient, removal of recyclable and reusable materials for beneficial use and the creation of construction jobs over the one to two year construction period and approximately 10 to 100 permanent jobs, depending on the size and complexity of the project. A drawback is that RDF facilities will have some air emissions directly from the processing (dust) as well as from the combustion of the RDF (this is discussed in the thermal technologies section). An economic drawback of RDF is that it produces a solid fuel similar to coal. So, production of the RDF product presumes a local appetite for a coal-substitute to be economically viable. 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.

3.5 Landfill

3.5.1 Modern Sanitary Landfill

Landfilling involves the transport of Metro's non-recovered discards, likely in larger transfer trucks, and disposal of the waste into lined cells. Modern landfill designs have several aspects that serve to protect the environment from inert and undesirable materials disposed of in the landfill and to collect and use landfill gas for energy production. These include liner systems, leachate (liquids) management systems, gas collection and landfill gas (LFG) to energy systems, and operational protocols as described below.

Liner Systems

In the U.S., all new landfills and all lateral expansions to existing landfills that receive MSW are required to have composite liners installed prior to the placement of waste. U.S. federal regulations require that these liners be composed of a flexible membrane liner (minimum 30-mil, or minimum 60-mil if HDPE liner) and over at least two feet of compacted soil that has a hydraulic conductivity of no more than $1x10^{-7}$ centimeters per second (cm/sec). Individual state regulations may add additional requirements for landfills under their jurisdiction.

Leachate Collection and Removal Systems

In the U.S., federal regulations require new landfills and lateral expansions for all landfills to include a leachate collection system that prevents leachate from accumulating on the liner to a depth of more than 30 centimeters, so that it does not pose a danger of leaking into the ground water. Variances can be secured whereby liquids, including leachate, can be reinserted into the landfill. The benefits of liquids recirculation include elevated productivity of landfill gas rates.

Landfill Gas Generation and Collection Systems

Landfill gas (LFG) is generated as the organic material in the landfill decomposes. The amount and composition of the LFG produced varies greatly according to the characteristics of the waste placed in the landfill and the climate at the landfill location. Factors that have the greatest impact on the LFG produced include waste composition (e.g., organic content, age), oxygen levels, and moisture content and temperature, which can be influenced by climate. Landfill gas is typically 50% methane and 50% carbon dioxide and water vapor, by volume. Trace amounts of nitrogen, oxygen, hydrogen, non-methane organic compounds (NMOCs), and inorganic compounds are also present. Some of these compounds are the source of odors. Emissions can be reduced through the installation of an efficient landfill gas collection system, and then flaring the LFG or combusting it to produce energy.

In general, LFG is collected from a landfill using a series of wells which are connected to a piping network equipped with a blower device that produces a vacuum. The vacuum allows

gases to be drawn from the landfill into the wells, through the collection manifold and into a gas pretreatment system then is flared or combusted to prevent the migration of the LFG in order to meet minimum regulatory environmental control requirements. The collection efficiency of a modern landfill gas system can vary according to a variety of factors such as the timing of collection, field installation, depth of waste, and timing of final capping system on the top of the waste. The requirements for collection system performance varies, but in general, landfill gas collection systems in modern landfills are in the range of 60% to 85% efficient, averaging about 75% efficiency. As discussed below, most all modern larger landfills extract and condition the LFG to remove impurities and prepare the LFG to meet the internal combustion (IC) engine or gas turbine requirements to produce electricity.

Landfill Gas to Energy (LFGTE) Systems

For most landfills the amount of LFG generated warrants the development and installation of a landfill collection control system and depending on the quantity and quality of the landfill gas, an LFGTE system. There are two commonly used gas to energy systems employed at a landfill; either an Internal Combustion (IC) Engine or a Microturbine. Internal combustion engines have traditionally been used at LFG projects of 800 kW and larger. This technology has a relatively high efficiency and low costs and has been in commercial operation on LFG for decades. IC engines are well-suited for landfill gas-to-energy projects. They are capable of producing between 200 kW to more than 1 MW of electricity per engine. IC engines can be linked together in series to handle larger flows of LFG as gas production increases from increased landfilling amounts. Additionally, they are able to run at less than full power, allowing the maximum amount of LFG to be used, with less need for a flare other than for shut down events of the engines. However, one of the drawbacks to IC engines is that they require relatively higher concentrations of methane to efficiently operate. They also produce higher emissions levels than microturbines. Microturbines are a relatively new electrical generation technology that is poised to fill a niche not occupied by internal combustion or traditional turbine technologies. As the name implies, the size of individual units is much smaller than conventional technologies. Units ranging between 30-250 kW can be used individually or grouped into larger sets to be more precisely sized for use at landfills where the gas output is too high for individual units. Microturbines are especially well suited for landfills where:

- LFG flow is low;
- LFG has low methane content;
- Air emissions are of concern;
- Electricity will be used onsite; and
- Electricity prices are high and generation can be used for retail deferral.; and
- Thermal demand exists.

In summary, landfilling is a very well demonstrated and commercially viable technology for disposal. Landfills of various sizes are currently operating in the U.S. and throughout the

world. The most beneficial use of a Landfill is that it can take in for disposal any regulated material that cannot be converted, recovered or reused by another technology and can produce LFG to be converted to electricity from the organic portion of the waste. In addition, potential local benefits include the creation of construction jobs during the construction period and a number of permanent jobs, depending on the size of the Landfill. Drawbacks include the space utilized for a Landfill, its non-aesthetic nature, leachate and gas by-products, potential for odors and leaks into the local water tables.

4.0 Summary Comparisons

Each of the Technology Options under review has been qualitatively described individually in Section 3 of this report. The purpose of this Technical Memorandum is to define and describe the array of technology options available by certain criteria discussed with Metro. These criteria include:

- The current stage of development of the technology;
- The extent to which the technology is capable of processing a feedstock similar to Metro's non-recovered discards;
- The minimum and maximum amount of non-recovered discards that the technology can process and the approximate range of the optimal throughput capacity;
- The potential type of products produced by the technology;
- The approximate range of useful operating life;
- Typical or commonly cited environmental benefits and drawbacks of the technology; and
- The potential for local economic benefit (e.g., job creation, correlation to other industrial uses/synergy).

Each of these criteria are applied to the Technology Options under review and summarized in **Table 2**.

Table 2 - Comparison of MSW Technology Options

	Criteria	Direct Combustion	Gasification	Plasma Arc Gasification
1. Commercial Viability (Development Stage)				
a	Status of technology in the US	Commercial	Demo/Pilot on MSW	Demo/Pilot on MSW
b	Years of commercial operating history in the US	30 plus years	None on MSW	None on MSW
c	Number of commercial operating facilities in the US	80 plus US facilities	None on MSW	None on MSW
d	Status of technology worldwide	Commercial	Commercial	Demo/Pilot on MSW
2. Capability of Processing Metro Feedstock				
a	Type of MSW Processed	Handle Entire MSW Stream	Handle Entire MSW Stream	Handle Entire MSW Stream
3. Technology Capacity Level				
a	Facility Capacity (tpd)	500 to more than 1000 tpd	500 to 1000 tpd	Less than 500 tpd
4. Diversion Potential of Technology				
a	Potential Landfill diversion (weight percent)	70%-90%	Claimed greater than 90%	Claimed greater than 90%
5. Marketability of End- and By-Products				
a	Availability and feasibility of markets for recovered materials	Good for metals and mixed ash for LF cover (as permitted)	Unknown for vitrified ash/slag for aggregate	Unknown for vitrified ash/slag for aggregate
b	Availability and feasibility of markets for energy produced	Good	Good	Good
c	Undesired By-Products	Fly ash if not mixed with bottom ash	Ash/Slag if not sold/given away as aggregate	Ash/Slag if not sold/given away as aggregate
6. Useful Operating Life				
a	Facility Life (yrs)	Greater than 25 years	Currently about 20 years	Currently about 10 to 15 years
7. Typical Environment Benefits/Drawbacks				
a	Benefits	Produces energy, metals for market and ash for cover (mixed)	Produces energy, possible aggregates from slag (need mkts)	Produces energy, possible aggregates from slag (need mkts)
b	Drawbacks	Air emissions to be mitigated by new APC equipment	Air emissions to be mitigated by new APC equipment	Air emissions to be mitigated by new APC equipment
8. Local Economic Benefits				
a	Permanent Full-time Jobs	40 to 80 permanent jobs	25 to 75 permanent jobs	25 to 60 permanent jobs
9. Financial				
a	Range of Capital and Operating unit cost	High	High	High

Table 2 – Comparison of Technology Options – Continued

	Criteria	Pyrolysis	Aerobic Composting	Anaerobic Digestion
1.	**Commercial Viability (Development Stage)**			
a	Status of technology in the US	Demo/Pilot on MSW	Commercial	Demo/Pilot
b	Years of commercial operating history in the US	None on MSW	Many on green/yard waste feedstock	None (Several under construction)
c	Number of commercial operating facilities in the US	None on MSW	Numerous	None (Demo only)
d	Status of technology worldwide	Demo/Pilot on MSW	Commercial	Commercial
2.	**Capability of Processing Metro Feedstock**			
a	Type of MSW Processed	Handle Entire MSW Stream	Ideally suited to process green/yard waste portion of MSW	Can treat only organic portion of MSW
3.	**Technology Capacity Level**			
a	Facility Capacity (tpd)	Under development; ~ 10 to 100 tpd	Usually 200 to 400 tpd, but can be larger	Wide range from 5-10 tpd to 500 tpd
4.	**Diversion Potential of Technology**			
a	Potential Landfill diversion (weight percent)	Not known	Metro shows about 2%-3% for yard debris	Metro's total organics ~ 48%; w/o wood/non digestables; ~25%
5.	**Marketability of End- and By-Products**			
a	Availability and feasibility of markets for recovered materials	Depends if gases, liquids and char can be used	Most materials can be cured into a marketable compost	Digestate after process can sometimes be turned to compost
b	Availability and feasibility of markets for energy produced	Depends if gases, liquids and char can be combusted	N/A	Biogas can be used to create energy
c	Undesired By-Products	Liquids, tars, chars and other by-products	Screened overs, such as bottle caps, glass and other small objects	Digestate must be assessed if compostable
6.	**Useful Operating Life**			
a	Facility Life (yrs)	One small facility operating in Germany since 80's	Life is 30+ years depending on equipment replacement	Operating internationally since the 80's
7.	**Typical Environment Benefits/Drawbacks**			
a	Benefits	Potentially create energy and useful by-products	Create useable compost	Create energy and potentially useable compost
b	Drawbacks	Air emissions to be mitigated by new APC equipment	Can create odor, noise and dust	Air emissions need mitigation & digestate may not be composted
8.	**Local Economic Benefits**			
a	Permanent Full-time Jobs	Not known	About 2 to 10 jobs, depending on the size of the operation	About 10 to 25 jobs, depending on the size of the operation
9.	**Financial**			
a	Range of Capital and Operating unit cost	High	Low	Medium

Table 2 – Comparison of Technology Options - Continued

	Criteria	Mechanical Biological Treatment	Hydrolysis	Catalytic & Thermal Depolymerization	Waste-to-Fuels
1. Commercial Viability (Development Stage)					
a	Status of technology in the US	Demo/Pilot	Demo/Pilot	Demo/Pilot	R&D on MSW
b	Years of commercial operating history in the US	None Commercialized	None Commercialized	None Commercialized	None Commercialized
c	Number of commercial operating facilities in the US	None Commercialized	None Commercialized	None Commercialized	None Commercialized
d	Status of technology worldwide	Commercial	Demo/Pilot	Demo/Pilot; one facility claimed in Spain	R&D/pilot on MSW
2. Capability of Processing Metro Feedstock					
a	Type of MSW Processed	Entire waste stream	Wood, green waste and paper; ~30% of Metro's MSW	Plastics & oils; ~ 12-13% of Metro's MSW	Entire or biomass portion of MSW
3. Technology Capacity Level					
a	Facility Capacity (tpd)	Probably 500 tpd; needs confirmation	Needs more research	Needs more research	Needs more research
4. Diversion Potential of Technology					
a	Potential Landfill diversion (weight percent)	This is a feedstock pre-process; recover recyclables	Approximately 25%-30% of Metro's MSW	Approximately 10%-12% of Metro's MSW	If gasification is used can be up to 90%
5. Marketability of End- and By-Products					
a	Availability and feasibility of markets for recovered materials	Markets for recyclables and fuel product	Markets for gypsum & lignin will need to be established	Needs more information on the bio-diesel created	Needs more information on the liquid fuel created
b	Availability and feasibility of markets for energy produced	There are markets for the potential biogas produced	There has not been a market for this fuel established	There has not been a market for this fuel established	There has not been a market for this fuel established
c	Undesired By-Products	None known	Potentially the CO2, gypsum & lignin	Needs more research	Needs more research
6. Useful Operating Life					
a	Facility Life (yrs)	Most probably 15 to 25 years	Needs more evaluation	Needs more research	Needs more research
7. Typical Environment Benefits/Drawbacks					
a	Benefits	Separates feedstock for recycling, digestion& thermal	May be able to produce a fuel with more evaluation	May be able to produce a fuel with more evaluation	May be able to produce a fuel with more evaluation
b	Drawbacks	Odors, dust & noise	Methane emissions and possible chemical spills	Hydrocarbons could be emitted; catalysts or solvents needed	Hydrocarbons could be emitted; catalysts or solvents needed
8. Local Economic Benefits					
a	Permanent Full-time Jobs	20 to 40 jobs	Not known	Not known	Not known
9. Financial					
a	Range of Capital and Operating unit cost	Medium	Medium	Medium	Medium/High

Table 2 – Comparison of Technology Options – Continued

	Criteria	Autoclave	Materials Recovery	RDF Processing	Landfill
1. Commercial Viability (Development Stage)					
a	Status of technology in the US	Demo/Pilot on MSW components	Commercial	Commercial	Commercial
b	Years of commercial operating history in the US	None on MSW components	30 + years	30 + years	30 + years
c	Number of commercial operating facilities in the US	None on MSW components	Numerous	Approximately 20 to 30	Numerous
d	Status of technology worldwide	Demo/Pilot on MSW components	Commercial	Commercial	Commercial
2. Capability of Processing Metro Feedstock					
a	Type of MSW Processed	Handle only organics; ~ 40% of Metro's MSW	Handle entire MSW stream	Handle entire MSW stream	Handle entire MSW stream
3. Technology Capacity Level					
a	Facility Capacity (tpd)	At this time only smaller 100-300 tpd available	~200 to 1,500 tpd	Up to about 3,000 tpd	Many tpd depending on size and inflow
4. Diversion Potential of Technology					
a	Potential Landfill diversion (weight percent)	~35-40% of the MSW	~10-25% of the MSW	Depends on the thermal process to combust RDF	~2-3% recovery of bulky items
5. Marketability of End- and By-Products					
a	Availability and feasibility of markets for recovered materials	Recyclables can be marketed	Recyclables can be marketed	Recyclables can be marketed; RDF as coal substitute for combustion	Bulky items markets
b	Availability and feasibility of markets for energy produced	Market needs to be developed for fiber/fuel	N/A	RDF can be converted to energy	LFG can be converted to energy
c	Undesired By-Products	Non-organics	Grit/glass/fines	Bulky items	Un-regulated materials
6. Useful Operating Life					
a	Facility Life (yrs)	Not known at this time	20 to 30 years	20 to 30 years	Many years depending on size and inflow
7. Typical Environment Benefits/Drawbacks					
a	Benefits	Possibly create fiber or fuel product	Recover recyclables; prepare feedstock	Preparation of feedstock for other processes	Waste encased in regulated area
b	Drawbacks	Risks of Autoclaving are not known	Odors, noise & dust to be mitigated	Odors, noise & dust to be mitigated	Odors, noise & dust to be mitigated
8. Local Economic Benefits					
a	Permanent Full-time Jobs	Not known at this time	20 to 60 jobs	20 to 100 jobs	2 to 20 jobs
9. Financial					
a	Range of Capital and Operating unit cost	Medium	Medium	Medium	Low

5.0 Conclusion

The findings from review and evaluation of the technologies included in this report indicate that some technologies appear to be less attractive than others, mostly due to the level of commercial development with respect to being capable of processing MSW as the feedstock. The technologies which are the least developed and therefore recommended for removal of further consideration include:

- Pyrolysis;
- Hydrolysis;
- Catalytic and Thermal Depolymerization; and
- Autoclaving.

Our findings also conclude that some of the technologies considered have limitations with respect to the types of feedstock they can process. For example biological technologies such as anaerobic digestion and composting can only affect the organic portion of the non-recyclable discards. As such, we find that while some technologies are not suited to process the entire spectrum of Metro's waste discards, the use of Materials Recovery Facilities in the waste management system raises the possibility to develop feedstock materials which are subsets of MSW. Assuming Materials Recovery Facilities are included in the waste management system, we find Pyrolysis of plastics is recommended.

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Appendix B

Process Flow Diagrams

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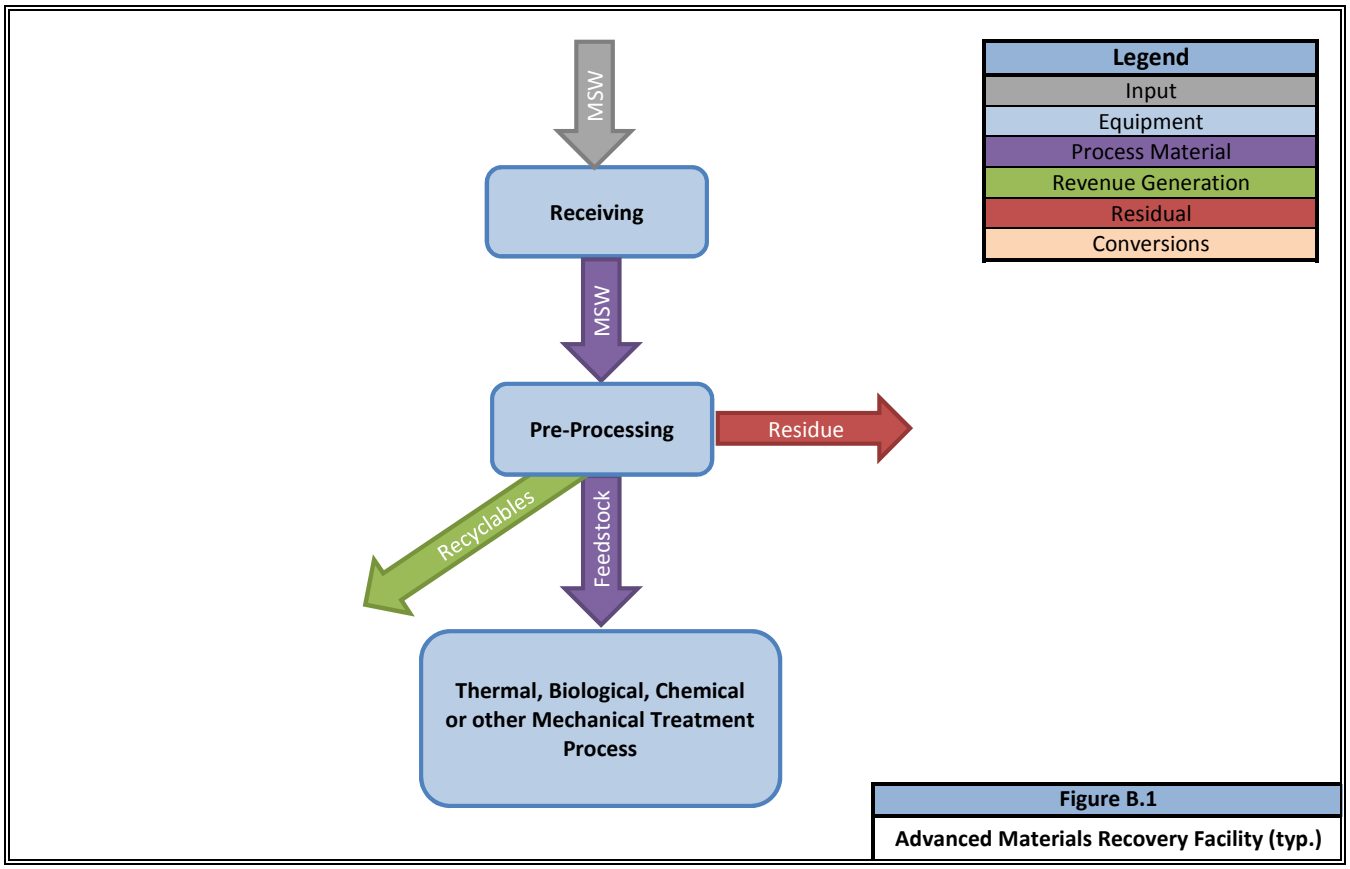
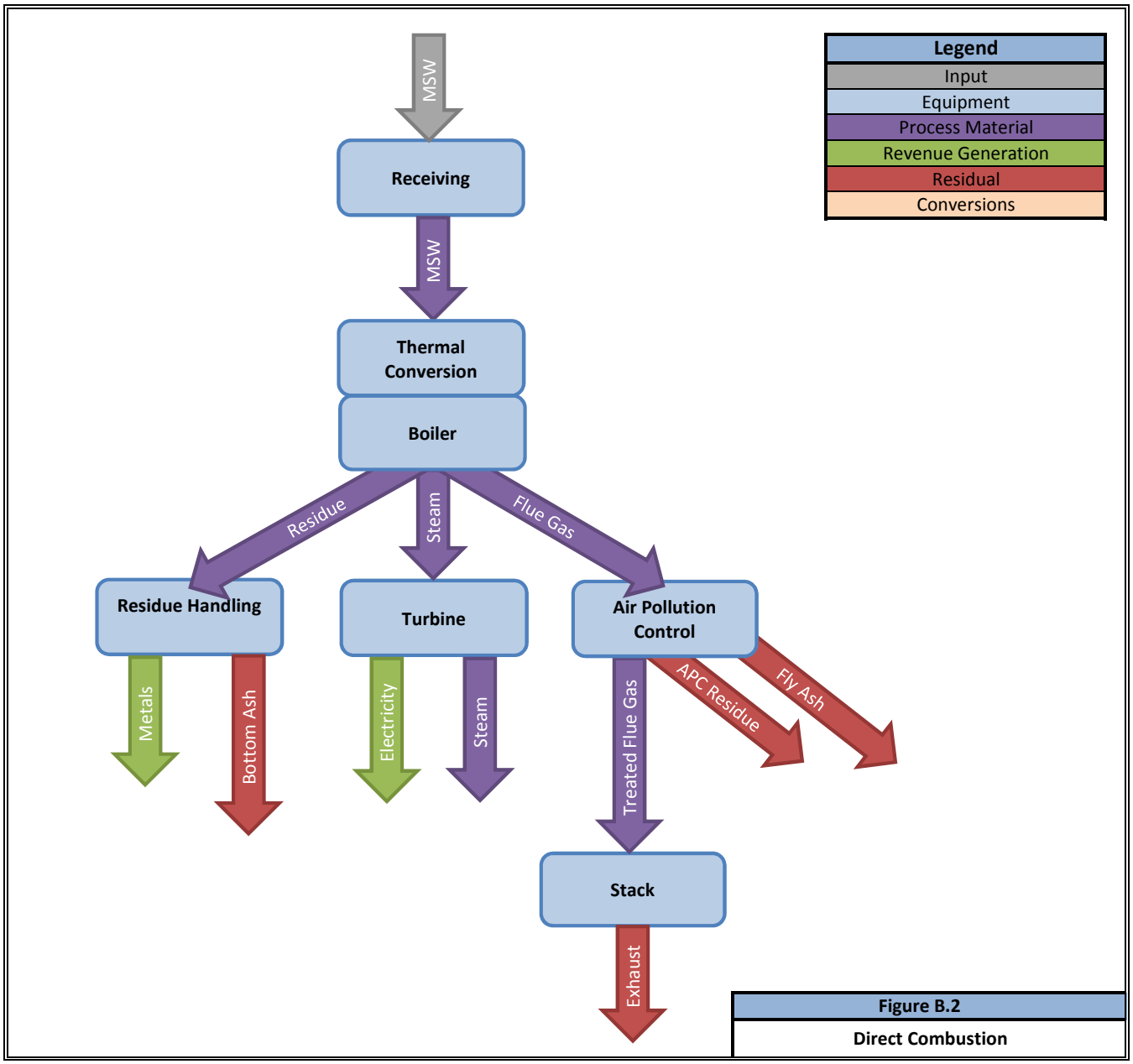
Figure B.1: Advanced Materials Recovery Facility



Description:
Within Advanced Materials Recovery Facilities (AMRFs), mechanical technologies generally remove metals, recyclables and un-processable material, in order to develop subsets of MSW which can be utilized to their fullest potential as feedstock in thermal and biological processes. The mechanical process often includes conveyors, magnets, Grizzly Screens, eddy current separators, trommel screens and shredders. The AMRFs modeled in the Metro scenarios vary in terms of their modeled performance to reflect the appropriate feedstock for the primary treatment in each of the scenarios. There are significant differences between several of the AMRF functions and corresponding configurations in terms of their ability to recover products, their use of equipment and the by-products they produce. The term AMRF is not the same facility from scenario to scenario; rather, it reflects the pre-processing requirements needed for the primary treatment technology.

