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Metro | Agenda

Meeting: Solid Waste Advisory Committee (SWAC)
Date: Wednesday, May 14, 2014
Time: 10 a.m. to 12 p.m. (noon)
Place: Metro, Council Chambers

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10 AM	**1.**		**CALL TO ORDER AND DECLARATION OF A QUORUM**	**Matt Korot, Chair**
10:02 AM	**2.**		**COMMENTS FROM THE CHAIR AND COMMITTEE MEMBERS**	
10:07 AM	**3.**	**	**CONSIDERATION OF SWAC MINUTES FOR MARCH 12, 2014**	
10:10 AM	**4.**		**DEMOGRAPHIC SURVEY OF METRO ADVISORY COMMITTEE MEMBERS**	**Marv Fjordbeck, Metro**
10:15 AM	**5.**	#	**SOLID WASTE ROADMAP SEQUENCING** • *<u>Purpose</u>*: Provide context for the discussion of Long-Term Options for Solid Waste Management. • *<u>Outcome</u>*: SWAC members are re-grounded in the broader context of the Solid Waste Roadmap by reviewing the current schedule of Metro Council engagements on Roadmap topics.	**Tom Chaimov, Metro**
10:30 AM	**6.**	**	**SOLID WASTE ROADMAP: LONG-TERM OPTIONS FOR SOLID WASTE MANAGEMENT** • *<u>Purpose</u>*: To inform SWAC of staff's preliminary analysis of Long-Term Management options for garbage in our region and to solicit SWAC's input on what additional information and analysis is needed, as well as how current and future programs and policies may impact the implementation of any options. • *<u>Outcome</u>*: Input from SWAC that will be shared with the Metro Council and will help inform further analysis and development of options.	**Rob Smoot, Metro**
11:50 AM	**7.**		**CITIZEN COMMUNICATIONS TO SWAC AGENDA ITEMS**	
11:55 AM	**8.**		**PREVIEW OF THE NEXT MEETING'S AGENDA AND FINAL COMMENTS**	**Matt Korot, Chair**
12 PM	**9.**		**ADJOURN**	

Continued on back…

* Material available on the Metro website.
** Material will be distributed in advance of the meeting.
\# Material will be distributed at the meeting.

Upcoming SWAC Meetings:

- Wednesday, June 11 from 10 a.m. to 12 p.m. (noon) at the Metro Regional Center
- Wednesday, July 9 from 10 a.m. to 12 p.m. (noon) at the Metro Regional Center

For agenda and schedule information, call Aidan Gronauer at 503-797-1651, e-mail: aidan.gronauer@oregonmetro.gov.
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Metro | Meeting minutes

Meeting: Solid Waste Advisory Committee (SWAC)

Date: March 12, 2014

Place: Metro Regional Center, Room 401

Members present
Amy Pepper, City of Troutdale
Theresa Koppang, Washington County
Dan Blue, City of Gresham
Bruce Walker, City of Portland
Alando Simpson, City of Roses Disposal & Recycling
Susan Millhauser, City of Lake Oswego
Kathy Kaatz, City of Tualatin
Keith Ristau, Far West Fibers
Mike Leichner, Pride Disposal
Leslie Kochan, Oregon Dept. of Environmental Quality
Matt Korot, Metro

Members Absent
Scott Keller, City of Beaverton
Amy Roth, Association of Oregon Recyclers
Paul Ehinger (alternate), Metro

1. CALL TO ORDER AND DECLARATION OF A QUORUM

Chair Matt Korot called the meeting to order and declared a quorum.

2. COMMENTS FROM THE CHAIR AND COMMITTEE MEMBERS

Chair Korot reviewed the meeting agenda. Then, as follow-up to last month's meeting, he reported that the Metro South Transfer Station project held its last stakeholder meeting on February 26. He sent the staff PowerPoint presentation from that meeting to SWAC members yesterday. It is also available on the Metro web site at www.oregonmetro.gov/metrosouth.

Chair Korot then shared a question that Alando Simpson asked yesterday about that stakeholder meeting: was there a consensus at the meeting on which options were most desirable. Chair Korot reported that Chuck Geyer, the project manager, had replied that option 1, with the building extension to the north and filling in the current load-out area was ranked highest. Option 3, with the off-site facility was a close second. At the request of stakeholders, Metro will re-look at Option 3 using a smaller footprint for the off-site facility.

3. CONSIDERATION OF SWAC MINUTES FOR FEB. 12, 2014

Approved with adding Susan Millhauser as present.

4. CHANGES TO THE COMMUNITY ENHANCEMENT FEE PROGRAM

Roy Brower began the presentation by explaining that the project that he and Bill Metzler will discuss entails a review of Metro's Solid Waste Community Enhancement Program and recommendations to Council for changes. He then explained that the current program is based on provisions in state statute and summarized the amount collected per ton, how the funds may be used and how the program is administered. Mr. Brower said that the program warrants a review because the solid waste system had changed significantly since the statute was adopted in 1987 and associated Metro Code almost 25 years ago. The code no longer is useful to decision-makers.

Mr. Brower then reviewed the facility types eligible and ineligible for enhancement fees under state statute. He noted that "hybrid" facilities, those that carry-out multiple activities are not specifically addressed in statute or Metro code. One option for addressing these facilities could be to base fees on the waste type and activities themselves, rather than the facility as a whole. He then listed the four Metro-region facilities (St. John's landfill, Metro South Transfer Station, Metro Central Transfer Station, Forest Grove Transfer Station) currently participating in the community enhancement program and described how each facility's program is administered, as well as those that are eligible, but not participating (Pride Disposal, Troutdale Transfer Station, WRI, Recology Suttle Road, Columbia Biogas, if built).

Mr. Brower summarized the key staff recommendations so far:

- Continue to rely on the framework established in state law
- List the program eligible solid waste facility activities
- Establish a process for starting programs in coordination with local governments
- Provide options for administering the program
- Increase the enhancement fee from $0.50 to $1.00 and include a process for considering future adjusts if the fee level is adjusted in statute

Mr. Brower then called out the key questions on which he and Mr. Metzler desired SWAC members' input:

1. Should the program be applied uniformly at all eligible facilities?
2. Which administrative models should remain under consideration?
3. Should a local government imposed tonnage tax on waste at a facility influence Metro's decision to collect a fee and establish a program?

Mr. Brower closed by reviewing the next steps in the project as determined at this time:

- April 15 - Council Work Session
- April 28 – Metro Policy Advisory Committee
- August – Ordinance to Council (1st reading)*
- September – Council public hearing*
- July 2015 – New program/fees effective

**Update since the meeting: these steps have been moved to October.*

Key Questions and Answers from SWAC members during the presentation

Mike Leichner: How is "area around site" defined?
Mr. Brower: Each committee defines that, but for smaller communities it may be the city limits.

