Report

Preliminary Resource Recovery Feasibility Report

Project I.D.: 13R003

Prepared For
Ramsey/Washington Counties
Resource Recovery Project Board

January 2014

RAMSEY/WASHINGTON COUNTY
RESOURCE RECOVERY PROJECT
RAMSEY AND WASHINGTON COUNTIES, MINNESOTA

Foth

75 YEARS

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January 22, 2014

Zack Hansen
Judy Hunter
Ramsey/Washington Counties Resource Recovery Project
2785 White Bear Ave. N
Maplewood, MN 55109

Dear Zack and Judy:

RE: Preliminary Resource Recovery Feasibility Report

Foth Infrastructure & Environment, LLC is pleased to provide this Preliminary Resource Recovery Feasibility Report for municipal solid waste for your consideration. This report addresses the technologies selected for continued evaluation by the Ramsey/Washington Counties Resource Recovery Project as part of the future waste processing decision process.

We look forward to presenting this report at the Project Board meeting along with the Technology Comparative Analysis Report as well as any follow up discussions.
Sincerely,

Foth Infrastructure & Environment, LLC

Warren Shuros
Client Director

Curt Hartog, P.E.
Technical Director

Preliminary Resource Recovery Feasibility Report

Distribution

No. of Copies	Sent To
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Background

The Ramsey/Washington Counties Resource Recovery Project Board (Board) is completing policy evaluations to determine how the Counties may continue waste processing after the current term of the Processing Agreement with Resource Recovery Technologies, LLC (RRT) expires at the end of 2015. Foth Infrastructure and Environment, LLC (Foth) is assisting with this policy evaluation process and is in the process of completing reports concerning the potential options.

Previous reports completed in this policy evaluation process include:

- *Alternative Technologies for Municipal Solid Waste*
- *Preliminary Technical Status of the Newport and Two Xcel Combustion Facilities*

The Alternative Technologies for Municipal Solid Waste (MSW) reviewed several potential alternatives at a high level to determine if the Board desired to review each technology at a more in-depth level. The Board chose to review the following technologies:

- Anaerobic Digestion
- Gasification
- Mass Burn
- Mixed Waste Processing
- Plastics to Fuel

The Board's Joint Staff Committee worked with Foth to frame the additional review of these technologies into a work plan for this *Preliminary Resource Recovery Feasibility Report.* This report provides a preliminary feasibility study for three different technology options including:

- A standalone mass burn facility;
- A combination of technologies including the existing Newport refuse derived fuel (RDF) facility with mixed waste processing (MWP) and gasification; and
- A combination of MWP, anaerobic digestion (AD), and plastics to fuel as a standalone facility.

Waste Stream Quantities and Composition

One of the first considerations for the feasibility of different resource recovery technologies is to define the waste stream. This starts with developing an understanding of the current waste stream available and extends into identifying trends for waste generation and composition into the future. Predicting the future for waste generation and composition presents challenges to match the technologies and facility capacities to the actual waste streams to assure reliability in meeting necessary future public health and safety needs.

The currently available waste stream for processing is approximately 400,000 tons per year (tpy). The Minnesota Pollution Control Agency (MPCA) has established Metropolitan Area MSW Management Objectives for the future for increasing the percentages of waste managed through source reduction, recycling, and organics recovery while decreasing the percentages managed by resource recovery and landfilling. The Joint Staff Committee developed three (3) scenarios for solid waste tonnage forecasts into the future. Each scenario incorporated at least the minimum regional solid waste master plan percentages for recycling and organics recovery. The scenarios increased recycling and organics recovery in three manners – gradually, more aggressively, and more aggressive recycling with much more aggressive organics recovery. Waste available for processing by 2025 was projected to range from 380,000 tpy down with the aggressive recovery to less than 300,000 tpy. Conversely, if the recovery goals are not met and waste generation grows beyond projections, the amount of waste available for processing could increase.

There have also been trends that affect the composition of materials still being disposed. Specific trends include:

- Paper and cardboard as a percentage of municipal solid waste (MSW) are generally in decline.
- Plastics are growing as a percentage of MSW.
- Food waste continues to comprise a substantial portion of MSW (~15%).

These waste generation projections and compositions will need to be continually considered in the planning process for future waste processing alternatives. For this preliminary planning process considering multiple technologies, an average of 400,000 tpy 1,096 tons per day (tpd) was used for the analysis. Additional waste projection and composition analysis should be conducted in the next stage of the feasibility analysis.

Key Assumptions and Report Structure

The preliminary analysis assumed the current 400,000 tpy of MSW would be processed. The composition study of the MSW completed by Resource Recovery Technologies, Inc. (RRT) in 2012 provided the most recent information regarding the composition of the wastes delivered to the Newport Resource Recovery Facility (Newport Facility).

Each of the technology options is described, the site/utility needs listed, and the required permits and public acceptance described. The MSW processed and the resulting market outputs and residues are also described.

Preliminary economics of each technology were developed as ranges for each of the following:

- Capital costs
- Operating costs
- Market revenues

- Breakeven costs per ton.

A preliminary estimate of the time required to develop each technology option was developed.

Results

The following matrix provides a summary of the results of the preliminary analysis for selected factors covering key assumptions, tons managed and diverted, products marketed, time period for development, the range of capital costs, and the range of breakeven costs.

Table ES-1
Preliminary Technology Feasibility Summary

Criteria	Mass Burn	Newport w/ MWP & Gasification	MWP w/ Anaerobic Digestion
Key Assumptions or Observations	♦ Not site specific ♦ Similar to HERC in size/operation	♦ Gasification is still an "emerging" technology ♦ Ethanol revenues significantly higher than electricity ♦ MWP added to Newport, targets only commercial wastes ♦ RDF to gasification, not Xcel ♦ Newport site too small for gasification plant	♦ Standalone facility ♦ Targets only recyclables and organics ♦ Remaining wastes landfilled ♦ MWP processes entire waste stream ♦ Plastics to fuel technology not ready, not analyzed further
Tons Managed/ Diverted	♦ 378,800 combusted ♦ 21,200 bulkies landfilled ♦ 90,000 tons of ash ♦ 288,800 diverted	♦ 324,960 gasified ♦ 21,840 recycled ♦ 53,200 landfilled ♦ 39,000 tons of ash ♦ 307,800 diverted	♦ 82,320 to AD ♦ 44,640 recycled ♦ 273,040 landfilled ♦ 126,960 diverted
Product(s)	♦ Electricity ♦ Potentially steam sales ♦ Metal recovery possible but not quantified	♦ Recyclables ♦ Ethanol	♦ Recyclables ♦ Energy as methane to natural gas or CNG, steam or electricity
Development Time	♦ 7 to 10 years (if successful)	♦ 5 to 7 years	♦ 4 to 5 years
Capital Cost Range	♦ $350M to $400M	♦ $170M to $250M	♦ $50M to $60 M
Breakeven Cost Range	♦ $70 to $100 per ton	♦ ($20) to $50 per ton	♦ $64 to $84 per ton

Key Assumptions or Observations

The mass burn analysis was not specific to a site. For reference, the facility would be similar to the Hennepin County Resource Center (HERC) located next to Target Field in size and operation.

Gasification is still an "emerging" technology and while it appears to have significant promise, it is not a proven technology managing MSW. Part of the promise is that the potential revenues from ethanol and tax credits are significantly higher than the revenues from other forms of energy. The mixed waste processing (MWP) system is assumed to only target the commercial waste stream that is anticipated to have a higher percentage of recyclable material. It appears that the Newport Facility site is too small for the gasification refinery equipment. The analysis assumed the use of a different site within 20 miles.

The MWP with Anaerobic Digestion (AD) was assumed to be a "standalone" facility receiving the entire 400,000 tpy. However, the MWP with AD only targets recyclables and organics with the remaining waste stream landfilled for the purposes of the analysis. It was noted that these remaining wastes could be processed into RDF. The MWP system was assumed to target the entire waste stream, not just the commercial wastes. Finally, Plastics to fuel was not considered beyond a description in this analysis due to closure of the commercially operating plant in the Twin Cities area. The technology does not yet appear to be fully commercially available for consideration by the Board.

Tons Managed/Diverted

While all three of the options received the entire 400,000 tpy, there were differences in the assumed tonnages by-passed from processing, differences relating to tons actually processed, recyclables recovered, ash produced, and finally tons diverted. The Newport with MWP and Gasification had the highest calculated tons diverted (307,800 tons) followed by Mass Burn (288,800 tons) with the MWP with AD having the lowest estimated amount of tons diverted (126,960 tons) due to the limited materials targeted by that technology system.

Products

The products to be marketed had some variability. Mass Burn primarily results in electrical sales, but depending on location and availability, could also sell steam for heating and air conditioning. Most Mass Burn facilities also recover ferrous metals. The Newport with MWP and Gasification has an advantage in products to be marketed with not only the recyclables, but also the ethanol with its higher revenue potential. The products from the MWP with AD also include recyclables, but the methane recovered and made into natural gas and products such as CNG and electricity have lower revenue potential.

Development Time

All three options will take more time to develop than the Board has remaining on the current processing agreement. Of the three, Mass Burn is anticipated to have the most difficulty with permitting and public acceptance. There may be difficulty with both other options as well, particularly with the gasification facility needing a different location and the AD technology with odor potential. The gasification technology while having lower emissions does not have a track record with permitting agencies in Minnesota. AD facilities are being successfully permitted in Minnesota.

Capital Cost Range

There is a wide range in capital costs with Mass Burn being by far the highest at $350M to $400M. That is a large sum to be financed. The Newport with MWP and Gasification at $170M to $250M is significantly lower and was projected to have better revenue potential. The MWP with AD has a lower capital cost, but also significantly fewer tons diverted overall and lower revenue potential.

Breakeven Cost Range

Breakeven cost refers to the cost per ton for the tipping fee revenues to cover the net costs remaining after the market revenues covering debt and operating costs. The Breakeven costs for the Newport with MWP and Gasification is by far the most favorable.

The information developed in this *Preliminary Resource Recovery Feasibility Report* will be used in the companion report developed by Foth for the Board entitled *Technology Comparative Analysis* which compares these three technology options to the Current RDF System and to a Sanitary Landfill.

List of Abbreviations, Acronyms, and Symbols

AD	Anaerobic Digestion
AERA	Air Emissions Risk Analysis
Air Permit	Operating Permit
BACT	Best Available Control Technology
BHS	Bulk Handling Systems
Btu	British Thermal Unit
C&D	Construction and Demolition
CA	California
Cd	Cadmium
CEM	Continuous Emissions Monitoring
CH_4	Methane
CHP	Combined Heat And Power
CN	Cyanide
CO	Carbon Monoxide
Cr	Chromium
Cu	Copper
CUP	Conditional Use Permit
DNR	Minnesota Department of Natural Resources
EAW	Environmental Assessment Worksheet
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
F	Fahrenheit
FAA	Federal Aviation Administration
Foth	Foth Infrastructure & Environment, LLC
H_2	Hydrogen
H_2O	Water
H_2S	Hydrogen Sulfide
Foth	Foth Infrastructure & Environment, LLC
HDPE	High Density Polyethylene
HERC	Hennepin Energy Resource Center
Hg	Mercury
HHW	Household Waste
HS	High Solids
IVC	In-Vessel Composting
kWh	Kilowatt Per Hour
LS	Low Solids
MCES	Metropolitan Council Environmental Services
MMBtu	Million Btus
MMPA	Minnesota Municipal Power Agency

MN	Minnesota
MPCA	Minnesota Pollution Control Agency
MS	Medium Solids
MSW	Municipal Solid Waste
MW	Municipal Waste
MWC	Municipal Solid Waste Combustor
MWh	Megawatt Hour
MWP	Mixed Waste Processing
Newport Facility	Newport Resource Recovery Facility
Ni	Nickel
NO_X	Nitrogen Oxides
NPDES	National Pollution Discharge Elimination System
O_2	Oxygen
OCC	Old Corrugated Cardboard
OWEF (Olmsted County)	Olmsted Waste To Energy Facility
Pb	Lead
Perham	Perham Resource Recovery Facility
PET	Polyethylene Terephthalate
pH	Measure of acidity
ppm	Parts per million
PSD	Prevention of Significant Deterioration
Psi	Pound per Square Inch
PSIG	Pounds Per Square Inch Gauge
PTF	Plastics To Fuel
PUC	Minnesota Public Utilities Commission
PVC	Polyvinyl Chloride
QC	Quality Control
R/W	Ramsey Washington
RDF	Refuse Derived Fuel
RGU	Responsible Government Unit
RRT	Resource Recovery Technologies, LLC
SIP	State Implementation Plan
SO_2	Sulfer Dioxide
SSO	Source Separated Organics
SSOM	Source Seperated Organic Material
SWA	Solid Waste Agency
SWDD	Solid Waste Disposal District
TCLP	Toxicity Characteristics Leaching Procedure
tpd	Tons Per Day
tpy	Tons Per Year
TS	Total Solids

UK	United Kingdom
US	United States
USACE	United States Army Corps Of Engineers
USF&WS	United States Fish And Wildlife Service
WTE	Waste To Energy
Xcel	Xcel Energy
Zn	Zinc

Definitions

British Thermal Unit (Btu):	Btu is a measure of the heating value of a fuel. It is the amount of heat required to raise one pound of water one degree Fahrenheit at atmospheric pressure.
Combustion:	Burning or incineration of a fuel using excess air or oxygen.
Criteria Air Pollutants:	Under the authority of the Clean Air Act, the U.S. Environmental Protection Agency has established ambient air quality standards for common air pollutants, such as carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.
Feedstock:	The material fed into a gasifier and converted into a synthesis gas (syngas).
Gasification:	Gasification is a thermo-chemical process that converts carbon-containing materials with little or no oxygen present and at high temperatures, into a synthesis gas (syngas). The syngas can then be used, to produce electric power, and valuable products such as chemicals, fertilizers, substitute natural gas, hydrogen, steam, and transportation fuels.
Gasifier:	A vessel where the gasification reactions take place. Temperatures in gasifiers range from 900-3,000 degrees Fahrenheit, depending technologies.
Mixed Waste Processing:	A facility that seperates unsegregated wastes into recyclable commodities using manual and mechanical sorting methods.
Syngas or Synthesis Gas:	The gas produced as the result of the gasification reactions of feedstock, oxygen (or air) and water (or steam). Syngas consists primarily of hydrogen and carbon monoxide.
Toxicity Characteristic Leaching Procedure (TCLP):	EPA method 1311 designed to determine the mobility of constituents in waste material.
Anaerobic Digester	A dedicated unit process for controlling the anaerobic decomposition of organic material. Typically consists of one or more enclosed, temperature controlled tanks with material handling equipment designed to prevent the introduction of oxygen from the atmosphere.