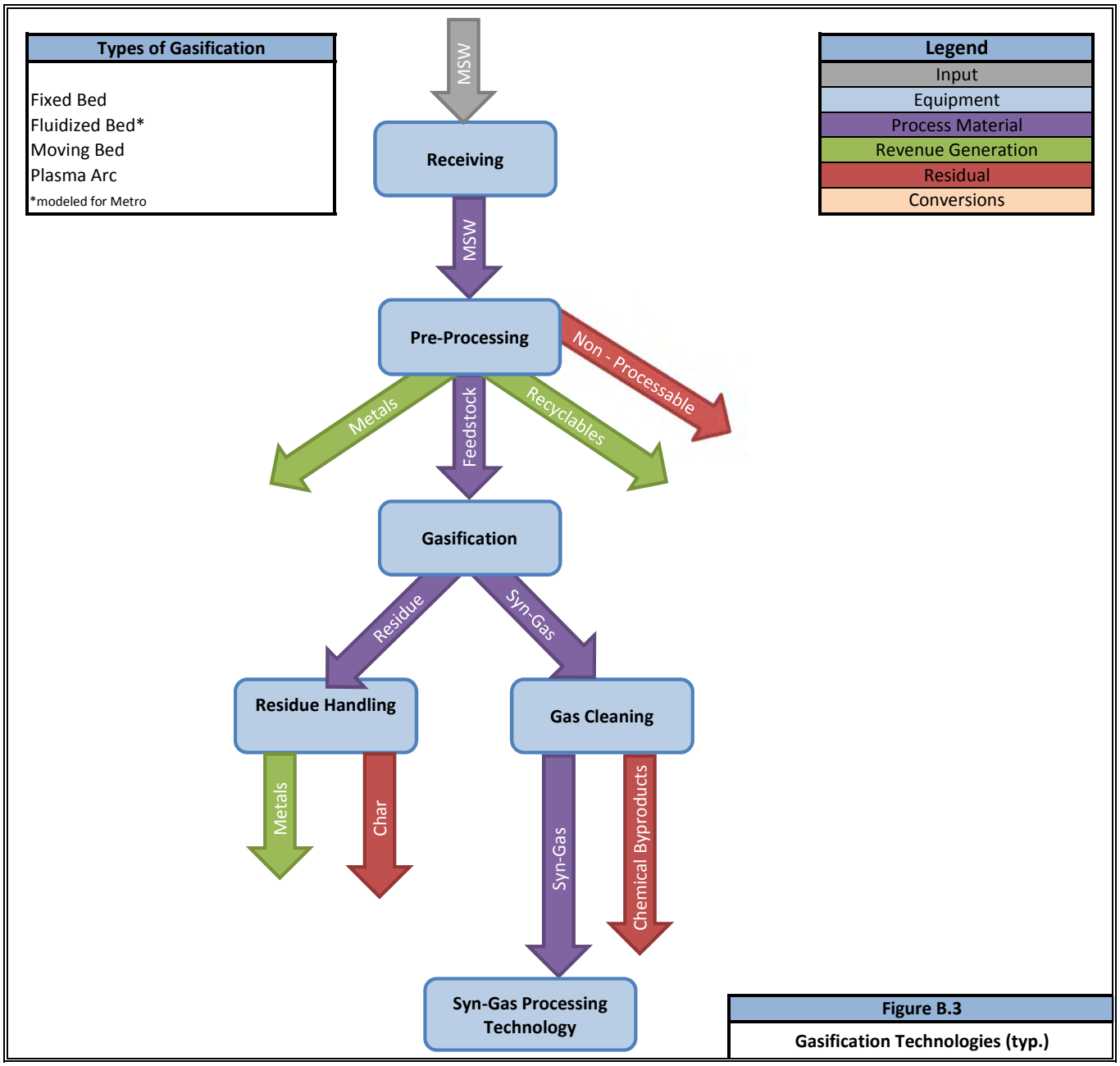
Figure B.2: Direct Combustion



Description:

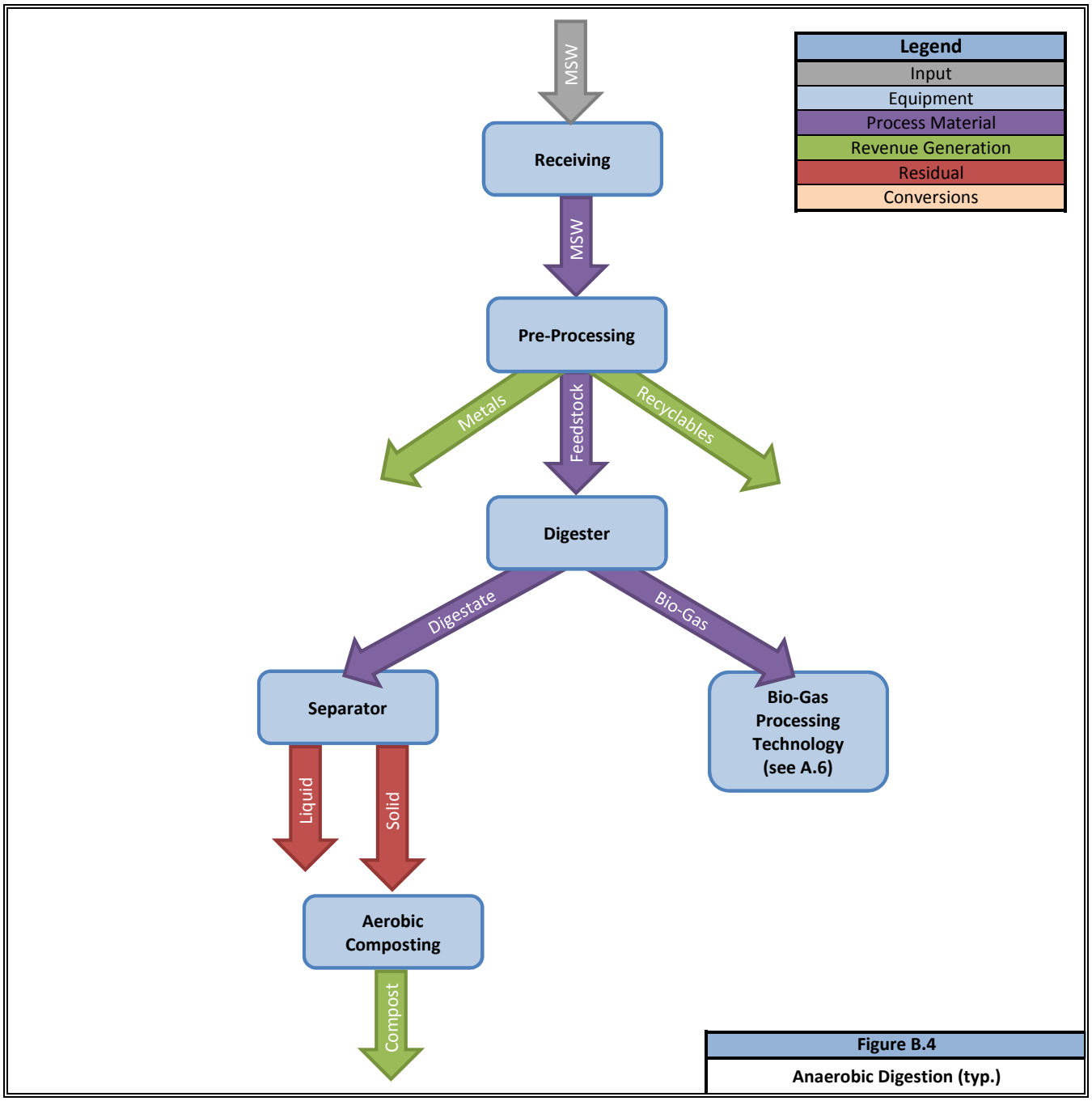
Direct Combustion, a modern mass burn type of waste to energy technology, can be divided into two main types: (a) grate based, waterwall boiler installations; and (b) modular, shop erected combustion units with shop fabricated waste heat recovery boilers. The modular units are typically limited to less than 200 tonnes per day and are historically used in facilities where the total throughput is under 500 tpd. In Mass Burn combustors, MSW is fed directly into a boiler system with no preprocessing other than the removal of large bulky items such as furniture and white goods. In the larger Mass Burn Combustion units, the MSW is typically pushed onto a grate by a ram connected to hydraulic cylinders. Air is admitted under the grates, into the bed of material, and additional air is supplied above the grates. The resulting flue gases pass through the boiler and the sensible heat energy is recovered in the boiler tubes to generate steam. In the smaller modular mass burn systems, MSW is fed into a refractory lined combustor where the waste is combusted on refractory lined hearths, or within a refractory lined oscillating combustor. The flue gases exit the combustors and enter a heat recovery steam generator, or waste heat boiler, where steam is generated by the sensible heat in the flue gas. In Direct Combustion, four main streams are generated; steam, flue gas, bottom ash and fly ash. The steam is either sent to a steam turbine to generate electricity or it can be piped directly to an end user as process or district heating steam, or a combination of these uses. Mass burn technologies utilize an extensive set of air pollution control (APC) devices for flue gas clean-up. The typical APC equipment used include: either selective catalytic reduction (SCR) or non-catalytic reduction (SNCR) for NOx emissions reduction; spray dryer absorbers (SDA) or scrubbers for acid gas reduction; activated carbon injection (CI) for mercury and dioxins reduction; and a fabric filter baghouse (FF) for particulate and heavy metals removal.

Figure B.3: Gasification



Description:
Gasification converts carbonaceous material into a synthesis gas or "syngas" composed primarily of carbon monoxide and hydrogen. Following a cleaning process to remove contaminants this syngas can be used as a fuel to generate electricity directly in a combustion turbine or engine, or the gas can be fired in a boiler to generate steam that can be used to generate electricity, for process uses or district heating, or a combination of both. The syngas generated can also be used as a chemical building block in the synthesis of gasoline or diesel fuel. The feedstock for most gasification technologies must be prepared into RDF developed from the incoming MSW, or the technology may only process a specific subset of waste materials such as wood waste, tires, carpet, scrap plastic, or other waste streams. Similar to Fluidized Bed Combustion, these processes typically require more front end separation and size reduction, and result in lower fuel yields (less fuel per tonne of MSW input). The feedstock reacts in the gasifier with steam and sometimes air or oxygen at high temperatures and pressures in a reducing (oxygen-starved) environment. The low- to mid-Megajoule syngas can be combusted in a boiler, or following a cleanup process a gas turbine, or engine or used in chemical refining. Of these alternatives, boiler combustion is the most common, but the cycle efficiency can be improved if the gas can be processed in an engine or gas turbine, particularly if the waste heat is then used to generate steam and additional electricity in a combined cycle facility. Industry experts generally expect that the flue gas will be lower in acid gases, combustion gases, organics, and metals, but APC equipment and syngas cleaning systems will still be required. The remaining ash and char produced by the syngas process may be marketed as a construction base, or disposed of in a landfill if a market does not exist.

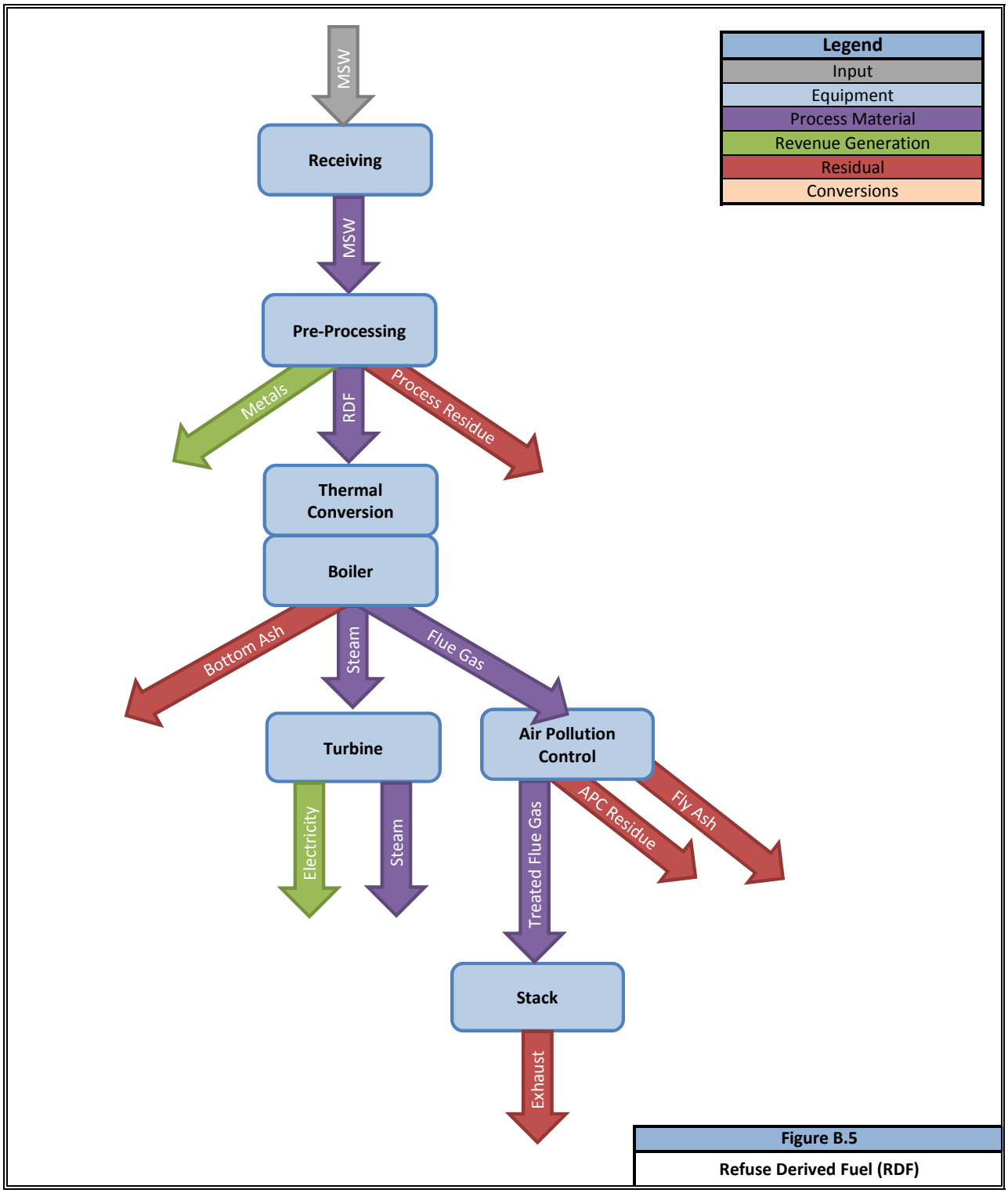
Figure B.4: Anaerobic Digestion



Description:

Anaerobic digestion (or AD) is the process of decomposing the solid organic fraction of the MSW stream in an oxygen-deficient environment. It has been extensively used to digest and stabilize sewage sludge and animal manures, and has had recent application treating Sanitary Sewer Overflow (or SSO). The AD process may either be a wet or dry process depending on the total solids content being treated in the reaction vessel. Dry bunker, batch AD was modeled for Metro. Both types of AD processes involve the injection of the organic material into an enclosed vessel where microbes are used to decompose the waste to produce a liquid, a solid digestate material, and a biogas that consists mainly of methane, water, and carbon dioxide (CO_2). The resulting low- to mid-energy-content biogas can be utilized in a reciprocating engine or gas turbine to produce electricity, or can be compressed into a vehicle fuel. The remaining digestate material, which can be up to 50 % of the input depending on the type of AD process used, can be treated further (e.g. cured aerobically) to produce a compost that can be marketed as a soil amendment. The incoming mixed MSW or SSO will require a pre-treatment process that involves shredding, pulping and separation of the non-digestible fraction of the waste stream. In many cases, this technology can be used in conjunction with composting, mechanical biological treatment (MBT), or a refuse-derived fuel (RDF) process.

Figure B.5: Refuse Derived Fuel (RDF) Combustion



Description:

This technology prepares MSW by shredding, screening, and removing non-combustible materials prior to additional processing. The goal of this technology is to derive a better, more homogenous, Refuse Derived Fuel (or RDF) that can be used in a more conventional solid-fuel boiler as compared to a mass-burn combustion waterwall boiler. The remaining MSW that is not converted to RDF is composed of either recovered ferrous metals which can be sold to market, or process residue 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 APC equipment arrangement for an RDF facility would be similar to that of a mass-burn combustion system.

Appendix C

Waste Composition, Design Basis, and Economic Analysis by Scenario

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Scenario 1: Landfilling

2019 Waste Compostion

Material	Adjusted Field Results	To Landfill	Tons to Landfill
TOTAL PAPER	**17.10%**	**17.10%**	**194,882**
Cardboard	3.57%	3.57%	40,654
Office paper	0.78%	0.78%	8,888
Newspaper and magazines	1.51%	1.51%	17,166
Mixed paper	1.90%	1.90%	21,602
Other compostable nonrecycl. paper	6.21%	6.21%	70,773
Other non-compostable nonrecycl. paper	3.14%	3.14%	35,799
TOTAL PLASTIC	**13.73%**	**13.73%**	**156,428**
Plastic bottles	0.63%	0.63%	7,155
Other rigid plastics	5.70%	5.70%	64,946
Plastic film - recyclable	1.86%	1.86%	21,246
Plastic film - non-recyclable	4.61%	4.61%	52,502
Mixed plastic / materials	0.93%	0.93%	10,580
OTHER ORGANICS	**46.69%**	**46.69%**	**532,025**
Yard Debris	2.20%	2.20%	25,121
Clean wood	4.19%	4.19%	47,780
Painted & treated lumber	1.47%	1.47%	16,805
Mixed wood / materials	4.93%	4.93%	56,185
Food waste	17.98%	17.98%	204,804
Rubber	0.57%	0.57%	6,551
Disposable diapers	3.36%	3.36%	38,226
Carpet/pad	2.50%	2.50%	28,460
Textiles	4.12%	4.12%	46,923
Other miscellaneous organics	5.37%	5.37%	61,170
GLASS	**1.65%**	**1.65%**	**18,815**
Deposit Beverage Glass	0.25%	0.25%	2,803
Window and other glass	1.41%	1.41%	16,012
METAL	**6.73%**	**6.73%**	**76,681**
Aluminum	0.37%	0.37%	4,206
Ferrous metals	2.61%	2.61%	29,694
Mixed Metals	2.28%	2.28%	26,028
Computers, brown goods, small apl.	1.47%	1.47%	16,753
OTHER INORGANICS	**11.73%**	**11.73%**	**133,664**
Rock, concrete, brick	1.07%	1.07%	12,143
Soil, sand, dirt	1.46%	1.46%	16,582
Gypsum wallboard	3.19%	3.19%	36,358
Other micellaneous inorganics	6.02%	6.02%	68,582
BULKY MATERIALS	**1.66%**	**1.66%**	**18,930**
MEDICAL WASTES	**0.48%**	**0.48%**	**5,423**
HAZARDOUS MATERIALS	**0.22%**	**0.22%**	**2,520**
TOTALS	**100.00%**	**100.00%**	**1,139,369**

Scenario 1: Landfilling

2038 Waste Compostion

Material	Adjusted Field Results	To Landfill	Tons to Landfill
TOTAL PAPER	**17.81%**	**17.81%**	**242,467**
Cardboard	3.80%	3.80%	51,683
Office paper	0.83%	0.83%	11,299
Newspaper and magazines	1.60%	1.60%	21,823
Mixed paper	2.42%	2.42%	32,889
Other compostable nonrecycl. paper	5.82%	5.82%	79,262
Other non-compostable nonrecycl. paper	3.34%	3.34%	45,510
TOTAL PLASTIC	**14.58%**	**14.58%**	**198,440**
Plastic bottles	0.57%	0.57%	7,747
Other rigid plastics	6.13%	6.13%	83,487
Plastic film - recyclable	1.98%	1.98%	27,010
Plastic film - non-recyclable	4.90%	4.90%	66,746
Mixed plastic / materials	0.99%	0.99%	13,450
OTHER ORGANICS	**43.60%**	**43.60%**	**593,637**
Yard Debris	2.35%	2.35%	31,937
Clean wood	4.46%	4.46%	60,742
Painted & treated lumber	1.57%	1.57%	21,364
Mixed wood / materials	5.25%	5.25%	71,427
Food waste	12.83%	12.83%	174,659
Rubber	0.61%	0.61%	8,328
Disposable diapers	3.57%	3.57%	48,597
Carpet/pad	2.66%	2.66%	36,181
Textiles	4.41%	4.41%	59,979
Other miscellaneous organics	5.91%	5.91%	80,423
GLASS	**1.76%**	**1.76%**	**23,920**
Deposit Beverage Glass	0.26%	0.26%	3,564
Window and other glass	1.50%	1.50%	20,356
METAL	**7.26%**	**7.26%**	**98,786**
Aluminum	0.39%	0.39%	5,346
Ferrous metals	2.77%	2.77%	37,750
Mixed Metals	2.43%	2.43%	33,090
Computers, brown goods, small apl.	1.66%	1.66%	22,600
OTHER INORGANICS	**12.48%**	**12.48%**	**169,927**
Rock, concrete, brick	1.13%	1.13%	15,437
Soil, sand, dirt	1.55%	1.55%	21,080
Gypsum wallboard	3.39%	3.39%	46,222
Other micellaneous inorganics	6.40%	6.40%	87,188
BULKY MATERIALS	**1.77%**	**1.77%**	**24,066**
MEDICAL WASTES	**0.51%**	**0.51%**	**6,894**
HAZARDOUS MATERIALS	**0.25%**	**0.25%**	**3,366**
TOTALS	**100.00%**	**100.00%**	**1,361,501**

Scenario 1: Landfilling

Design Basis

	2019	2038
Input tons per year		
Landfill	1,139,369	1,361,501
AMRF	0	0
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Diverted tons per year		
AMRF	0	0
Floor Sort	0	0
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Total Diverted	**0**	**0**
Percent of Input Diverted	**0.0%**	**0.0%**
Landfill		
Haul Distance RT (miles)	300	300
RT Time including Loading/Unloading (hrs)	6.0	6.0
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	33,511	40,045
Methane captured by LFG system per year (cf)	16,831,064	16,831,064
Methane daily flow rate (cf)	46,113	46,113
Gross Energy Generated in MMBTU/hr	1.92	1.92
Gross Energy in KW	563	563
Net Energy Generated (kWh/yr)	1,639,724	1,639,724
Availability (LFGTE IC engine)	0.95	0.95
Potential Electricity Revenues ($/year)	$ 130,000	$ 130,000

AMRF		
Not Used	N/A	N/A
Direct Combustion		
Not Used	N/A	N/A
Gasification		
Not Used	N/A	N/A
Anaerobic Digestion		
Not Used	N/A	N/A
RDF		
Not Used	N/A	N/A

Scenario 1: Landfilling

Economic Analysis

	2019	2038
Landfill		
Capital Cost		
Assume cost is built into tip fee	**$ -**	**$ -**
Annual Operations & Maintenance Cost		
Haul Distance RT (miles)	300	300
RT Time including Loading/Unloading (hrs)	6.0	6.0
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	33,511	40,045
Estimated hourly transfer trailer cost ($/hr)	$ 95	$ 95
Annual Transfer Cost ($/year)	**$ 18,956,563**	**$ 22,652,728**
Landfill Tip Fee ($/ton)	$ 22.79	$ 22.79
Annual Landfill Tip Fee ($/year)	**$ 25,966,211**	**$ 31,028,608**
Total Landilling Cost ($/year)	**$ 44,923,000**	**$ 53,681,000**
TOTAL		
Revenues from LFGTE system ($/year)	$ 130,000.00	$ 130,000.00
TOTAL ANNUAL COST ($/year)	**$ 44,793,000**	**$ 53,551,000**