Mr. Leichner: Can a neighboring community have any input on the fee, e.g., Hillsboro to Forest Grove?
Mr. Brower and Mr. Metzler: The program is intended to recover fees for exactly that reason: all users pay for the privilege of using a facility hosted by another jurisdiction. Neighboring jurisdictions could have representatives on the committee.

Leslie Kochan: Why are the other identified facilities not currently paying?
Mr. Metzler: Because most of these began as material recovery facilities that evolved to become transfer stations. We didn't have clear code direction; so didn't put program in place.

Theresa Koppang: Is the assumption that facilities outside of the region that take Metro waste would have to do their own program?
Mr. Metzler: Yes, under state statute.

Bruce Walker: My understanding is that yard debris–only composting facilities are eligible.
Mr. Brower: True, under state law. We are not proposing to included them at this time, but could consider later if Council desired.

Mr. Walker: Yard debris facilities can generate odors. Can flexibility be allowed to give LGs right to include them?
Roy: I don't disagree with you, but we don't want to address now. We want to start with higher level, multipurpose facilities and transfer stations.
Mr. Metzler: If they took food waste, they would be included. Bringing in all yard debris facilities would make the program very large.
Mr. Brower: We are not prepared to take on a bigger scope at this time.
Mr. Metzler: We are trying to maintain consistency with state law and maintain a level playing field.

Ms. Kochan: If there was a stinky yard debris facility in Portland, could the city invoke state law to apply the fee itself?
Mr. Metzler: Yes, keeping in mind that state law requires that a local government already be collecting another fee.
Mr. Brower: To note, this does not replace enforcement for violation

Alando Simpson: Could two government entities (Portland & Metro) both collect fees for community enhancement?
Mr. Metzler: No, that is prohibited by state law.

Comments from SWAC members regarding question #1

Susan Millhauser: How would fees impact rates?
Mr. Metzler: About $0.75/year/household ($0.50-$1.00 range) with a different impact on commercial customers.

Amy Pepper: What would Metro do if a fee was applied to a facility and the host local government wanted nothing to do with it?
Mr. Metzler: Establish a Metro-administered community-based committee.

Mr. Leichner: If there is not uniform application, then a local government could decide to keep the $0.75 in rate-payers pockets. $0.75 won't affect competition; a truck running at a cost of $1.00/minute can't go very far on that. Given pressures on rate, the fee should not be applied uniformly, but left to local governments to decide.

Mr. Blue: Uniformity makes sense, but first choice should go to local governments. I recognize that Gresham is a community of 105,000 and not doing anything for impact on Troutdale.
Mr. Leichner: Most facilities are in industrial zone, so really not an impact on traffic because that's part of being in the neighborhood.
Ms. Kochan: There needs to be a consistent way of compensating communities that have facilities in their backyards.

<u>Comments from SWAC members regarding question #2</u>
Mr. Brower: Should any of those options fall off? Should any be sure to go forward?
Mr. Metzler: The first two options work well. We are unsure about the last.

Ms. Pepper: Does Metro hold the money? How is it distributed?
Mr. Brower: For Oregon City and Forest Grove we remit quarterly to the local government.

Mr. Blue: My preference is to maintain the Metro-administered and IGA options, but give local governments the ability to enter into agreements with neighborhood associations or facilities. Keep the relationship between Metro & local governments.

Mr. Walker: If a facility has a successful partnership with a neighborhood association, why does a local government have to get involved?
Mr. Blue: From my experience and thinking of long-term, we want some controls and authority relative to neighborhood association use of funds.

Keith Ristau: Do all eligible facilities have a neighborhood association?
Mr. Brower: Not necessarily.

Ms. Millhauser: I echo what Mr. Blue says. Would also add that from my experience changes in neighborhood association leadership result in a lack of continuity.

Kathy Kaatz: the City of Tualatin would want to be involved regarding type of projects.

<u>Comments from SWAC members regarding question #3</u>
Mr. Metzler: By example, this question is asking how the fee would apply in a community like Troutdale that has a tonnage tax in place.
Ms. Pepper: We collect $0.65/ton tax. At the time, Council discussed whether to make a community enhancement fee or a tax and selected a tax that goes to the general fund.

Mr. Blue: Regardless of whether a local government collects a tax, there should be uniform application of a community enhancement fee program.
Ms. Koppang: I agree.

Ms. Pepper: If Metro limited itself from collecting a fee where a tax is in place, could a local government invoke state law to put a community enhancement fee in place?
Mr. Metzler: Yes

5. CITIZEN COMMUNICATIONS TO SWAC AGENDA ITEMS

If the fee is applied at a transfer station that briefly manages material, will another fee be applied on the facility that actually processes the material? All of this affects rates and can impact programs, particularly budding ones like food waste.
Mr. Metzler: Good point. It would be allowed, but this is worthy of discussion.

What about administration fees?
Mr. Metzler: We will recommend to Council that a certain amount or percentage be allowed.

Facility administration or neighborhood option could be problematic if there is a difficult relationship with the facility.

What about differing fees by whether industrial or non-industrial area is affected?
Mr. Walker: The Columbia Biogas example shows how this is hard. It is in industrial but ¼ mile from residential.

The issue came up a couple of years ago about communities saying they don't host a facility, but are impacted by truck traffic.
Mr. Brower: For this, we would rely on a committee's designation of impact area.

6. PREVIEW OF THE NEXT MEETING'S AGENDA AND FINAL COMMENTS

Chair Korot said that a discussion of Metro authorities relative to the Solid Waste Roadmap may be held at the April meeting. If not, we will next meet in May.

7. ADJOURN

Chair Korot adjourned the meeting at 11:55.