Greenhouse Gas (GHG):	A greenhouse gas absorbs and emits light in the infrared range.
Fly Ash:	This refers to the fine dust and ash residues that are created from the combustion.
Bottom Ash:	This refers to the heavier dust and ash residues that are created from the combustion.
Pyrolysis:	The decomposition of materials using high temperatures in the absence of oxygen.
Ferrous Metals:	Ferrous metals mostly comprise of iron or its alloys
Non-Ferrous Metals:	Non ferrous metals do not contain iron or its alloys – copper, brass, bronze, zinc
Combined Heat and Power (CHP):	Combined Heat and Power is a term used to describe the generation of power and the recovery of useful residual heat.

Acknowledgements

Thanks to Springsted Incorporated for providing the debt service financial projection for each of the technology options capital costs.

1 Introduction

The Ramsey/Washington Counties Resource Recovery Project Board (Board) is completing policy evaluations to determine how the Counties may continue waste processing after the current term of the Processing Agreement with Resource Recovery Technologies, LLC (RRT) expires at the end of 2015. Foth Infrastructure and Environment, LLC (Foth) is assisting with this policy evaluation process and is preparing various reports to assist the Board with information on the potential options.

Previous reports completed in this policy evaluation process include:

- *Alternative Technologies for Municipal Solid Waste*
- *Preliminary Technical Status of the Newport and Two Xcel Combustion Facilities*

The Alternative Technologies for Municipal Solid Waste (MSW) reviewed several potential alternatives at a high level to determine if the Board desired to review each technology at a more in-depth level. The Board chose to review the following technologies:

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- Gasification
- Mass Burn
- Mixed Waste Processing
- Plastics to Fuel

The Board's Joint Staff Committee worked with Foth to frame the additional review of these technologies into a work plan for this *Preliminary Resource Recovery Feasibility Report.* This report provides a preliminary feasibility study for three different technology options including:

- A standalone mass burn facility;
- A combination of technologies including the existing Newport refuse derived fuel (RDF) facility with mixed waste processing (MWP) and gasification added; and
- A combination of MWP, anaerobic digestion (AD), and plastics to fuel in a standalone facility.

An additional analysis (*Technology Comparitive Analysis*) will compare the above technologies to the current RDF system as well as a sanitary landfill. Based on the results of the preliminary feasibility study and comparisons of the technologies, the Board may provide further direction regarding future MSW processing activities or identify addition evaluations required to facilitate the decision making process.

2 Waste Stream

One of the first considerations for the feasibility of different resource recovery technologies is to define the waste stream. This starts with developing a good understanding of the current waste stream available for processing and extends into identifying current and projected trends for waste generation and composition into the future. Predicting the future for waste generation and composition presents challenges to match the technologies and facility capacities to the actual waste streams to assure reliability in meeting necessary public health and safety needs into the future.

A preliminary analysis of the waste stream available for processing was developed in the 2013 report titled *"Alternative Technologies for Municipal Solid Waste"*. Table 2-1 Projected Available Waste for Processing below was developed for that report

Table 2-1
Projected Available Waste for Processing

Year	Annual Growth[1] (%)	Cumulative Growth[2] (%)	Available Tonnage[3]
2012	1.0	0	391,000
2017	1.0	5.05	410,000
2022	1.0	10.10	430,000
2027	1.0	15.15	450,000
2032	1.0	20.2	470,000
2037	1.0	25.25	490,000

1 Annual growth assumed corollary to population of 1.0%
2 Cumulative growth estimates starting from the year 2012
3 Available Tonnage represents the availability of waste in R/W counties for processing.

Table 2-1 shows waste currently available for processing to be plus or minus 400,000 tons per year (tpy). The Minnesota Pollution Control Agency (MPCA) has established Metropolitan Area MSW Management Objectives for future increases in the percentages of waste managed through source reduction, recycling, and organics recovery while decreasing the percentages managed by resource recovery and landfilling. If the percentage objectives are met for the source reduction, recycling, and organics recovery and depending on waste stream generation changes associated with population growth and economic activity, the amount of wastes available for processing in the future could decrease over time.

In a memo report to the Board at the October 31, 2013 Board meeting, the Joint Staff Committee presented three (3) scenarios for solid waste tonnage forecasts into the future. Each scenario incorporated at least the minimum regional solid waste master plan percentages for recycling and organics recovery The scenarios then increased recycling and organics recovery in three manners – gradually, more aggressively, and more aggressive recycling with much more aggressive organics recovery. Waste available for processing by 2025 was projected to range from 380,000 tpy down to under 300,000 tpy with aggressive recovery. Conversely, if the recovery goals are not met and waste generation grows beyond projections, the amount of waste available for processing could increase over time.

There have also been trends that affect the composition of materials still being disposed. Specific trends noted in the Joint Staff Committee memo to the Board included:

- Paper and cardboard as a percentage of MSW are generally in decline.
- Plastics are growing as a percentage of MSW.
- Food waste continues to comprise a substantial portion of MSW (~15%).

These waste generation projections and compositions will need to be continually considered in the planning process for future waste processing alternatives. For this preliminary planning process considering multiple technologies, an average of 400,000 tpy 1,096 tons per day (tpd) will be used for the analysis. But additional waste projection and composition analysis should be conducted in the next stage of feasibility analysis.

A waste composition study was completed by RRT on the wastes being delivered to the Newport Facility in July, 2012. The composition results are shown in Table 2-2 along with the estimated tons associated with each of the material categories based on a plant size of 1,096 tpd.

Table 2-2
Newport Resource Recovery Facility Solid Waste Composition Results
July 2012

Material Group	Mean (%)	Tons/Day
Paper	**23.1%**	**253**
Newsprint	1.6%	18
Magazines/Catalogs	0.7%	8
High Grade Office	1.0%	11
OCC & Kraft Bags	2.8%	31
Mixed Recycle Paper	5.2%	57
Non-Recyclable Paper	12.0%	132
Plastic	**17.1%**	**187**
#1 PET Bottles	1.5%	16
#2 HDPE Bottles	0.8%	9
Other Containers	1.0%	11
Other Non-Containers	8.1%	89
Film/Wrap/Bags	5.7%	62
Metal	**5.0%**	**55**
Aluminum Beverage Containers	0.7%	8
Ferrous Food & Beverage Containers	0.6%	7
Other Ferrous Metal	2.6%	28
Other Non-Ferrous Scrap	1.1%	12

Material Group	Mean (%)	Tons/Day
Glass	**2.6%**	**28**
Container Glass	2.2%	24
Non-Container Glass	0.4%	4
Organics	**28.3%**	**310**
Yard Waste	3.4%	37
Food Waste	14.6%	160
Non-Treated Wood	1.2%	13
Treated Wood	4.8%	53
Diapers	2.4%	26
Other Organics	1.9%	21
Construction/Demolition /Renovation Debris	**3.9%**	**43**
Problem Materials	**3.6%**	**39**
Lead Acid Batteries	0.0%	0
Other Batteries	0.1%	1
Cell Phones	0.0%	0
Other Electronics	0.4%	4
Mercury Containing Products	0.0%	0
Sharp and Infectious Waste	0.0%	0
Computer Monitors	0.0%	0
All Computer Equipment/Peripherals	1.2%	13
Televisions	0.0%	0
Other Electrical & Household Appliances	1.9%	21
Household Hazardous Waste	**0.1%**	**1**
Automotive Products	0.0%	0
Paints & Solvents	0.0%	0
Pesticides, Herbicides, & Fungicides	0.0%	0
Household Cleaners	0.0%	0
Other HHW	0.0%	0
Miscellaneous	**16.3%**	**179**
Furniture	1.7%	19
Carpet	3.3%	36
Textiles & Leather	6.7%	73
Rubber	0.8%	9
Mattresses	1.0%	11
Other Inorganics	2.8%	31
GRAND TOTALS	**100%**	**1,096**

It is important to note that while the composition study shows exact percentages of the different materials, the actual recoverable quantities of materials from the mixed MSW are not typically achievable due to contamination and incomplete material separations.

It is also important to note that the July 2012 Waste Composition Study did not include separate composition analysis of residential and commercial/industustrial waste streams delivered to

Newport. Prior to further implementation activity for some of the potential technologies, We recommend the Board complete additional waste composition analyses.

The following three sections of this report provide the preliminary feasibility for the three technologies or combinations of technologies including:

- A standalone mass burn facility;
- A combination of technologies including the existing Newport refuse derived fuel (RDF) facility with mixed waste processing (MWP) and gasification added; and
- A combination of MWP, anaerobic digestion (AD), and plastics to fuel.

The final section addresses conclusions and potential next steps.

3 Mass Burn

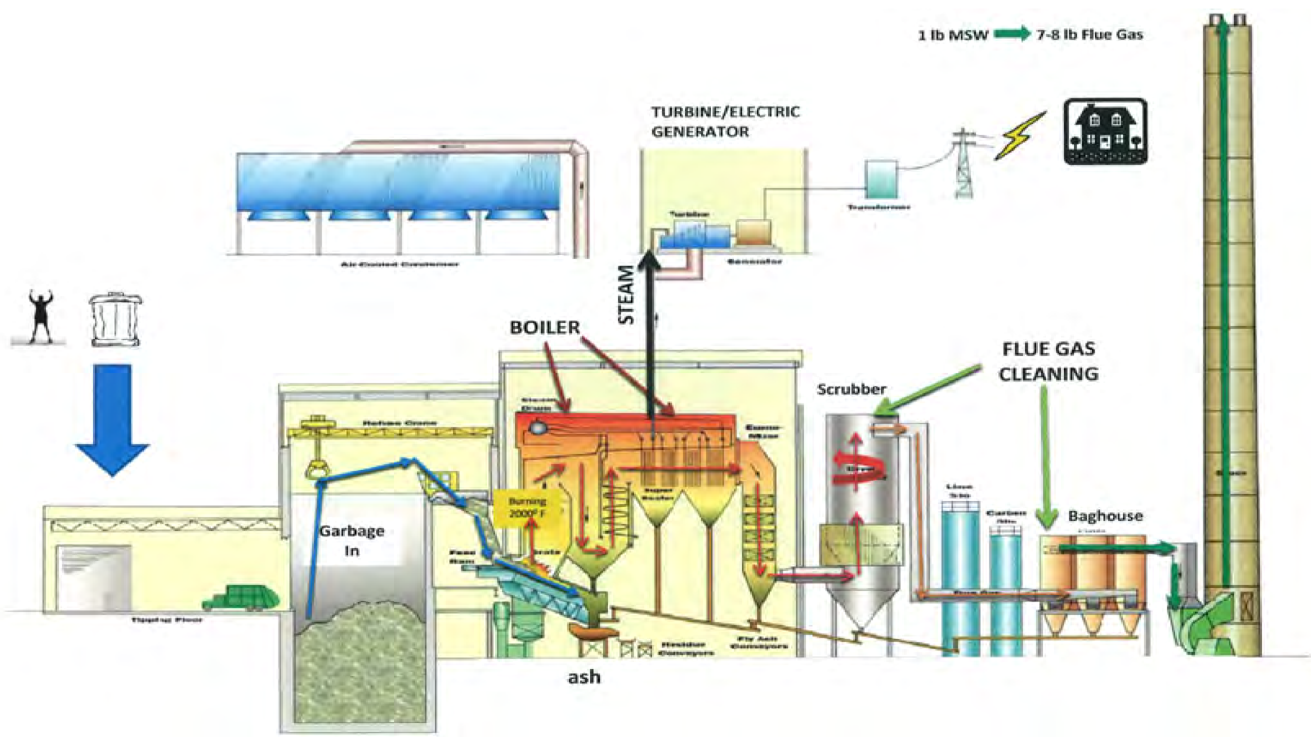
A mass burn facility would be capable of receiving and processing all the municipal solid waste (MSW) that is not reduced, recycled, composted, or otherwise recovered in another manner. For purposes of this preliminary analysis, the assumed facility size is receiving 400,000 tons per year (tpy) or approximately 1,096 tons per day.

3.1 Brief Technology Description

This section provides a general description of a mass burn facility and is not yet specific to a final project description. Much further development will need to be conducted if a mass burn technology is selected for further consideration.

Figure 3-1 depicts a typical mass burn facility. MSW is brought to the facility by truck, roll-off or transfer trailer and dumped on the tipping floor. The waste is pushed into the pit, where the crane operator mixes waste in the pit and removes unprocessible material. Mixing the waste also helps avoid slugs of very wet or very high Btu material in the combustion chamber that would decrease the efficiency of the operation.

Figure 3-1
Waste to Energy Plant Diagram



The crane operator also picks out waste not suitable for burning if it is too large (e.g. mattresses, furniture), is not combustible (e.g. concrete blocks) or would result in air quality problems not treatable with the facility's air quality systems (e.g. televisions, computers). The rejected waste is recycled if possible or landfilled. The crane operator grabs an amount of the waste and loads it from the pit to the feed hopper. Waste travels through the feed hopper to the gravity-feed or hydraulic ram-feed systems that deliver waste at a controlled rate to the combustion chamber.

The walls of the combustion chamber are waterwall chambers lined with tubes that contain circulating water which recovers the heat generated by combustion. In the actively burning region of the combustion chamber, where corrosive conditions may exist, the walls are generally lined. Heat is also recovered in the convective sections (i.e., superheater, economizer) of the combustor. Most mass burn designs use inclined reciprocating grates or roller grates to move the waste through the combustion chamber.