Scenario 1A: Status Quo, Landfilling with AMRF as variance

2019 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	To Landfill	Recovered Tons	Tons to Landfill
TOTAL PAPER	**17.10%**		**3.84%**	**13.26%**	**43,777**	**151,106**
Cardboard	3.57%	60%	2.14%	1.43%	24,392	16,262
Office paper	0.78%	0%	0.00%	0.78%	0	8,888
Newspaper and magazines	1.51%	50%	0.75%	0.75%	8,583	8,583
Mixed paper	1.90%	50%	0.95%	0.95%	10,801	10,801
Other compostable nonrecycl. paper	6.21%	0%	0.00%	6.21%	0	70,773
Other non-compostable nonrecycl. paper	3.14%	0%	0.00%	3.14%	0	35,799
TOTAL PLASTIC	**13.73%**		**3.79%**	**9.94%**	**43,139**	**113,289**
Plastic bottles	0.63%	60%	0.38%	0.25%	4,293	2,862
Other rigid plastics	5.70%	50%	2.85%	2.85%	32,473	32,473
Plastic film - recyclable	1.86%	30%	0.56%	1.31%	6,374	14,872
Plastic film - non-recyclable	4.61%	0%	0.00%	4.61%	0	52,502
Mixed plastic / materials	0.93%	0%	0.00%	0.93%	0	10,580
OTHER ORGANICS	**46.69%**		**7.84%**	**38.85%**	**89,328**	**442,697**
Yard Debris	2.20%	50%	1.10%	1.10%	12,561	12,561
Clean wood	4.19%	60%	2.52%	1.68%	28,668	19,112
Painted & treated lumber	1.47%	0%	0	1.47%	0	16,805
Mixed wood / materials	4.93%	50%	2.47%	2.47%	28,092	28,092
Food waste	17.98%	0%	0.00%	17.98%	0	204,804
Rubber	0.57%	60%	0.34%	0.23%	3,930	2,620
Disposable diapers	3.36%	0%	0.00%	3.36%	0	38,226
Carpet/pad	2.50%	40%	1.00%	1.50%	11,384	17,076
Textiles	4.12%	10%	0.41%	3.71%	4,692	42,231
Other miscellaneous organics	5.37%	0%	0.00%	5.37%	0	61,170
GLASS	**1.65%**		**0.00%**	**1.65%**	**0**	**18,815**
Deposit Beverage Glass	0.25%	0%	0.00%	0.25%	0	2,803
Window and other glass	1.41%	0%	0.00%	1.41%	0	16,012
METAL	**6.73%**		**3.96%**	**2.77%**	**45,121**	**31,561**
Aluminum	0.37%	70%	0.26%	0.11%	2,944	1,262
Ferrous metals	2.61%	70%	1.82%	0.78%	20,786	8,908
Mixed Metals	2.28%	50%	1.14%	1.14%	13,014	13,014
Computers, brown goods, small apl.	1.47%	50%	0.74%	0.74%	8,376	8,376
OTHER INORGANICS	**11.73%**		**0.96%**	**10.77%**	**10,907**	**122,757**
Rock, concrete, brick	1.07%	0%	0	1.07%	0	12,143
Soil, sand, dirt	1.46%	0%	0.00%	1.46%	0	16,582
Gypsum wallboard	3.19%	30%	0.96%	2.23%	10,907	25,451
Other micellaneous inorganics	6.02%	0%	0.00%	6.02%	0	68,582
BULKY MATERIALS	**1.66%**	**0%**	0	**1.66%**	0	**18,930**
MEDICAL WASTES	**0.48%**	**0%**	**0.00%**	**0.48%**	**0**	**5,423**
HAZARDOUS MATERIALS	**0.22%**	**0%**	**0.00%**	**0.22%**	**0**	**2,520**
TOTALS	**100.00%**		**20.39%**	**79.61%**	**232,272**	**907,097**

Scenario 1A: Status Quo, Landfilling with AMRF as variance

2038 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	To Landfill	Recovered Tons	Tons to Landfill
TOTAL PAPER	**17.81%**		**4.29%**	**13.52%**	**58,366**	**184,101**
Cardboard	3.80%	60%	2.28%	1.52%	31,010	20,673
Office paper	0.83%	0%	0.00%	0.83%	0	11,299
Newspaper and magazines	1.60%	50%	0.80%	0.80%	10,912	10,912
Mixed paper	2.42%	50%	1.21%	1.21%	16,444	16,444
Other compostable nonrecycl. paper	5.82%	0%	0.00%	5.82%	0	79,262
Other non-compostable nonrecycl. paper	3.34%	0%	0.00%	3.34%	0	45,510
TOTAL PLASTIC	**14.58%**		**4.00%**	**10.57%**	**54,495**	**143,945**
Plastic bottles	0.57%	60%	0.34%	0.23%	4,648	3,099
Other rigid plastics	6.13%	50%	3.07%	3.07%	41,744	41,744
Plastic film - recyclable	1.98%	30%	0.60%	1.39%	8,103	18,907
Plastic film - non-recyclable	4.90%	0%	0.00%	4.90%	0	66,746
Mixed plastic / materials	0.99%	0%	0.00%	0.99%	0	13,450
OTHER ORGANICS	**43.60%**		**8.34%**	**35.26%**	**113,594**	**480,043**
Yard Debris	2.35%	50%	1.17%	1.17%	15,968	15,968
Clean wood	4.46%	60%	2.68%	1.78%	36,445	24,297
Painted & treated lumber	1.57%	0%	0	1.57%	0	21,364
Mixed wood / materials	5.25%	50%	2.62%	2.62%	35,713	35,713
Food waste	12.83%	0%	0.00%	12.83%	0	174,659
Rubber	0.61%	60%	0.37%	0.24%	4,997	3,331
Disposable diapers	3.57%	0%	0.00%	3.57%	0	48,597
Carpet/pad	2.66%	40%	1.06%	1.59%	14,473	21,709
Textiles	4.41%	10%	0.44%	3.96%	5,998	53,981
Other miscellaneous organics	5.91%	0%	0.00%	5.91%	0	80,423
GLASS	**1.76%**		**0.00%**	**1.76%**	**0**	**23,920**
Deposit Beverage Glass	0.26%	0%	0.00%	0.26%	0	3,564
Window and other glass	1.50%	0%	0.00%	1.50%	0	20,356
METAL	**7.26%**		**4.26%**	**2.99%**	**58,012**	**40,774**
Aluminum	0.39%	70%	0.27%	0.12%	3,743	1,604
Ferrous metals	2.77%	70%	1.94%	0.83%	26,425	11,325
Mixed Metals	2.43%	50%	1.22%	1.22%	16,545	16,545
Computers, brown goods, small apl.	1.66%	50%	0.83%	0.83%	11,300	11,300
OTHER INORGANICS	**12.48%**		**1.02%**	**11.46%**	**13,867**	**156,060**
Rock, concrete, brick	1.13%	0%	0	1.13%	0	15,437
Soil, sand, dirt	1.55%	0%	0.00%	1.55%	0	21,080
Gypsum wallboard	3.39%	30%	1.02%	2.38%	13,867	32,355
Other micellaneous inorganics	6.40%	0%	0.00%	6.40%	0	87,188
BULKY MATERIALS	**1.77%**	**0%**	0	**1.77%**	0	**24,066**
MEDICAL WASTES	**0.51%**	**0%**	**0.00%**	**0.51%**	**0**	**6,894**
HAZARDOUS MATERIALS	**0.25%**	**0%**	**0.00%**	**0.25%**	**0**	**3,366**
TOTALS	**100.00%**		**21.91%**	**78.09%**	**298,334**	**1,063,167**

Scenario 1A: Status Quo, Landfilling with AMRF as variance

Design Basis

	2019	2038
Input tons per year		
Landfill	907,097	1,063,167
AMRF	1,139,369	1,361,501
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Diverted tons per year		
AMRF	232,272	298,334
Floor Sort	0	0
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Total Diverted	**232,272**	**298,334**
Percent of Input Diverted	**20.4%**	**21.9%**
Landfill		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	26,680	31,270
Methane captured by LFG system per year (cf)	14,210,281	14,210,281
Methane daily flow rate (cf)	38,932	38,932
Gross Energy Generated in MMBTU/hr	1.62	1.62
Gross Energy in KW	475	475
Net Energy Generated (kWh/yr)	1,384,401	1,384,401
Availability (LFGTE IC engine)	0.95	0.95
Potential Electricity Revenues ($/year)	$ 110,000	$ 110,000

AMRF		
Haul Distance RT (miles)	100	100
RT Time including Loading/Unloading (hrs)	2.3	2.3
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	33,511	40,045
Facility Capacity (tons/day)	750	750
Rounded Number of Facilities Required	5	6
Exact Number of Facilities Required	4.5	5.4
Difference for Adjusting Last Facility Operations	0.48	0.59
Operating Hours per Day	20	20
Availability	92%	92%
For Each Facility		
Power Requirement (kWh/yr)	3,300,000	3,300,000
Water Consumption (CF of water per year)	320	320
Effluent Requirement	270	270
Number of Pieces of Mobie Equipment	7	7
Estmated Fuel Usage (gals/year)	134,000	134,000
Number of Sorters (all shifts)	39	39
Additional Sorters for Plastics (all shitfs)	0	0
Mgrs, Eq Ops, Mech, etc. (all shifts)	23	23
Number of Office Personnel (one shift)	4	4
Total Staff	66	66
Acreage Required	5	5

Scenario 1A: Status Quo, Landfilling with AMRF as variance

Design Basis (continued)

	2019	2038
Direct Combustion		
Not Used	N/A	N/A
Gasification		
Not Used	N/A	N/A
Anaerobic Digestion		
Not Used	N/A	N/A
RDF		
Not Used	N/A	N/A

Scenario 1A: Status Quo, Landfilling with AMRF as variance

Economic Analysis

	2019	2038
Landfill		
Capital Cost		
Assume cost is built into tip fee	**$ -**	**$ -**
Annual Operations & Maintenance Cost		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	26,680	31,270
Estimated hourly transfer trailer cost ($/hr)	$ 95	$ 95
Annual Transfer Cost ($/year)	**$ 10,484,027**	**$ 12,287,689**
Landfill Tip Fee ($/ton)	$ 22.79	$ 22.79
Annual Landfill Tip Fee ($/year)	**$ 20,672,740**	**$ 24,229,582**
Total Landilling Cost ($/year)	**$ 31,157,000**	**$ 36,517,000**
AMRF (per facility)		
Capital Cost		
Site improvements & buildings	$ 11,319,000	$ 11,319,000
Startup and acceptance testing (1 month)	$ 852,000	$ 852,000
Subtotal	**$ 12,171,000**	**$ 12,171,000**
Environmental Impact	$ 226,000	$ 226,000
Planning	$ 340,000	$ 340,000
Permits	$ 453,000	$ 453,000
Design	$ 792,000	$ 792,000
Construction administration	$ 566,000	$ 566,000
Subtotal	**$ 14,548,000**	**$ 14,548,000**
Contingency (15%)	$ 2,182,000	$ 2,182,000
Land	$ -	$ -
Stationary equipment installed(w/spare parts)	$ 10,293,000	$ 10,293,000
Rolling stock	$ 720,000	$ 720,000
Total Capital Costs	**$ 27,743,000**	**$ 27,743,000**
Annual Operations & Maintenance Cost		
Labor	$ 6,301,000	$ 6,301,000
Facilities maintenance	$ 50,000	$ 50,000
Rolling stock maintenance	$ 154,000	$ 154,000
Rolling stock replacement costs	$ 103,000	$ 103,000
Stationary equip maintenance/replace	$ 406,000	$ 406,000
Utilities	$ 390,000	$ 390,000
Fuel	$ 534,000	$ 534,000
General & administration/legal,/accnt.	$ 50,000	$ 50,000
Contractor overhead	$ 799,000	$ 799,000
Insurance	$ 100,000	$ 100,000
Property taxes	$ -	$ -
Subtotal	**$ 8,887,000**	**$ 8,887,000**
Contingency (15%)	$ 1,333,000	$ 1,333,000
Total O&M costs (per facility)	$ 10,220,000	$ 10,220,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 2,067,000	$ 2,067,000
Total Annual Cost (per facility)	$ 12,287,000	$ 12,287,000
Potential Materials Market Revenues ($/year)	$ 1,284,000	$ 1,380,000
Net Annual Cost (per facility)	**$ 11,003,000**	**$ 10,907,000**
Number of Facilities	5	6
Total Annual Cost (all facilities)	**$ 55,015,000**	**$ 65,442,000**
TOTAL		
Economic make-up rounding number of facilities	$ (4,313,000)	$ (5,298,000)
Revenues from LFGTE system ($/year)	$ 110,000	$ 110,000
Haul from Metro to Facilities	$ 7,380,036	$ 8,819,001
TOTAL ANNUAL COST ($/year)	**$ 89,129,036**	**$ 105,370,001**

Scenario 2: Direct Combustion with Landfill

2019 Waste Compostion

Material	Adjusted Field Results	Floor Sort Recovery	Recovered Amount	Diverted to Landfill	To Direct Combustion	Recovered Tons	Tons Diverted to Landfill	Tons to Direct Combustion
TOTAL PAPER	**17.10%**		**0.36%**		**16.75%**	**4,065**		**190,817**
Cardboard	3.57%	10%	0.36%		3.21%	4,065		36,589
Office paper	0.78%	0%	0.00%		0.78%	-		8,888
Newspaper and magazines	1.51%	0%	0.00%		1.51%	-		17,166
Mixed paper	1.90%	0%	0.00%		1.90%	-		21,602
Other compostable nonrecycl. paper	6.21%	0%	0.00%		6.21%	-		70,773
Other non-compostable nonrecycl. paper	3.14%	0%	0.00%		3.14%	-		35,799
TOTAL PLASTIC	**13.73%**		**0.00%**		**13.73%**	**-**		**156,428**
Plastic bottles	0.63%	0%	0.00%		0.63%	-		7,155
Other rigid plastics	5.70%	0%	0.00%		5.70%	-		64,946
Plastic film - recyclable	1.86%	0%	0.00%		1.86%	-		21,246
Plastic film - non-recyclable	4.61%	0%	0.00%		4.61%	-		52,502
Mixed plastic / materials	0.93%	0%	0.00%		0.93%	-		10,580
OTHER ORGANICS	**46.69%**		**1.16%**	**0.15%**	**45.53%**	**13,242**	**1,681**	**517,102**
Yard Debris	2.20%	0%	0.00%		2.20%	-		25,121
Clean wood	4.19%	10%	0.42%		3.77%	4,778		43,002
Painted & treated lumber	1.47%	10%		0.15%	1.33%		1,681	15,125
Mixed wood / materials	4.93%	10%	0.49%		4.44%	5,618		50,566
Food waste	17.98%	0%	0.00%		17.98%	-		204,804
Rubber	0.57%	0%	0.00%		0.57%	-		6,551
Disposable diapers	3.36%	0%	0.00%		3.36%	-		38,226
Carpet/pad	2.50%	10%	0.25%		2.25%	2,846		25,614
Textiles	4.12%	0%	0.00%		4.12%	-		46,923
Other miscellaneous organics	5.37%	0%	0.00%		5.37%	-		61,170
GLASS	**1.65%**		**0.00%**		**1.65%**	**-**		**18,815**
Deposit Beverage Glass	0.25%	0%	0.00%		0.25%	-		2,803
Window and other glass	1.41%	0%	0.00%		1.41%	-		16,012
METAL	**6.73%**		**0.34%**		**6.39%**	**3,834**		**72,847**
Aluminum	0.37%	5%	0.02%		0.35%	210		3,995
Ferrous metals	2.61%	5%	0.13%		2.48%	1,485		28,210
Mixed Metals	2.28%	5%	0.11%		2.17%	1,301		24,727
Computers, brown goods, small apl.	1.47%	5%	0.07%		1.40%	838		15,915
OTHER INORGANICS	**11.73%**		**0.00%**	**0.05%**	**11.73%**	**-**	**607**	**133,057**
Rock, concrete, brick	1.07%	5%		0.05%	1.01%		607	11,535
Soil, sand, dirt	1.46%	0%	0.00%		1.46%	-		16,582
Gypsum wallboard	3.19%	0%	0.00%		3.19%	-		36,358
Other micellaneous inorganics	6.02%	0%	0.00%		6.02%	-		68,582
BULKY MATERIALS*	**1.66%**	**76%**		**1.27%**	**0.39%**		**14,463**	**4,468**
MEDICAL WASTES	**0.48%**	**0%**	**0.00%**		**0.48%**	**-**		**5,423**
HAZARDOUS MATERIALS	**0.22%**	**0%**	**0.00%**		**0.22%**	**-**		**2,520**
TOTALS	**100.00%**		**1.86%**	**1.47%**	**96.67%**	**21,142**	**16,750**	**1,101,476**

* Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% for the matresses and furniture would be pulled for disposal and only 10% of the tires would be let through as disposal as would be good combustion material.

Scenario 2: Direct Combustion with Landfill

2038 Waste Compostion

Material	Adjusted Field Results	Floor Sort Recovery	Recovered Amount	Diverted to Landfill	To Direct Combustion	Recovered Tons	Tons Diverted to Landfill	Tons to Direct Combustion
TOTAL PAPER	**17.81%**		**0.38%**		**17.43%**	**5,168**		**237,298**
Cardboard	3.80%	10%	0.38%		3.42%	5,168		46,515
Office paper	0.83%	0%	0.00%		0.83%	-		11,299
Newspaper and magazines	1.60%	0%	0.00%		1.60%	-		21,823
Mixed paper	2.42%	0%	0.00%		2.42%	-		32,889
Other compostable nonrecycl. paper	5.82%	0%	0.00%		5.82%	-		79,262
Other non-compostable nonrecycl. paper	3.34%	0%	0.00%		3.34%	-		45,510
TOTAL PLASTIC	**14.58%**		**0.00%**		**14.58%**	**-**		**198,440**
Plastic bottles	0.57%	0%	0.00%		0.57%	-		7,747
Other rigid plastics	6.13%	0%	0.00%		6.13%	-		83,487
Plastic film - recyclable	1.98%	0%	0.00%		1.98%	-		27,010
Plastic film - non-recyclable	4.90%	0%	0.00%		4.90%	-		66,746
Mixed plastic / materials	0.99%	0%	0.00%		0.99%	-		13,450
OTHER ORGANICS	**43.60%**		**1.24%**	**0.16%**	**42.37%**	**16,835**	**2,136**	**574,665**
Yard Debris	2.35%	0%	0.00%		2.35%	-		31,937
Clean wood	4.46%	10%	0.45%		4.02%	6,074		54,668
Painted & treated lumber	1.57%	10%		0.16%	1.41%		2,136	19,228
Mixed wood / materials	5.25%	10%	0.52%		4.72%	7,143		64,284
Food waste	12.83%	0%	0.00%		12.83%	-		174,659
Rubber	0.61%	0%	0.00%		0.61%	-		8,328
Disposable diapers	3.57%	0%	0.00%		3.57%	-		48,597
Carpet/pad	2.66%	10%	0.27%		2.39%	3,618		32,563
Textiles	4.41%	0%	0.00%		4.41%	-		59,979
Other miscellaneous organics	5.91%	0%	0.00%		5.91%	-		80,423
GLASS	**1.76%**		**0.00%**		**1.76%**	**-**		**23,920**
Deposit Beverage Glass	0.26%	0%	0.00%		0.26%	-		3,564
Window and other glass	1.50%	0%	0.00%		1.50%	-		20,356
METAL	**7.26%**		**0.36%**		**6.89%**	**4,939**		**93,847**
Aluminum	0.39%	5%	0.02%		0.37%	267		5,079
Ferrous metals	2.77%	5%	0.14%		2.63%	1,888		35,863
Mixed Metals	2.43%	5%	0.12%		2.31%	1,654		31,435
Computers, brown goods, small apl.	1.66%	5%	0.08%		1.58%	1,130		21,470
OTHER INORGANICS	**12.48%**		**0.00%**	**0.06%**	**12.48%**	**-**	**772**	**169,155**
Rock, concrete, brick	1.13%	5%		0.06%	1.08%		772	14,665
Soil, sand, dirt	1.55%	0%	0.00%		1.55%	-		21,080
Gypsum wallboard	3.39%	0%	0.00%		3.39%	-		46,222
Other micellaneous inorganics	6.40%	0%	0.00%		6.40%	-		87,188
BULKY MATERIALS*	**1.77%**	**76%**		**1.35%**	**0.42%**		**18,386**	**5,680**
MEDICAL WASTES	**0.51%**	**0%**	**0.00%**		**0.51%**	**-**		**6,894**
HAZARDOUS MATERIALS	**0.25%**	**0%**	**0.00%**		**0.25%**	**-**		**3,366**
TOTALS	**100.00%**		**1.98%**	**1.56%**	**96.46%**	**26,943**	**21,295**	**1,313,264**

* Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% for the matresses and furniture would be pulled for disposal and only 10% of the tires would be let through as disposal as would be good combustion material.

Scenario 2: Direct Combustion with Landfill

Design Basis

	2019	2038
Input tons per year		
Landfill	319,656	382,442
AMRF	0	0
Direct Combustion Plant	1,101,476	1,313,264
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Diverted tons per year		
AMRF	0	0
Floor Sort	21,142	26,943
Direct Combustion Plant	798,570	952,116
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Total Diverted	**819,712**	**979,059**
Percent of Input Diverted	**71.9%**	**71.9%**
Landfill		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	9,402	11,249
AMRF		
Not Used	N/A	N/A
Direct Combustion		
Haul Distance RT (miles)	100	100
RT Time including Loading/Unloading (hrs)	2.3	2.3
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	32,397	38,626
Facility Capacity (tons/day)	1,000	1,000
Rounded Number of Facilities Required	4	4
Exact Number of Facilities Required	3.4	4.0
Difference for Adjusting Last Facility Operations	0.65	0.002
Operating Hours per Day	24	24
Availability	90%	90%
For Each Facility		
Hourly Throughput (tons/hour)	37.5	37.5
Steam Production (1000 lbs/hr)	2,300,000	2,300,000
Gross Energy Generated (MW)	28.7	28.7
Internal Parasitic Load (MW)	4.3	4.3
Net Energy Generated (MW)	24.4	24.4
Ash Production Rate (%)	30%	30%
Ash Production (tons/year)	98,600	98,600
Auxillary Fuel- natural gas/propane (MMBtu/yr)	100,400	100,400
Water Consumption (1000 cf/year)	3,100	3,100
Effluent Requirement (1000 cf/year)	220	220
Number of Personnel	40	40
Acreage Required	8-20	8-20
Gasification		
Not Used	N/A	N/A
Anaerobic Digestion		
Not Used	N/A	N/A
RDF		
Not Used	N/A	N/A

Scenario 2: Direct Combustion with Landfill

Economic Analysis

	2019	2038
Landfill		
Capital Cost		
Assume cost is built into tip fee	**$ -**	**$ -**
Annual Operations & Maintenance Cost		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	9,402	11,249
Estimated hourly transfer trailer cost ($/hr)	$ 95	$ 95
Annual Transfer Cost ($/year)	**$ 3,694,559**	**$ 4,420,346**
Landfill Tip Fee ($/ton)	$ 22.79	$ 22.79
Annual Landfill Tip Fee ($/year)	**$ 7,284,968**	**$ 8,715,856**
Total Landilling Cost ($/year)	**$ 10,980,000**	**$ 13,136,000**
Direct Combustion (per facility)		
Capital Cost		
Design, Permits, CM and Ancillary Costs	$ 38,700,000	$ 38,700,000
Site Work and Utilities	$ 15,000,000	$ 15,000,000
Landscaping	$ 1,000,000	$ 1,000,000
Buildings, Structures and Architectural	$ 59,000,000	$ 59,000,000
Equipment & Installation	$ 278,500,000	$ 278,500,000
Electrical Interconnection	$ 12,900,000	$ 12,900,000
Waste Water Treatment Plant	$ 3,500,000	$ 3,500,000
Subtotal - Direct Construction Costs	**$ 408,600,000**	**$ 408,600,000**
Spare Parts, Tools, Other Equip and Materials	$ 3,000,000	$ 3,000,000
Mobile Equipment	$ 1,000,000	$ 1,000,000
Facility Start-up, Testing, CM and Commissioning	$ 10,800,000	$ 10,800,000
Insurance During Construction	$ 6,500,000	$ 6,500,000
Subtotal – Indirect Construction Costs	**$ 21,300,000**	**$ 21,300,000**
Subtotal - Construction Costs	**$ 429,900,000**	**$ 429,900,000**
Contingency (15%)	$ 64,500,000	$ 64,500,000
Total Capital Costs	**$ 494,400,000**	**$ 494,400,000**
Annual Operations & Maintenance Cost		
Labor	$ 4,440,000	$ 4,440,000
Facilities, Equipment and Rolling Stock Maintenance	$ 6,750,000	$ 6,750,000
Consumables	$ 3,000,000	$ 3,000,000
Auxillary Fuel Costs	$ 900,000	$ 900,000
Purchased Utilities	$ 550,000	$ 550,000
Contract, Rental, or Lease Services	$ 140,000	$ 140,000
Adminstrative Costs (including regulatory)	$ 380,000	$ 380,000
Insurance Costs	$ 300,000	$ 300,000
Subtotal - O&M	**$ 16,460,000**	**$ 16,460,000**
Contingency (15%)	$ 2,470,000	$ 2,470,000
Total O&M costs (per facility)	**$ 18,930,000**	**$ 18,930,000**
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	**$ 36,830,000**	**$ 36,830,000**
Potential Electricity Revenues ($/year)	$ 15,370,000	$ 15,370,000
Potential Metal Sales Revenues ($/year)	$ 180,000	$ 180,000
Potential Revenues ($/year)	**$ 15,550,000**	**$ 15,550,000**
Net Annual Cost (per facility)	**$ 40,210,000**	**$ 40,210,000**
Number of Facilities	4	4
Total Annual Cost (all facilities)	**$ 160,840,000**	**$ 160,840,000**
TOTAL		
Economic make-up rounding number of facilities	$ (2,305,000)	$ (351,000)
Haul from Metro to Facilities	$ 7,134,703	$ 8,506,499
TOTAL ANNUAL COST ($/year)	**$ 176,649,703**	**$ 182,131,499**