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

HDR

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

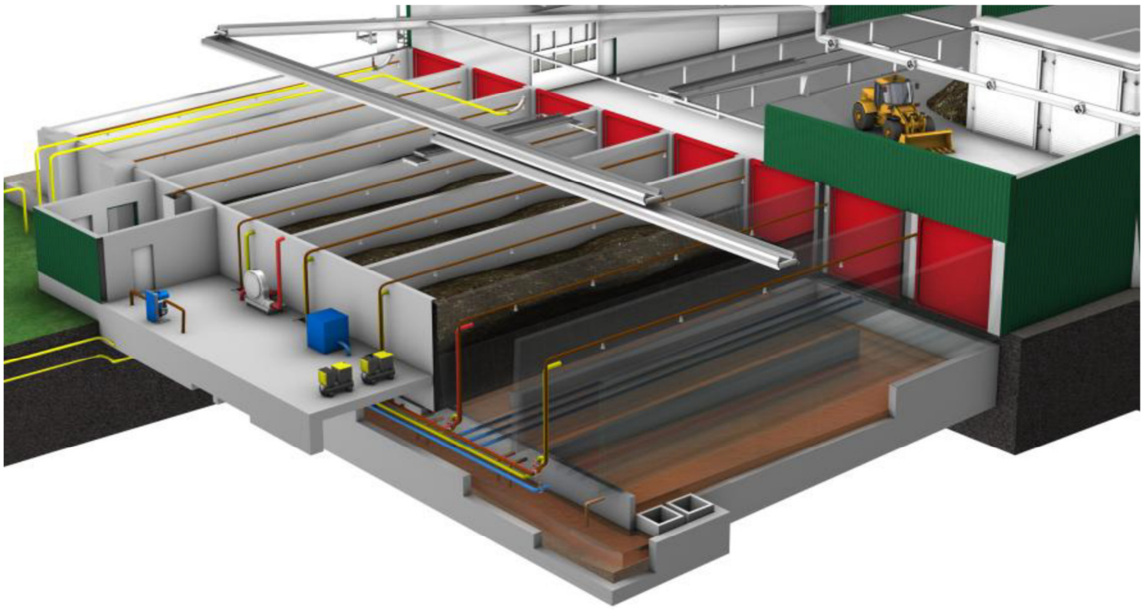

**Illustration courtesy of Kompoferm*

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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14 Waste Management Technologies

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

- **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

14 Waste Management Technologies Explained

1.0 Landfill

Modern landfills are lined and managed to prevent the escape of undesirable materials, such as wind-blown debris, liquid leachate and landfill gas. Landfills can be used for disposal of any non-hazardous material. Gas generated at most landfills is collected and used to produce electricity.

2.0 Thermal Technologies

2.1 Direct Combustion

Direct combustion is burning the garbage to generate heat. The heat that is generated, usually between 1,500 and 3,000 degrees Fahrenheit, is used to boil water, which generates steam. The steam is used to drive turbine generators that produce electricity. In addition, the steam can also be used for heating local or nearby buildings or providing steam energy to an industrial process.

Aerial View of a Direct Combustion in Mullverwertung Rugenberger Damm (MVR) Facility in Hamburg, Germany

2.2 Gasification

Gasification is a process that cooks garbage that is first extensively processed. Garbage is screened, sorted, ground up and mixed to make a uniform feedstock. Often, non-burnable items (glass, metal, etc.) are removed during this pre-processing operation because they reduce the heat potential of the feedstock. The cooking process takes place at temperatures above 1,800 degrees Fahrenheit, with controlled amounts of oxygen to prevent combustion. Without true combustion, a gas is produced containing mostly carbon monoxide, hydrogen, and methane, which can be further “cleaned” or “scrubbed” to a suitable grade for use in an engine to generate electricity or as a feedstock to produce chemicals.

*HDR Photo of TRP Gasification Plant in Tokyo, Japan

2.3 Plasma Arc Gasification

In Plasma Arc gasification, garbage (after extensive processing) is heated to about 4,500 degrees Fahrenheit and then exposed to a very-high-temperature (5,000 to 12,000 degrees Fahrenheit) electric arc that is generated between carbon electrodes. This process breaks the garbage down into simpler compounds forming a mixture of gases and a liquid slag. The gases can be processed/purified for uses in chemical manufacturing or could be used on site to generate steam or electricity. The slag could be used for daily cover and aggregate at a landfill.


Computer Drawing of the Proposed Plasco Energy Plasma Arc Gasification Facility in Ottawa, Ontario

2.4 Pyrolysis

Pyrolysis is a process whereby material such as wood, carpet, and plastic are converted to gases, liquids, and solid fuels (e.g. charcoal from wood) under high temperatures (700° to 1,500°F) and pressure, with no (or nearly no) oxygen. Pyrolysis is similar to the Gasification process, but requires even more preprocessing to separate out specific materials, such as film plastics, and then create a uniformly sized and mixed feedstock from that separated material. This process does not work with a mixture of varying materials such as is found in garbage.

* Photo of Pyrolysis Demonstration Facility at the IES Romoland Pyrolysis Facility, Romoland, California

3.0 Biological Technologies

3.1 Aerobic Composting

Aerobic composting is generally an open-air operation where green material (yard debris, wood and food waste) is placed in elongated piles called windrows that are kept aerated by physically turning the piles with a machine or by ensuring that air flows through the piles. Generally, within 30-60 days the green material breaks down, leaving a rich soil amendment that can be used in farms and gardens. Composted garbage could not be used as soil amendment, it would likely be sent to a landfill.

Example of Windrow Aerobic Composting

3.2 Anaerobic Digestion (AD)

Anaerobic Digestion (AD) is a series of processes in which bacteria act to break down biodegradable material in the absence of oxygen to produce a biogas (primarily methane and carbon dioxide). The biogas can be cleaned for use in a direct combustion engine to produce electricity, cleaned and compressed for vehicle fuel or cleaned for sale into a local natural gas pipeline.

Anaerobic digestion can be categorized into two types of processes:

- Wet systems that grind the feedstock (mostly food wastes from commercial sources, e.g. grocers, restaurants, etc.) into a liquid slurry that is then piped into tank or lagoon-type digesters. This process would not work for garbage.
- Dry systems, often referred to as Dry Fermentation, have higher tolerance for contamination and do not require pre-processing of the feedstock. Instead, garbage is piled in closed “bunkers” (sealed air tight) and sprinkled with bacteria-rich liquid to initiate digestion, which will produce a methane-rich gas. The gas is used in an engine to produce electricity. After digestion the garbage is typically sent to landfill due to contamination.

*HDR Photo of Wet system, the University of California Davis Anaerobic Phased Solids (APS) Digester

Example of Bunker type - Dry Fermentation Process Photo inside of San Jose ZWED facility

3.3 Mechanical Biological Treatment (MBT)

Mechanical Biological Treatment (MBT) is a type of process that combines a sorting facility (e.g. Advanced Materials Recovery described below) with composting or anaerobic digestion. Typical products of this process are electricity generation and landfill.

4.0 Chemical Technologies

4.1 Hydrolysis

The Hydrolysis process involves the reaction of water and fiber-based substances (e.g., paper, yard waste, etc.) in garbage with a strong acid (e.g., sulfuric acid) to produce sugars. These sugars are fermented to produce an alcohol that is then distilled to produce a liquid fuel.

4.2 Catalytic and Thermal Depolymerization

Depolymerization targets plastics, waste oils, grease, fats and animal parts and converts them into a crude oil-like substance, which can be further processed into fuels such as gasoline or diesel. There are two depolymerization methods, thermal and catalytic.

Thermal Depolymerization

- Thermal depolymerization utilizes relatively high temperatures (1,000° to 1,400° Fairenheit) and pressure to produce crude oil.

Catalytic Depolymerization

- Catalytic depolymerization uses lower temperatures (500° to 700°F) and pressures, but adds a chemical catalyst to aid in the process of breaking down the feedstock into crude. Zeolite, silica-alumina, and bauxite are common types of catalysts used in the process. The plastics, synthetic-fiber components and water in the feedstock react with the catalyst under pressure and heat to produce a crude oil.