The grates typically include three (3) sections. The first grate section, referred to as the drying grate, reduces the moisture content of the waste prior to ignition. The second grate section, the burning grate, is where the majority of active burning takes place. The third grate section, the burnout or finishing grate, is where remaining combustibles in the waste are burned.

The majority of the mass burn combustors supply underfire air to the individual grate sections through multiple pressurized inlets, or plenums. This improves the control of the burning rate and heat release from the grates. Overfire air is injected through rows of high-pressure nozzles located in the side walls of the combustor. Overfire air oxidizes fuel-rich gases put off from the grates, to complete the combustion process. Mass burn combustion units operate at relatively high temperatures, in the range of 1,800^{o}F to 2,200^{o}F. As the gasses pass out of the combustion chamber, they pass through additional heat recovery units, and air pollution control devices.

Bottom ash is discharged from the finishing grate into a water-filled ash quench pit. From there, the moist ash is discharged to a conveyor system and transported to an ash load-out or storage area prior to disposal. Metals recovery equipment is typically included in the ash conveyor system to recycle metals and reduce ash tonnage.

Continuous emissions monitoring (CEM) equipment is used to regulate waste delivery rates and air flow to the combustion chamber to optimize facility performance and maintain air pollution control standards.

The large amounts of air necessary to combust waste creates a negative air differential in the boiler; the air pressure in the boiler is lower than the ambient air pressure. This negative air pressure ensures that fumes and exhausts do not exit the boiler, except through the stack and air emissions control equipment. Most mass burn facilities draw the combustion air from outside across the enclosed tipping floor and then through the boiler, creating one-way air flow only into the facility, providing the side benefit of odor minimization.

Energy from combustion is used to heat water to produce superheated steam. Steam temperatures can exceed 900^{o}F and pressures can exceed 900 pounds per square inch gauge (PSIG). The steam can be used to power a turbine to generate electricity, to heat or cool buildings in a local "energy district" or to supply energy for industrial processes. Mass burn facilities that generate electricity and sell steam for other purposes are termed co-generation (co-gen) facilities, because of the dual use of the recovered energy.

3.2 Site/Utility Needs

A mass burn facility site would include a parking lot, offices, a scale house, roads, the main mass burn facility itself (waste pit and storage area, unacceptable material storage area, control room, boilers, turbines and generators, air emissions control system, potentially a separate metal recovery and ash load out building, cooling towers, and potentially a public tour and observation area). A leading developer of mass burn facilities suggests a median desired site size would be 10 to 15 acres.

Utilities required include water, sewer, electricity, and natural gas or oil for start-up and shut down. If steam is produced for district heating or industrial uses, a high pressure steam pipe would also be required.

3.3 Permitting and Public Acceptance

This section summarizes the regulatory agencies involved in permitting a mass burn facility; the required permits; and the expected regulations applicable to construction and operation of a new mass burn facility in Minnesota. Most of the permitting process is coordinated with the Minnesota Pollution Control Agency (MPCA). Siting a mass burn facility anywhere in the state will likely take several years and cost several million dollars. Factors that increase the timeline for permitting and construction are site specific. These factors include habitation by endangered species, limitations to air emissions, public response, and protection for humans from health risks. Each additional factor makes the permitting process more complex and expensive. Historically, mass burn facilities have faced significant public opposition. It should be anticipated that the permitting process for this potential mass burn facility will take several years for completion, with no assurance of success.

In addition to the MPCA, depending on location, several other agencies may be involved with permitting, including:

- United States Environmental Protection Agency (EPA)
- United States Anny Corps of Engineers (USACE)
- United States Fish & Wildlife Service (USF&WS)
- Federal Aviation Administration (FAA)
- Minnesota Public Utilities Commission (PUC)
- Minnesota Department of Natural Resources (DNR)
- Local County
- Local City
- Historical Society
- Department of Health

Examples of some of the permits that may be required from the various agencies include:

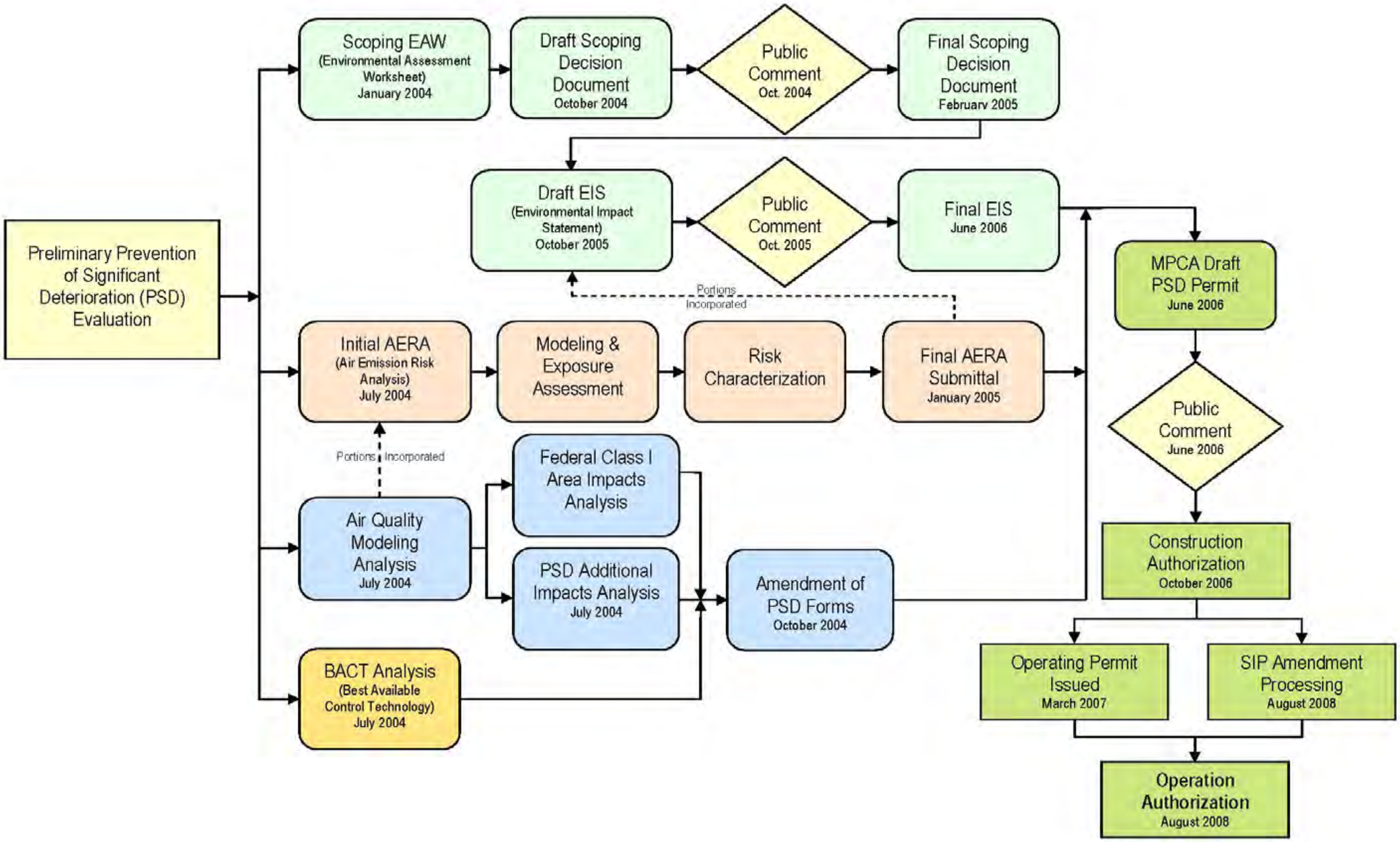
- MPCA – Environmental Assessment Worksheet (EAW), Environmental Impact Statement (EIS), Operating Permit (Air Permit), National Pollution Discharge Elimination System (NPDES) Permit, Industrial Stormwater Permit, Construction Stormwater Permit, Construction Air Permit.
- County and City – Conditional Use Permit (CUP) and any variances, Sanitary Sewer Discharge Permit, Solid Waste Facility License.
- DNR or Department of Health - Water Appropriations Permit (if water is not provided from a municipal source).
- Industrial wastewater pre-treatment agreement from MCES.

The first step in approval for a mass burn facility is to complete a Preliminary Prevention of Significant Deterioration (PSD) Evaluation. This is made up of six separate reports/studies that are to be completed before permit and include:

- Scoping EAW.
- Initial AERA (Air Emissions Risk Analysis).
- Air Quality Modeling Analysis – includes monitoring nearby sources.
- BACT (Best Available Control Technology) Analysis.
- An alternatives study (environmental impact if the mass burn facility is not constructed).
- Siting Analysis.

Olmsted County, Minnesota, built a 200 tpd mass burn facility in the mid-1980s and completed permitting for a 200 tpd expansion in 2006. A flowchart showing Olmsted County's process and timeline to complete the expansion permitting process is included as Figure 3-2 which is provided as a good example of the process anticipated to be required for a new mass burn facility in Minnesota.

Figure 3-2
Olmsted County Mass Burn Expansion Permitting Process



For a new facility, Minnesota law would require an EIS. An EIS for a typical mass burn facility takes about 18 months to five years to prepare. In the process, a responsible government unit (RGU) determines what the EIS must address. The MPCA would be the RGU for this type of facility. A summary list of the items that the EIS must contain (an EIS Preparation Notice) is required to be published in a local newspaper. The EIS is then prepared by the MPCA. The MPCA usually hires consultants to assist in writing the EIS. The expenses for preparation of the EIS are paid by the applicant. The EIS is specific to a facility design and location.

When first produced, the document is referred to as a Draft EIS. At this point, a public comment period would solicit comments on the draft EIS, and the MPCA would respond to comments on the draft EIS. The response could lead to additional studies. After review and comment, the draft EIS would be revised into final form. At this point, the MPCA would decide if the EIS is adequate and would publish its impending decisions. Ten days after publication the MPCA's decision is final.

Data from the Environmental Review documents would be used in preparation of the actual permit. Two permits would be issued for the mass burn facility, if it reaches this stage – one for construction and one for operation. Ideally the two permits should be approved at the same time to minimize risk.[1]

As part of an EIS for a mass burn facility the following information would likely be included:

- Air modeling to predict how parameters such as air temperature, visibility, humidity, and pollutant concentrations will be impacted;
- If water is pumped from, or discharged into a river, impacts to the river would be evaluated;
- Potential for impact to critical habitat, protected wetlands, or archaeological sites would be examined;
- A health risk assessment, including an Air Toxics Review would be performed to determine human exposure through inhalation, skin, food consumption, drinking and surface water; and
- A comparison of the potentially significant impacts of the proposal with those of other reasonable alternatives to the project. Alternatives analysis may include alternative sites, technologies, design, scale or magnitude, and other reasonable mitigation measures.

Environmental review, particularly during scoping and the public comment period have historically been the step when projects have failed to proceed through the permitting process. Environmental considerations surrounding mass burn technology have been centered on air emissions, ash handling and the lack of commitment to waste activities higher in the waste hierarchy when mass burn is employed. Public perception, leading to opposition, is sometimes a major issue affecting mass burn or other energy conversion projects.

[1] Phone interview with John Helmers of Olmsted County on 10-24-13.

If a permit is issued and the facility is constructed and operating, the Operating Permit (Air Permit) must be renewed every five years. Requirements of the permit include significant monitoring and reporting. For example, mercury and metals monitoring must be completed quarterly and annually, respectively, for the first three years of the permit. CEMS (continuous emissions monitoring) for SO_2, CO, O_2, NOx, and opacity are reported quarterly. Additionally an annual report is required that summarizes the air emission from the facility.

3.4 Technical Applicability of Mass Burn to R/W Waste

3.4.1 Inputs

Wastes for the mass burn facility will likely be brought to the facility by haulers of residential and commercial routes, self-haulers, as well as from transfer stations. Haulers who bring material to the facility will require training of what materials are not acceptable (e.g., tires, bulky material, electronics).

Unacceptable materials may include those that cause air emissions issues (e.g., electronics), are non- combustible (e.g., concrete blocks), or cause issues within the processing equipment (e.g., bulky material – size issue).

Some material that is acceptable can still cause problems within the system if not managed properly. Typically problem materials are delivered from industrial/commercial customers that have a very specific waste stream. Problem materials will need to be identified early and staff well trained in best management practices for certain waste streams.

Olmsted County carefully manages loads of sheet rock which can cause air emission issues associated with sulfur and sulfur dioxide. Small amounts of this material are not an issue, but it can become a problem if received in large quantities.[2]

HERC is also concerned about sheet rock, not only for the sulfur dioxide problem but also for causing problems with the grates. Industrial wastes in large quantities can plug the grates. Also, wastes with a high dust content that can cause clouds and problems with vision or foul the grates. Oversized or bulky wastes such as a hide-a-bed sometimes reach the grates by mistake, stretch out on the grates causing problems.[3]

Other materials that may cause issues are those which melt such as glass and aluminum which can cause slagging on the grates. In some instances, material must be diverted directly to a landfill. Olmsted County learned they needed to divert some industrial material directly to the landfill due to the large amounts of PVC in the waste.

3.4.2 Outputs

There are two main outputs for a mass burn facility, energy in the form of steam or electricity (customer dependent) and ash (metals may be recovered). A leading developer estimates the

[2] Phone interview with John Helmers of Olmsted County on 10-24-13.
[3] Phone conversation with Randy Kiser of Hennepin County on 1-15-14.

amount of ash produced will be between 25 to 28% by weight of incoming waste, net of ferrous and nonferrous metals recovery. [4] The EPA estimates the amount of ash generated ranges from 15 to 25 percent by weight of the MSW processed and from 5 to 15 percent of the volume of the MSW processed.[5] Olmsted County estimates that the ratio of processed material to ash generated is 10% by volume and 15% by weight. [6]

Using this range of generation rates, a 1,000 ton per day mass burn facility (operating at 90-95%) will generate between 50,000 and 97,000 tons of ash each year. For example, HERC has approximately 90,000 tpy of ash from the 1,000 tpd processed there.

A leading developer estimates a mass burn facility can generate between 650 and 700 kWh per ton of refuse processed or 6,000 pounds of steam per ton of refuse processed.[7] Using these generation rates, a 1,000 ton per day facility could produce up to 6 million pounds of steam or 700,000 kWh daily.