Scenario 2A: Direct Combustion with an AMRF as a variance

2019 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	Plastics to Pyrolysis	To Direct Combustion	Recovered Tons	Tons to Landfill	Tons to Pyrolysis	Tons to Direct Combustion
TOTAL PAPER	**17.10%**		**3.84%**			**13.26%**	**43,777**		**0**	**151,106**
Cardboard	3.57%	60%	2.14%			1.43%	24,392		0	16,262
Office paper	0.78%	0%	0.00%			0.78%	0		0	8,888
Newspaper and magazines	1.51%	50%	0.75%			0.75%	8,583		0	8,583
Mixed paper	1.90%	50%	0.95%			0.95%	10,801		0	10,801
Other compostable nonrecycl. paper	6.21%	0%	0.00%			6.21%	0		0	70,773
Other non-compostable nonrecycl. paper	3.14%	0%	0.00%			3.14%	0		0	35,799
TOTAL PLASTIC	**13.73%**		**4.35%**		**2.76%**	**6.62%**	**49,513**		**31,501**	**75,414**
Plastic bottles	0.63%	60%	0.38%			0.25%	4,293		0	2,862
Other rigid plastics	5.70%	50%	2.85%			2.85%	32,473		0	32,473
Plastic film - recyclable	1.86%	60%	1.12%			0.75%	12,747		0	8,498
Plastic film - non-recyclable	4.61%	60%			2.76%	1.84%	0		31,501	21,001
Mixed plastic / materials	0.93%	0%	0.00%			0.93%	0		0	10,580
OTHER ORGANICS	**46.69%**		**7.84%**	**0.15%**		**38.71%**	**89,328**	**1,681**	**0**	**441,017**
Yard Debris	2.20%	50%	1.10%			1.10%	12,561		0	12,561
Clean wood	4.19%	60%	2.52%			1.68%	28,668		0	19,112
Painted & treated lumber	1.47%	0%	0	0.15%		1.33%	0	1,681	0	15,125
Mixed wood / materials	4.93%	50%	2.47%			2.47%	28,092		0	28,092
Food waste	17.98%	0%	0.00%			17.98%	0		0	204,804
Rubber	0.57%	60%	0.34%			0.23%	3,930		0	2,620
Disposable diapers	3.36%	0%	0.00%			3.36%	0		0	38,226
Carpet/pad	2.50%	40%	1.00%			1.50%	11,384		0	17,076
Textiles	4.12%	10%	0.41%			3.71%	4,692		0	42,231
Other miscellaneous organics	5.37%	0%	0.00%			5.37%	0		0	61,170
GLASS	**1.65%**		**0.00%**			**1.65%**	**0**		**0**	**18,815**
Deposit Beverage Glass	0.25%	0%	0.00%			0.25%	0		0	2,803
Window and other glass	1.41%	0%	0.00%			1.41%	0		0	16,012
METAL	**6.73%**		**3.96%**			**2.77%**	**45,121**		**0**	**31,561**
Aluminum	0.37%	70%	0.26%			0.11%	2,944		0	1,262
Ferrous metals	2.61%	70%	1.82%			0.78%	20,786		0	8,908
Mixed Metals	2.28%	50%	1.14%			1.14%	13,014		0	13,014
Computers, brown goods, small apl.	1.47%	50%	0.74%			0.74%	8,376		0	8,376
OTHER INORGANICS	**11.73%**		**0.96%**	**0.05%**		**11.81%**	**10,907**	**607**	**0**	**122,150**
Rock, concrete, brick	1.07%	0%	0	0.05%		1.01%	0	607	0	11,535
Soil, sand, dirt	1.46%	0%	0.00%			1.46%	0		0	16,582
Gypsum wallboard	3.19%	30%	0.96%			2.23%	10,907		0	25,451
Other micellaneous inorganics	6.02%	0%	0.00%			6.02%	0		0	68,582
BULKY MATERIALS*	**1.66%**	**76%**		**1.27%**		**0.39%**		14,463	**0**	**4,468**
MEDICAL WASTES	**0.48%**	**0%**	**0.00%**			**0.48%**	**0**		**0**	**5,423**
HAZARDOUS MATERIALS	**0.22%**	**0%**	**0.00%**			**0.22%**	**0**		**0**	**2,520**
TOTALS**	**100.00%**		**20.95%**	**1.47%**	**2.76%**	**75.91%**	**238,645**	**16,750**	**31,501**	**852,472**

*Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% for the matresses and furniture would be pulled for disposal and only 10% of the tires would be let through as disposal as would be good combustion material.

**Increase in recovery is due to additional plastics sorters are employed in this scenario to recover additional plastics for the pyrolysis technology.

Scenario 2A: Direct Combustion with an AMRF as a variance

2038 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	Plastics to Pyrolysis	To Direct Combustion	Recovered Tons	Tons to Landfill	Tons to Pyrolysis	Tons to Direct Combustion
TOTAL PAPER	**17.81%**		**4.29%**			**13.52%**	**58,366**		**0**	**184,101**
Cardboard	3.80%	60%	2.28%			1.52%	31,010		0	20,673
Office paper	0.83%	0%	0.00%			0.83%	0		0	11,299
Newspaper and magazines	1.60%	50%	0.80%			0.80%	10,912		0	10,912
Mixed paper	2.42%	50%	1.21%			1.21%	16,444		0	16,444
Other compostable nonrecycl. paper	5.82%	0%	0.00%			5.82%	0		0	79,262
Other non-compostable nonrecycl. paper	3.34%	0%	0.00%			3.34%	0		0	45,510
TOTAL PLASTIC	**14.58%**		**4.60%**		**2.94%**	**7.04%**	**62,598**		**40,047**	**95,795**
Plastic bottles	0.57%	60%	0.34%			0.23%	4,648		0	3,099
Other rigid plastics	6.13%	50%	3.07%			3.07%	41,744		0	41,744
Plastic film - recyclable	1.98%	60%	1.19%			0.79%	16,206		0	10,804
Plastic film - non-recyclable	4.90%	60%			2.94%	1.96%	0		40,047	26,698
Mixed plastic / materials	0.99%	0%	0.00%			0.99%	0		0	13,450
OTHER ORGANICS	**43.60%**		**8.34%**	**0.16%**		**35.10%**	**113,594**	**2,136**	**0**	**477,906**
Yard Debris	2.35%	50%	1.17%			1.17%	15,968		0	15,968
Clean wood	4.46%	60%	2.68%			1.78%	36,445		0	24,297
Painted & treated lumber	1.57%	0%	0	0.16%		1.41%	0	2,136	0	19,228
Mixed wood / materials	5.25%	50%	2.62%			2.62%	35,713		0	35,713
Food waste	12.83%	0%	0.00%			12.83%	0		0	174,659
Rubber	0.61%	60%	0.37%			0.24%	4,997		0	3,331
Disposable diapers	3.57%	0%	0.00%			3.57%	0		0	48,597
Carpet/pad	2.66%	40%	1.06%			1.59%	14,473		0	21,709
Textiles	4.41%	10%	0.44%			3.96%	5,998		0	53,981
Other miscellaneous organics	5.91%	0%	0.00%			5.91%	0		0	80,423
GLASS	**1.76%**		**0.00%**			**1.76%**	**0**		**0**	**23,920**
Deposit Beverage Glass	0.26%	0%	0.00%			0.26%	0		0	3,564
Window and other glass	1.50%	0%	0.00%			1.50%	0		0	20,356
METAL	**7.26%**		**4.26%**			**2.99%**	**58,012**		**0**	**40,774**
Aluminum	0.39%	70%	0.27%			0.12%	3,743		0	1,604
Ferrous metals	2.77%	70%	1.94%			0.83%	26,425		0	11,325
Mixed Metals	2.43%	50%	1.22%			1.22%	16,545		0	16,545
Computers, brown goods, small apl.	1.66%	50%	0.83%			0.83%	11,300		0	11,300
OTHER INORGANICS	**12.48%**		**1.02%**	**0.06%**		**12.58%**	**13,867**	**772**	**0**	**155,288**
Rock, concrete, brick	1.13%	0%	0	0.06%		1.08%	0	772	0	14,665
Soil, sand, dirt	1.55%	0%	0.00%			1.55%	0		0	21,080
Gypsum wallboard	3.39%	30%	1.02%			2.38%	13,867		0	32,355
Other micellaneous inorganics	6.40%	0%	0.00%			6.40%	0		0	87,188
BULKY MATERIALS*	**1.77%**	**76%**		**1.35%**		**0.42%**		18,386	**0**	**5,680**
MEDICAL WASTES	**0.51%**	**0%**	**0.00%**			**0.51%**	**0**		**0**	**6,894**
HAZARDOUS MATERIALS	**0.25%**	**0%**	**0.00%**			**0.25%**	**0**		**0**	**3,366**
TOTALS**	**100.00%**		**22.51%**	**1.56%**	**2.94%**	**74.16%**	**306,437**	**21,295**	**40,047**	**993,722**

*Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% for the matresses and furniture would be pulled for disposal and only 10% of the tires would be let through as disposal as would be good combustion material.

**Increase in recovery is due to additional plastics sorters are employed in this scenario to recover additional plastics for the pyrolysis technology.

Scenario 2A: Direct Combustion with an AMRF as a variance

Design Basis

	2019	2038
Input tons per year		
Landfill	272,492	319,411
AMRF	1,139,369	1,361,501
Direct Combustion Plant	852,472	993,722
To Non-Metro Pyrolysis Plant	31,501	40,047
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Diverted tons per year		
AMRF	238,645	306,437
Floor Sort	0.03	0.03
Direct Combustion Plant	596,730	695,606
To Non-Metro Pyrolysis Plant	31,501	40,047
Gasification Plant	0	0
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Total Diverted	**866,877**	**1,042,090**
Percent of Input Diverted	**76.1%**	**76.5%**
Landfill		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	8,015	9,395
AMRF		
Haul Distance RT (miles)	100	100
RT Time including Loading/Unloading (hrs)	2.3	2.3
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	33,511	40,045
Facility Capacity (tons/day)	750	750
Rounded Number of Facilities Required	5	6
Exact Number of Facilities Required	4.5	5.4
Difference for Adjusting Last Facility Operations	0.48	0.59
Operating Hours per Day	20	20
Availability	92%	92%
For Each Facility		
Power Requirement (kWh/yr)	3,300,000	3,300,000
Water Consumption (1000 CF/year)	340	340
Effluent Requirement (1000 CF/year)	280	280
Number of Pieces of Mobie Equipment	7	7
Estmated Fuel Usage (gals/year)	134,000	134,000
Number of Sorters (all shifts)	39	39
Additional Sorters for Plastics (all shitfs)	7	7
Mgrs, Eq Ops, Mech, etc. (all shifts)	23	23
Number of Office Personnel (one shift)	4	4
Total Staff	73	73
Acreage Required	5	5
Direct Combustion		
Haul Distance RT (miles)	0	0
RT Time including Loading/Unloading (hrs)	0.0	0.0
Average Transfer Trailer Load (tons)	0	0
Required Number of Trips per Year	0	0
Facility Capacity (tons/day)	1,000	1,000
Rounded Number of Facilities Required	3	3
Exact Number of Facilities Required	2.6	3.0
Difference for Adjusting Last Facility Operations	0.40	-0.03
Operating Hours per Day	24	24
Availability	90%	90%

Scenario 2A: Direct Combustion with an AMRF as a variance

Design Basis (continued)

	2019	2038
Direct Combustion (continued)		
For Each Facility		
Hourly Throughput (tons/hour)	37.5	37.5
Steam Production (1000 lbs/hr)	2,300,000	2,300,000
Gross Energy Generated (MW)	28.7	28.7
Internal Parasitic Load (MW)	4.3	4.3
Net Energy Generated (MW)	24.4	24.4
Ash Production Rate (%)	30%	30%
Ash Production (tons/year)	98,600	98,600
Auxillary Fuel- natural gas/propane (MMBtu/yr)	100,400	100,400
Water Consumption (1000 cf/year)	3,100	3,100
Effluent Requirement (1000 cf/year)	220	220
Number of Personnel	40	40
Acreage Required	8-20	8-20
Gasification		
Not Used	N/A	N/A
Anaerobic Digestion		
Not Used	N/A	N/A
RDF		
Not Used	N/A	N/A

Scenario 2A: Direct Combustion with an AMRF as a variance

Economic Analysis

	2019	2038
Landfill		
Capital Cost		
Assume cost is built into tip fee	**$ -**	**$ -**
Annual Operations & Maintenance Cost		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	8,015	9,395
Estimated hourly transfer trailer cost ($/hr)	$ 95	$ 95
Annual Transfer Cost ($/year)	**$ 3,149,531**	**$ 3,691,808**
Landfill Tip Fee ($/ton)	$ 22.79	$ 22.79
Annual Landfill Tip Fee ($/year)	**$ 6,210,089**	**$ 7,279,384**
Total Landilling Cost ($/year)	**$ 9,360,000**	**$ 10,971,000**
AMRF (per facility)		
Capital Cost		
Site improvements & buildings	$ 11,319,000	$ 11,319,000
Startup and acceptance testing (1 month)	$ 852,000	$ 852,000
Subtotal	**$ 12,171,000**	**$ 12,171,000**
Environmental Impact	$ 226,000	$ 226,000
Planning	$ 340,000	$ 340,000
Permits	$ 453,000	$ 453,000
Design	$ 792,000	$ 792,000
Construction administration	$ 566,000	$ 566,000
Subtotal	**$ 14,548,000**	**$ 14,548,000**
Contingency (15%)	$ 2,182,000	$ 2,182,000
Land	$ -	$ -
Stationary equipment installed(w/spare parts)	$ 10,293,000	$ 10,293,000
Rolling stock	$ 720,000	$ 720,000
Total Capital Costs	**$ 27,743,000**	**$ 27,743,000**
Annual Operations & Maintenance Cost		
Labor	$ 6,301,000	$ 6,301,000
Facilities maintenance	$ 50,000	$ 50,000
Rolling stock maintenance	$ 154,000	$ 154,000
Rolling stock replacement costs	$ 103,000	$ 103,000
Stationary equip maintenance/replace	$ 406,000	$ 406,000
Utilities	$ 390,000	$ 390,000
Fuel	$ 534,000	$ 534,000
General & administration/legal,/accnt.	$ 50,000	$ 50,000
Contractor overhead	$ 799,000	$ 799,000
Insurance	$ 100,000	$ 100,000
Property taxes	$ -	$ -
Subtotal	**$ 8,887,000**	**$ 8,887,000**
Contingency (15%)	$ 1,333,000	$ 1,333,000
Total O&M costs (per facility)	$ 10,220,000	$ 10,220,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 2,067,000	$ 2,067,000
Total Annual Cost (per facility)	$ 12,287,000	$ 12,287,000
Potential Materials Market Revenues ($/year)	$ 1,319,000	$ 1,417,000
Net Annual Cost (per facility)	**$ 10,968,000**	**$ 10,870,000**
Number of Facilities	5	6
Total Annual Cost (all facilities)	**$ 54,840,000**	**$ 65,220,000**

Scenario 2A: Direct Combustion with an AMRF as a variance

Economic Analysis (continued)

	2019	2038
Direct Combustion (per facility)		
Capital Cost		
Design, Permits, CM and Ancillary Costs	$ 38,700,000	$ 38,700,000
Site Work and Utilities	$ 15,000,000	$ 15,000,000
Landscaping	$ 1,000,000	$ 1,000,000
Buildings, Structures and Architectural	$ 59,000,000	$ 59,000,000
Equipment & Installation	$ 278,500,000	$ 278,500,000
Electrical Interconnection	$ 12,900,000	$ 12,900,000
Waste Water Treatment Plant	$ 3,500,000	$ 3,500,000
Subtotal - Direct Construction Costs	**$ 408,600,000**	**$ 408,600,000**
Spare Parts, Tools, Other Equip and Materials	$ 3,000,000	$ 3,000,000
Mobile Equipment	$ 1,000,000	$ 1,000,000
Facility Start-up, Testing, CM and Commissioning	$ 10,800,000	$ 10,800,000
Insurance During Construction	$ 6,500,000	$ 6,500,000
Subtotal – Indirect Construction Costs	**$ 21,300,000**	**$ 21,300,000**
Subtotal - Construction Costs	**$ 429,900,000**	**$ 429,900,000**
Contingency (15%)	$ 64,500,000	$ 64,500,000
Total Capital Costs	**$ 494,400,000**	**$ 494,400,000**
Annual Operations & Maintenance Cost		
Labor	$ 4,440,000	$ 4,440,000
Facilities, Equipment and Rolling Stock Maintenance	$ 6,750,000	$ 6,750,000
Consumables	$ 3,000,000	$ 3,000,000
Auxillary Fuel Costs	$ 900,000	$ 900,000
Purchased Utilities	$ 550,000	$ 550,000
Contract, Rental, or Lease Services	$ 140,000	$ 140,000
Adminstrative Costs (including regulatory)	$ 380,000	$ 380,000
Insurance Costs	$ 300,000	$ 300,000
Subtotal - O&M	**$ 16,460,000**	**$ 16,460,000**
Contingency (15%)	$ 2,470,000	$ 2,470,000
Total O&M costs (per facility)	$ 18,930,000	$ 18,930,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 36,830,000	$ 36,830,000
Potential Electricity Revenues ($/year)	$ 15,370,000	$ 15,370,000
Potential Metal Sales Revenues ($/year)	$ 180,000	$ 180,000
Potential Revenues ($/year)	$ 15,550,000	$ 15,550,000
Net Annual Cost (per facility)	**$ 40,210,000**	**$ 40,210,000**
Number of Facilities	3	3
Total Annual Cost (all facilities)	**$ 120,630,000**	**$ 120,630,000**
TOTAL		
Economic make-up rounding number of facilities	$ (5,939,000)	$ (5,545,000)
Haul from Metro to Facilities	$ 7,380,036	$ 8,819,001
TOTAL ANNUAL COST ($/year)	**$ 186,271,036**	**$ 200,095,001**

Scenario 3: AMRF with Gasification or Plasma Arc Gasification

2019 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	Plastics to Pyrolysis	To Gasification	Recovered Tons	Tons to Landfill	Tons to Pyrolysis	Tons to Gasification
TOTAL PAPER	**17.10%**		**3.84%**			**13.26%**	**43,777**		**0**	**151,106**
Cardboard	3.57%	60%	2.14%			1.43%	24,392		0	16,262
Office paper	0.78%	0%	0.00%			0.78%	0		0	8,888
Newspaper and magazines	1.51%	50%	0.75%			0.75%	8,583		0	8,583
Mixed paper	1.90%	50%	0.95%			0.95%	10,801		0	10,801
Other compostable nonrecycl. paper	6.21%	0%	0.00%			6.21%	0		0	70,773
Other non-compostable nonrecycl. paper	3.14%	0%	0.00%			3.14%	0		0	35,799
TOTAL PLASTIC	**13.73%**		**4.35%**		**2.76%**	**6.62%**	**49,513**		**31,501**	**75,414**
Plastic bottles	0.63%	60%	0.38%			0.25%	4,293		0	2,862
Other rigid plastics	5.70%	50%	2.85%			2.85%	32,473		0	32,473
Plastic film - recyclable	1.86%	60%	1.12%			0.75%	12,747		0	8,498
Plastic film - non-recyclable	4.61%	60%			2.76%	1.84%	0		31,501	21,001
Mixed plastic / materials	0.93%	0%	0.00%			0.93%	0		0	10,580
OTHER ORGANICS	**46.69%**		**7.84%**	**0.15%**		**38.71%**	**89,328**	**1,681**	**0**	**441,017**
Yard Debris	2.20%	50%	1.10%			1.10%	12,561		0	12,561
Clean wood	4.19%	60%	2.52%			1.68%	28,668		0	19,112
Painted & treated lumber	1.47%	0%	0	0.15%		1.33%	0	1,681	0	15,125
Mixed wood / materials	4.93%	50%	2.47%			2.47%	28,092		0	28,092
Food waste	17.98%	0%	0.00%			17.98%	0		0	204,804
Rubber	0.57%	60%	0.34%			0.23%	3,930		0	2,620
Disposable diapers	3.36%	0%	0.00%			3.36%	0		0	38,226
Carpet/pad	2.50%	40%	1.00%			1.50%	11,384		0	17,076
Textiles	4.12%	10%	0.41%			3.71%	4,692		0	42,231
Other miscellaneous organics	5.37%	0%	0.00%			5.37%	0		0	61,170
GLASS	**1.65%**		**0.00%**			**1.65%**	**0**		**0**	**18,815**
Deposit Beverage Glass	0.25%	0%	0.00%			0.25%	0		0	2,803
Window and other glass	1.41%	0%	0.00%			1.41%	0		0	16,012
METAL	**6.73%**		**3.96%**			**2.77%**	**45,121**		**0**	**31,561**
Aluminum	0.37%	70%	0.26%			0.11%	2,944		0	1,262
Ferrous metals	2.61%	70%	1.82%			0.78%	20,786		0	8,908
Mixed Metals	2.28%	50%	1.14%			1.14%	13,014		0	13,014
Computers, brown goods, small apl.	1.47%	50%	0.74%			0.74%	8,376		0	8,376
OTHER INORGANICS	**11.73%**		**0.96%**	**0.05%**		**11.81%**	**10,907**	**607**	**0**	**122,150**
Rock, concrete, brick	1.07%	0%	0	0.05%		1.01%	0	607	0	11,535
Soil, sand, dirt	1.46%	0%	0.00%			1.46%	0		0	16,582
Gypsum wallboard	3.19%	30%	0.96%			2.23%	10,907		0	25,451
Other micellaneous inorganics	6.02%	0%	0.00%			6.02%	0		0	68,582
BULKY MATERIALS*	**1.66%**	**76%**		**1.27%**		**0.39%**		14,463	**0**	**4,468**
MEDICAL WASTES	**0.48%**	**0%**	**0.00%**			**0.48%**	**0**		**0**	**5,423**
HAZARDOUS MATERIALS	**0.22%**	**0%**	**0.00%**			**0.22%**	**0**		**0**	**2,520**
TOTALS**	**100.00%**		**20.95%**	**1.47%**	**2.76%**	**75.91%**	**238,645**	**16,750**	**31,501**	**852,472**

*Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% for the matresses and furniture would be pulled for disposal and only 10% of the tires would be let through as disposal as would be good combustion material.

**Increase in recovery is due to additional plastics sorters are employed in this scenario to recover additional plastics for the pyrolysis technology.

Scenario 3: AMRF with Gasification or Plasma Arc Gasification

2038 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	Plastics to Pyrolysis	To Gasification	Recovered Tons	Tons to Landfill	Tons to Pyrolysis	Tons to Gasification
TOTAL PAPER	**17.81%**		**4.29%**			**13.52%**	**58,366**		**0**	**184,101**
Cardboard	3.80%	60%	2.28%			1.52%	31,010		0	20,673
Office paper	0.83%	0%	0.00%			0.83%	0		0	11,299
Newspaper and magazines	1.60%	50%	0.80%			0.80%	10,912		0	10,912
Mixed paper	2.42%	50%	1.21%			1.21%	16,444		0	16,444
Other compostable nonrecycl. paper	5.82%	0%	0.00%			5.82%	0		0	79,262
Other non-compostable nonrecycl. paper	3.34%	0%	0.00%			3.34%	0		0	45,510
TOTAL PLASTIC	**14.58%**		**4.60%**		**2.94%**	**7.04%**	**62,598**		**40,047**	**95,795**
Plastic bottles	0.57%	60%	0.34%			0.23%	4,648		0	3,099
Other rigid plastics	6.13%	50%	3.07%			3.07%	41,744		0	41,744
Plastic film - recyclable	1.98%	60%	1.19%			0.79%	16,206		0	10,804
Plastic film - non-recyclable	4.90%	60%			2.94%	1.96%	0		40,047	26,698
Mixed plastic / materials	0.99%	0%	0.00%			0.99%	0		0	13,450
OTHER ORGANICS	**43.60%**		**8.34%**	**0.16%**		**35.10%**	**113,594**	**2,136**	**0**	**477,906**
Yard Debris	2.35%	50%	1.17%			1.17%	15,968		0	15,968
Clean wood	4.46%	60%	2.68%			1.78%	36,445		0	24,297
Painted & treated lumber	1.57%	0%	0	0.16%		1.41%	0	2,136	0	19,228
Mixed wood / materials	5.25%	50%	2.62%			2.62%	35,713		0	35,713
Food waste	12.83%	0%	0.00%			12.83%	0		0	174,659
Rubber	0.61%	60%	0.37%			0.24%	4,997		0	3,331
Disposable diapers	3.57%	0%	0.00%			3.57%	0		0	48,597
Carpet/pad	2.66%	40%	1.06%			1.59%	14,473		0	21,709
Textiles	4.41%	10%	0.44%			3.96%	5,998		0	53,981
Other miscellaneous organics	5.91%	0%	0.00%			5.91%	0		0	80,423
GLASS	**1.76%**		**0.00%**			**1.76%**	**0**		**0**	**23,920**
Deposit Beverage Glass	0.26%	0%	0.00%			0.26%	0		0	3,564
Window and other glass	1.50%	0%	0.00%			1.50%	0		0	20,356
METAL	**7.26%**		**4.26%**			**2.99%**	**58,012**		**0**	**40,774**
Aluminum	0.39%	70%	0.27%			0.12%	3,743		0	1,604
Ferrous metals	2.77%	70%	1.94%			0.83%	26,425		0	11,325
Mixed Metals	2.43%	50%	1.22%			1.22%	16,545		0	16,545
Computers, brown goods, small apl.	1.66%	50%	0.83%			0.83%	11,300		0	11,300
OTHER INORGANICS	**12.48%**		**1.02%**	**0.06%**		**12.58%**	**13,867**	**772**	**0**	**155,288**
Rock, concrete, brick	1.13%	0%	0	0.06%		1.08%	0	772	0	14,665
Soil, sand, dirt	1.55%	0%	0.00%			1.55%	0		0	21,080
Gypsum wallboard	3.39%	30%	1.02%			2.38%	13,867		0	32,355
Other micellaneous inorganics	6.40%	0%	0.00%			6.40%	0		0	87,188
BULKY MATERIALS*	**1.77%**	**76%**		**1.35%**		**0.42%**		18,386	**0**	**5,680**
MEDICAL WASTES	**0.51%**	**0%**	**0.00%**			**0.51%**	**0**		**0**	**6,894**
HAZARDOUS MATERIALS	**0.25%**	**0%**	**0.00%**			**0.25%**	**0**		**0**	**3,366**
TOTALS**	**100.00%**		**22.51%**	**1.56%**	**2.94%**	**74.16%**	**306,437**	**21,295**	**40,047**	**993,722**

*Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% for the matresses and furniture would be pulled for disposal and only 10% of the tires would be let through as disposal as would be good combustion material.