4.3 Waste-to-Fuel Technology

The generation of liquid fuels from garbage is an evolving technology and reportedly involves the use of a thermal conversion process to generate a synthetic gas (“syngas”), followed by the use of a chemical process to convert the syngas into a fuel.

5.0 Mechanical Technologies

5.1 Autoclave/Steam Classification

Autoclaves are large rotating vessels that have steam injected and are kept at a high temperature and pressure over a 2 to 3 hour period. Autoclaving is classified as a “mechanical” process that is used to separate paper like material from other portions of the garbage to be recovered for further processing for pulp, digestion to fuel, or drying for combustion. The remaining garbage is landfilled

Example of an Autoclave *HDR photo of Autoclave Unit, Salinas, California

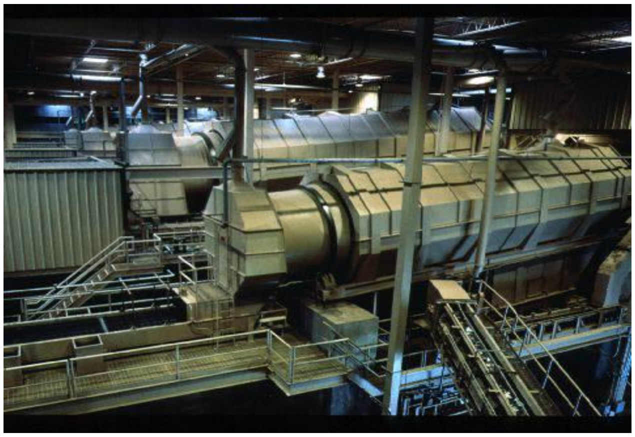
5.2 Advanced Materials Recovery

An Advanced Materials Recovery Facility (AMRF) is a specialized plant that receives, separates and prepares materials for marketing to end-user manufacturers. The function of advanced materials recovery is to extract recyclables and reusable materials from garbage and not to process curbside recyclables. The by-product or residual will be what is left after removing what are typically smaller or harder-to-recover pieces of marketable materials. The residual can be used as a feedstock for other processes (thermal, chemical or biological). These types of advanced facilities usually recover about 10 to 25 percent of incoming garbage, depending on the facility design, performance, and the nature of what is being processed.

Republic Services' Newby Island materials recovery facility in Milpitas CA

5.3 Refuse Derived Fuel (RDF) Production

An RDF processing system prepares garbage by using shredding, screening, air classifying and other equipment to produce a fuel product for combustion, either on-site or off or for use in another conversion technology that requires a prepared feedstock. RDF consists largely of combustible components of garbage such as plastics, textiles, paper and wood waste. RDF facilities may be developed to supply coal-equivalent fuel for coal burning power plants or other industrial processes.



*HDR Photo of Southeastern Public Service Authority, VA, RDF Processing Facility

*HDR photo of Rennerod, Germany Facility, Stockpiled RDF

Landfill

Modern landfills are lined and managed to prevent the escape of undesirable materials, such as wind-blown debris, liquid leachate and landfill gas. Landfills can be used for disposal of any non-hazardous material. Gas generated at most landfills is collected and used to produce electricity.

Direct Combustion

Direct combustion is burning the garbage to generate heat. The heat that is generated, usually between 1,500 and 3,000 degrees Fahrenheit, is used to boil water, which generates steam. The steam is used to drive turbine generators that produce electricity. In addition, the steam can also be used for heating local or nearby buildings or providing steam energy to an industrial process.

Gasification

Gasification is a process that cooks garbage that is first extensively processed. Garbage is screened, sorted, ground up and mixed to make a uniform feedstock. Often, non-burnable items (glass, metal, etc.) are removed during this pre-processing operation because they reduce the heat potential of the feedstock. The cooking process takes place at temperatures above 1,800 degrees Fahrenheit, with controlled amounts of oxygen to prevent combustion. Without true combustion, a gas is produced containing mostly carbon monoxide, hydrogen, and methane, which can be further "cleaned" or "scrubbed" to a suitable grade for use in an engine to generate electricity or as a feedstock to produce chemicals.

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Pyrolysis

Pyrolysis is a process whereby material such as wood, carpet, and plastic are converted to gases, liquids, and solid fuels (e.g. charcoal from wood) under high temperatures (700° to 1500°F) and pressure, with no (or nearly no) oxygen. Pyrolysis is similar to the Gasification process, but requires even more preprocessing to separate out specific materials, such as film plastics, and then create a uniformly sized and mixed feedstock from that separated material. This process does not work with a mixture of varying materials such as is found in garbage.

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Dry systems, often referred to as Dry Fermentation, have a higher tolerance for contamination and do not require pre-processing of the feedstock. Instead, garbage is piled in closed "bunkers" (sealed air tight) and sprinkled with bacteria-rich liquid to initiate digestion, which will produce a methane rich gas. The gas used in an engine to produce electricity. After digestion the garbage is typically sent to landfill due to contamination. (The entire process takes about 30 days at the ZWED facility in San Jose.)

Mechanical Biological Treatment (MBT)
Mechanical Biological Treatment (MBT) is a type of process that combines a sorting facility (e.g. Advanced Materials Recovery described below) with composting or anaerobic digestion. Typical products of this process are electricity generation and landfill.

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Thank you for being here today

Presenter: Rob Smoot, a senior engineer for the Solid Waste division of Parks and Environmental Services here at Metro, a licensed Chemical Engineer with over 27 years working in the Solid Waste field.

Purpose: To inform you of Metro's long term management of garbage project and ask for your feedback.

Duration: about 30 minutes,

Outline: Describe the Technologies and the evaluation process then explain how scenarios were selected, what has been learned and what information is still being researched. Field questions during the presentation and finish with an exercise to elicit feedback.

Initial List of Technologies

- Hydrolysis
- Catalytic & Thermal Depolymerization
- Autoclave
- Pyrolysis
- Aerobic Composting
- Mechanical Biological Treatment
- Waste-to-Fuels

- Advanced Materials Recovery
- Landfill
- Direct Combustion
- Gasification

  And
- Plasma Arc Gasification
- Dry Anaerobic Digestion
- Refuse Derived Fuel Processing

2

Initially 14 technologies were indentified to evaluate as options for managing garbage.

These are listed on this slide and were described. See the supplemental handout for these definitions .

Initial screening was primarily based on whether the technology has been proven to process at least 100 tons per day of garbage or that pilot studies are showing promise, in other words might be Commercially Viable.

The 7 technologies on the left of the slide are those that failed the first screening.

•**Hydrolysis and Depolymerization** would be fun for a Chemical Engineer, but have not shown any success with garbage; and are not likely to.