3.4.2.1 Markets for Steam and Electricity

Mass burn facilities can market steam, electricity, or both. Although steam is more efficient and economical, it is more difficult to find convenient steam markets. Electricity is more flexible and easier to market.

3.4.2.2 Steam Markets

Steam and hot water markets may consist of industrial manufacturing firms, industrial development parks, district heating and cooling systems, institutions, and commercial firms. The potential revenues to the mass burn facility are generally based on the costs that the steam customer can defer by not producing the steam in-house. No specific steam markets are included in this analysis as no specific site selection process has been considered.

The most advantageous steam customers would have the following characteristics:

- Require steam use on a 24-hour-per-day, 365 day-per-year schedule;
- A low pressure steam market may allow for cogeneration (producing electricity and steam for sale), maximizing two revenue sources;
- Expresses an interest in purchasing energy generated from a mass burn facility;
- History of stability in its business or service at the specific location and a long-term Business Plan to continue operation;
- Willing to enter into a long-term agreement for the purchase of steam;

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[4] Email response from John Phillips of Covanta Energy dated 9-13-13.
[5] http://www.epa.gov/waste/nonhaz/municipal/wte/basic.htm accessed 12-3-13.
[6] Phone interview with John Helmers of Olmsted County on 10-24-13.
[7] Email response from John Phillips of Covanta Energy dated 9-13-13.

- Current cost to produce steam is high, increasing the market's interest in alternative steam sources as well as increasing the rate paid (steam prices are typically negotiated on a case-by-case basis); and,
- Located in an industrially zoned area or within one mile of an area zoned industrial to accommodate the location of the mass burn facility (or close enough for a steam line connection).

Steam potentially provides greater revenue than electricity per ton of waste. Depending on the average steam production rates and the average market price of steam, steam may generate a revenue of $40 to $50 per ton of waste.

Nationally, only 20 percent of the WTE facilities (WTE includes mass burn and RDF incinerators) are dedicated steam producers, and 17 percent are cogeneration facilities (producing both steam and electricity). Approximately 70 percent of mass burn facilities are dedicated electricity producers.

As noted, the price paid for steam by the steam customer is typically tied to the cost of alternatives for the steam customer. This is determined by the efficiency of their boiler operation and the price of the alternate fuel—most often natural gas. Prices for natural gas may be low, impacting the steam markets.

3.4.2.3 Electrical Markets

A mass burn facility's electric turbine generators are connected to a utility sub-station. From there, the local utility manages the electricity. Based on the national average, plants sell their electricity for 5.09 cents per kWh and have an average net electricity production of 512 kWh per ton of MSW. This is equal to a revenue of $26 per ton of waste. The actual market values vary widely from site to site. Electricity prices are generally lower in the Midwest than the East Coast, and rates received in Minnesota are therefore lower.

Hennepin County with their 1,000 tpd facility – HERC, receives a capacity payment and an energy payment for their electricity sales. The capacity payment is a fixed amount per month. From 1992 to 2008, the facility averaged selling 215 million kWh per year. The energy payment is a certain amount per megawatt hour (MW) that varies during on peak versus off peak hours and also is adjusted for transmission lines losses.[8] Overall, the math is somewhat complex, but an average price per kWh is likely over $0.06 per kWh. Multiplying the estimated average rate times the 215 million kWh per year provides an estimated revenue over $13 million per year. Hennepin County also receives some revenue from steam sales.

3.4.2.4 Residues

The primary residues from a mass burn facility are bottom ash and fly ash. On average, the ash residue from mass burn facilities comprises approximately 25 percent of the weight of the

[8] Phone conversation with Roel Ranken, Hennepin County on 1-15-14.

incoming waste. Because the ash is very dense, the ash volume is typically about 10 percent of the original volume of MSW.

Metals are typically recovered from a mass burn facility. The ferrous and non-ferrous metal markets fluctuate. However, metal recovery from the bottom ash has proven to be a dependable and preferred method for managing metals.

3.4.2.5 Residues Management

Fly ash refers to the fine particles that are removed from the flue gas and includes residues from other air pollution control devices, such as scrubbers. The rest of the ash is called bottom ash. The main chemical components of bottom ash are silica (sand and quartz), calcium, iron oxide, and aluminum oxide. The chemical composition of the ash varies depending on the characteristics of the processed material and the combustion process. Typically, the ash is sent to a landfill for disposal.[9]

Most facilities including those in Minnesota combine the bottom and fly ash. Landfilling ash is a significant operating cost for a mass burn facility. For a 1,000 ton per day facility, at 92.5 percent availability, 25 percent by weight ash residual, and transport and disposal fees at $31 per ton (current approximate disposal cost for HERC)[10], it would cost over $3 million per year to landfill the ash.

In Minnesota, Polk County has performed six waste combustor ash utilization projects. Three projects used the ash as an amendment to the asphalt mix. Three used the ash as a substitute for the clay binder of Class 5 aggregate used to construct the road base. In total, 33,500 tons of screened ash has been used for road construction projects with a majority being used in the Class 5 aggregate. The beneficial use determination allows for 25% substitution rate to use ash instead of clay in Class 5 aggregate. All the ash used on the road projects were totally encapsulated so leaching of metal from ash was not a concern.[11] Cost savings for using the ash in the Class 5 aggregate are estimated to be $0.37 per ton.[12]

Testing of ash is required as part of permit for a mass burn facility. This testing is completed and reported on a quarterly basis. The leachate generated from the ash cells at the landfill is also tested as part of the landfill permit requirements.

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[9] http://www.epa.gov/waste/nonhaz/municipal/wte/basic.htm accessed on 12-3-13.
[10] Phone conversation with Randy Kiser, Hennepin County on 1-15-14
[11] http://www.mnresourcerecovery.com/index.php/faqs/
[12] Wilson, Willard (Bill). "Waste Combustor Ash Utilization." Proceedings 17th Annual NAWTEC. May 18-20, 2009, Chantilly, Virgina. Page 9.

3.5 Preliminary Economics

The eight (8) facilities in Minnesota are shown below:

Table 3-1
Minnesota 2013 Mass Burn Facilities Tipping Fees

Facility	Ownership	Published MSW Tipping Fee[13]
Polk County Resource Recovery Plant	Public	$ 70
Red Wing Integrated Solid Waste Management Campus	Public	$ 72
Pope-Douglas Resource Recovery Facility	Public	$ 82
Perham Renewable Resource Facility	Public	$100
Olmsted Waste to Energy Facility (OWEF)	Public	$ 83
Covanta Hennepin Energy Resource Company (HERC)	Public	$ 60

It should be noted that "Published Tipping Fees" are not necessarily the actual costs or rates paid. The contract rate at HERC is was adjusted January 1, 2014 from $47 to $49 per ton and the gate rate is now $65 per ton[14]. The actual cost at OWEF in Rochester is $106 per ton plus debt service. The difference between the tip fee and the actual cost is funded via a service charge collected on hauler bills by licensed commercial haulers as a percentage of gross receipts for hauler services. The residential percentage is 29% and the commercial percentage is 50%. The Olmsted County service area includes Olmsted and Dodge Counties. The two counties do not currently generate the 400 tpd needed to fill the plant's capacity. This further drives up the cost per ton. There are economies of scale in solid waste management and some public facilities pay for other solid waste services besides the waste-to-energy facility using their tipping fees.

This section provides some preliminary cost estimates for a 1,000 tpd facility (actually receiving 400,000 tpy) for this initial feasibility review.

3.5.1 Capital Costs

Foth obtained preliminary cost estimates from one of the leading waste-to-energy facility developers and operators in the U.S.[15] A two line, 1,000 tpd mass burn, electric generation facility, similar to the Hennepin County facility was estimated to cost $350 to $400 million. This would include all permitting, engineering, construction, start-up commissioning of facility systems, building, roadways, etc. It did not include the site acquisition costs, procurement/legal/consulting costs, or any financing costs. This calculates to a range of $350,000 to $400,000 cost per daily design throughput ton. This is consistent with the recent actual costs from the facility expansion at Olmsted County, MN.

[13] Waste Business Journal. Directory of Waste Processing and Disposal Sites. 2012. Pages 646-647.
[14] Phone conversation with Randy Kiser, Hennepin County on 1-15-14.
[15] Correspondence from W. John Phillips, Covanta Vice President, Business Development , September 2013

Estimates for the annual debt service were developed by Springsted with a summary shown in Table 3-3. There are four basic debt service projections that help provide a preliminary range of the annual debt service costs for both the $350 million and $400 million range of costs. In each of the scenarios, the total dollar amount financed includes 2% issuance costs, two (2) years of capitalized interest, and one (1) year of debt service reserve. The bonds were assumed by Springsted to be "A" credit rated revenue bonds.

Table 3-3
Preliminary Estimated Annual Debt Service Costs[1]

Capital Cost	*$350,000,000*	*$350,000,000*	*$400,000,000*	*$400,000,000*
Term	20 Years	25 Years	20 Years	25 Years
Net Interest Cost	4.40%	4.76%	4.40%	4.76%
Annual Debt Service	$31,715,000	$28,770,000	$36,250,000	$32,880,000
Tons per Year	400,000	400,000	400,000	400,000
$ per Ton	$79	$72	$91	$82

[1] Debt service cost estimates provided by Springsted Incorporated

The cost per ton for the annual debt service ranges from a low of $72 ($350 million/25 years) to a high of $91 ($400 million/20 years).

3.5.2 Operating Costs

Foth obtained a preliminary operating cost estimate from the same leading system developer/operator who operates the Hennepin County facility locally.[16] The preliminary cost estimate for the annual operating cost was $12 to $15 million. A guaranteed not to exceed cost could be established once all the variables are finalized. At 400,000 tpy, this provides a range of $30 to $37.50 per ton.

3.5.3 Revenues

There will be revenues associated with the sale of electricity and marginally from the recovery of ferrous metals. With a range of 650 to 700 kWh of electricity generated from a ton of MSW and a power sales price of $0.05 per kWh, the annual revenue ranges may be estimated using the following assumptions for each parameter as follows:

- Tons = 400,000 total tons
- Availability range from 90% to 95%
- Tons combusted = 400,000 x 90% = 360,000 & 400,000 x 95% = 380,000
- Electricity price = $0.05 per kWh
- Electricity generated per ton = 650 to 700 kWh
- Range of total annual revenue = 360,000 tons x 650 kWh x $0.05 = $11,700,000 versus
= 380,000 tons x 700 kWh x $0.05 = $13,300,000

[16] Ibid

There may be some revenue associated with ferrous or other metals recovery which can be estimated in a future phase if mass burn is considered further. There will obviously be revenue associated with tipping fees for the disposal of MSW.

3.5.4 Breakeven

Using the high and low ranges of the estimated cost per ton for annual debt service, operating costs, and revenues, a range in the break even costs per ton operating at 400,000 tpy is shown in Table 3-4.

Table 3-4
Preliminary Estimated Breakeven Cost per Ton

Low Debt Service	$72.00	High Debt Service	$91.00
Low O&M	$30.00	High O&M	$37.50
High Revenue	$33.25	Low Revenue	$29.25
Low Total	$68.75	High Total	$99.25

In round numbers, the estimated breakeven costs range from $70 to $100 per ton.

3.6 Timeline Needed To Implement Mass Burn

Permitting and constructing a new mass burn facility in Minnesota will likely take several years to complete if it is approved.

Olmsted County recently expanded their facilities and were required to go through permit amendments that would be similar to an initial permitting process for a new facility. Olmsted County began the regulatory permitting process for their plant expansion in February 2003 Project milestones included:

- EAW Completed – Winter 2005
- EIS Completed – Summer 2006
- Notice of Intent to Construct Issued – September 2007
- Unit Online – August 2010

This whole process took more than seven years to complete for an expansion to an existing facility.

A leading developer estimated two years for permitting and three years for construction.[17] Based on actual experience from Olmsted County, this estimate seems very low. Permitting especially could take longer. A planning period of seven (7) to ten (10) tears should be considered.

It should be noted that new mass burn facilities have been extremely difficult to develop due to organized public opposition groups that invariably form. Success will require a very dedicated commitment from local elected officials.

[17] Email response from John Phillips of Covanta Energy dated 9-13-13.