**Increase in recovery is due to additional plastics sorters are employed in this scenario to recover additional plastics for the pyrolysis technology.

Scenario 3: AMRF with Gasification or Plasma Arc Gasification

Design Basis

	2019	2038
Input tons per year		
Landfill	229,868	269,725
AMRF	1,139,369	1,361,501
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	31,501	40,047
Gasification Plant	852,472	993,722
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Diverted tons per year		
AMRF	238,645	306,437
Floor Sort	0.00	0.00
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	31,501	40,047
Gasification Plant	681,977	794,978
Anerobic Digestion Plant	0	0
RDF Plant	0	0
Total Diverted	**952,124**	**1,141,462**
Percent of Input Diverted	**83.6%**	**83.8%**
Landfill		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	6,761	7,934
AMRF		
Haul Distance RT (miles)	100	100
RT Time including Loading/Unloading (hrs)	2.3	2.3
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	33,511	40,045
Facility Capacity (tons/day)	750	750
Rounded Number of Facilities Required	5	6
Exact Number of Facilities Required	4.5	5.4
Difference for Adjusting Last Facility Operations	0.48	0.59
Operating Hours per Day	20	20
Availability	92%	92%
For Each Facility		
Power Requirement (kWh/yr)	3,300,000	3,300,000
Water Consumption (1000 CF/year)	340	340
Effluent Requirement (1000 CF/year)	280	280
Number of Pieces of Mobie Equipment	7	7
Estmated Fuel Usage (gals/year)	134,000	134,000
Number of Sorters (all shifts)	39	39
Additional Sorters for Plastics (all shitfs)	7	7
Mgrs, Eq Ops, Mech, etc. (all shifts)	23	23
Number of Office Personnel (one shift)	4	4
Total Staff	73	73
Acreage Required	5	5
Direct Combustion		
Not Used	N/A	N/A
Gasification		
Haul Distance RT (miles)	0	0
RT Time including Loading/Unloading (hrs)	0.0	0.0
Average Transfer Trailer Load (tons)	0	0
Required Number of Trips per Year	0	0
Facility Capacity (tons/day)	1,000	1,000
Rounded Number of Facilities Required	3	3
Exact Number of Facilities Required	2.7	3.2
Difference for Adjusting Last Facility Operations	0.25	-0.20
Operating Hours per Day	24	24
Availability	85%	85%

Scenario 3: AMRF with Gasification or Plasma Arc Gasification

Design Basis (continued)

	2019	2038
Gasification (continued)		
For Each Facility		
Hourly Throughput (tons/hour)	35.4	35.4
Gross Energy Generated (MW)	29.2	29.2
Internal Parasitic Load (MW)	4.4	4.4
Net Energy Generated (MW)	24.8	24.8
Ash & Non-Processible Production Rate (%)	25%	25%
Ash &Non-Processible Production (tons/year)	77,600	77,600
Water Consumption (1000 cf/year)	700	700
Effluent Requirement (1000 cf/year)	210	210
Number of Personnel	45	45
Acreage Required	8-20	8-20
Anaerobic Digestion		
Not Used	N/A	N/A
RDF		
Not Used	N/A	N/A

Scenario 3: AMRF with Gasification or Plasma Arc Gasification

Economic Analysis

	2019	2038
Landfill		
Capital Cost		
Assume cost is built into tip fee	**$ -**	**$ -**
Annual Operations & Maintenance Cost		
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	6,761	7,934
Estimated hourly transfer trailer cost ($/hr)	$ 95	$ 95
Annual Transfer Cost ($/year)	**$ 2,656,766**	**$ 3,117,701**
Landfill Tip Fee ($/ton)	$ 22.79	$ 22.79
Annual Landfill Tip Fee ($/year)	**$ 5,238,697**	**$ 6,147,037**
Total Landilling Cost ($/year)	**$ 7,895,000**	**$ 9,265,000**
AMRF (per facility)		
Capital Cost		
Site improvements & buildings	$ 11,319,000	$ 11,319,000
Startup and acceptance testing (1 month)	$ 852,000	$ 852,000
Subtotal	**$ 12,171,000**	**$ 12,171,000**
Environmental Impact	$ 226,000	$ 226,000
Planning	$ 340,000	$ 340,000
Permits	$ 453,000	$ 453,000
Design	$ 792,000	$ 792,000
Construction administration	$ 566,000	$ 566,000
Subtotal	**$ 14,548,000**	**$ 14,548,000**
Contingency (15%)	$ 2,182,000	$ 2,182,000
Land	$ -	$ -
Stationary equipment installed(w/spare parts)	$ 10,293,000	$ 10,293,000
Rolling stock	$ 720,000	$ 720,000
Total Capital Costs	**$ 27,743,000**	**$ 27,743,000**
Annual Operations & Maintenance Cost		
Labor	$ 6,301,000	$ 6,301,000
Facilities maintenance	$ 50,000	$ 50,000
Rolling stock maintenance	$ 154,000	$ 154,000
Rolling stock replacement costs	$ 103,000	$ 103,000
Stationary equip maintenance/replace	$ 406,000	$ 406,000
Utilities	$ 390,000	$ 390,000
Fuel	$ 534,000	$ 534,000
General & administration/legal,/accnt.	$ 50,000	$ 50,000
Contractor overhead	$ 799,000	$ 799,000
Insurance	$ 100,000	$ 100,000
Property taxes	$ -	$ -
Subtotal	**$ 8,887,000**	**$ 8,887,000**
Contingency (15%)	$ 1,333,000	$ 1,333,000
Total O&M costs (per facility)	$ 10,220,000	$ 10,220,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 2,067,000	$ 2,067,000
Total Annual Cost (per facility)	$ 12,287,000	$ 12,287,000
Potential Materials Market Revenues ($/year)	$ 1,319,000	$ 1,417,000
Net Annual Cost (per facility)	**$ 10,968,000**	**$ 10,870,000**
Number of Facilities	5	6
Total Annual Cost (all facilities)	**$ 54,840,000**	**$ 65,220,000**

Scenario 3: AMRF with Gasification or Plasma Arc Gasification

Economic Analysis (continued)

	2019	2038
Gasification (per facility)		
Capital Cost		
Design, Permits, CM and Ancillary Costs	$ 45,000,000	$ 45,000,000
Site Work and Utilities	$ 15,000,000	$ 15,000,000
Landscaping	$ 1,000,000	$ 1,000,000
Buildings, Structures and Architectural	$ 62,000,000	$ 62,000,000
Equipment & Installation	$ 380,900,000	$ 380,900,000
Electrical Interconnection	$ 12,900,000	$ 12,900,000
Waste Water Treatment Plant	$ 3,500,000	$ 3,500,000
Subtotal - Direct Construction Costs	**$ 520,300,000**	**$ 520,300,000**
Spare Parts, Tools, Other Equip and Materials	$ 3,500,000	$ 3,500,000
Mobile Equipment	$ 1,000,000	$ 1,000,000
Facility Start-up, Testing, CM and Commissioning	$ 11,500,000	$ 11,500,000
Insurance During Construction	$ 8,100,000	$ 8,100,000
Subtotal – Indirect Construction Costs	**$ 24,100,000**	**$ 24,100,000**
Subtotal - Construction Costs	**$ 544,400,000**	**$ 544,400,000**
Contingency (25%)	$ 136,100,000	$ 136,100,000
Total Capital Costs	**$ 680,500,000**	**$ 680,500,000**
Annual Operations & Maintenance Cost		
Labor	$ 4,990,000	$ 4,990,000
Facilities, Equipment and Rolling Stock Maintenance	$ 7,500,000	$ 7,500,000
Consumables	$ 3,250,000	$ 3,250,000
Auxillary Fuel Costs	$ 200,000	$ 200,000
Purchased Utilities	$ 550,000	$ 550,000
Contract, Rental, or Lease Services	$ 140,000	$ 140,000
Adminstrative Costs (including regulatory)	$ 380,000	$ 380,000
Insurance Costs	$ 450,000	$ 450,000
Subtotal - O&M	**$ 17,460,000**	**$ 17,460,000**
Contingency (25%)	$ 2,620,000	$ 2,620,000
Total O&M costs (per facility)	$ 20,080,000	$ 20,080,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 50,700,000	$ 50,700,000
Potential Electricity Revenues ($/year)	$ 14,770,000	$ 14,770,000
Net Annual Cost (per facility)	**$ 56,010,000**	**$ 56,010,000**
Number of Facilities	3	3
Total Annual Cost (all facilities)	**$ 168,030,000**	**$ 168,030,000**
TOTAL		
Economic make-up rounding number of facilities	$ (6,020,000)	$ (4,821,000)
Haul from Metro to Facilities	$ 7,380,036	$ 8,819,001
TOTAL ANNUAL COST ($/year)	**$ 232,125,036**	**$ 246,513,001**

Scenario 4: AMRF with Anaerobic Digestion

2019 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	To Anaerobic Digestion	Digestate to Landfill	Recovered Tons	Tons to Landfill	Tons to Anaerobic Digestion	Digestate Tons to Landfill
TOTAL PAPER	**17.10%**		**3.84%**		**13.26%**	**12.10%**	**43,777**		**151,106**	**137,918**
Cardboard	3.57%	60%	2.14%		1.43%	1.14%	24,392		16,262	13,009
Office paper	0.78%	0%	0.00%		0.78%	0.62%	0		8,888	7,110
Newspaper and magazines	1.51%	50%	0.75%		0.75%	0.75%	8,583		8,583	8,583
Mixed paper	1.90%	50%	0.95%		0.95%	0.85%	10,801		10,801	9,721
Other compostable nonrecycl. paper	6.21%	0%	0.00%		6.21%	5.59%	0		70,773	63,696
Other non-compostable nonrecycl. paper	3.14%	0%	0.00%		3.14%	3.14%	0		35,799	35,799
TOTAL PLASTIC	**13.73%**		**3.79%**		**9.94%**	**9.94%**	**43,139**		**113,289**	**113,289**
Plastic bottles	0.63%	60%	0.38%		0.25%	0.25%	4,293		2,862	2,862
Other rigid plastics	5.70%	50%	2.85%		2.85%	2.85%	32,473		32,473	32,473
Plastic film - recyclable	1.86%	30%	0.56%		1.31%	1.31%	6,374		14,872	14,872
Plastic film - non-recyclable	4.61%	0%	0.00%		4.61%	4.61%	0		52,502	52,502
Mixed plastic / materials	0.93%	0%	0.00%		0.93%	0.93%	0		10,580	10,580
OTHER ORGANICS	**46.69%**		**7.84%**	**0.15%**	**38.71%**	**25.02%**	**89,328**	**1,681**	**441,017**	**285,054**
Yard Debris	2.20%	50%	1.10%		1.10%	0.99%	12,561		12,561	11,305
Clean wood	4.19%	60%	2.52%		1.68%	1.68%	28,668		19,112	19,112
Painted & treated lumber	1.47%	0%	0	0.15%	1.33%	1.33%	0	1,681	15,125	15,125
Mixed wood / materials	4.93%	50%	2.47%		2.47%	2.34%	28,092		28,092	26,688
Food waste	17.98%	0%	0.00%		17.98%	5.39%	0		204,804	61,441
Rubber	0.57%	60%	0.34%		0.23%	0.23%	3,930		2,620	2,620
Disposable diapers	3.36%	0%	0.00%		3.36%	3.02%	0		38,226	34,403
Carpet/pad	2.50%	40%	1.00%		1.50%	1.50%	11,384		17,076	17,076
Textiles	4.12%	10%	0.41%		3.71%	3.71%	4,692		42,231	42,231
Other miscellaneous organics	5.37%	0%	0.00%		5.37%	4.83%	0		61,170	55,053
GLASS	**1.65%**		**0.00%**		**1.65%**	**1.65%**	**0**		**18,815**	**18,815**
Deposit Beverage Glass	0.25%	0%	0.00%		0.25%	0.25%	0		2,803	2,803
Window and other glass	1.41%	0%	0.00%		1.41%	1.41%	0		16,012	16,012
METAL	**6.73%**		**3.96%**		**2.77%**	**2.77%**	**45,121**		**31,561**	**31,561**
Aluminum	0.37%	70%	0.26%		0.11%	0.11%	2,944		1,262	1,262
Ferrous metals	2.61%	70%	1.82%		0.78%	0.78%	20,786		8,908	8,908
Mixed Metals	2.28%	50%	1.14%		1.14%	1.14%	13,014		13,014	13,014
Computers, brown goods, small apl.	1.47%	50%	0.74%		0.74%	0.74%	8,376		8,376	8,376
OTHER INORGANICS	**11.73%**		**0.96%**	**0.05%**	**10.72%**	**11.58%**	**10,907**	**607**	**122,150**	**122,150**
Rock, concrete, brick	1.07%	0%	0	0.05%	1.01%	1.01%	0	607	11,535	11,535
Soil, sand, dirt	1.46%	0%	0.00%		1.46%	1.46%	0		16,582	16,582
Gypsum wallboard	3.19%	30%	0.96%		2.23%	2.23%	10,907		25,451	25,451
Other micellaneous inorganics	6.02%	0%	0.00%		6.02%	6.02%	0		68,582	68,582
BULKY MATERIALS*	**1.66%**	**90%**		**1.50%**	**0.17%**	**0.17%**		17,037	**1,893**	**1,893**
MEDICAL WASTES	**0.48%**	**0%**	**0.00%**		**0.48%**	**0.48%**	**0**		**5,423**	**5,423**
HAZARDOUS MATERIALS	**0.22%**	**0%**	**0.00%**		**0.22%**	**0.22%**	**0**		**2,520**	**2,520**
TOTALS	**100.00%**		**20.39%**	**1.70%**	**77.92%**	**63.94%**	**232,272**	**19,325**	**887,772**	**718,622**

* Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% of the matresses,furniture and tires would be pulled for disposal.

Scenario 4: AMRF with Anaerobic Digestion

2038 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	To Anaerobic Digestion	Digestate to Landfill	Recovered Tons	Tons to Landfill	Tons to Anaerobic Digestion	Digestate Tons to Landfill
TOTAL PAPER	**17.81%**		**4.29%**		**13.52%**	**12.35%**	**58,366**		**184,101**	**168,136**
Cardboard	3.80%	60%	2.28%		1.52%	1.21%	31,010		20,673	16,539
Office paper	0.83%	0%	0.00%		0.83%	0.66%	0		11,299	9,039
Newspaper and magazines	1.60%	50%	0.80%		0.80%	0.80%	10,912		10,912	10,912
Mixed paper	2.42%	50%	1.21%		1.21%	1.09%	16,444		16,444	14,800
Other compostable nonrecycl. paper	5.82%	0%	0.00%		5.82%	5.24%	0		79,262	71,336
Other non-compostable nonrecycl. paper	3.34%	0%	0.00%		3.34%	3.34%	0		45,510	45,510
TOTAL PLASTIC	**14.58%**		**4.00%**		**10.57%**	**10.57%**	**54,495**		**143,945**	**143,945**
Plastic bottles	0.57%	60%	0.34%		0.23%	0.23%	4,648		3,099	3,099
Other rigid plastics	6.13%	50%	3.07%		3.07%	3.07%	41,744		41,744	41,744
Plastic film - recyclable	1.98%	30%	0.60%		1.39%	1.39%	8,103		18,907	18,907
Plastic film - non-recyclable	4.90%	0%	0.00%		4.90%	4.90%	0		66,746	66,746
Mixed plastic / materials	0.99%	0%	0.00%		0.99%	0.99%	0		13,450	13,450
OTHER ORGANICS	**43.60%**		**8.34%**	**0.16%**	**35.10%**	**24.93%**	**113,594**	**2,136**	**477,906**	**339,360**
Yard Debris	2.35%	50%	1.17%		1.17%	1.06%	15,968		15,968	14,371
Clean wood	4.46%	60%	2.68%		1.78%	1.78%	36,445		24,297	24,297
Painted & treated lumber	1.57%	0%	0	0.16%	1.41%	1.41%	0	2,136	19,228	19,228
Mixed wood / materials	5.25%	50%	2.62%		2.62%	2.49%	35,713		35,713	33,928
Food waste	12.83%	0%	0.00%		12.83%	3.85%	0		174,659	52,398
Rubber	0.61%	60%	0.37%		0.24%	0.24%	4,997		3,331	3,331
Disposable diapers	3.57%	0%	0.00%		3.57%	3.21%	0		48,597	43,737
Carpet/pad	2.66%	40%	1.06%		1.59%	1.59%	14,473		21,709	21,709
Textiles	4.41%	10%	0.44%		3.96%	3.96%	5,998		53,981	53,981
Other miscellaneous organics	5.91%	0%	0.00%		5.91%	5.32%	0		80,423	72,381
GLASS	**1.76%**		**0.00%**		**1.76%**	**1.76%**	**0**		**23,920**	**23,920**
Deposit Beverage Glass	0.26%	0%	0.00%		0.26%	0.26%	0		3,564	3,564
Window and other glass	1.50%	0%	0.00%		1.50%	1.50%	0		20,356	20,356
METAL	**7.26%**		**4.26%**		**2.99%**	**2.99%**	**58,012**		**40,774**	**40,774**
Aluminum	0.39%	70%	0.27%		0.12%	0.12%	3,743		1,604	1,604
Ferrous metals	2.77%	70%	1.94%		0.83%	0.83%	26,425		11,325	11,325
Mixed Metals	2.43%	50%	1.22%		1.22%	1.22%	16,545		16,545	16,545
Computers, brown goods, small apl.	1.66%	50%	0.83%		0.83%	0.83%	11,300		11,300	11,300
OTHER INORGANICS	**12.48%**		**1.02%**	**0.06%**	**11.41%**	**12.34%**	**13,867**	**772**	**155,288**	**155,288**
Rock, concrete, brick	1.13%	0%	0	0.06%	1.08%	1.08%	0	772	14,665	14,665
Soil, sand, dirt	1.55%	0%	0.00%		1.55%	1.55%	0		21,080	21,080
Gypsum wallboard	3.39%	30%	1.02%		2.38%	2.38%	13,867		32,355	32,355
Other micellaneous inorganics	6.40%	0%	0.00%		6.40%	6.40%	0		87,188	87,188
BULKY MATERIALS*	**1.77%**	**90%**		**1.59%**	**0.18%**	**0.18%**		21,659	**2,407**	**2,407**
MEDICAL WASTES	**0.51%**	**0%**	**0.00%**		**0.51%**	**0.51%**	**0**		**6,894**	**6,894**
HAZARDOUS MATERIALS	**0.25%**	**0%**	**0.00%**		**0.25%**	**0.25%**	**0**		**3,366**	**3,366**
TOTALS	**100.00%**		**21.91%**	**1.80%**	**76.28%**	**65.87%**	**298,334**	**24,568**	**1,038,600**	**884,089**

* Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% of the matresses,furniture and tires would be pulled for disposal.

Scenario 4: AMRF with Anaerobic Digestion

Design Basis

	2019	2038
Input tons per year		
Landfill	737,947	908,657
AMRF	1,139,369	1,361,501
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	887,772	1,038,600
RDF Plant	0	0
Diverted tons per year		
AMRF	232,272	298,334
Floor Sort	0.00	0.00
Direct Combustion Plant	0	0
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	169,150	154,511
RDF Plant	0	0
Total Diverted	**401,422**	**452,844**
Percent of Input Diverted	**35.2%**	**33.3%**
Landfill		
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	21,705	26,726
Methane captured by LFG system per year (cf)	9,669,509	9,669,509
Methane daily flow rate (cf)	26,492	26,492
Gross Energy Generated in MMBTU/hr	1.10	1.10
Gross Energy in KW	323	323
Net Energy Generated (kWh/yr)	942,028	942,028
Availability (LFGTE IC engine)	0.95	0.95
Potential Electricity Revenues ($/year)	$ 80,000	$ 80,000

AMRF		
Haul Distance RT (miles)	100	100
RT Time including Loading/Unloading (hrs)	2.3	2.3
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	33,511	40,045
Facility Capacity (tons/day)	750	750
Rounded Number of Facilities Required	5	6
Exact Number of Facilities Required	4.5	5.4
Difference for Adjusting Last Facility Operations	0.48	0.59
Operating Hours per Day	20	20
Availability	92%	92%
For Each Facility		
Power Requirement (kWh/yr)	3,300,000	3,300,000
Water Consumption (1000 CF/year)	320	320
Effluent Requirement (1000 CF/year)	270	270
Number of Pieces of Mobie Equipment	7	7
Estmated Fuel Usage (gals/year)	134,000	134,000
Number of Sorters (all shifts)	39	39
Additional Sorters for Plastics (all shitfs)	0	0
Mgrs, Eq Ops, Mech, etc. (all shifts)	23	23
Number of Office Personnel (one shift)	4	4
Total Staff	66	66
Acreage Required	5	5
Direct Combustion		
Not Used	N/A	N/A
Gasification		
Not Used	N/A	N/A

Scenario 4: AMRF with Anaerobic Digestion

Design Basis (continued)

	2019	2038
Anaerobic Digestion		
Haul Distance RT (miles)	0	0
RT Time including Loading/Unloading (hrs)	0	0
Average Transfer Trailer Load (tons)	0	0
Required Number of Trips per Year	0	0
Facility Capacity (tons/day)	300	300
Rounded Number of Facilities Required	9	10
Exact Number of Facilities Required	8.7	10.2
Difference for Adjusting Last Facility Operations	0.28	-0.20
Operating Hours per Day	24	24
Availability (portions of system always operating)	93%	93%
For Each Facility		
Biogas generated - food/prutrecible (cf/day)	294,100	214,400
Biogas generated - wood/yard (cf/day)	128,700	142,000
Biogas generated - fiber/paper (cf/day)	31,200	32,000
Gross Biogas Generated (cf/day)	454,000	388,400
Parasitics to Produce CNG (cf/day)	22,700	19,420
Net CNG Produced (cf/day)	431,300	368,980
Gross Energy Generated in MMBTU	10.78	9.22
Gross Energy in KW	3,159	2,703
Net Energy Generated (kWh/yr)	9,202,013	7,872,383
Water Consumption (gal/day)	15,000	15,000
Effluent Requirement	-	-
Number of Personnel	8	8
Acreage Required	3	3
RDF		
Not Used	N/A	N/A

Scenario 4: AMRF with Anaerobic Digestion

Economic Analysis

	2019	2038
Landfill		
Capital Cost		
Assume cost is built into tip fee	**$ -**	**$ -**
Annual Operations & Maintenance Cost		
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	21,705	26,726
Estimated hourly transfer trailer cost ($/hr)	$ 95	$ 95
Annual Transfer Cost ($/year)	**$ 8,529,078**	**$ 10,502,103**
Landfill Tip Fee ($/ton)	$ 22.79	$ 22.79
Annual Landfill Tip Fee ($/year)	**$ 16,817,802**	**$ 20,708,284**
Total Landilling Cost ($/year)	**$ 25,347,000**	**$ 31,210,000**
AMRF (per facility)		
Capital Cost		
Site improvements & buildings	$ 11,319,000	$ 11,319,000
Startup and acceptance testing (1 month)	$ 852,000	$ 852,000
Subtotal	**$ 12,171,000**	**$ 12,171,000**
Environmental Impact	$ 226,000	$ 226,000
Planning	$ 340,000	$ 340,000
Permits	$ 453,000	$ 453,000
Design	$ 792,000	$ 792,000
Construction administration	$ 566,000	$ 566,000
Subtotal	**$ 14,548,000**	**$ 14,548,000**
Contingency (15%)	$ 2,182,000	$ 2,182,000
Land	$ -	$ -
Stationary equipment installed(w/spare parts)	$ 10,293,000	$ 10,293,000
Rolling stock	$ 720,000	$ 720,000
Total Capital Costs	**$ 27,743,000**	**$ 27,743,000**
Annual Operations & Maintenance Cost		
Labor	$ 6,301,000	$ 6,301,000
Facilities maintenance	$ 50,000	$ 50,000
Rolling stock maintenance	$ 154,000	$ 154,000
Rolling stock replacement costs	$ 103,000	$ 103,000
Stationary equip maintenance/replace	$ 406,000	$ 406,000
Utilities	$ 390,000	$ 390,000
Fuel	$ 534,000	$ 534,000
General & administration/legal,/accnt.	$ 50,000	$ 50,000
Contractor overhead	$ 799,000	$ 799,000
Insurance	$ 100,000	$ 100,000
Property taxes	$ -	$ -
Subtotal	**$ 8,887,000**	**$ 8,887,000**
Contingency (15%)	$ 1,333,000	$ 1,333,000
Total O&M costs (per facility)	$ 10,220,000	$ 10,220,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 2,067,000	$ 2,067,000
Total Annual Cost (per facility)	$ 12,287,000	$ 12,287,000
Potential Materials Market Revenues ($/year)	$ 1,284,000	$ 1,380,000
Net Annual Cost (per facility)	**$ 11,003,000**	**$ 10,907,000**
Number of Facilities	5	6
Total Annual Cost (all facilities)	**$ 55,015,000**	**$ 65,442,000**