•**Autoclave** is primarily used to sterilize waste, but could aid in separating paper. Our region does a relatively good job of recycling paper, so it would not be economical to employ this technology for such a small return.

•**Pyrolysis** works with specific feedstock (such as plastic), but has not been shown to work with garbage. Pyrolysis may do well with clean plastic from our garbage after it has been separated and processed.

•**Aerobic composting** of garbage has been shown to not work in our region; remember the Riedel Compost facility of the 1990's.

•**Mechanical Biological** Treatment is being considered in our scenarios four and five using advanced materials recovery and anaerobic digestion. We prefer to consider and discuss the two processes separately.

•**Waste to fuels** is a post process or add-on to a primary process and might be considered later, but is not being evaluated now.

The 7 technologies on the right of the slide are those that are being analyzed further, because they have been working at a commercial scale some where in the world. These will be presented on the next several slides.

The region's garbage

3

Just to reiterate that we are considering the garbage of the entire region for our analysis and comparison of technologies and scenarios. We are looking to the future, 2019 and beyond.

However, we are not including recyclable and source separated materials. In fact we anticipate and have forecasted increases for recycling and source separation for future garbage volume and composition.

Material Recovery

4

We are talking about materials recovery on the wet waste delivered to transfer stations in the region. This process is similar to what we use now to separate materials from the comingled recyclables collected from residences and businesses. Metro attempted this at MCS in the early 90’s and was unsuccessful; however, there is new machinery today that might improve success.

{This could be similar to the Enhanced Dry Waste Recovery Program or could become the front end of a new technology}

We estimate that an additional 10 points on the regions recovery rate could be achieved from the Metro area garbage through use of advanced sorting and processing.

This is the Newby Island facility in San Jose (I toured this last spring break).

This photo was taken at the Greenwaste Materials Recover Facility during my trip to San Jose CA. Materials recovery can be both labor intensive, as seen here, and machine intensive, as depicted in the previous slide.

Some details of the facilities visited in San Jose.

Greenwaste MRF – Processes San Jose's multi-family mixed waste.

Sunnyvale MRF (SMaRT) – processes post recycling waste.

Newby Island Resource Recovery Park – is processing San Jose's wet and dry commercial wastes and residential commingled. They can process about 1,400 tons per day with 65 sorters per shift and two shifts per day.

Landfills of the past

6

When we are considering landfills; it is not the landfills of the past. We must be sure to inform our constituents and the public that there have been significant changes in methods of landfilling.

The modern landfill

7

Modern landfills are lined and managed to prevent the escape of undesirable materials, such as wind-blown debris, liquid leachate and landfill gas.

Today's landfills also include landfill gas to energy, as here at the Columbia Ridge landfill. This also shows a pilot plasma arc gasification facility in the background.

There is lots of landfill capacity within 200 miles of our region.

This is our current method for managing garbage and it may be the lowest cost option for managing garbage and the most adaptable to changes, but disposal in a landfill is the bottom of waste hierarchy.

Direct Combustion of the past

9

Portland mid 1900's Direct Combustion. These are the furnaces at the Chimney Park facility located across the street from the St. John's landfill.

Portland has had waste incinerators before, but new technologies have come a long way since we had incinerators here and even since Metro's last look at selecting this technology in the late 1980's process of reviewing proposals that resulted in the siting of MCS (there was at least one proposal for a waste-to-energy facility).

Direct combustion today

Peekskill, New York

10

New facilities are thousands of times cleaner then they were several decades ago, meeting and exceeding all environmental regulations.

There are over 800 installations world wide, with over 88 in North America.
The Covanta facility in Marion Co. has been successfully operating for over 25 years and is only 30 minutes south of Portland.

We could get electric energy and heat from this type of facility, which would move our use of the garbage up the hierarchy, but they come with high capital costs.

This facility in Peekskill, New York manages about 2,250 tons per day and produces enough electricity to power about 88,000 homes.

Direct combustion

Barcelona, Spain waste to energy plant

11

The industry has learned how to blend their facilities into the surroundings, as seen here in Barcelona, Spain.

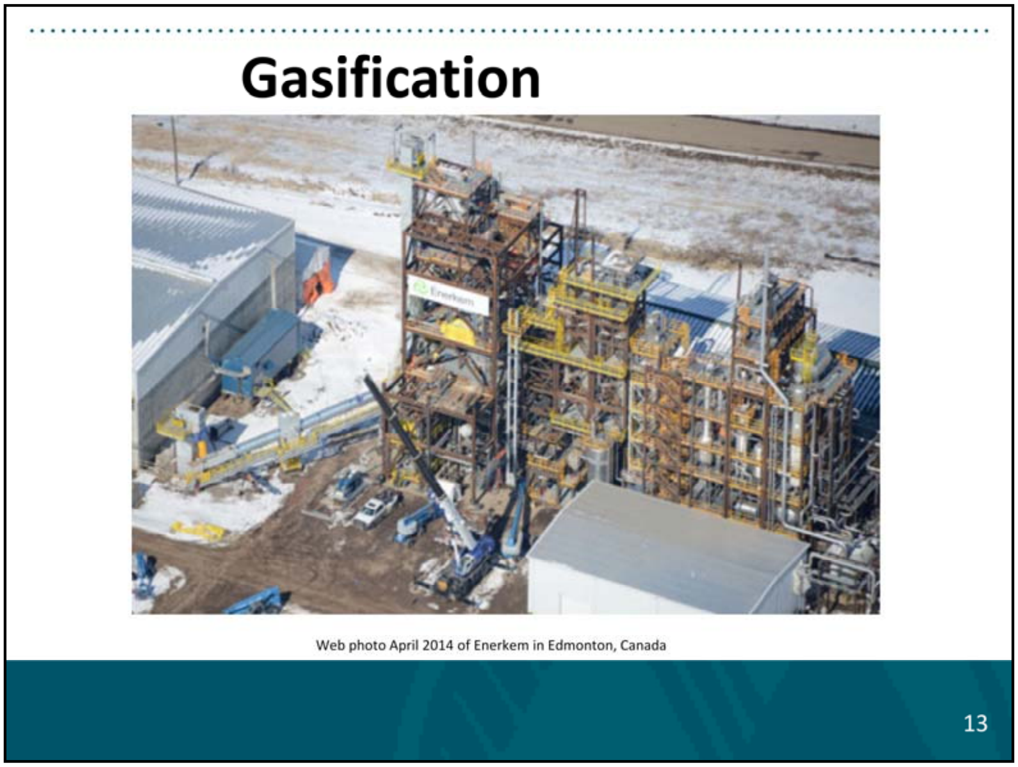
This facility was also able to take advantage of selling steam to a local user. Being able to make use of the heat from the steam, along with generating electricity with the steam, can double the efficiency of using the energy from the garbage.

Direct combustion

Maishima, Japan

12

Even in an industrial setting, facility architects have found ways to be creative and make this facility attractive; this is in Maishima Japan.