4 Newport with MWP and Gasification

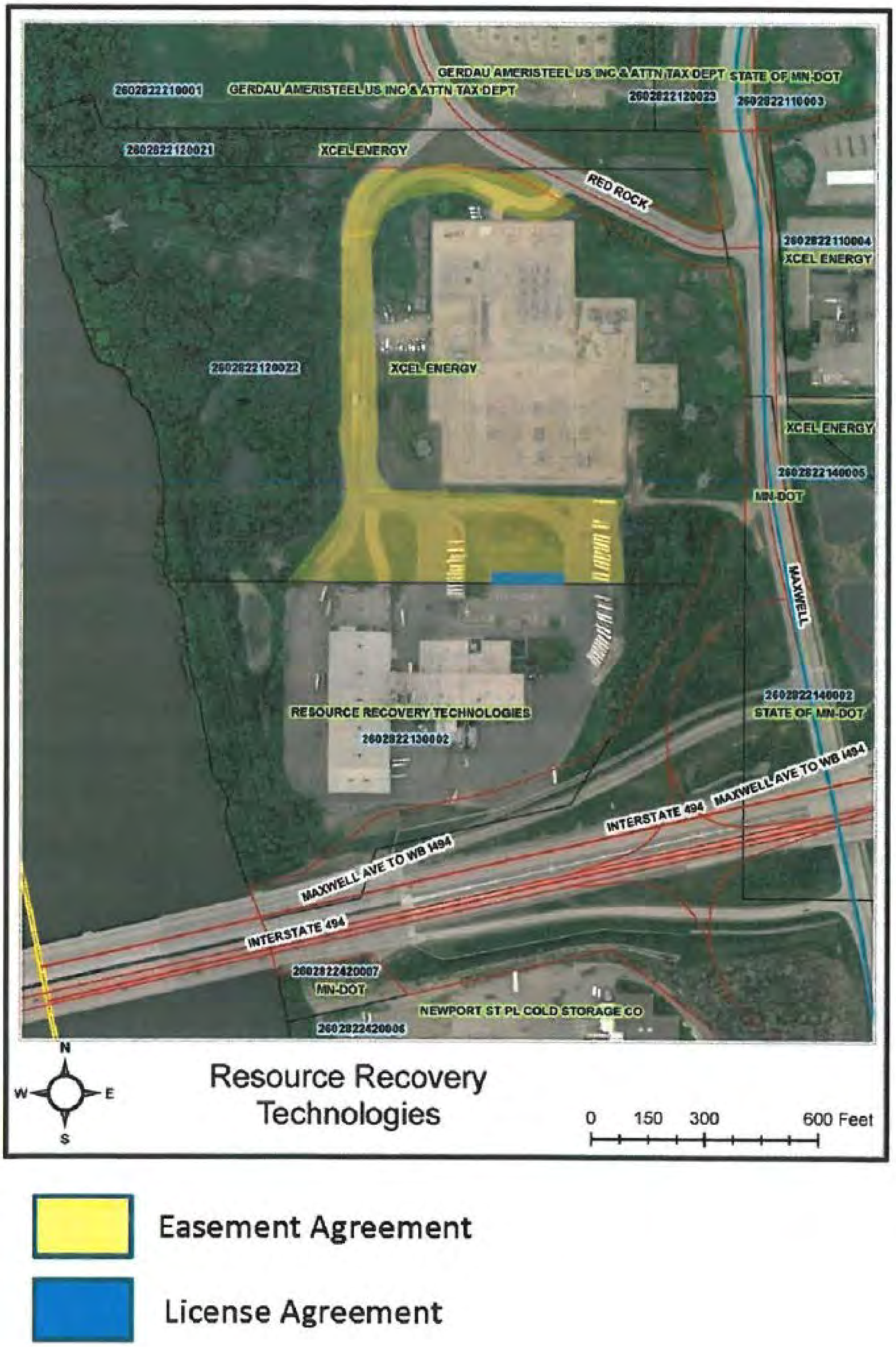
This section addresses adding specific technologies to the Newport Resource Recovery Facility (Newport facility), currently owned and operated by Resource Recovery Technologies, LLC (RRT). The technologies reviewed in this section could be owned and operated by RRT or any other entity. No ownership considerations are included in this analysis.

The current Newport facility is a 129,000 square foot building on an 18 acre parcel of land. The facility was originally constructed in 1986-87. An easement includes inbound and outbound lanes with scales adjacent to a scalehouse and trailer parking areas. The actual site includes a 64,000 square foot (approximately 160'x400') receiving building/tipping floor; a bulky waste residue shredder and loadout; processing building; administration building; service center; dust collection facilities; recyclables loadout; and residue and RDF loadout areas.

A facility site layout showing the parcel of land, buildings and associated support facilities (scales, etc.) is provided as Figure 4-1 (includes adjoining properties). The current equipment at the Newport facility can process approximately 1,700 to 2,000 tons per day of MSW into RDF.

Figure 4-1 shows a areas shared in yellow and blue. These areas are owned by Xcel Energy. The areas are not part of the current site. The areas are leased to RRT and have some limitations on development in the leased areas.

Figure 4-1
Newport Facility & Surrounding Properties



4.1 Brief Technology Descriptions

The potential to modify the Newport facility to add MWP and gasification technologies is considered in this section

4.1.1 Mixed Waste Processing

The purpose of a MWP facility is to separate and remove recyclable materials from incoming mixed waste (i.e., divert the recyclable materials from the waste stream). Recently announced waste processing projects include some type of front-end separation or mixed waste processing technologies.

The application considered in this analysis is a high-technology MWP facility targeting recovery of corrugated cardboard, mixed paper, PET (# 1) containers, HDPE (# 2) containers, ferrous metals, and aluminum from commercially-sourced MSW only. All other solid wastes, and the residuals from MWP, would continue on to the RDF processing system.

Based on discussions with Bulk Handling Systems (BHS)[18] (a large recyclables processing system vendor), the processing line is anticipated to include:

- Metered infeed – to provide an even, steady flow of material.
- Manual Pre-sort – to remove large, bulky items that might cause problems downstream. In order for the automated separation equipment to operate at the highest possible level of efficiency, a manual pre-sorting of materials is performed. The role of sorters at this stage is to remove large, bulky items that might cause problems downstream. These items include large residue, scrap metal, large rigid plastics, and wood.
- Bag Breaker – All material advancing past the pre-sort feeds into a bag breaker. The bag breaker opens the bags without shredding the contents and stages the material for the initial screening process.
- Initial Material Sizing – Segregating the material by size is a critical step in applying MWP to MSW. The first sizing step uses a debris screen to remove the smallest fraction, 2" diameter or less material. These fines are predominately organic material. Removing these fines creates a cleaner material stream for manual and optical separation downstream.
- Density Separation – This stage separates the light or low-density material (lights) from the heavy or high-density materials (heavies). The low density materials contain the vast majority of recoverable commodities such as paper, plastics, aluminum, and ferrous cans. The other fraction, high-density material, contains mostly organics, inert materials, soiled paper, textiles, and non-recyclable materials. The light and heavy materials are separated by a combination of a rotating drum and high volumes of air.
- Separation by Shape (2-Dimensional and 3-Dimensional) – The light materials recovered by the density separation are comprised of two main fractions as well as some remaining fines.

[18] Reference December 12, 2013 correspondence from Eric Loof, BHS

The 2-Dimensional, flat fraction is mostly fiber and plastic film. The 3-Dimensional, round fraction is mostly plastic, aluminum, and ferrous containers. These shapes are separated by disc screens. Any remaining fines (< 2") fall through the openings in the disc screen. At this point in the process, the material fractions have been sufficiently segregated so that they are ready for final sorting and quality control.

- Final sorting of two dimensional and three dimensional fractions – the two dimensional materials are transferred to a sorting conveyor for separating any recoverable fibers. The rejected paper continues to a conveyor for the RDF processing system. The three dimensional materials (container stream) passes through a combination of automatic and manual sort stations including:
  - A magnet to remove ferrous materials.
  - Manual sorting of Natural HDPE.
  - Manual sorting of Colored HDPE.
  - Eddy current separator to remove aluminum.
- Quality control stations to remove contaminants.
- Storage in bunkers or silos prior to baling.
- Baling prior to shipping to market.

Optical sorters can automatically sort out different types of materials with a combination infrared light beam and air pulses at relatively high speeds and through puts. Optical sorters are used for plastics, glass, and even fibers. No optical sorting was included in this analysis.

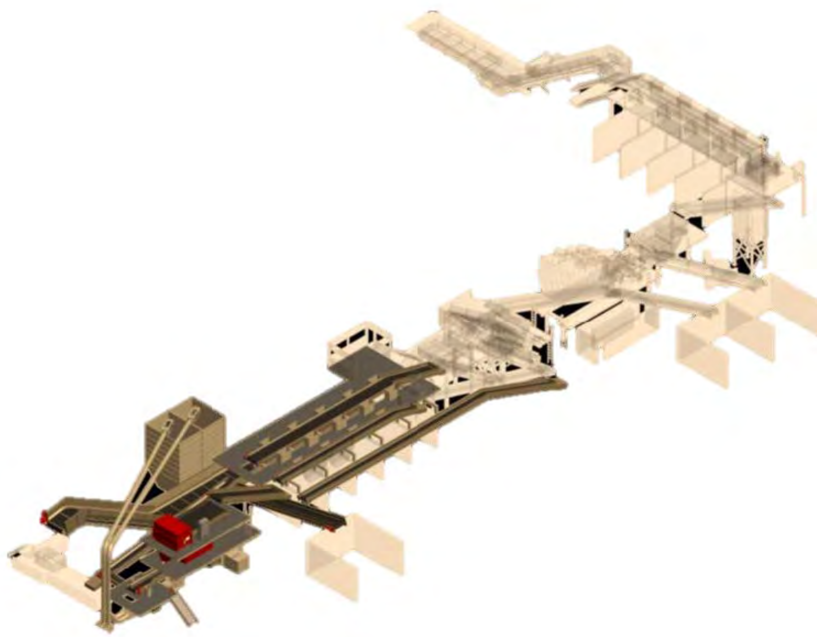
Typically the materials are conveyed through the process from one piece of equipment to another on belt conveyors. Pneumatic conveyors have been used to move lightweight sorted recyclables such as film plastic or aluminum cans from a sorting station to a bunker or bin prior to baling.

The markets for the recyclables include the standard markets utilized by source-separated recycling programs. These include paper mills, insulation manufacturers, aluminum mills, metal mills, and plastic recyclers. It should be noted that recyclables recovered via MWP facilities have a higher likelihood of contamination. Depending on market specifications and economic conditions, marketing recyclables from MWP facilities may be more difficult than recyclables obtained from source-separated programs.

A MWP facility is used to remove the targeted recyclable material from the mixed waste stream delivered. The residue will include the rest of the waste stream, which may be largely unchanged from the state it was delivered and would continue on to the RDF processing system. For this scenario, it is assumed that only commercially-sourced MSW materials would be diverted through MWP. It is assumed that the commercial wastes will have a higher percentage of the targeted recyclable materials than residential MSW. Residential MSW, representing an assumed 50% of the input to Newport, would proceed directly to the RDF processing system. For the facility to process residentially-sourced MSW in addition to commercially sourced materials, a second MWP line would need to be provided. This analysis did not address whether there is adequate room on the site for a second line as this will involve more detailed engineering analysis.

Drawings have been provided by BHS for a conceptual 30-35 ton per hour single-line MWP operation utilizing the system components described in Section 4.1.1. A three-dimensional rendering of the conceptual drawings is provided below (Figure 4-2) with optional eddy current and PET optical enhancements.

Figure 4-2
Schematic Rendering of a Mixed Waste Processing Line[19]



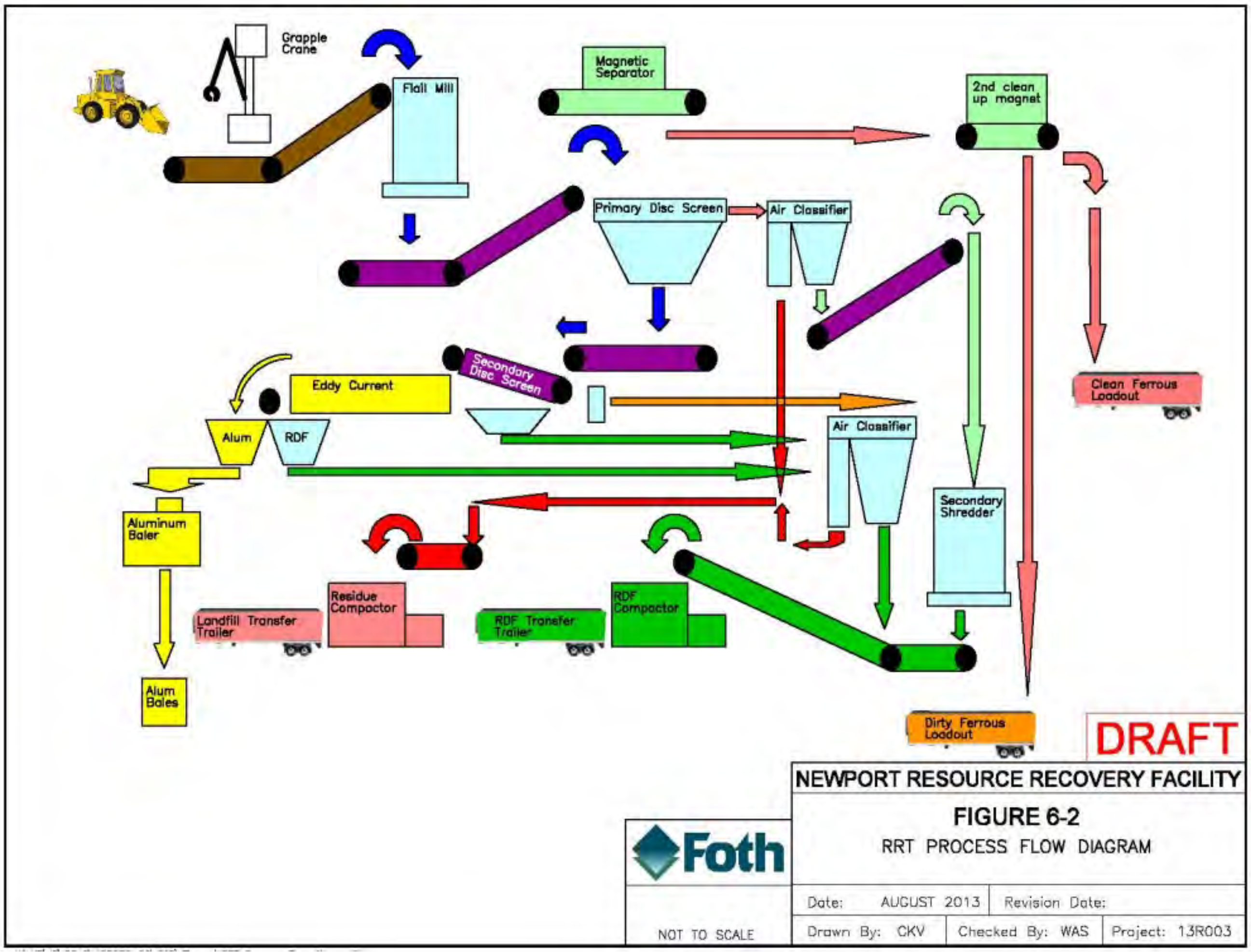
The entire processing line, from infeed conveyor to residue transfer occupies a length of approximately 405 feet. As illustrated in the rendering, the first leg of the system (upper right), incorporating the infeed conveyor, manual presort station, and bag breaker would be 125 feet in length and approximately 30 feet in width. The additional processes along the main line of the system, from initial sizing through residual management, would encompass an additional 280 feet of length. Leaving room for the organics, heavy items, and residue conveyors and associated bunkers, and room for material removal from the bunkers, the system as illustrated would require approximately 125 feet on either side along the main line where the receiving bunkers for organics, heavy items, and residue would be located. Based on these assumed dimensions, the MWP equipment for a single MWP line would occupy as much as 38,750 square feet of the 64,000 square feet (approximately 160' x 400') currently available in the MSW receiving/tipping floor area, since this would leave just 25,250 square feet for all other receiving/tip floor activities, including receipt of residential MSW for direct processing as RDF a modified configuration with a new building is anticipated. This would maintain more of the existing tip floor for residential MSW and direct processing as RDF. Additional details pertaining to the layout and process flow of materials for the enhanced Newport option are provided in Section 4.1.5.