Scenario 4: AMRF with Anaerobic Digestion

Economic Analysis (continued)

	2019	2038
Anaerobic Digestion (per facility)		
Capital Cost		
Design, Permits, CM and Ancillary Costs	$ 3,600,000	$ 3,600,000
Site Work and Utilities	$ 1,000,000	$ 1,000,000
Landscaping	$ 500,000	$ 500,000
Buildings, Structures and Architectural	$ 9,200,000	$ 9,200,000
Equipment & Installation	$ 12,000,000	$ 12,000,000
Electrical Interconnection	$ 500,000	$ 500,000
Waste Water Treatment Plant	$ -	$ -
Subtotal - Direct Construction Costs	**$ 26,800,000**	**$ 26,800,000**
Spare Parts, Tools, Other Equip and Materials	$ 800,000	$ 800,000
Mobile Equipment	$ 1,200,000	$ 1,200,000
Facility Start-up, Testing, CM and Commissioning	$ 500,000	$ 500,000
Insurance During Construction	$ 321,600	$ 321,600
Subtotal – Indirect Construction Costs	**$ 2,821,600**	**$ 2,821,600**
Subtotal - Construction Costs	**$ 29,621,600**	**$ 29,621,600**
Contingency (15%)	$ 4,400,000	$ 4,400,000
Total Capital Costs	**$ 34,021,600**	**$ 34,021,600**
Annual Operations & Maintenance Cost		
Labor	$ 624,000	$ 624,000
Facilities, Equipment and Rolling Stock Maintenance	$ 500,000	$ 500,000
Consumables	$ -	$ -
Auxillary Fuel Costs	$ 200,000	$ 200,000
Purchased Utilities	$ -	$ -
Contract, Rental, or Lease Services	$ -	$ -
Adminstrative Costs (including regulatory)	$ 200,000	$ 200,000
Insurance Costs	$ -	$ -
Subtotal - O&M	**$ 1,524,000**	**$ 1,524,000**
Contingency (15%)	$ 230,000	$ 230,000
Total O&M costs (per facility)	$ 1,754,000	$ 1,754,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 2,530,000	$ 2,530,000
Potential Electricity Revenues ($/year)	$ 680,000	$ 580,000
Net Annual Cost (per facility)	**$ 3,604,000**	**$ 3,704,000**
Number of Facilities	9	10
Total Annual Cost (all facilities)	**$ 32,436,000**	**$ 37,040,000**
TOTAL		
Economic make-up rounding number of facilities	$ (4,610,000)	$ (5,060,000)
Revenues from LFGTE system ($/year)	$ 80,000	$ 80,000
Haul from Metro to Facilities	$ 7,380,036	$ 8,819,001
TOTAL ANNUAL COST ($/year)	**$ 115,488,036**	**$ 137,371,001**

Scenario 5: AMRF with Anaerobic Digestion and RDF/Direct Combustion

2019 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	MRF Fines	To Anaerobic Digestion as MRF Fines	AD Residue	To RDF	Recovered Tons	Tons to Landfill	Tons to Anaerobic Digestion	Tons to RDF
TOTAL PAPER	**17.10%**		**3.84%**			**0.66%**	**0.60%**	**13.20%**	**43,777**		**7,555**	**150,414**
Cardboard	3.57%	60%	2.14%		5.00%	0.07%	0.06%	1.41%	24,392		813	16,099
Office paper	0.78%	0%	0.00%		5.00%	0.04%	0.03%	0.77%	0		444	8,799
Newspaper and magazines	1.51%	50%	0.75%		5.00%	0.04%	0.03%	0.75%	8,583		429	8,497
Mixed paper	1.90%	50%	0.95%		5.00%	0.05%	0.05%	0.95%	10,801		540	10,801
Other compostable nonrecycl. paper	6.21%	0%	0.00%		5.00%	0.31%	0.28%	6.18%	0		3,539	70,419
Other non-compostable nonrecycl. paper	3.14%	0%	0.00%		5.00%	0.16%	0.16%	3.14%	0		1,790	35,799
TOTAL PLASTIC	**13.73%**		**3.79%**			**0.30%**	**0.30%**	**9.94%**	**43,139**		**3,369**	**113,289**
Plastic bottles	0.63%	60%	0.38%			0.00%	0.00%	0.25%	4,293		0	2,862
Other rigid plastics	5.70%	50%	2.85%			0.00%	0.00%	2.85%	32,473		0	32,473
Plastic film - recyclable	1.86%	30%	0.56%		5.00%	0.07%	0.07%	1.31%	6,374		744	14,872
Plastic film - non-recyclable	4.61%	0%	0.00%		5.00%	0.23%	0.23%	4.61%	0		2,625	52,502
Mixed plastic / materials	0.93%	0%	0.00%			0.00%	0.00%	0.93%	0		0	10,580
OTHER ORGANICS	**46.69%**		**7.84%**	**0.15%**		**11.99%**	**4.37%**	**31.09%**	**89,328**	**1,681**	**136,661**	**354,181**
Yard Debris	2.20%	50%	1.10%		20.00%	0.22%	0.20%	1.08%	12,561		2,512	12,309
Clean wood	4.19%	60%	2.52%		5.00%	0.08%	0.08%	1.68%	28,668		956	19,112
Painted & treated lumber	1.47%	0%	0	0.15%	5.00%	0.07%	0.07%	1.33%	0	1,681	840	15,125
Mixed wood / materials	4.93%	50%	2.47%		5.00%	0.12%	0.12%	2.46%	28,092		1,405	28,022
Food waste	17.98%	0%	0.00%		60.00%	10.79%	3.24%	10.43%	0		122,882	118,786
Rubber	0.57%	60%	0.34%		5.00%	0.01%	0.01%	0.23%	3,930		131	2,620
Disposable diapers	3.36%	0%	0.00%		5.00%	0.17%	0.15%	3.34%	0		1,911	38,035
Carpet/pad	2.50%	40%	1.00%		5.00%	0.07%	0.07%	1.50%	11,384		854	17,076
Textiles	4.12%	10%	0.41%		5.00%	0.19%	0.19%	3.71%	4,692		2,112	42,231
Other miscellaneous organics	5.37%	0%	0.00%		5.00%	0.27%	0.24%	5.34%	0		3,058	60,864
GLASS	**1.65%**		**0.00%**			**0.08%**	**0.08%**	**1.65%**	**0**		**941**	**18,815**
Deposit Beverage Glass	0.25%	0%	0.00%		5.00%	0.01%	0.01%	0.25%	0		140	2,803
Window and other glass	1.41%	0%	0.00%		5.00%	0.07%	0.07%	1.41%	0		801	16,012
METAL	**6.73%**		**3.96%**			**0.14%**	**0.14%**	**2.77%**	**45,121**		**1,578**	**31,561**
Aluminum	0.37%	70%	0.26%		5.00%	0.01%	0.01%	0.11%	2,944		63	1,262
Ferrous metals	2.61%	70%	1.82%		5.00%	0.04%	0.04%	0.78%	20,786		445	8,908
Mixed Metals	2.28%	50%	1.14%		5.00%	0.06%	0.06%	1.14%	13,014		651	13,014
Computers, brown goods, small apl.	1.47%	50%	0.74%		5.00%	0.04%	0.04%	0.74%	8,376		419	8,376
OTHER INORGANICS	**11.73%**		**0.96%**	**0.05%**		**0.54%**	**0.54%**	**10.72%**	**10,907**	**607**	**6,138**	**122,150**
Rock, concrete, brick	1.07%	0%	0	0.05%	5.00%	0.05%	0.05%	1.01%	0	607	607	11,535
Soil, sand, dirt	1.46%	0%	0.00%		5.00%	0.07%	0.07%	1.46%	0		829	16,582
Gypsum wallboard	3.19%	30%	0.96%		5.00%	0.11%	0.11%	2.23%	10,907		1,273	25,451
Other micellaneous inorganics	6.02%	0%	0.00%		5.00%	0.30%	0.30%	6.02%	0		3,429	68,582
BULKY MATERIALS*	**1.66%**	**90%**		**1.50%**	**5.00%**	**0.01%**	**0.01%**	**0.17%**		17,037	**95**	**1,893**
MEDICAL WASTES	**0.48%**	**0%**	**0.00%**		**5.00%**	**0.02%**	**0.02%**	**0.48%**	**0**		**271**	**5,423**
HAZARDOUS MATERIALS	**0.22%**	**0%**	**0.00%**		**5.00%**	**0.01%**	**0.01%**	**0.22%**	**0**		**126**	**2,520**
TOTALS	**100.00%**		**20.39%**	**1.70%**		**13.76%**	**6.07%**	**70.24%**	**232,272**	**19,325**	**156,734**	**800,245**

* Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% of the matresses,furniture and tires would be pulled for disposal.

Scenario 5: AMRF with Anaerobic Digestion and RDF/Direct Combustion

2038 Waste Compostion

Material	Adjusted Field Results	AMRF Recovery	Recovered Amount	Diverted to Landfill	MRF Fines	To Anaerobic Digestion as MRF Fines	AD Residue	To RDF	Recovered Tons	Tons to Landfill	Tons to Anaerobic Digestion	Tons to RDF
TOTAL PAPER	**17.81%**		**4.29%**			**0.68%**	**0.62%**	**13.46%**	**58,366**		**9,205**	**183,276**
Cardboard	3.80%	60.00%	2.28%		5.00%	0.08%	0.06%	1.50%	31,010		1,034	20,466
Office paper	0.83%	0.00%	0.00%		5.00%	0.04%	0.03%	0.82%	0		565	11,186
Newspaper and magazines	1.60%	50.00%	0.80%		5.00%	0.04%	0.03%	0.79%	10,912		546	10,803
Mixed paper	2.42%	50.00%	1.21%		5.00%	0.06%	0.06%	1.21%	16,444		822	16,444
Other compostable nonrecycl. paper	5.82%	0.00%	0.00%		5.00%	0.29%	0.26%	5.79%	0		3,963	78,866
Other non-compostable nonrecycl. paper	3.34%	0.00%	0.00%		5.00%	0.17%	0.17%	3.34%	0		2,276	45,510
TOTAL PLASTIC	**14.58%**		**4.00%**			**0.31%**	**0.31%**	**10.57%**	**54,495**		**4,283**	**143,945**
Plastic bottles	0.57%	60.00%	0.34%			0.00%	0.00%	0.23%	4,648		0	3,099
Other rigid plastics	6.13%	50.00%	3.07%			0.00%	0.00%	3.07%	41,744		0	41,744
Plastic film - recyclable	1.98%	30.00%	0.60%		5.00%	0.07%	0.07%	1.39%	8,103		945	18,907
Plastic film - non-recyclable	4.90%	0.00%	0.00%		5.00%	0.25%	0.25%	4.90%	0		3,337	66,746
Mixed plastic / materials	0.99%	0.00%	0.00%			0.00%	0.00%	0.99%	0		0	13,450
OTHER ORGANICS	**43.60%**		**8.34%**	**0.16%**		**8.99%**	**3.53%**	**29.64%**	**113,594**	**2,136**	**122,460**	**403,496**
Yard Debris	2.35%	50.00%	1.17%		20.00%	0.23%	0.21%	1.15%	15,968		3,194	15,649
Clean wood	4.46%	60.00%	2.68%		5.00%	0.09%	0.09%	1.78%	36,445		1,215	24,297
Painted & treated lumber	1.57%	0.00%	0.00%	0.16%	5.00%	0.08%	0.08%	1.41%	0	2,136	1,068	19,228
Mixed wood / materials	5.25%	50.00%	2.62%		5.00%	0.13%	0.12%	2.62%	35,713		1,786	35,624
Food waste	12.83%	0.00%	0.00%		60.00%	7.70%	2.31%	7.44%	0		104,795	101,302
Rubber	0.61%	60.00%	0.37%		5.00%	0.01%	0.01%	0.24%	4,997		167	3,331
Disposable diapers	3.57%	0.00%	0.00%		5.00%	0.18%	0.16%	3.55%	0		2,430	48,354
Carpet/pad	2.66%	40.00%	1.06%		5.00%	0.08%	0.08%	1.59%	14,473		1,085	21,709
Textiles	4.41%	10.00%	0.44%		5.00%	0.20%	0.20%	3.96%	5,998		2,699	53,981
Other miscellaneous organics	5.91%	0.00%	0.00%		5.00%	0.30%	0.27%	5.88%	0		4,021	80,021
GLASS	**1.76%**		**0.00%**			**0.09%**	**0.09%**	**1.76%**	**0**		**1,196**	**23,920**
Deposit Beverage Glass	0.26%	0.00%	0.00%		5.00%	0.01%	0.01%	0.26%	0		178	3,564
Window and other glass	1.50%	0.00%	0.00%		5.00%	0.07%	0.07%	1.50%	0		1,018	20,356
METAL	**7.26%**		**4.26%**			**0.15%**	**0.15%**	**2.99%**	**58,012**		**2,039**	**40,774**
Aluminum	0.39%	70.00%	0.27%		5.00%	0.01%	0.01%	0.12%	3,743		80	1,604
Ferrous metals	2.77%	70.00%	1.94%		5.00%	0.04%	0.04%	0.83%	26,425		566	11,325
Mixed Metals	2.43%	50.00%	1.22%		5.00%	0.06%	0.06%	1.22%	16,545		827	16,545
Computers, brown goods, small apl.	1.66%	50.00%	0.83%		5.00%	0.04%	0.04%	0.83%	11,300		565	11,300
OTHER INORGANICS	**12.48%**		**1.02%**	**0.06%**		**0.57%**	**0.57%**	**11.41%**	**13,867**	**772**	**7,803**	**155,288**
Rock, concrete, brick	1.13%	0.00%	0.00%	0.06%	5.00%	0.06%	0.06%	1.08%	0	772	772	14,665
Soil, sand, dirt	1.55%	0.00%	0.00%		5.00%	0.08%	0.08%	1.55%	0		1,054	21,080
Gypsum wallboard	3.39%	30.00%	1.02%		5.00%	0.12%	0.12%	2.38%	13,867		1,618	32,355
Other micellaneous inorganics	6.40%	0.00%	0.00%		5.00%	0.32%	0.32%	6.40%	0		4,359	87,188
BULKY MATERIALS*	**1.77%**	**90.00%**		**1.59%**	**5.00%**	**0.01%**	**0.01%**	**0.18%**		21,659	**120**	**2,407**
MEDICAL WASTES	**0.51%**	**0.00%**	**0.00%**		**5.00%**	**0.03%**	**0.03%**	**0.51%**	**0**		**345**	**6,894**
HAZARDOUS MATERIALS	**0.25%**	**0.00%**	**0.00%**		**5.00%**	**0.01%**	**0.01%**	**0.25%**	**0**		**168**	**3,366**
TOTALS	**100.00%**		**21.91%**	**1.80%**		**10.84%**	**5.32%**	**70.76%**	**298,334**	**24,568**	**147,618**	**963,364**

* Bulky Materials includes matresses, furniture & tires (white goods already pulled from waste stream). For this scenario it was assumed that 90% of the matresses,furniture and tires would be pulled for disposal.

Scenario 5: AMRF with Anaerobic Digestion and RDF/Direct Combustion

Design Basis

	2019	2038
Input tons per year		
Landfill	259,398	313,577
AMRF	1,139,369	1,361,501
RDF Plant/Direct Combustion Plant	800,245	963,364
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	156,734	147,618
Diverted tons per year		
AMRF	232,272	298,334
Floor Sort	0.00	0.00
RDF Plant/Direct Combustion Plant	560,171	674,355
To Non-Metro Pyrolysis Plant	0	0
Gasification Plant	0	0
Anerobic Digestion Plant	87,527	75,236
Total Diverted	**879,970**	**1,047,924**
Percent of Input Diverted	**77.2%**	**77.0%**
Landfill	**2019**	**2038**
Haul Distance RT (miles)	200	200
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	7,630	9,223
AMRF		
Haul Distance RT (miles)	100	100
RT Time including Loading/Unloading (hrs)	2.3	2.3
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	33,511	40,045
Facility Capacity (tons/day)	750	750
Rounded Number of Facilities Required	5	6
Exact Number of Facilities Required	4.5	5.4
Difference for Adjusting Last Facility Operations	0.48	0.59
Operating Hours per Day	20	20
Availability	92%	92%
For Each Facility		
Power Requirement (kWh/yr)	3,300,000	3,300,000
Water Consumption (1000 CF/year)	320	320
Effluent Requirement (1000 CF/year)	270	270
Number of Pieces of Mobile Equipment	7	7
Estimated Fuel Usage (gals/year)	134,000	134,000
Number of Sorters (all shifts)	39	39
Additional Sorters for Plastics (all shifts)	0	0
Mgrs, Eq Ops, Mech, etc. (all shifts)	23	23
Number of Office Personnel (one shift)	4	4
Total Staff	66	66
Acreage Required	5	5
RDF / Direct Combustion		
Haul Distance RT (miles)	0	0
RT Time including Loading/Unloading (hrs)	0.0	0.0
Average Transfer Trailer Load (tons)	0	0
Required Number of Trips per Year	0	0
Facility Capacity (tons/day)	1,000	1,000
Rounded Number of Facilities Required	3	3
Exact Number of Facilities Required	2.4	2.9
Difference for Adjusting Last Facility Operations	0.56	0.07
Operating Hours per Day	24	24
Availability	90%	90%

Scenario 5: AMRF with Anaerobic Digestion and RDF/Direct Combustion

Design Basis (continued)

	2019	2038
RDF / Direct Combustion (continued)		
For Each Facility		
Hourly Throughput (tons/hour)	37.5	37.5
Steam Production (1000 lbs/hr)	2,300,000	2,300,000
Gross Energy Generated (MW)	28.7	28.7
Internal Parasitic Load (MW)	4.3	4.3
Net Energy Generated (MW)	24.4	24.4
Ash Production Rate (%)	30%	30%
Ash Production (tons/year)	98,600	98,600
Auxillary Fuel- natural gas/propane (MMBtu/yr)	100,400	100,400
Water Consumption (1000 cf/year)	3,100	3,100
Effluent Requirement (1000 cf/year)	220	220
Number of Personnel	40	40
Acreage Required	8-20	8-20
Gasification		
Not Used	N/A	N/A
Anaerobic Digestion		
Haul Distance RT (miles)	0	0
RT Time including Loading/Unloading (hrs)	0	0
Average Transfer Trailer Load (tons)	0	0
Required Number of Trips per Year	0	0
Facility Capacity (tons/day)	300	300
Rounded Number of Facilities Required	2	2
Exact Number of Facilities Required	1.5	1.4
Difference for Adjusting Last Facility Operations	0.46	0.55
Operating Hours per Day	24	24
Availability (portions of system always operating)	93%	93%
For Each Facility		
Biogas generated - food/prutrecible (cf/day)	999,600	905,100
Biogas generated - wood/yard (cf/day)	47,000	64,200
Biogas generated - fiber/paper (cf/day)	8,800	11,300
Gross Biogas Generated (cf/day)	1,055,400	980,600
Parasitics to Produce CNG (cf/day)	52,770	49,030
Net CNG Produced (cf/day)	1,002,630	931,570
Gross Energy Generated in MMBTU	25.07	23.29
Gross Energy in KW	7,344	6,824
Net Energy Generated (kWh/yr)	21,391,640	19,875,537
Water Consumption (gal/day)	15,000	15,000
Effluent Requirement	-	-
Number of Personnel	8	8
Acreage Required	3	3

Scenario 5: AMRF with Anaerobic Digestion and RDF/Direct Combustion

Economic Analysis

	2019	2038
Landfill		
Capital Cost		
Assume cost is built into tip fee	**$ -**	**$ -**
Annual Operations & Maintenance Cost		
RT Time including Loading/Unloading (hrs)	4.1	4.1
Average Transfer Trailer Load (tons)	34	34
Required Number of Trips per Year	7,630	9,223
Estimated hourly transfer trailer cost ($/hr)	$ 95	$ 95
Annual Transfer Cost ($/year)	**$ 2,998,243**	**$ 3,624,220**
Landfill Tip Fee ($/ton)	$ 22.79	$ 22.79
Annual Landfill Tip Fee ($/year)	**$ 5,911,687**	**$ 7,146,416**
Total Landilling Cost ($/year)	**$ 8,910,000**	**$ 10,771,000**
AMRF (per facility)		
Capital Cost		
Site improvements & buildings	$ 11,319,000	$ 11,319,000
Startup and acceptance testing (1 month)	$ 852,000	$ 852,000
Subtotal	**$ 12,171,000**	**$ 12,171,000**
Environmental Impact	$ 226,000	$ 226,000
Planning	$ 340,000	$ 340,000
Permits	$ 453,000	$ 453,000
Design	$ 792,000	$ 792,000
Construction administration	$ 566,000	$ 566,000
Subtotal	**$ 14,548,000**	**$ 14,548,000**
Contingency (15%)	$ 2,182,000	$ 2,182,000
Land	$ -	$ -
Stationary equipment installed(w/spare parts)	$ 10,293,000	$ 10,293,000
Rolling stock	$ 720,000	$ 720,000
Total Capital Costs	**$ 27,743,000**	**$ 27,743,000**
Annual Operations & Maintenance Cost		
Labor	$ 6,301,000	$ 6,301,000
Facilities maintenance	$ 50,000	$ 50,000
Rolling stock maintenance	$ 154,000	$ 154,000
Rolling stock replacement costs	$ 103,000	$ 103,000
Stationary equip maintenance/replace	$ 406,000	$ 406,000
Utilities	$ 390,000	$ 390,000
Fuel	$ 534,000	$ 534,000
General & administration/legal,/accnt.	$ 50,000	$ 50,000
Contractor overhead	$ 799,000	$ 799,000
Insurance	$ 100,000	$ 100,000
Property taxes	$ -	$ -
Subtotal	**$ 8,887,000**	**$ 8,887,000**
Contingency (15%)	$ 1,333,000	$ 1,333,000
Total O&M costs (per facility)	$ 10,220,000	$ 10,220,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 2,067,000	$ 2,067,000
Total Annual Cost (per facility)	$ 12,287,000	$ 12,287,000
Potential Materials Market Revenues ($/year)	$ 1,284,000	$ 1,380,000
Net Annual Cost (per facility)	**$ 11,003,000**	**$ 10,907,000**
Number of Facilities	5	6
Total Annual Cost (all facilities)	**$ 55,015,000**	**$ 65,442,000**

Scenario 5: AMRF with Anaerobic Digestion and RDF/Direct Combustion

Economic Analysis (continued)

	2019	2038
RDF / Direct Combustion (per facility)		
Capital Cost		
Design, Permits, CM and Ancillary Costs	$ 38,700,000	$ 38,700,000
Site Work and Utilities	$ 15,000,000	$ 15,000,000
Landscaping	$ 1,000,000	$ 1,000,000
Buildings, Structures and Architectural	$ 59,000,000	$ 59,000,000
Equipment & Installation	$ 278,500,000	$ 278,500,000
Electrical Interconnection	$ 12,900,000	$ 12,900,000
Waste Water Treatment Plant	$ 3,500,000	$ 3,500,000
Subtotal - Direct Construction Costs	**$ 408,600,000**	**$ 408,600,000**
Spare Parts, Tools, Other Equip and Materials	$ 3,000,000	$ 3,000,000
Mobile Equipment	$ 1,000,000	$ 1,000,000
Facility Start-up, Testing, CM and Commissioning	$ 10,800,000	$ 10,800,000
Insurance During Construction	$ 6,500,000	$ 6,500,000
Subtotal – Indirect Construction Costs	**$ 21,300,000**	**$ 21,300,000**
Subtotal - Construction Costs	**$ 429,900,000**	**$ 429,900,000**
Contingency (15%)	$ 64,500,000	$ 64,500,000
Total Capital Costs	**$ 494,400,000**	**$ 494,400,000**
Annual Operations & Maintenance Cost		
Labor	$ 4,440,000	$ 4,440,000
Facilities, Equipment and Rolling Stock Maintenance	$ 6,750,000	$ 6,750,000
Consumables	$ 3,000,000	$ 3,000,000
Auxillary Fuel Costs	$ 900,000	$ 900,000
Purchased Utilities	$ 550,000	$ 550,000
Contract, Rental, or Lease Services	$ 140,000	$ 140,000
Adminstrative Costs (including regulatory)	$ 380,000	$ 380,000
Insurance Costs	$ 300,000	$ 300,000
Subtotal - O&M	**$ 16,460,000**	**$ 16,460,000**
Contingency (15%)	$ 2,470,000	$ 2,470,000
Total O&M costs (per facility)	$ 18,930,000	$ 18,930,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 36,830,000	$ 36,830,000
Potential Electricity Revenues ($/year)	$ 15,370,000	$ 15,370,000
Potential Metal Sales Revenues ($/year)	$ 180,000	$ 180,000
Potential Revenues ($/year)	$ 15,550,000	$ 15,550,000
Net Annual Cost (per facility)	**$ 40,210,000**	**$ 40,210,000**
Number of Facilities	3	3
Total Annual Cost (all facilities)	**$ 120,630,000**	**$ 120,630,000**