This is a very recent photo of a facility being constructed in Edmonton, Canada.

Gasification is being used in Japan and Germany with reported success. However, information from those facilities is often lacking, which makes it challenging to estimate how these systems could be successful here in our region. To date there are no successful plants of this type in the U.S.

Thermal conversion without combustion produces synthetic gas (mostly carbon monoxide and hydrogen) and char.

The gases can be utilized to produce electricity or further processed to create liquid fuels. The char could be sold for other uses; however, when created from garbage it is usually landfilled. This process moves garbage management up the hierarchy, but again has high capital costs and uncertain operating costs.

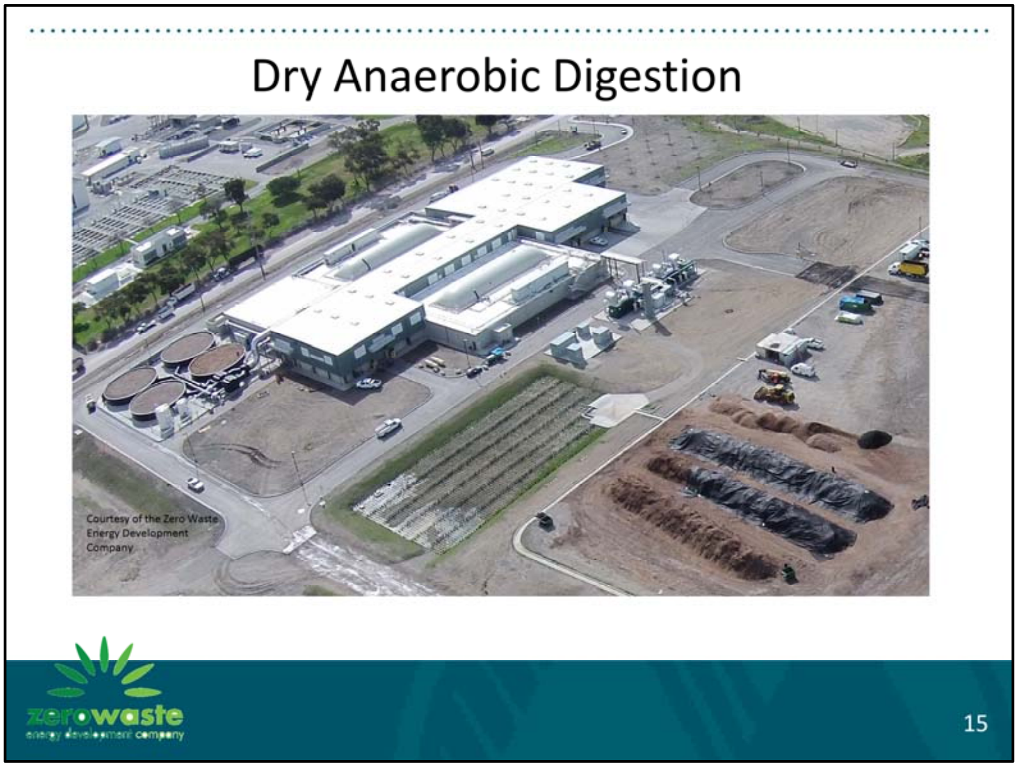
Gasification

Plasco Trail Road project in Ottawa Canada.

14

Gasification can be used alone, but is often combined with plasma arc gasification as in this facility in Ottawa, Canada.

This facility in Canada is now being tested. We will be keeping an eye on this to see if it is successful.



I visited this Dry anaerobic digestion facility in San Jose, California last March.

The facility was still in its shake down process and was not completely operational.

The compost you see outside is not going to be your garden variety, but will be likely be sent to a landfill for use as daily cover. The material might also be used in road construction for ditches and slope stabilization.

Dry Anaerobic Digestion

16

This is a close-up of the inside of the building and the outdoor waste pile from the previous slide.

These chambers are filled with the garbage, sealed to control air and sprayed with a bacteria rich liquid to start the digestion process. Methane gas will be produced (about 60% methane and 40% carbon dioxide) during digestion.

The gas at this facility is being used to fuel electric generators. The leftover garbage coming out of this process is likely headed to a landfill; in CA they are using it for daily cover and along side roads. We think that this material would also be good feedstock for a Refuse Derived Fuel process.

Garbage could be sorted and separated for use in Refuse Derived Fuel (RDF).

Back in the mid 90's Metro had a demonstration process set up at Metro Central to create RDF. This turned out to be too expensive at that time.

Refuse derived fuel can take many forms depending on how it is to be used. Here is a photo of pelletized garbage (post sorted) and a photo of baled garbage (post sorted).

1st photo from the web

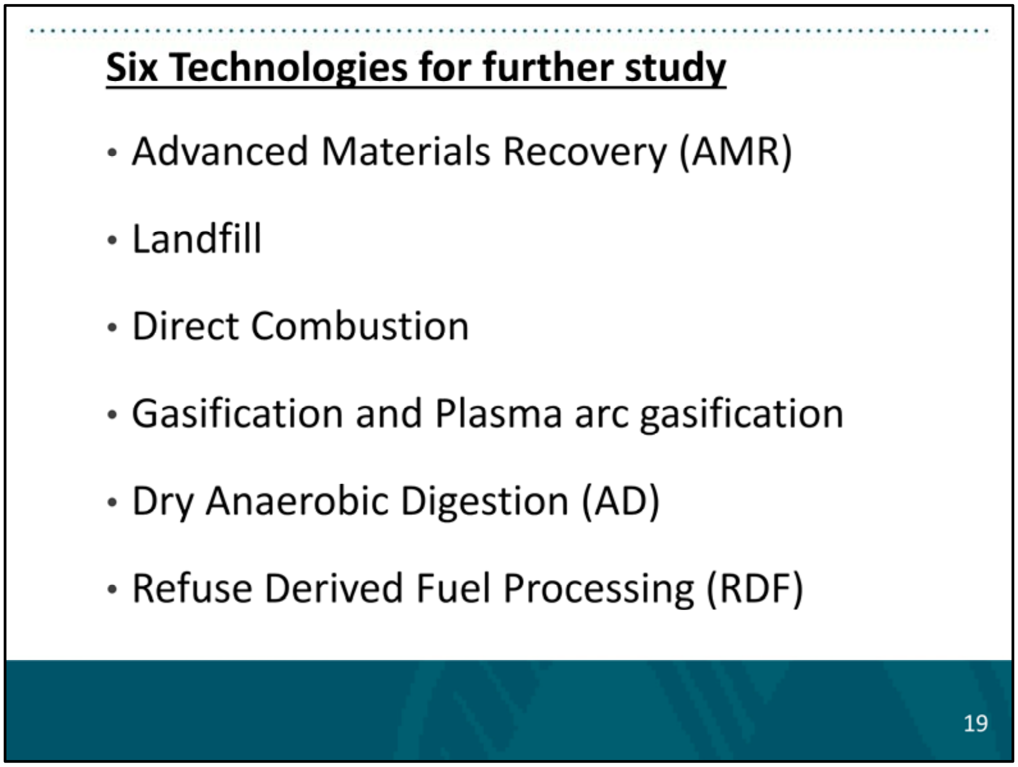
2nd photo from *HDR photo of stockpiled RDF at the Rennerod, Germany Facility.