[19] Provided by Bulk Handling Systems

4.1.2 Refuse-Derived Fuel (RDF)

The existing RDF plant has two processing lines designated as A line and B line, which are similar in design and capacity. Each starts at the in-feed area in the MSW tipping floor area and ends at the RDF trailer loading area. Figure 4-3, RRT Process Flow Diagram, and written description (specifically describing the process at the Newport RDF facility) of the processing lines are provided. The process steps at Newport are as follows:

Figure 4-3
RRT Process Flow Diagram



1. Incoming trucks are weighed.
2. Trucks unload MSW on the Tipping Floor.
3. Primary sorting and transport of the MSW to the in-feed conveyors, bulky waste shredder (if the material is bulky), ferrous or residue. This is accomplished by the front end loaders and grapples in the tipping floor area.
4. In-feed conveyors move the MSW to the hammer mill for size reduction.

5. Conveyors move the material exiting the hammer mill to the magnetic separator for removal of ferrous materials. Material that is generally free of ferrous is conveyed to the primary disc screen. Additional details relating to ferrous materials processing is described in Step 10.
6. The primary disc screen separates material by physical size, under four (4) inches, called "throughs", and over four (4) inches, called "overs". The "throughs" are conveyed to the secondary disc screen for further processing. The material considered "overs" are conveyed to the primary air classifier which is described in Step 11.
7. The secondary disc screen separates material under two (2) inches in size from the "throughs" of the primary disc screen. Material larger than two (2) inches in size is conveyed to the non-ferrous eddy current separator. The material less than two (2) inches in size is considered RDF and is conveyed to RDF loadout.
8. The over 2 inch material from Step 7 is conveyed to the eddy current separator for aluminum removal. Material exiting the eddy current sperator is conveyed to an air classifier.
9. Aluminum-free material from the eddy current step (Step 8) and the secondary disc screen "throughs" (Step 7) are combined and conveyed to the air classifier, where additional residue is removed leaving RDF.
10. Ferrous material, from (Step 5) is conveyed to a second "clean-up" magnet where "clean" ferrous materials are removed and conveyed to the clean ferrous loadout. The remaining ferrous material is considered "dirty ferrous" and is conveyed to a separate dirty ferrous loadout.
11. Overs from the primary disc screen (Step 6) are conveyed to an air classifier in order to separate the material into "heavy" and "light". Heavy materials are considered residue and are conveyed to the residue loadout for eventual delivery to the landfill. Light materials are large pieces of RDF and are conveyed to the secondary shredder.
12. The light materials enter the secondary shredder in order to reduce the size of the materials to an acceptable size for RDF.
13. "Throughs" from the secondary disc screen (Step 7) are conveyed to an air classifier, where heavy residue materials are removed and conveyed to the residue loadout for the eventual delivery to the landfill. Light material from the air classifier is RDF.

4.1.3 Gasification

Gasification is a thermal process (uses heat) that converts carbon based materials into a syngas (synthetic gas which is usually composed of carbon monoxide, hydrogen, short chain alkanes, and carbon dioxide). The process uses limited amounts of air or oxygen. Some gasification processes also inject steam to promote the production of carbon dioxide and hydrogen.[20] Gasification that uses air in the process typically produces a low Btu fuel that is nitrogen rich. Gasification dissociates water from the waste into hydrogen and oxygen.[21] Gasification typically

[20] Young, Gary C. Municipal Solid Waste to Energy Conversion Process. John Wiley & Sons, Inc. 2010. Page 3
[21] Alemeda Power & Telecom, Investigation into Municipal Solid Waste Gasification for Power Generation. May 27, 2004. Page 6

operates at temperatures ranging from 1,450°F to 3,000°F. Production of fuels (typically ethanol or methanol) from gasification using MSW has three major processes:[22]

1. MSW Handling and Processing
2. Conversion of MSW into Syngas
3. Fuel Production

MSW handling and processing is the first step in the gasification process. Receipt of MSW is typically completed in a building to control odor and windblown litter. The building is sized to handle the expected daily waste input and the waste storage area is typically large enough to store two to three days of waste to assure adequate waste input should interruption in the waste flow occur. Gasification systems typically require MSW to be converted to RDF to be properly gasified.

The gasification process that converts the MSW into syngas can be completed in either fixed or fluidized bed configurations. The chemical reactions that occur in a gasification process are:

1. $C + O_2 \rightarrow CO_2$
2. $C + H_2O \rightarrow CO + H_2$
3. $C + CO_2 \rightarrow 2CO$
4. $C + 2H_2 \rightarrow CH_4$
5. $CO + H_2O \rightarrow CO_2 + H_2$
6. $CO + 3H_2 \rightarrow CH_4 + H_2O$

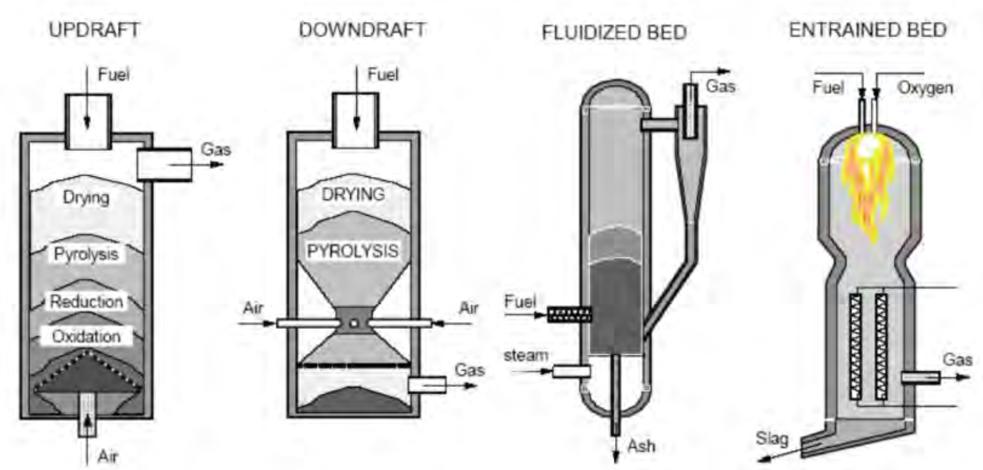
The reactions are all reversible and are dependent on the pressure, temperature, and oxygen in the gasifier.[23]

Fixed bed gasifiers are designed with a grate to support the RDF in the reaction zone. The downside of fixed bed gasifiers is the syngas yield can be variable in composition and quality. Fixed bed gasifiers are easier to design and operate compared to fluidized beds, but are not well suited for large scale operations.[24] Two typical fixed bed gasifier designs include downdraft and updraft. Both feed RDF from the top of the gasifier. The advantage of the updraft gasifier is that no drying of the waste is required. Additionally, the syngas leaving the process is typically cooler than with a downdraft gasifier. [25] The fluidized bed gasifiers typically use a solid material such as coarse sand or limestone as a bed. RDF is introduced into the reactor either on top of the bed or into the bed. Fluidized bed can be either bubbling fluidized bed or circulating fluidized bed reactors. Typically, fluidized bed reactors are used for larger capacity applications than fixed bed reactors[26]

[22] Ibid.
[23] Krigmont, H. (1999), "IBGCC Power Generation Concept: A Gateway for a Cleaner Future." Allied Environmental Technologies, white paper.www.alentecinc.com/papers/IGCC/ADVGASIFICATION.pdf
[24] Klien, A. (2002). Thesis. "Gasification: an Alternative Process for Energy Recovery and Disposal of Municipal Solid Wastes." Columbia University.
[25] Ibid.
[26] Ibid.

There also exists a single or two chamber gasification process that does not require front end processing of MSW (to size reduce the MSW before gasification).[27] The syngas produced from this gasification process is used in a waste heat boiler to produce steam. Thus, the quality of syngas produced is not critical since it is essentially burned to power a boiler. The steam from the boiler is then used to turn a turbine to produce electricity. This is generally the simplest form of the gasification approaches and is offered by several vendors in the U.S. Typical designs of the various gasification technologies are provided in Figure 4-4. Syngas produced from gasification of MSW or RDF can be used to heat a boiler, directly burned to produce electricity, or chemically converted into fuels and chemicals.

Figure 4-4
Typical Gasifier Configurations[28]



4.1.3.1 Enerkem (thermochemical conversion)

Enerkem has a thermochemical process that converts RDF into biofuels and chemicals. Enerkem has developed a gasification technology over the past 10 years to convert RDF into specialty chemicals (methanol) and fuels (ethanol). Enerkem has two pilot plants that were developed as "proof of concept" plants. These two plants in Sherbrooke and Westbury, Quebec have been operating for several years. Additionally, Enerkem has two full scale plants in development. The two plants are designed to produce 10 million gallons per year of ethanol. The commercial scale plants are located in Edmonton, Alberta and also in Pontonac, Mississippi. The Edmonton plant is expected to be operational in 2014. Each plant is designed to accept 100,000 metric tons (110,000 tons) per year of RDF to produce the 10 million gallons of ethanol.

The Enerkem process is shown in Figure 4-5.

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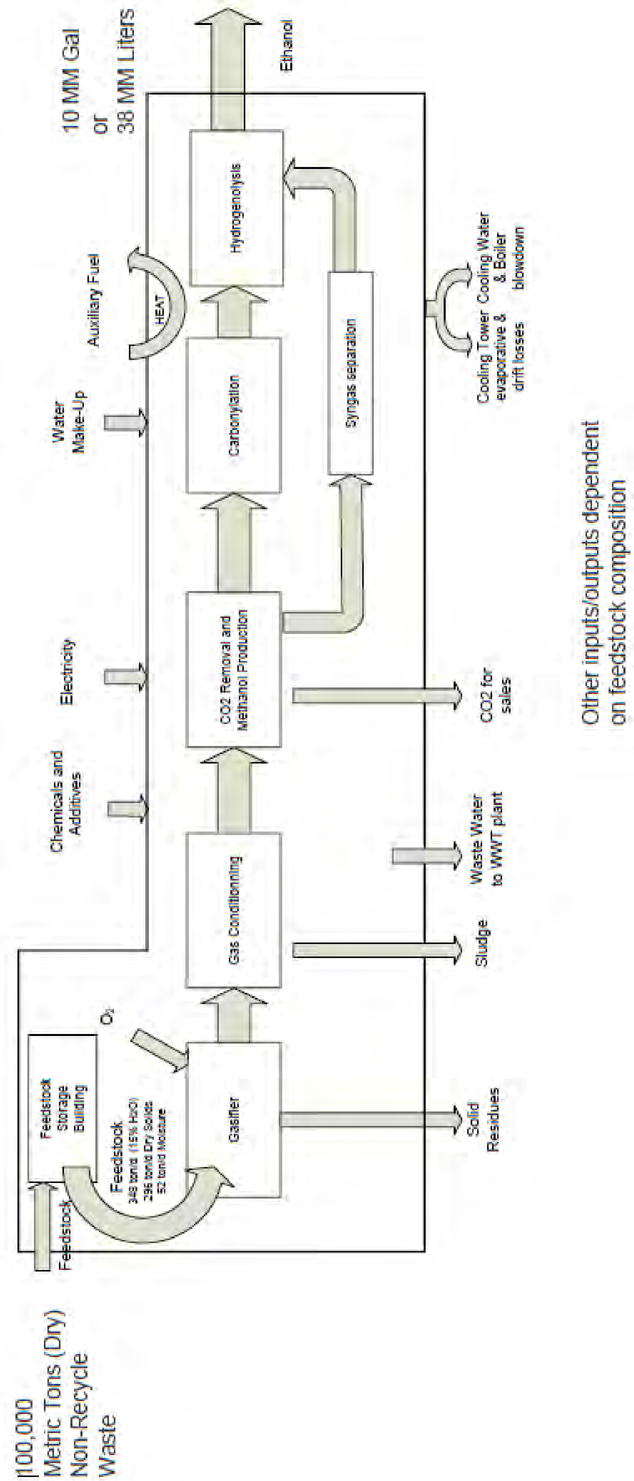
[27] HDR (2013), "Alternative Disposal Feasibility Final" prepared for Metro Waste Authority. Page ES-10
[28] Source: Juhani Laurikko Riitta Pipatti Mikael Ohlstrom, Tuula Makinen. New concepts for biofuels in transportation