Scenario 5: AMRF with Anaerobic Digestion and RDF/Direct Combustion

Economic Analysis (continued)

	2019	2038
Anaerobic Digestion (per facility)		
Capital Cost		
Design, Permits, CM and Ancillary Costs	$ 3,600,000	$ 3,600,000
Site Work and Utilities	$ 1,000,000	$ 1,000,000
Landscaping	$ 500,000	$ 500,000
Buildings, Structures and Architectural	$ 9,200,000	$ 9,200,000
Equipment & Installation	$ 12,000,000	$ 12,000,000
Electrical Interconnection	$ 500,000	$ 500,000
Waste Water Treatment Plant	$ -	$ -
Subtotal - Direct Construction Costs	**$ 26,800,000**	**$ 26,800,000**
Spare Parts, Tools, Other Equip and Materials	$ 800,000	$ 800,000
Mobile Equipment	$ 1,200,000	$ 1,200,000
Facility Start-up, Testing, CM and Commissioning	$ 500,000	$ 500,000
Insurance During Construction	$ 321,600	$ 321,600
Subtotal – Indirect Construction Costs	**$ 2,821,600**	**$ 2,821,600**
Subtotal - Construction Costs	**$ 29,621,600**	**$ 29,621,600**
Contingency (15%)	$ 4,400,000	$ 4,400,000
Total Capital Costs	**$ 34,021,600**	**$ 34,021,600**
Annual Operations & Maintenance Cost		
Labor	$ 624,000	$ 624,000
Facilities, Equipment and Rolling Stock Maintenance	$ 500,000	$ 500,000
Consumables	$ -	$ -
Auxillary Fuel Costs	$ 200,000	$ 200,000
Purchased Utilities	$ -	$ -
Contract, Rental, or Lease Services	$ -	$ -
Adminstrative Costs (including regulatory)	$ 200,000	$ 200,000
Insurance Costs	$ -	$ -
Subtotal - O&M	**$ 1,524,000**	**$ 1,524,000**
Contingency (15%)	$ 230,000	$ 230,000
Total O&M costs (per facility)	$ 1,754,000	$ 1,754,000
Annualized Capital Cost (5.0%, 25 yrs, 5% fin cost)	$ 2,530,000	$ 2,530,000
Potential Electricity Revenues ($/year)	$ 1,710,000	$ 1,590,000
Net Annual Cost (per facility)	**$ 2,574,000**	**$ 2,694,000**
Number of Facilities	2	2
Total Annual Cost (all facilities)	**$ 5,148,000**	**$ 5,388,000**
TOTAL		
Economic make-up rounding number of facilities	$ (6,378,000)	$ (6,095,000)
Haul from Metro to Facilities	$ 7,380,036	$ 8,819,001
TOTAL ANNUAL COST ($/year)	**$ 190,705,036**	**$ 204,955,001**

Appendix D

Greenhouse Gas Emissions Modeling and Calculations

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GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 1A

Prepared by: HDR

Project Period for this Analysis: 01/01/19 to 12/31/19

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (63,828)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	4,205.5	-	NA	240
Steel Cans	-	29,694.3	-	NA	1,694
Glass	-	18,815.3	-	NA	1,073
LDPE	NA	52,502.2	-	NA	2,994
PET	-	7,154.6	-	NA	408
Corrugated Containers	-	40,653.9	-	NA	(8,363)
Magazines/third-class mail	-	17,166.2	-	NA	850
Office Paper	-	8,887.8	-	NA	5,206
Dimensional Lumber	-	103,964.1	-	NA	(104,603)
Food Waste (non-meat)	NA	204,804.1	-	-	61,114
Yard Trimmings	NA	25,121.3	-	-	(8,421)
Mixed Paper (general)	-	128,174.4	-	NA	(26,932)
Mixed Metals	-	26,028.3	-	NA	1,485
Mixed Plastics	-	96,771.5	-	NA	5,519
Mixed Organics	NA	61,169.6	-	-	173
Mixed MSW	NA	63,205.3	-	NA	7,025
Carpet	-	75,383.9	-	NA	4,299
Personal Computers	-	16,753.0	-	NA	955
Concrete	-	28,724.2	NA	NA	1,638
Tires	-	8,443.7	-	NA	482
Asphalt Concrete	-	68,581.8	NA	NA	3,912
Drywall	-	36,358.3	NA	NA	(882)
Wood Flooring	NA	16,805.3	-	NA	(13,694)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (509,342)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	2,943.9	1,261.6	-	NA	(26,728)	(26,968)
Steel Cans	-	20,786.0	8,908.3	-	NA	(37,056)	(38,750)
Glass	-	-	18,815.3	-	NA	1,073	0
LDPE	-	NA	52,502.2	-	NA	2,994	0
PET	-	4,292.8	2,861.8	-	NA	(4,675)	(5,083)
Corrugated Containers	-	24,392.3	16,261.6	-	NA	(79,319)	(70,956)
Magazines/third-class mail	-	8,583.1	8,583.1	-	NA	(25,889)	(26,739)
Office Paper	-	-	8,887.8	-	NA	5,206	0
Dimensional Lumber	-	56,760.1	47,204.0	-	NA	(186,955)	(82,351)
Food Waste (non-meat)	-	NA	204,804.1	-	-	61,114	0
Yard Trimmings	NA	NA	12,560.7	12,560.6	-	(6,092)	2,329
Mixed Paper (general)	NA	10,801.2	117,373.2	-	NA	(62,705)	(35,772)
Mixed Metals	NA	13,014.2	13,014.1	-	NA	(56,153)	(57,638)
Mixed Plastics	NA	38,846.7	57,924.8	-	NA	(36,645)	(42,164)
Mixed Organics	NA	NA	61,169.6	-	-	173	0
Mixed MSW	NA	NA	63,205.3	-	NA	7,025	0
Carpet	-	16,076.5	59,307.4	-	NA	(34,492)	(38,792)
Personal Computers	-	8,376.5	8,376.5	-	NA	(20,540)	(21,495)
Concrete	NA	-	28,724.2	NA	NA	1,638	0
Tires	-	3,930.4	4,513.3	-	NA	(1,245)	(1,726)
Asphalt Concrete	-	-	68,581.8	NA	NA	3,912	0
Drywall	-	10,907.5	25,450.8	NA	NA	(289)	593
Wood Flooring	-	NA	16,805.3	-	NA	(13,694)	0
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Total Change in GHG Emissions ($MTCO_2E$): (445,514)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Removing annual emissions from	**93,792**	Passenger Vehicles
Conserving	**50,130,987**	Gallons of Gasoline
Conserving	**18,563,087**	Cylinders of Propane Used for Home Barbeques
Conserving	**2,389**	Railway Cars of Coal
	0.02561%	Annual CO_2 emissions from the U.S. transportation sector
	0.02203%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 2

Prepared by: HDR

Project Period for this Analysis: 01/01/19 to 12/31/19

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (63,828)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	4,205.5	-	NA	240
Steel Cans	-	29,694.3	-	NA	1,694
Glass	-	18,815.3	-	NA	1,073
LDPE	NA	52,502.2	-	NA	2,994
PET	-	7,154.6	-	NA	408
Corrugated Containers	-	40,653.9	-	NA	(8,363)
Magazines/third-class mail	-	17,166.2	-	NA	850
Office Paper	-	8,887.8	-	NA	5,206
Dimensional Lumber	-	103,964.1	-	NA	(104,603)
Food Waste (non-meat)	NA	204,804.1	-	-	61,114
Yard Trimmings	NA	25,121.3	-	-	(8,421)
Mixed Paper (general)	-	128,174.4	-	NA	(26,932)
Mixed Metals	-	26,028.3	-	NA	1,485
Mixed Plastics	-	96,771.5	-	NA	5,519
Mixed Organics	NA	61,169.6	-	-	173
Mixed MSW	NA	63,205.3	-	NA	7,025
Carpet	-	75,383.9	-	NA	4,299
Personal Computers	-	16,753.0	-	NA	955
Concrete	-	28,724.2	NA	NA	1,638
Tires	-	8,443.7	-	NA	482
Asphalt Concrete	-	68,581.8	NA	NA	3,912
Drywall	-	36,358.3	NA	NA	(882)
Wood Flooring	NA	16,805.3	-	NA	(13,694)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (31,424)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	210.3	-	3,995.2	NA	(1,685)	(1,925)
Steel Cans	-	1,484.7	-	28,209.6	NA	(46,406)	(48,100)
Glass	-	-	-	18,815.3	NA	935	(139)
LDPE	-	NA	-	52,502.2	NA	67,149	64,155
PET	-	-	-	7,154.6	NA	8,901	8,493
Corrugated Containers	-	4,065.4	-	36,588.5	NA	(30,223)	(21,860)
Magazines/third-class mail	-	-	-	17,166.2	NA	(5,855)	(6,705)
Office Paper	-	-	-	8,887.8	NA	(4,098)	(9,304)
Dimensional Lumber	-	10,396.5	-	93,567.6	NA	(79,602)	25,001
Food Waste (non-meat)	-	NA	-	204,804.1	-	(23,829)	(84,943)
Yard Trimmings	NA	NA	-	25,121.3	-	(3,763)	4,658
Mixed Paper (general)	NA	-	-	128,174.4	NA	(61,778)	(34,846)
Mixed Metals	NA	1,301.4	-	24,726.9	NA	(30,025)	(31,509)
Mixed Plastics	NA	-	-	96,771.5	NA	121,397	115,878
Mixed Organics	NA	NA	-	61,169.6	-	(8,105)	(8,278)
Mixed MSW	NA	NA	13,016.4	50,188.9	NA	1,115	(5,911)
Carpet	-	2,846.1	-	72,537.8	NA	73,529	69,230
Personal Computers	-	837.7	-	15,915.3	NA	(4,706)	(5,662)
Concrete	NA	-	28,724.2	NA	NA	1,638	0
Tires	-	-	1,446.3	6,997.5	NA	3,779	3,297
Asphalt Concrete	-	-	68,581.8	NA	NA	3,912	0
Drywall	-	-	36,358.3	NA	NA	(882)	0
Wood Flooring	-	NA	1,680.6	15,124.7	NA	(12,821)	874
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Total Change in GHG Emissions ($MTCO_2E$): 32,404

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Adding annual emissions from	**6,822**	Passenger Vehicles
Consuming	**3,646,233**	Gallons of Gasoline
Consuming	**1,350,170**	Cylinders of Propane Used for Home Barbeques
Consuming	**174**	Railway Cars of Coal
	0.00186%	Annual CO_2 emissions from the U.S. transportation sector
	0.00160%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 2A
Prepared by: HDR
Project Period for this Analysis: 01/01/19 to 12/31/19

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (65,624)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	4,205.5	-	NA	240
Steel Cans	-	29,694.3	-	NA	1,694
Glass	-	18,815.3	-	NA	1,073
LDPE	NA	21,000.9	-	NA	1,198
PET	-	7,154.6	-	NA	408
Corrugated Containers	-	40,653.9	-	NA	(8,363)
Magazines/third-class mail	-	17,166.2	-	NA	850
Office Paper	-	8,887.8	-	NA	5,206
Dimensional Lumber	-	103,964.1	-	NA	(104,603)
Food Waste (non-meat)	NA	204,804.1	-	-	61,114
Yard Trimmings	NA	25,121.3	-	-	(8,421)
Mixed Paper (general)	-	128,174.4	-	NA	(26,932)
Mixed Metals	-	26,028.3	-	NA	1,485
Mixed Plastics	-	96,771.5	-	NA	5,519
Mixed Organics	NA	61,169.6	-	-	173
Mixed MSW	NA	63,205.3	-	NA	7,025
Carpet	-	75,383.9	-	NA	4,299
Personal Computers	-	16,753.0	-	NA	955
Concrete	-	28,724.2	NA	NA	1,638
Tires	-	8,443.7	-	NA	482
Asphalt Concrete	-	68,581.8	NA	NA	3,912
Drywall	-	36,358.3	NA	NA	(882)
Wood Flooring	NA	16,805.3	-	NA	(13,694)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (518,190)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	2,943.9	-	1,261.6	NA	(26,728)	(26,968)
Steel Cans	-	20,786.0	-	8,908.3	NA	(51,371)	(53,065)
Glass	-	-	-	18,815.3	NA	935	(139)
LDPE	-	NA	-	21,000.9	NA	26,860	25,662
PET	-	4,292.8	-	2,861.8	NA	(1,278)	(1,686)
Corrugated Containers	-	24,392.3	-	16,261.6	NA	(83,778)	(75,416)
Magazines/third-class mail	-	8,583.1	-	8,583.1	NA	(29,241)	(30,092)
Office Paper	-	-	-	8,887.8	NA	(4,098)	(9,304)
Dimensional Lumber	-	56,760.1	-	47,204.0	NA	(166,732)	(62,129)
Food Waste (non-meat)	-	NA	-	204,804.1	-	(23,829)	(84,943)
Yard Trimmings	NA	NA	-	25,121.3	-	(3,763)	4,658
Mixed Paper (general)	NA	10,801.2	-	117,373.2	NA	(94,614)	(67,682)
Mixed Metals	NA	13,014.2	-	13,014.1	NA	(69,703)	(71,188)
Mixed Plastics	NA	45,220.4	-	51,551.1	NA	18,167	12,647
Mixed Organics	NA	NA	-	61,169.6	-	(8,105)	(8,278)
Mixed MSW	NA	NA	13,016.4	50,188.9	NA	1,115	(5,911)
Carpet	-	16,076.6	-	59,307.3	NA	27,725	23,425
Personal Computers	-	8,376.5	-	8,376.5	NA	(22,388)	(23,344)
Concrete	NA	-	28,724.2	NA	NA	1,638	0
Tires	-	3,930.4	1,446.3	3,067.1	NA	200	(281)
Asphalt Concrete	-	-	68,581.8	NA	NA	3,912	0
Drywall	-	10,907.5	25,450.8	NA	NA	(289)	593
Wood Flooring	-	NA	1,680.5	15,124.8	NA	(12,821)	874
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Total Change in GHG Emissions ($MTCO_2E$): (452,565)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…		
Removing annual emissions from	**95,277**	Passenger Vehicles
Conserving	**50,924,420**	Gallons of Gasoline
Conserving	**18,856,888**	Cylinders of Propane Used for Home Barbeques
Conserving	**2,427**	Railway Cars of Coal
	0.02602%	Annual CO_2 emissions from the U.S. transportation sector
	0.02237%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 3
Prepared by: HDR
Project Period for this Analysis: 01/01/19 to 12/31/19

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (65,624)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	4,205.5	-	NA	240
Steel Cans	-	29,694.3	-	NA	1,694
Glass	-	18,815.3	-	NA	1,073
LDPE	NA	21,000.9	-	NA	1,198
PET	-	7,154.6	-	NA	408
Corrugated Containers	-	40,653.9	-	NA	(8,363)
Magazines/third-class mail	-	17,166.2	-	NA	850
Office Paper	-	8,887.8	-	NA	5,206
Dimensional Lumber	-	103,964.1	-	NA	(104,603)
Food Waste (non-meat)	NA	204,804.1	-	-	61,114
Yard Trimmings	NA	25,121.3	-	-	(8,421)
Mixed Paper (general)	-	128,174.4	-	NA	(26,932)
Mixed Metals	-	26,028.3	-	NA	1,485
Mixed Plastics	-	96,771.5	-	NA	5,519
Mixed Organics	NA	61,169.6	-	-	173
Mixed MSW	NA	63,205.3	-	NA	7,025
Carpet	-	75,383.9	-	NA	4,299
Personal Computers	-	16,753.0	-	NA	955
Concrete	-	28,724.2	NA	NA	1,638
Tires	-	8,443.7	-	NA	482
Asphalt Concrete	-	68,581.8	NA	NA	3,912
Drywall	-	36,358.3	NA	NA	(882)
Wood Flooring	NA	16,805.3	-	NA	(13,694)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (518,189)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	2,943.9	-	1,261.6	NA	(26,728)	(26,968)
Steel Cans	-	20,786.0	-	8,908.3	NA	(51,371)	(53,065)
Glass	-	-	-	18,815.3	NA	935	(139)
LDPE	-	NA	-	21,000.9	NA	26,860	25,662
PET	-	4,292.8	-	2,861.8	NA	(1,278)	(1,686)
Corrugated Containers	-	24,392.3	-	16,261.6	NA	(83,778)	(75,416)
Magazines/third-class mail	-	8,583.1	-	8,583.1	NA	(29,241)	(30,092)
Office Paper	-	-	-	8,887.8	NA	(4,098)	(9,304)
Dimensional Lumber	-	56,760.1	-	47,204.0	NA	(166,732)	(62,129)
Food Waste (non-meat)	-	NA	-	204,804.1	-	(23,829)	(84,943)
Yard Trimmings	NA	NA	-	25,121.3	-	(3,763)	4,658
Mixed Paper (general)	NA	10,801.2	-	117,373.2	NA	(94,614)	(67,682)
Mixed Metals	NA	13,014.2	-	13,014.1	NA	(69,703)	(71,188)
Mixed Plastics	NA	45,220.4	-	51,551.1	NA	18,167	12,647
Mixed Organics	NA	NA	-	61,169.6	-	(8,105)	(8,278)
Mixed MSW	NA	NA	13,016.4	50,188.9	NA	1,115	(5,911)
Carpet	-	16,076.4	-	59,307.5	NA	27,726	23,426
Personal Computers	-	8,376.5	-	8,376.5	NA	(22,388)	(23,344)
Concrete	NA	-	28,724.2	NA	NA	1,638	0
Tires	-	3,930.4	1,446.3	3,067.1	NA	200	(281)
Asphalt Concrete	-	-	68,581.8	NA	NA	3,912	0
Drywall	-	10,907.5	25,450.8	NA	NA	(289)	593
Wood Flooring	-	NA	1,680.5	15,124.8	NA	(12,821)	874
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Total Change in GHG Emissions ($MTCO_2E$): (452,565)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…		
Removing annual emissions from	**95,277**	Passenger Vehicles
Conserving	**50,924,342**	Gallons of Gasoline
Conserving	**18,856,860**	Cylinders of Propane Used for Home Barbeques
Conserving	**2,427**	Railway Cars of Coal
	0.02602%	Annual CO_2 emissions from the U.S. transportation sector
	0.02237%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 4

Prepared by: HDR

Project Period for this Analysis: 01/01/19 to 12/31/19

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (104,862)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	4,205.5	-	NA	240
Steel Cans	-	29,694.3	-	NA	1,694
Glass	-	18,815.3	-	NA	1,073
LDPE	NA	52,502.2	-	NA	2,994
PET	-	7,154.6	-	NA	408
Corrugated Containers	-	37,401.5	-	NA	(7,694)
Magazines/third-class mail	-	17,166.2	-	NA	850
Office Paper	-	7,110.2	-	NA	4,165
Dimensional Lumber	-	103,964.2	-	NA	(104,603)
Food Waste (non-meat)	NA	61,441.2	-	-	18,334
Yard Trimmings	NA	23,865.3	-	-	(8,000)
Mixed Paper (general)	-	120,016.9	-	NA	(25,218)
Mixed Metals	-	26,028.3	-	NA	1,485
Mixed Plastics	-	96,771.5	-	NA	5,519
Mixed Organics	NA	55,052.6	-	-	156
Mixed MSW	NA	63,205.3	-	NA	7,025
Carpet	-	75,383.9	-	NA	4,299
Personal Computers	-	16,753.0	-	NA	955
Concrete	-	28,724.2	NA	NA	1,638
Tires	-	8,443.7	-	NA	482
Asphalt Concrete	-	68,581.8	NA	NA	3,912
Drywall	-	36,358.3	NA	NA	(882)
Wood Flooring	NA	16,805.3	-	NA	(13,694)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (550,376)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	2,943.9	1,261.6	-	NA	(26,728)	(26,968)
Steel Cans	-	20,786.0	8,908.3	-	NA	(37,056)	(38,750)
Glass	-	-	18,815.3	-	NA	1,073	0
LDPE	-	NA	52,502.2	-	NA	2,994	0
PET	-	4,292.8	2,861.8	-	NA	(4,675)	(5,083)
Corrugated Containers	-	24,392.3	13,009.2	-	NA	(78,650)	(70,956)
Magazines/third-class mail	-	8,583.1	8,583.1	-	NA	(25,889)	(26,739)
Office Paper	-	-	7,110.2	-	NA	4,165	0
Dimensional Lumber	-	56,760.1	47,204.1	-	NA	(186,955)	(82,351)
Food Waste (non-meat)	-	NA	61,441.2	-	-	18,334	0
Yard Trimmings	NA	NA	11,304.6	12,560.7	-	(5,671)	2,329
Mixed Paper (general)	NA	10,801.2	109,215.7	-	NA	(60,990)	(35,772)
Mixed Metals	NA	13,014.2	13,014.1	-	NA	(56,153)	(57,638)
Mixed Plastics	NA	38,846.7	57,924.8	-	NA	(36,645)	(42,164)
Mixed Organics	NA	NA	55,052.6	-	-	156	0
Mixed MSW	NA	NA	63,205.3	-	NA	7,025	0
Carpet	-	16,076.5	59,307.4	-	NA	(34,492)	(38,792)
Personal Computers	-	8,376.5	8,376.5	-	NA	(20,540)	(21,495)
Concrete	NA	-	28,724.2	NA	NA	1,638	0
Tires	-	3,930.4	4,513.3	-	NA	(1,245)	(1,726)
Asphalt Concrete	-	-	68,581.8	NA	NA	3,912	0
Drywall	-	10,907.5	25,450.8	NA	NA	(289)	593
Wood Flooring	-	NA	16,805.3	-	NA	(13,694)	0
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Total Change in GHG Emissions ($MTCO_2E$): (445,514)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Removing annual emissions from	**93,792**	Passenger Vehicles
Conserving	**50,130,985**	Gallons of Gasoline
Conserving	**18,563,086**	Cylinders of Propane Used for Home Barbeques
Conserving	**2,389**	Railway Cars of Coal
	0.02561%	Annual CO_2 emissions from the U.S. transportation sector
	0.02203%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 5

Prepared by: HDR

Project Period for this Analysis: 01/01/19 to 12/31/19

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (89,311)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	4,205.5	-	NA	240
Steel Cans	-	29,694.3	-	NA	1,694
Glass	-	18,815.3	-	NA	1,073
LDPE	NA	52,502.2	-	NA	2,994
PET	-	7,154.6	-	NA	408
Corrugated Containers	-	40,491.2	-	NA	(8,329)
Magazines/third-class mail	-	17,080.4	-	NA	846
Office Paper	-	8,798.9	-	NA	5,154
Dimensional Lumber	-	103,893.9	-	NA	(104,533)
Food Waste (non-meat)	NA	118,786.4	-	-	35,446
Yard Trimmings	NA	24,870.2	-	-	(8,337)
Mixed Paper (general)	-	127,820.5	-	NA	(26,858)
Mixed Metals	-	26,028.3	-	NA	1,485
Mixed Plastics	-	96,771.5	-	NA	5,519
Mixed Organics	NA	60,863.8	-	-	172
Mixed MSW	NA	63,014.2	-	NA	7,004
Carpet	-	75,383.7	-	NA	4,299
Personal Computers	-	16,753.0	-	NA	955
Concrete	-	28,724.2	NA	NA	1,638
Tires	-	8,443.7	-	NA	482
Asphalt Concrete	-	68,581.8	NA	NA	3,912
Drywall	-	36,358.3	NA	NA	(882)
Wood Flooring	NA	16,805.2	-	NA	(13,694)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (452,750)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	2,943.9	-	1,261.6	NA	(26,728)	(26,968)
Steel Cans	-	20,786.0	-	8,908.3	NA	(51,371)	(53,065)
Glass	-	-	-	18,815.3	NA	935	(139)
LDPE	-	NA	-	52,502.2	NA	67,149	64,155
PET	-	4,292.7	-	2,861.9	NA	(1,278)	(1,686)
Corrugated Containers	-	24,392.3	-	16,098.9	NA	(83,700)	(75,371)
Magazines/third-class mail	-	8,583.1	-	8,497.3	NA	(29,212)	(30,058)
Office Paper	-	-	-	8,798.9	NA	(4,057)	(9,211)
Dimensional Lumber	-	56,760.1	-	47,133.8	NA	(166,692)	(62,159)
Food Waste (non-meat)	-	NA	-	118,786.4	-	(13,821)	(49,267)
Yard Trimmings	NA	NA	-	24,870.2	-	(3,726)	4,611
Mixed Paper (general)	NA	10,801.2	-	117,019.3	NA	(94,444)	(67,586)
Mixed Metals	NA	13,014.2	-	13,014.1	NA	(69,703)	(71,188)
Mixed Plastics	NA	38,846.6	-	57,924.9	NA	32,717	27,198
Mixed Organics	NA	NA	-	60,863.8	-	(8,064)	(8,236)
Mixed MSW	NA	NA	15,333.5	47,680.7	NA	1,389	(5,615)
Carpet	-	16,076.4	-	59,307.3	NA	27,725	23,426
Personal Computers	-	8,376.5	-	8,376.5	NA	(22,388)	(23,344)
Concrete	NA	-	28,724.2	NA	NA	1,638	0
Tires	-	3,930.4	1,703.7	2,809.6	NA	79	(403)
Asphalt Concrete	-	-	68,581.8	NA	NA	3,912	0
Drywall	-	10,907.5	25,450.8	NA	NA	(289)	593
Wood Flooring	-	NA	1,680.5	15,124.7	NA	(12,821)	874
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Total Change in GHG Emissions ($MTCO_2E$): (363,439)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Removing annual emissions from	**76,513**	Passenger Vehicles
Conserving	**40,895,588**	Gallons of Gasoline
Conserving	**15,143,295**	Cylinders of Propane Used for Home Barbeques
Conserving	**1,949**	Railway Cars of Coal
	0.02089%	Annual CO_2 emissions from the U.S. transportation sector
	0.01797%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 1A
Prepared by: HDR
Project Period for this Analysis: 01/01/38 to 12/31/38