Refuse-derived fuels

- Hawaii refuse derived fuel facility

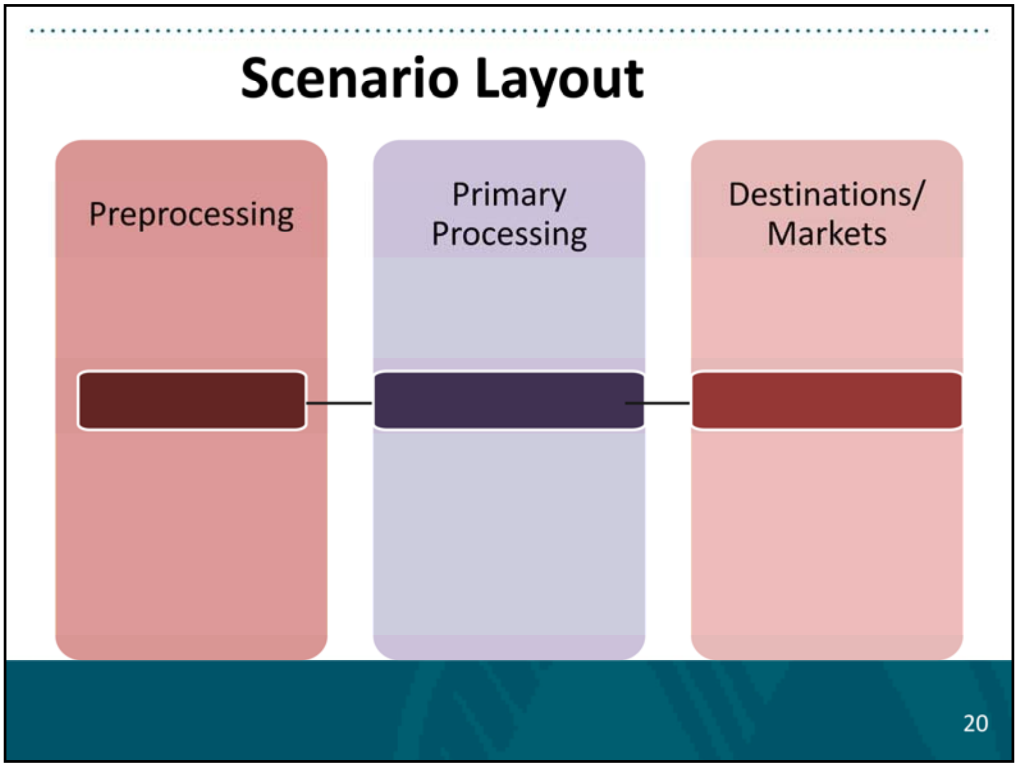
18

Hawaii’s refuse derived fuel facility.



Again we are considering gasification and plasma arc gasification together, as we continue to find examples where they are used together.

From these six technologies we developed potential packages, or scenarios, for managing the region's garbage.

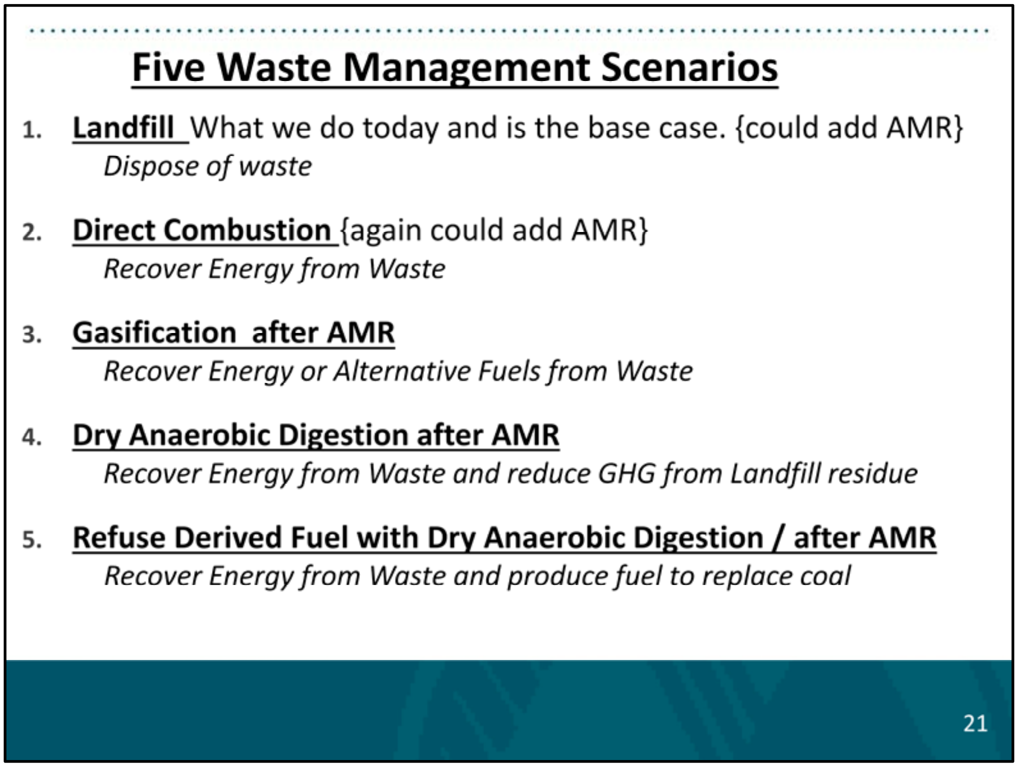


This graphic shows how we are compartmentalizing our thinking of technologies for development of scenarios.

Advanced Materials Recovery is preprocessing

Direct Combustion, Gasification, Anaerobic Digestion and Refuse Derived Fuel are processing

Landfills would fall into final destinations with recovery markets, energy markets, etc..