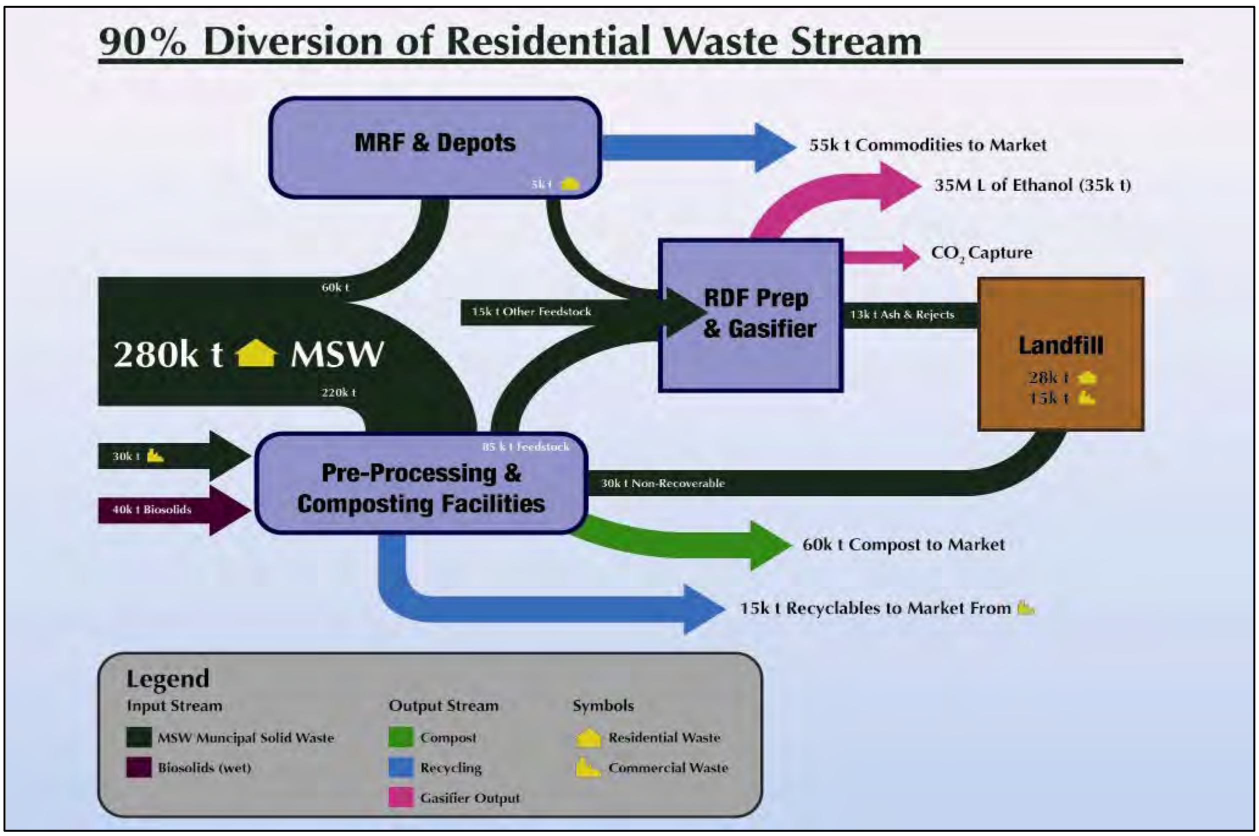
Figure 4-5
Simple Block Flow Process Diagram: Enerkem, Edomonton[29]



[29] Source: Enerkem

The Enerkem Edmonton process accepts RDF from the City of Edmonton. The City of Edmonton collects all the residential waste from households. They have a blue bag (recycling) and black bag (waste) system. The City provides collection services to its residents for a total cost for all services for $35 per month. Commercial collection is somewhat an open market; however, the only facility for disposal is the City of Edmonton facility. (Note: a smaller Waste Management landfill is located on the west edge of Edmonton and is scheduled to close in 2014. The closest landfill is 65 miles). There is no yard waste collection system. The City of Edmonton encourages mulching lawn mowers for yard waste management. The City delivers the residential waste to their City owned processing facility that produces the RDF for Enerkem. Figure 4-6 provides a diagram of the City of Edmonton's waste management system.

Figure 4-6
City of Edmonton Waste Flows



The City of Edmonton compensates Enerkem at a rate of $45 per ton of RDF converted to ethanol. However, the contract also requires Enerkem to pay disposal fees of $80 per ton for tons less than 110,000 that are not converted to ethanol (or other chemicals). This public private partnership provides incentives for both parties to ensure success. The Enerkem Edmonton facility is scheduled to be operational in 2014 producing methanol. The ethanol conversion process is scheduled for installation in late 2014 or 2015. A recent photo of Enerkem's facility in Edmonton is provided in Figure 4-7.

Figure 4-7
World's First Full-Scale MSW-to-Biosolids Facility
Edmonton, Alberta (Canada)

As of January 2014

Waste is received at the City of Edmonton Waste Management Center and directed to the main processing building. Source separated recyclables are sent to a separate material recovery facility. Waste is unloaded on the tipping floor and fed onto a conveyor and into a separation process area to mainly size separate organics from the waste stream. There is some limited recovery of valuable material using labor to hand pick the materials. Additionally, the material passes through a magnetic separator to gather ferrous metals. Once the material passes through the screening area, it is sent to a slow speed shear shedder for further size reduction and separation. The final process is a high speed shear shedder that sizes the residuals into a specified RDF for use in the Enerkem gasification process. The RDF is then conveyed to a holding bunker next to the Enerkem gasification skid.

RDF is loaded into the gasification process using bucket conveyors. The material leaves the RDF storage facility and moves to the top of the gasifier. From there, the RDF is exposed to carbon dioxide to "inert" the RDF. The goal of this process is to limit the amount of air that is entrained in the RDF. Air in a gasification process can cause unwanted chemical reactions. Once the RDF is inerted, the RDF enters the gasification process near the fluidized bed. RDF is then converted to syngas. The syngas is scrubbed and converted to chemicals using catalysts and other standard techniques used in refineries. Initially, the output from the Enerkem, Edmonton plant will be methanol but will be converted to ethanol sometime in 2014 or 2015.

4.1.3.2 IneosBio (Thermo-fermentation Conversion)

IneosBio is part of a larger company, INEOS, is a large petrochemical and specialty chemical manufacturer headquartered in the United Kingdom. It consists of 15 businesses with 51 manufacturing facilities in 11 countries, and with annual sales of around $43 billion

IneosBio designed and developed the Indian River Bioenergy Facility in Vero Beach, Florida and has started production of ethanol from green waste (yard wastes). This is the facility that provided a tour during the Renewable Energy from Waste Conference in November, 2103 attended by some representatives of the Board. The new plant was built with an investment of more than $130 million. The Vero Beach plant is designed to produce 8 million gallons of bioethanol annually and also produce six megawatts of renewable power for its needs. Excess power generated at the plant will be supplied to the local Floridian market and is expected to be enough to power 1,400 households. The maximum theoretical yield of ethanol from biomass at the Vero Beach plant is about 82 gallons per ton of material.

The IneosBio plant uses a gas fermentation technology that converts waste into a syngas through gasification. The syngas then goes into a bioreactor and comes out as a mixture of ethanol and water that is distilled and dried, or can be further purified and used as a pharmaceutical grade alcohol as well. To produce bioethanol, the plant currently uses 150,000 tons of green wastes (future plans include the use of other renewable biomass including household, agricultural and municipal solid waste). The green waste is collected by the Solid Waste Disposal District (SWDD) curbside collection program, delivered to the county's collection centers, or delivered directly to the facility by the public.

The process used by INEOS has four major steps: feed reception and drying, gasification, fermentation, and distillation.

Feed Reception and Drying

Trucks delivering the feedstock are accepted on a twelve hours per day, seven days per week basis, excluding some holidays; similar to present landfill operation hours. Trucks removing ash will operate on the same schedule. Trucks deliver vegetative waste and clean woody construction debris to the tipping floor in the materials handling area. Front-end loaders are used to maneuver the materials from the truck tipping floor to the storage and processing areas. The processing area shreds the waste into specific size requirements. Shredded waste is stored for drying.

The two feedstock dryers receive shredded feedstock from the storage piles and use low-pressure steam, provided by the boiler and heat recovery systems, to reduce the feedstock moisture to around 15 percent. Flue gas from the dryers is vented to the atmosphere through a dust control system. The dried feedstock is then sent to the gasifiers by way of a covered conveyor system. Particulate emissions from the dryer exhaust are controlled with a baghouse.

Gasification

Two gasifiers convert the shredded input feedstock to syngas through a two-stage process. First, a dedicated ram feeder pushes dried feedstock into the lower gasification zone. During startup, natural gas is introduced into the lower zone burner to bring the system up to speed, but once steady operation is achieved, only additional oxygen will need to be supplied. There will be no vent from the gasifier, other than emergency pressure relief through diversion to the gasifier flare.

The hot syngas produced by the gasification of the green waste is cooled and cleaned before being introduced to the fermenter. As the hot syngas leaves the gasifier upper chamber it is conditioned, before being passed through heat recovery exchangers to recover the heat as high pressure steam. This is used to generate renewable power for use in the process and for export. After the heat recovery exchanger the syngas passes through a dry scrubber and then a water quench. The cooled, cleaned syngas is compressed to pass it through the fermenter.

Fermentation

The cooled, cleaned, syngas is introduced into the fermentation process, where naturally occurring bacteria selectively combine molecules from the syngas to produce bioethanol. The fermenter is agitated to aid gas-liquid transfer. The IneosBio fermentation process takes only a few minutes. The fermentation system includes nutrient feed tanks and alkali for pH control.

The microbes used in the IneosBio process technology are a naturally occurring micro-organism (i.e., it is not genetically modified). The bacteria efficiently convert the syngas into ethanol and extract the carbon and energy they require for cell division and metabolism directly from the syngas. As the bacterium is anaerobic, the bacteria die upon exposure to oxygen. Liquid ethanol is sent to the distillation system, and vent gas from the fermenter is routed to a vent gas scrubber.

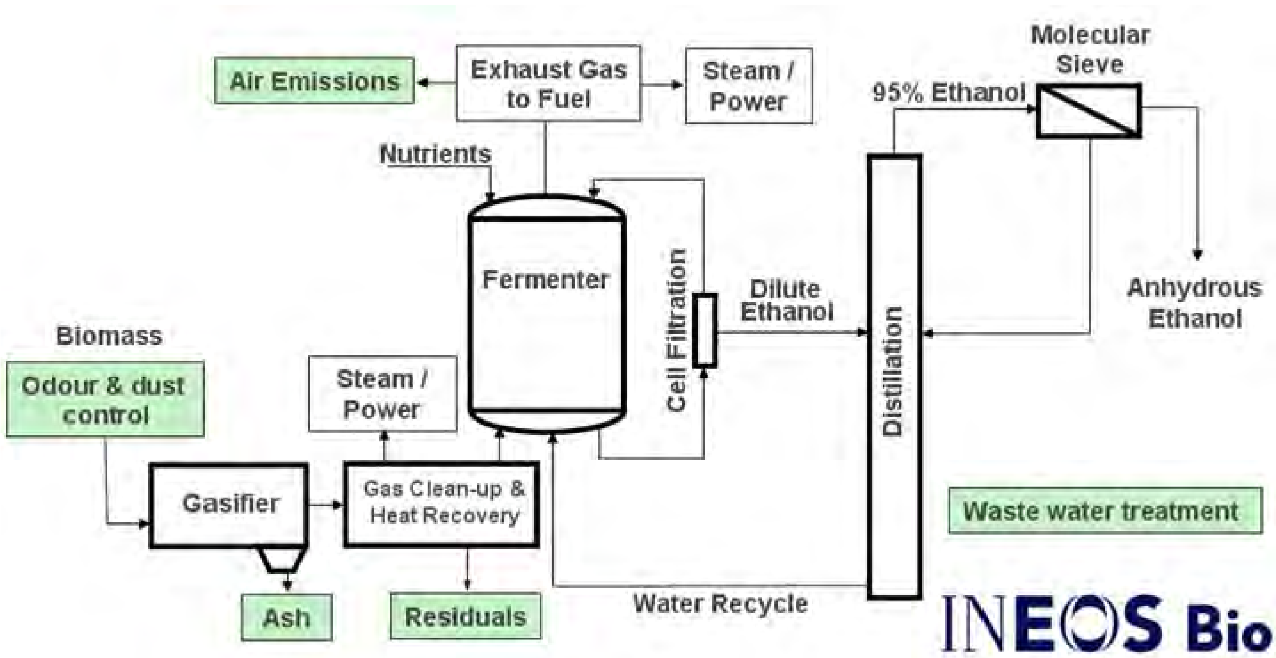
Distillation

The distillation system accepts the filtered fermentation broth as well as the vent gas scrubber bottoms. The distillation tower receives the broth (a mixture of water, ethanol, acetic acid and heavy alcohols) from the distillation feed tank, and overhead vapor leaving the distillation tower is collected in a reflux drum and pumped back into the tower. There is off-gas from the feed tank and the reflux drum. Off-gas from both is routed to the vent gas boiler with some fugitive emissions from the distillation system.

The fermenter liquid is continuously extracted, filtered to remove the bacteria and nutrients, distilled and then purified by molecular sieve to anhydrous bioethanol. Steam generated by recovering heat from the gasification process is used to provide the required heat energy for distillation. Water from the distillation column is recycled back to the fermenter. Water purge from distillation is treated in a waste water treatment facility.

A flow chart of the process is provided in Figure 4-8. A link to an informative video is located at: https://www.youtube.com/watch?v=9x4AajQJ5z8&feature=player_embedded

Figure 4-8
INEOS Process Flow Diagram



4.1.4 Key Differences Between Enerkem and IneosBio

The primary differences between the Enerkem System and the IneosBio system are feedstock and conversion technologies for ethanol production. Enerkem feedstock is basically RDF from MSW; while IneosBio uses primarily green waste as a feedstock (though IneosBio does report that using MSW may occur in the future). Both facilities convert the feedstock into syngas using a gasification process. The syngas is then converted to ethanol. For the Enerkem facility the conversion to ethanol is completed by a catalyst system. For IneosBio the conversion is completed using a fermentation process that utilizes bacteria to convert the syngas to ethanol. Both processes have demonstrated success in making ethanol.