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (105,514)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	5,346.5	-	NA	305
Steel Cans	-	37,750.1	-	NA	2,153
Glass	-	23,919.7	-	NA	1,364
LDPE	NA	66,745.7	-	NA	3,807
PET	-	7,746.7	-	NA	442
Corrugated Containers	-	51,683.0	-	NA	(10,631)
Magazines/third-class mail	-	21,823.3	-	NA	1,081
Office Paper	-	11,299.0	-	NA	6,619
Dimensional Lumber	-	132,168.9	-	NA	(132,981)
Food Waste (non-meat)	NA	174,658.7	-	-	52,118
Yard Trimmings	NA	31,936.6	-	-	(10,706)
Mixed Paper (general)	-	157,661.3	-	NA	(33,128)
Mixed Metals	-	33,089.6	-	NA	1,887
Mixed Plastics	-	123,947.3	-	NA	7,069
Mixed Organics	NA	80,423.2	-	-	227
Mixed MSW	NA	80,515.3	-	NA	8,949
Carpet	-	96,160.5	-	NA	5,484
Personal Computers	-	22,600.2	-	NA	1,289
Concrete	-	36,516.9	NA	NA	2,083
Tires	-	10,734.5	-	NA	612
Asphalt Concrete	-	87,187.6	NA	NA	4,973
Drywall	-	46,222.0	NA	NA	(1,121)
Wood Flooring	NA	21,364.4	-	NA	(17,409)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (682,170)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	3,742.6	1,603.9	-	NA	(33,980)	(34,285)
Steel Cans	-	26,425.1	11,325.0	-	NA	(47,109)	(49,262)
Glass	-	-	23,919.7	-	NA	1,364	0
LDPE	-	NA	66,745.7	-	NA	3,807	0
PET	-	4,648.0	3,098.7	-	NA	(5,062)	(5,503)
Corrugated Containers	-	31,009.8	20,673.2	-	NA	(100,837)	(90,206)
Magazines/third-class mail	-	10,911.7	10,911.6	-	NA	(32,913)	(33,994)
Office Paper	-	-	11,299.0	-	NA	6,619	0
Dimensional Lumber	-	72,158.7	60,010.2	-	NA	(237,674)	(104,693)
Food Waste (non-meat)	-	NA	174,658.7	-	-	52,118	0
Yard Trimmings	NA	NA	15,968.3	15,968.3	-	(7,745)	2,961
Mixed Paper (general)	NA	16,444.4	141,216.9	-	NA	(87,590)	(54,462)
Mixed Metals	NA	16,544.8	16,544.8	-	NA	(71,387)	(73,274)
Mixed Plastics	NA	49,846.7	74,100.6	-	NA	(47,034)	(54,103)
Mixed Organics	NA	NA	80,423.2	-	-	227	0
Mixed MSW	NA	NA	80,515.3	-	NA	8,949	0
Carpet	-	20,470.5	75,690.0	-	NA	(43,910)	(49,394)
Personal Computers	-	11,300.1	11,300.1	-	NA	(27,709)	(28,998)
Concrete	NA	-	36,516.9	NA	NA	2,083	0
Tires	-	4,996.7	5,737.8	-	NA	(1,583)	(2,195)
Asphalt Concrete	-	-	87,187.6	NA	NA	4,973	0
Drywall	-	13,866.6	32,355.4	NA	NA	(368)	754
Wood Flooring	-	NA	21,364.4	-	NA	(17,409)	0
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Total Change in GHG Emissions ($MTCO_2E$): (576,656)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Removing annual emissions from	**121,401**	Passenger Vehicles
Conserving	**64,887,565**	Gallons of Gasoline
Conserving	**24,027,325**	Cylinders of Propane Used for Home Barbeques
Conserving	**3,092**	Railway Cars of Coal
	0.03315%	Annual CO_2 emissions from the U.S. transportation sector
	0.02851%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 2
Prepared by: HDR
Project Period for this Analysis: 01/01/38 to 12/31/38

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (105,514)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	5,346.5	-	NA	305
Steel Cans	-	37,750.1	-	NA	2,153
Glass	-	23,919.7	-	NA	1,364
LDPE	NA	66,745.7	-	NA	3,807
PET	-	7,746.7	-	NA	442
Corrugated Containers	-	51,683.0	-	NA	(10,631)
Magazines/third-class mail	-	21,823.3	-	NA	1,081
Office Paper	-	11,299.0	-	NA	6,619
Dimensional Lumber	-	132,168.9	-	NA	(132,981)
Food Waste (non-meat)	NA	174,658.7	-	-	52,118
Yard Trimmings	NA	31,936.6	-	-	(10,706)
Mixed Paper (general)	-	157,661.3	-	NA	(33,128)
Mixed Metals	-	33,089.6	-	NA	1,887
Mixed Plastics	-	123,947.3	-	NA	7,069
Mixed Organics	NA	80,423.2	-	-	227
Mixed MSW	NA	80,515.3	-	NA	8,949
Carpet	-	96,160.5	-	NA	5,484
Personal Computers	-	22,600.2	-	NA	1,289
Concrete	-	36,516.9	NA	NA	2,083
Tires	-	10,734.5	-	NA	612
Asphalt Concrete	-	87,187.6	NA	NA	4,973
Drywall	-	46,222.0	NA	NA	(1,121)
Wood Flooring	NA	21,364.4	-	NA	(17,409)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (28,309)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	267.4	-	5,079.1	NA	(2,143)	(2,447)
Steel Cans	-	1,887.5	-	35,862.6	NA	(58,996)	(61,149)
Glass	-	-	-	23,919.7	NA	1,188	(176)
LDPE	-	NA	-	66,745.7	NA	85,367	81,560
PET	-	-	-	7,746.7	NA	9,637	9,195
Corrugated Containers	-	5,168.3	-	46,514.7	NA	(38,422)	(27,790)
Magazines/third-class mail	-	-	-	21,823.3	NA	(7,443)	(8,524)
Office Paper	-	-	-	11,299.0	NA	(5,209)	(11,828)
Dimensional Lumber	-	13,216.9	-	118,952.0	NA	(101,198)	31,783
Food Waste (non-meat)	-	NA	-	174,658.7	-	(20,322)	(72,440)
Yard Trimmings	NA	NA	-	31,936.6	-	(4,784)	5,922
Mixed Paper (general)	NA	-	-	157,661.3	NA	(75,991)	(42,863)
Mixed Metals	NA	1,654.5	-	31,435.1	NA	(38,170)	(40,057)
Mixed Plastics	NA	-	-	123,947.3	NA	155,489	148,419
Mixed Organics	NA	NA	-	80,423.2	-	(10,655)	(10,883)
Mixed MSW	NA	NA	16,547.8	63,967.6	NA	1,416	(7,533)
Carpet	-	3,618.2	-	92,542.3	NA	93,837	88,353
Personal Computers	-	1,130.0	-	21,470.2	NA	(6,349)	(7,638)
Concrete	NA	-	36,516.9	NA	NA	2,083	0
Tires	-	-	1,838.6	8,895.9	NA	4,804	4,191
Asphalt Concrete	-	-	87,187.6	NA	NA	4,973	0
Drywall	-	-	46,222.0	NA	NA	(1,121)	0
Wood Flooring	-	NA	2,136.4	19,228.0	NA	(16,299)	1,111
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Total Change in GHG Emissions ($MTCO_2E$): 77,205

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Adding annual emissions from	**16,254**	Passenger Vehicles
Consuming	**8,687,440**	Gallons of Gasoline
Consuming	**3,216,887**	Cylinders of Propane Used for Home Barbeques
Consuming	**414**	Railway Cars of Coal
	0.00444%	Annual CO_2 emissions from the U.S. transportation sector
	0.00382%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 2A
Prepared by: HDR
Project Period for this Analysis: 01/01/38 to 12/31/38

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (107,798)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	5,346.5	-	NA	305
Steel Cans	-	37,750.1	-	NA	2,153
Glass	-	23,919.7	-	NA	1,364
LDPE	NA	26,698.3	-	NA	1,523
PET	-	7,746.7	-	NA	442
Corrugated Containers	-	51,683.0	-	NA	(10,631)
Magazines/third-class mail	-	21,823.3	-	NA	1,081
Office Paper	-	11,299.0	-	NA	6,619
Dimensional Lumber	-	132,168.9	-	NA	(132,981)
Food Waste (non-meat)	NA	174,658.7	-	-	52,118
Yard Trimmings	NA	31,936.6	-	-	(10,706)
Mixed Paper (general)	-	157,661.3	-	NA	(33,128)
Mixed Metals	-	33,089.6	-	NA	1,887
Mixed Plastics	-	123,947.3	-	NA	7,069
Mixed Organics	NA	80,423.2	-	-	227
Mixed MSW	NA	80,515.3	-	NA	8,949
Carpet	-	96,160.5	-	NA	5,484
Personal Computers	-	22,600.2	-	NA	1,289
Concrete	-	36,516.9	NA	NA	2,083
Tires	-	10,734.5	-	NA	612
Asphalt Concrete	-	87,187.6	NA	NA	4,973
Drywall	-	46,222.0	NA	NA	(1,121)
Wood Flooring	NA	21,364.4	-	NA	(17,409)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (655,999)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	3,742.6	-	1,603.9	NA	(33,979)	(34,284)
Steel Cans	-	26,425.1	-	11,325.0	NA	(65,308)	(67,461)
Glass	-	-	-	23,919.7	NA	1,188	(176)
LDPE	-	NA	-	26,698.3	NA	34,147	32,624
PET	-	4,648.0	-	3,098.7	NA	(1,383)	(1,825)
Corrugated Containers	-	31,009.8	-	20,673.2	NA	(106,507)	(95,875)
Magazines/third-class mail	-	10,911.7	-	10,911.6	NA	(37,175)	(38,256)
Office Paper	-	-	-	11,299.0	NA	(5,209)	(11,828)
Dimensional Lumber	-	72,158.7	-	60,010.2	NA	(211,966)	(78,984)
Food Waste (non-meat)	-	NA	-	174,658.7	-	(20,322)	(72,440)
Yard Trimmings	NA	NA	-	31,936.6	-	(4,784)	5,922
Mixed Paper (general)	NA	16,444.4	-	141,216.9	NA	(125,982)	(92,854)
Mixed Metals	NA	16,544.8	-	16,544.8	NA	(88,613)	(90,501)
Mixed Plastics	NA	57,949.6	-	65,997.7	NA	23,199	16,130
Mixed Organics	NA	NA	-	80,423.2	-	(10,655)	(10,883)
Mixed MSW	NA	NA	16,547.7	63,967.6	NA	1,416	(7,533)
Carpet	-	20,470.5	-	75,690.0	NA	35,494	30,010
Personal Computers	-	11,300.1	-	11,300.1	NA	(30,203)	(31,492)
Concrete	NA	-	36,516.9	NA	NA	2,083	0
Tires	-	4,996.7	1,838.6	3,899.2	NA	255	(358)
Asphalt Concrete	-	-	87,187.6	NA	NA	4,973	0
Drywall	-	13,866.6	32,355.4	NA	NA	(368)	754
Wood Flooring	-	NA	2,136.4	19,228.0	NA	(16,299)	1,111
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Total Change in GHG Emissions ($MTCO_2E$): (548,201)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Removing annual emissions from	**115,411**	Passenger Vehicles
Conserving	**61,685,734**	Gallons of Gasoline
Conserving	**22,841,713**	Cylinders of Propane Used for Home Barbeques
Conserving	**2,939**	Railway Cars of Coal
	0.03151%	Annual CO_2 emissions from the U.S. transportation sector
	0.02710%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 3
Prepared by: HDR
Project Period for this Analysis: 01/01/38 to 12/31/38

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (107,798)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	5,346.5	-	NA	305
Steel Cans	-	37,750.1	-	NA	2,153
Glass	-	23,919.7	-	NA	1,364
LDPE	NA	26,698.3	-	NA	1,523
PET	-	7,746.7	-	NA	442
Corrugated Containers	-	51,683.0	-	NA	(10,631)
Magazines/third-class mail	-	21,823.3	-	NA	1,081
Office Paper	-	11,299.0	-	NA	6,619
Dimensional Lumber	-	132,168.9	-	NA	(132,981)
Food Waste (non-meat)	NA	174,658.7	-	-	52,118
Yard Trimmings	NA	31,936.6	-	-	(10,706)
Mixed Paper (general)	-	157,661.3	-	NA	(33,128)
Mixed Metals	-	33,089.6	-	NA	1,887
Mixed Plastics	-	123,947.3	-	NA	7,069
Mixed Organics	NA	80,423.2	-	-	227
Mixed MSW	NA	80,515.3	-	NA	8,949
Carpet	-	96,160.5	-	NA	5,484
Personal Computers	-	22,600.2	-	NA	1,289
Concrete	-	36,516.9	NA	NA	2,083
Tires	-	10,734.5	-	NA	612
Asphalt Concrete	-	87,187.6	NA	NA	4,973
Drywall	-	46,222.0	NA	NA	(1,121)
Wood Flooring	NA	21,364.4	-	NA	(17,409)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (655,999)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	3,742.6	-	1,603.9	NA	(33,979)	(34,284)
Steel Cans	-	26,425.1	-	11,325.0	NA	(65,308)	(67,461)
Glass	-	-	-	23,919.7	NA	1,188	(176)
LDPE	-	NA	-	26,698.3	NA	34,147	32,624
PET	-	4,648.0	-	3,098.7	NA	(1,383)	(1,825)
Corrugated Containers	-	31,009.8	-	20,673.2	NA	(106,507)	(95,875)
Magazines/third-class mail	-	10,911.7	-	10,911.6	NA	(37,175)	(38,256)
Office Paper	-	-	-	11,299.0	NA	(5,209)	(11,828)
Dimensional Lumber	-	72,158.7	-	60,010.2	NA	(211,966)	(78,984)
Food Waste (non-meat)	-	NA	-	174,658.7	-	(20,322)	(72,440)
Yard Trimmings	NA	NA	-	31,936.6	-	(4,784)	5,922
Mixed Paper (general)	NA	16,444.4	-	141,216.9	NA	(125,982)	(92,854)
Mixed Metals	NA	16,544.8	-	16,544.8	NA	(88,613)	(90,501)
Mixed Plastics	NA	57,949.6	-	65,997.7	NA	23,199	16,130
Mixed Organics	NA	NA	-	80,423.2	-	(10,655)	(10,883)
Mixed MSW	NA	NA	16,547.8	63,967.6	NA	1,416	(7,533)
Carpet	-	20,470.5	-	75,690.0	NA	35,494	30,010
Personal Computers	-	11,300.1	-	11,300.1	NA	(30,203)	(31,492)
Concrete	NA	-	36,516.9	NA	NA	2,083	0
Tires	-	4,996.7	1,838.6	3,899.2	NA	255	(358)
Asphalt Concrete	-	-	87,187.6	NA	NA	4,973	0
Drywall	-	13,866.6	32,355.4	NA	NA	(368)	754
Wood Flooring	-	NA	2,136.4	19,228.0	NA	(16,299)	1,111
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Total Change in GHG Emissions ($MTCO_2E$): (548,201)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Removing annual emissions from	**115,411**	Passenger Vehicles
Conserving	**61,685,732**	Gallons of Gasoline
Conserving	**22,841,713**	Cylinders of Propane Used for Home Barbeques
Conserving	**2,939**	Railway Cars of Coal
	0.03151%	Annual CO_2 emissions from the U.S. transportation sector
	0.02710%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 4
Prepared by: HDR
Project Period for this Analysis: 01/01/38 to 12/31/38

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (138,690)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	5,346.5	-	NA	305
Steel Cans	-	37,750.1	-	NA	2,153
Glass	-	23,919.7	-	NA	1,364
LDPE	NA	66,745.7	-	NA	3,807
PET	-	7,746.7	-	NA	442
Corrugated Containers	-	47,548.4	-	NA	(9,781)
Magazines/third-class mail	-	21,823.3	-	NA	1,081
Office Paper	-	9,039.2	-	NA	5,295
Dimensional Lumber	-	130,383.2	-	NA	(131,185)
Food Waste (non-meat)	NA	52,397.6	-	-	15,635
Yard Trimmings	NA	30,339.8	-	-	(10,171)
Mixed Paper (general)	-	148,090.7	-	NA	(31,117)
Mixed Metals	-	33,089.6	-	NA	1,887
Mixed Plastics	-	123,947.3	-	NA	7,069
Mixed Organics	NA	72,380.8	-	-	205
Mixed MSW	NA	75,655.7	-	NA	8,409
Carpet	-	96,160.5	-	NA	5,484
Personal Computers	-	22,600.2	-	NA	1,289
Concrete	-	36,516.9	NA	NA	2,083
Tires	-	10,734.5	-	NA	612
Asphalt Concrete	-	87,187.6	NA	NA	4,973
Drywall	-	46,222.0	NA	NA	(1,121)
Wood Flooring	NA	21,364.4	-	NA	(17,409)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (715,346)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	3,742.6	1,603.9	-	NA	(33,980)	(34,285)
Steel Cans	-	26,425.1	11,325.0	-	NA	(47,109)	(49,262)
Glass	-	-	23,919.7	-	NA	1,364	0
LDPE	-	NA	66,745.7	-	NA	3,807	0
PET	-	4,648.0	3,098.7	-	NA	(5,062)	(5,503)
Corrugated Containers	-	31,009.8	16,538.6	-	NA	(99,987)	(90,206)
Magazines/third-class mail	-	10,911.7	10,911.6	-	NA	(32,913)	(33,994)
Office Paper	-	-	9,039.2	-	NA	5,295	0
Dimensional Lumber	-	72,158.7	58,224.5	-	NA	(235,877)	(104,693)
Food Waste (non-meat)	-	NA	52,397.6	-	-	15,635	0
Yard Trimmings	NA	NA	14,371.5	15,968.3	-	(7,210)	2,961
Mixed Paper (general)	NA	16,444.4	131,646.3	-	NA	(85,579)	(54,462)
Mixed Metals	NA	16,544.8	16,544.8	-	NA	(71,387)	(73,274)
Mixed Plastics	NA	49,846.7	74,100.6	-	NA	(47,034)	(54,103)
Mixed Organics	NA	NA	72,380.8	-	-	205	0
Mixed MSW	NA	NA	75,655.7	-	NA	8,409	0
Carpet	-	20,470.5	75,690.0	-	NA	(43,910)	(49,394)
Personal Computers	-	11,300.1	11,300.1	-	NA	(27,709)	(28,998)
Concrete	NA	-	36,516.9	NA	NA	2,083	0
Tires	-	4,996.7	5,737.8	-	NA	(1,583)	(2,195)
Asphalt Concrete	-	-	87,187.6	NA	NA	4,973	0
Drywall	-	13,866.6	32,355.4	NA	NA	(368)	754
Wood Flooring	-	NA	21,364.4	-	NA	(17,409)	0
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Total Change in GHG Emissions ($MTCO_2E$): (576,656)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…		
Removing annual emissions from	**121,401**	Passenger Vehicles
Conserving	**64,887,565**	Gallons of Gasoline
Conserving	**24,027,325**	Cylinders of Propane Used for Home Barbeques
Conserving	**3,092**	Railway Cars of Coal
	0.03315%	Annual CO_2 emissions from the U.S. transportation sector
	0.02851%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

GHG Emissions Analysis -- Summary Report

Version 13

GHG Emissions Waste Management Analysis for Metro Scenario 5
Prepared by: HDR
Project Period for this Analysis: 01/01/38 to 12/31/38

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): (127,181)

Commodity	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$
Aluminum Cans	-	5,346.5	-	NA	305
Steel Cans	-	37,750.1	-	NA	2,153
Glass	-	23,919.7	-	NA	1,364
LDPE	NA	66,745.7	-	NA	3,807
PET	-	7,746.7	-	NA	442
Corrugated Containers	-	51,476.3	-	NA	(10,589)
Magazines/third-class mail	-	21,714.2	-	NA	1,076
Office Paper	-	11,186.0	-	NA	6,553
Dimensional Lumber	-	132,079.6	-	NA	(132,891)
Food Waste (non-meat)	NA	101,302.1	-	-	30,229
Yard Trimmings	NA	31,617.2	-	-	(10,599)
Mixed Paper (general)	-	157,265.0	-	NA	(33,045)
Mixed Metals	-	33,089.6	-	NA	1,887
Mixed Plastics	-	123,947.3	-	NA	7,069
Mixed Organics	NA	80,021.0	-	-	226
Mixed MSW	NA	80,272.3	-	NA	8,922
Carpet	-	96,160.5	-	NA	5,484
Personal Computers	-	22,600.2	-	NA	1,289
Concrete	-	36,516.9	NA	NA	2,083
Tires	-	10,734.5	-	NA	612
Asphalt Concrete	-	87,187.6	NA	NA	4,973
Drywall	-	46,222.0	NA	NA	(1,121)
Wood Flooring	NA	21,364.4	-	NA	(17,409)
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (577,020)

Commodity	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	3,742.6	-	1,603.9	NA	(33,979)	(34,284)
Steel Cans	-	26,425.1	-	11,325.0	NA	(65,308)	(67,461)
Glass	-	-	-	23,919.7	NA	1,188	(176)
LDPE	-	NA	-	66,745.7	NA	85,367	81,560
PET	-	4,648.0	-	3,098.7	NA	(1,383)	(1,825)
Corrugated Containers	-	31,009.8	-	20,466.5	NA	(106,408)	(95,819)
Magazines/third-class mail	-	10,911.6	-	10,802.6	NA	(37,137)	(38,213)
Office Paper	-	-	-	11,186.0	NA	(5,157)	(11,710)
Dimensional Lumber	-	72,158.7	-	59,920.9	NA	(211,914)	(79,022)
Food Waste (non-meat)	-	NA	-	101,302.1	-	(11,787)	(42,015)
Yard Trimmings	NA	NA	-	31,617.2	-	(4,737)	5,862
Mixed Paper (general)	NA	16,444.4	-	140,820.6	NA	(125,791)	(92,746)
Mixed Metals	NA	16,544.8	-	16,544.8	NA	(88,613)	(90,501)
Mixed Plastics	NA	49,846.7	-	74,100.6	NA	41,697	34,628
Mixed Organics	NA	NA	-	80,021.0	-	(10,602)	(10,828)
Mixed MSW	NA	NA	19,493.4	60,778.9	NA	1,764	(7,158)
Carpet	-	20,470.5	-	75,690.0	NA	35,494	30,010
Personal Computers	-	11,300.1	-	11,300.1	NA	(30,203)	(31,492)
Concrete	NA	-	36,516.9	NA	NA	2,083	0
Tires	-	4,996.7	2,165.9	3,571.9	NA	100	(512)
Asphalt Concrete	-	-	87,187.6	NA	NA	4,973	0
Drywall	-	13,866.6	32,355.4	NA	NA	(368)	754
Wood Flooring	-	NA	2,136.4	19,228.0	NA	(16,299)	1,111
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						0	0
						0	0
						0	0
						0	0
						0	0

Total Change in GHG Emissions ($MTCO_2E$): (449,839)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…

Removing annual emissions from	**94,703**	Passenger Vehicles
Conserving	**50,617,651**	Gallons of Gasoline
Conserving	**18,743,294**	Cylinders of Propane Used for Home Barbeques
Conserving	**2,412**	Railway Cars of Coal
	0.02586%	Annual CO_2 emissions from the U.S. transportation sector
	0.02224%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks -- available on the Internet at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

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