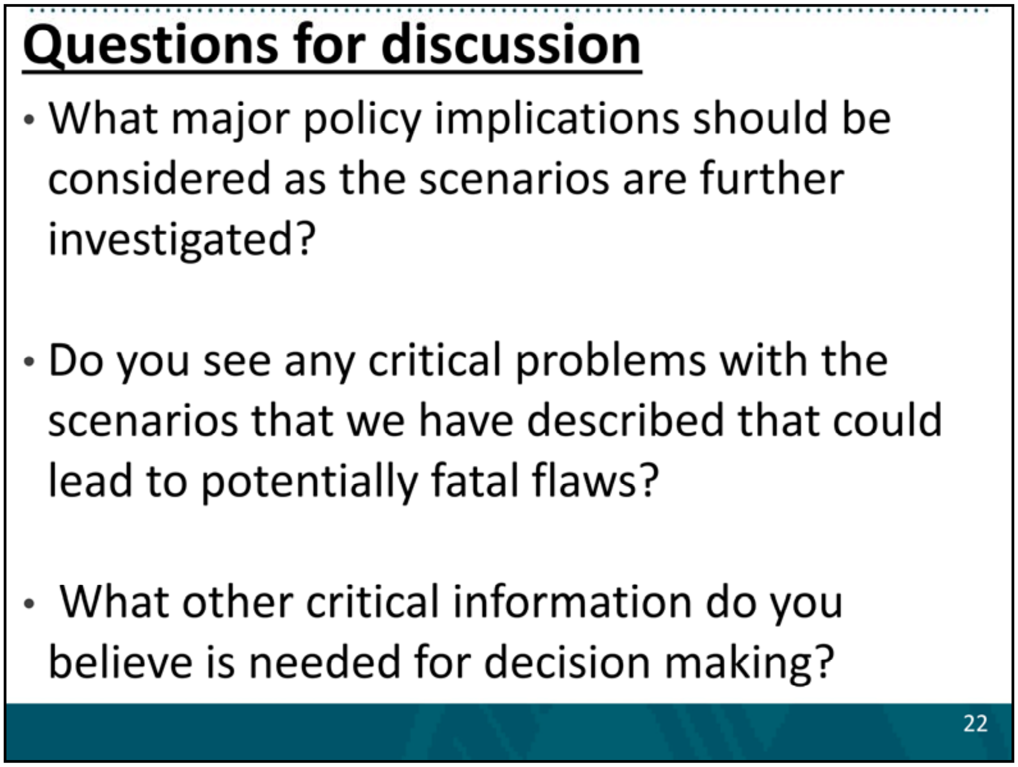


What we do today is our base case, Landfilling.

Advanced Materials Recovery could be considered with the Landfilling and the Direct Combustion scenarios; however, it is required for Gasification, Dry anaerobic digestion and Refuse derived fuel processes or those would not likely be viable options.

Even with advanced recovery the material sent to dry anaerobic digestion will have too many contaminants to make use of the digested material for landscaping amendment or agriculture. In scenario four we assume it would go to a landfill, but in scenario five it could be used for Refuse derived fuel.

These scenarios illustrate potential options that could be integrated into our existing disposal system. We purposefully created single technology scenarios for the first four, so that we could better compare the advantages of the individual technologies. The final scenario illustrates how technologies might logically be combined.



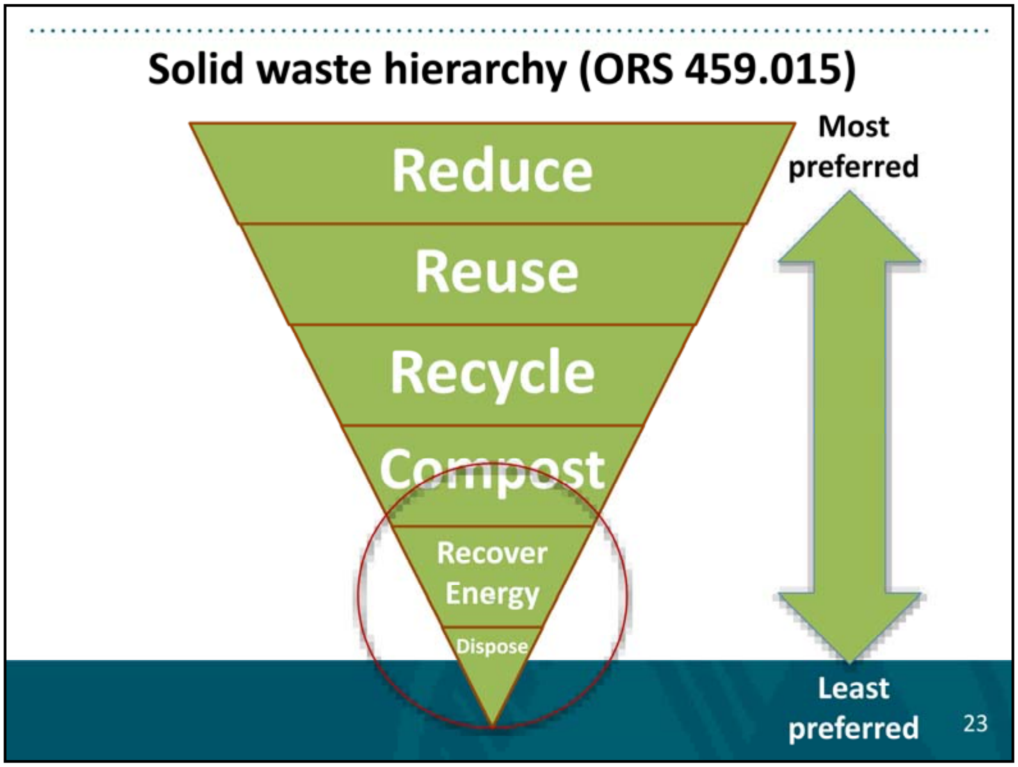
These questions will be displayed during the meeting.

•What major policy implications should be considered as the scenarios are further investigated?

(For example: will recovery or residual standards need to be established to ensure success.)

•Do you see any critical problems with the scenarios that we have described that could lead to potentially fatal flaws?

•What information do you believe is needed for decision making?



This is a slide of one of the posters on display at the meeting.

Metro could gain additional recycling from its waste by using advanced materials recovery technologies.

Expanding programs for source separated food waste and yard debris could improve/increase energy recovery (with anaerobic digestion) and composting.

There will still be a significant amount of garbage discarded in the region that could be managed to do more for us by moving up the hierarchy.

This is also a slide of one of the posters on display at the meeting.

These benefits are used to guide our discussion and evaluation of solid waste management options.

What do we mean by *policy implications?*

Some example questions:

1. What else should the Metro Council keep in mind *besides the six public benefits* to consider these scenarios with eyes wide open?

2. Look into your crystal ball, to a future in which Scenario X has been very successful. What were the keys to success?

3. Look into the future in which Scenario X was a complete disaster. What went wrong? What did we miss?

4. Scenario X really only makes sense if *<<fill in the blank>>* .

5. Scenario Y will be problematic because *<<fill in the blank>>* .

6. Which of these scenarios—in your mind—will never fly? Why? (fatal flaws)

7. What would be the primary motivations for pursuing/avoiding Scenario X?

8. Recall the P – R – O tools that Council wields: Policy – Regulation – Operations. What combination of these tools is the right balance in order to make a scenario successful?