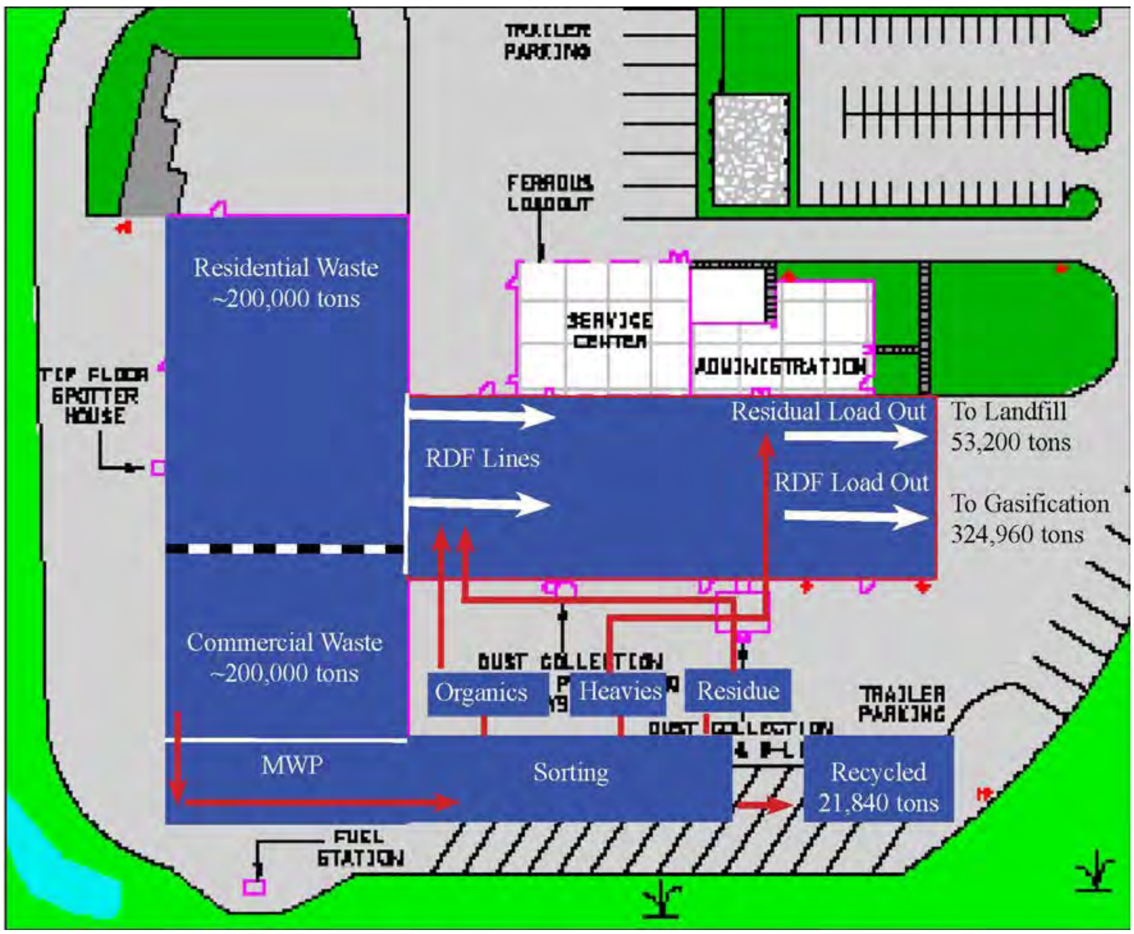
4.1.5 Key Assumptions for Process Flow Modifications

The current RDF system could be continued during modifications with the continued shipment of RDF to the Xcel Energy (Xcel) combustion plants on an interim basis while the gasification technology is designed, permitted, and constructed

For the Newport option with MWP, RDF processing, and gasification, the receipt of MSW at Newport would be divided into commercial waste and residential MSW. The commercial waste would be targeted for MWP activities. The existing and expanded tipping floor would be used for acceptance of both waste streams. Generally, the commercial waste would be unloaded on the south side of the existing tipping floor to allow for metered infeed into the conveyor of the MWP equipment. Conceptually, the MWP equipment shown in the drawing provided by BHS would be placed to incorporate the infeed conveyor, manual presort station, and bag breaker within the existing tipping floor area.

For preliminary purposes of this feasibility analysis, the remaining MWP equipment may be positioned within a new building along the south side of the existing Newport facility (there will need to be much more analysis of this conceptual arrangement if this concept is pursued further). Organics and MWP residue resulting from MWP is anticipated to be conveyed to the existing RDF processing line. Heavies from the MWP would be conveyed to the existing residue management area within the Newport facility. Due to space limitations at the Newport site, the resulting RDF from the Facility would be trucked to a gasification facility that is assumed to be located within 20 miles for this analysis. Heavies and RDF residue would be trucked to a landfill. Figure 4-9 shows a schematic of the general process flow of material for this option.

Figure 4-9
Process Flow Schematic For Enhanced Newport Option



4.2 Site/Utility Needs at Newport

The overall area and utilities necessary to successfully construct and operate a facility that incorporates MWP and gasification at the existing Newport facility will require the use of additional space and may require installation of additional utilities depending on the technology selected.

4.2.1 MWP and RDF

As discussed previously, it is anticipated that there is sufficient space to have a single MWP line targeting commercial waste (~30-35 TPH) at the existing RDF facility.

It is anticipated that the current utilities at the site are capable of handling the added demands from the MWP equipment with minor infrastructure improvements.

4.2.2 Gasification

Discussions with Enerkem representatives indicate that an Enerkem gasification facility using RDF from the existing Facility would require an additional 20 acres. Therefore, for this Newport option, a gasification facility accepting the RDF would be sited at a different location.
The new Enerkem facility in Edmonton is approximately seven (7) acres for the RDF storage facility, gasification-fuel processing facility and fuels load out areas. The Edmonton facility is designed to produce 10 million gallons of ethanol each year. This requires an RDF supply of approximately 125,000 tpy (wet). For this option and the estimated 324,960 tpy of RDF, three (3) gasification/fuel units would be required. Enerkem estimates about 20 acres would be needed to provide the area with required storage needed to store the RDF, gasification and fuel train, and load out facility.

The site for a gasification facility would need to be accessible from major transportation routes since the RDF would need to be transported to the gasification facility much like it is now to Xcel facilities. Additionally, ethanol produced must be transported to a user. The site would require water and sewer access. The gasification to fuels process requires significant water quantities and several facilities (waste water treatment, CO_2 compression facility, and other mechanical systems associated with a refinery) to support the conversion of syngas to ethanol. The RDF storage facility would also require fire protection. Additionally, the gasification facility would need access to natural gas for startup of the gasifier and heating of buildings. Electric power would also be needed

Ideally, to minimize transportation costs, the gasification facility would be sited close to the existing Newport facility to limit hauling costs as well as in the vicinity of a refinery so transportation of the ethanol produced can be efficient. For reference, both the Vero Beach IneosBio and Edmonton Enerkem facilities are located at landfill facilities. In the case of Enerkem, the facility is also within ten (10) miles of a refinery. Should gasification be considered for further study; a comprehensive siting analysis is recommended to identify potential parcels that could be used for the gasification facility.

4.3 Permitting and Public Acceptance

It is anticipated that permitting the MWP portion of this option would be relatively easy considering the MWP operations would occur at the Newport facility where MSW processing is already taking place. A modification to the existing Facility permit is likely to be required.

However, permitting and public acceptance of the gasification plant may present added challenges since it is a relatively new technology, there are no operating plants in Minnesota and there is no existing permitting structure (rules or process) in Minnesota to permit a gasification facility.

Since there is a lack of permitting framework for a stand alone gasification facility, it is likely the facility would follow some form of permit structure similar to the MSW combustion facility requirements currently in rule. However, since the emissions profile for gasification is significantly less than an MSW combustion facility, the permit process if likely to be viewed favorably, but will also take considerable time due to several unknowns. The basic framework for permitting would include several agencies including the MPCA, Local County, Local City (depending on siting), MCES, DNR (if water appropriation is required)

Examples of some of the permits that may be required from the agencies include:

- **MPCA**
  - Environmental Assessment Worksheet (EAW)
  - Environmental Impact Statement (EIS)
  - Operating Permit (Air Permit)
  - Solid Waste Permit (to accept and store RDF on site)
  - National Pollution Discharge Elimination System (NPDES) Permit
  - Industrial Stormwater Permit
  - Construction Stormwater Permit
  - Construction Permit
- **County and City**
  - Conditional Use Permit (CUP) and any variances
  - Sanitary Sewer Discharge Permit
- **DNR/Department of Health**
  - Water Appropriations Permit (if water is not provided from a municipal source)
- **MCES**
  - Industrial Wastewater Pre-Treatment Agreement

A gasification process as proposed does not easily fit into the existing regulatory structure for waste facilities. However, it is likely some or all of the following reports would be required to such a facility:

- Scoping EAW
- Initial AERA (Air Emissions Risk Analysis)
- Air Quality Modeling Analysis
- Siting Analysis

The reports and studies addressed above are typical for an MSW combustion facility. However, the emissions profile for a gasification facility can be considerably less. Some of the reports may be waived by the MPCA upon completing a permit application and providing information in an EAW. For the proposed facility it will be important to draw on gasification plant air emissions levels permitted in Florida and Mississippi as a starting point for the proposed facility.

In regards to developing an EIS, it is not anticipated to be required unless there is significant public opposition to a gasification facility. Should an EIS be required, Foth anticipates the process to take 12 to 18 months, depending on the scope of the EIS. The project proposer may also choose to complete a voluntary EIS. Development of a voluntary EIS has been done for expansions of MSW combustors as a strategic method to limit opposition to an expansion of an existing plant. For a new technology at a new site, a voluntary EIS is recommended.

4.4 Technical Applicability to R/W Waste

4.4.1 Inputs

Input material for the Newport with MWP and gasification option will come direct hauled from commercial haulers, self-haulers, as well as from transfer stations. The current inputs that are received at the existing RDF facility are anticipated to stay the same. The process inputs include approximately 200,000 tpy of residential waste and 200,000 tpy of commercial waste that would be delivered to the existing Newport facility. From the material received, the commercial portion is anticipated to be processed for recycling while the residential waste would be directly converted to RDF with only removal of ferrous and non-ferrous materials using magnets and eddy-current separators as is the current practice.

The commercial materials that are received would be sent through MWP to gather recyclable materials. The processing equipment is assumed to recover 60% of each of the targeted recyclable materials (ferrous, non-ferrous, plastics, corrugated materials and various forms of paper) that would be sent to markets. Additionally, the process would include some materials that would require landfilling including inert materials like brick, drywall, concrete, etc. The remainder of the material not recycled or sent to a landfill, would be sent to the RDF plant to be converted to RDF along with all the residential waste that is directly converted to RDF.

Specifications requirements for the RDF include moisture content of 20% or less and inert content at 15% or less. While the particle size of the RDF has some impact, the RDF currently produced at Newport meets the size requirements for the RDF entering the gasifier. Additional RDF testing may be needed for a selected gasification vendor. However, generally the RDF currently produced at the Newport facility is believed to be adequate for gasification to fuels process.

4.4.2 Outputs

Outputs from the MWP of commercial waste include various recyclable materials (corrugated cardboard, mixed paper, PET (# 1) containers, HDPE (# 2) containers, ferrous metals, and aluminum) with an estimated amount of 21,840 tpy. For purposes of this analysis considering this is an additional to the existing Newport facility, it was assumed the RDF process would continue to generate an estimated 53,200 tpy of inert materials that would be landfilled. The remaining waste (residential and a portion of commercial waste) would be processed into 324,960 tpy of RDF. The RDF would then be trucked to the gasification facility for conversion to fuels.

Outputs from a gasifier are in the form of tars, halogens/acid gases, alkali compounds, and syngas.

Tars range from 0.1 to 10% of the syngas production and are removed from the syngas soon after gasification. Tars can be damaging to the catalysts, pumps, compressors, and other equipment. Tars can be removed by wet scrubbers, chemical treatment, thermal destruction and dolomite catalysts.

Halogens and acid gases are formed during the gasification process when the nitrogen in the fuel is converted to ammonia and the sulfur is converted to H_2S (hydrogen sulfide) and COS (Carbonyl sulfide). The halogens and acid gases are treated using a wet scrubber or a dolomite catalyst. Alkali compounds are produced from potassium, sodium, chloride, and silica in the RDF. Typically, RDF contains 3000-5000 ppm of chlorine. Alkali compounds can form fused deposits that can damage equipment. The compounds can be captured and managed in a bag house and other pollution control systems.

Syngas produced from the gasification of RDF typically contains hydrogen (20%), carbon monoxide (20-40%), carbon dioxide (15-35%), methane (15-20%), and trace gases (5-11%). Syngas from RDF typically has a high heating value of 200 to 500 Btu/ft^3; 6.4 – 6.7 BTUs per ton of MSW. Syngas production is estimated at 32,000 cubic feet per ton of MSW. Energy consumption is estimated to be 130 kWh/ton of MSW.

Enerkem reports that one dry ton of RDF can yield 100 gallons of ethanol using gasification. Based on an input volume of 324,960 tpy (wet) of RDF and assuming the moisture content at the maximum allowed (20%) would provide for gasification 259,968 tpy (dry). Therefore, the expected ethanol yield would be a minimum of 25,996,800 gallons of ethanol per year. Additional outputs would include liquid wastewater from various processes, CO_2, bag house residue and ash materials.

No estimates are available on the amount of wastewater generated, however it is important the gasification plant is directly connected to a municipal sanitary sewer. Generally, ash output is approximately 10-15% of the RDF input by dry weight.[30]

4.4.2.1 Markets for Outputs

The markets for the recyclable materials that would be recovered from enhanced Newport and MWP of the commercial waste are well established and currently accept materials from various material recovery facilities. Most of the materials collected have varying values in the markets

[30] Moline, Antonio, et al. Steam Gasification of Refuse Derived Fuel in a Rotary Kiln Pilot Plant: Experimental Tests. Chemical Engineering Transactions. Vol 32, 2013.

with good prices for ferrous and non-ferrous metals, average prices for plastics and generally lower prices for paper products.

The primary output from the proposed gasification process would be ethanol and or methanol. Ethanol production is estimated to be in the range of 26 million gallons per year. The ethanol would be classified as cellulosic ethanol (non-corn based) and may provide tax incentives and price enhancements to a owner/operator.

Output markets for ethanol produced would be a refinery that blends traditional gasoline with ethanol. Minnesota has just two operating refineries:

- Flint Hills Resources Pine Bend Refinery, Rosemont, Minnesota
- Northern Tier Refinery, St. Paul Park, Minnesota

The Pine Bend Refinery has a production rate of 320,000 barrels/day. Northern Tier Refinery has a production rate of 89,500 barrels/day. Given the amount of ethanol that could be produced by the gasification technology, it is likely to be marketed to the Pine Bend Refinery.

Other outputs for the gasification process include air pollution and water pollution control treatment residues. These residues may have value in the cement industry as an additive. Especially if a dolomite based pollution control system is used. However, further testing of the residues would be required to market the materials.

The ash output from gasification (and likely some of the residues from pollution control equipment) would be landfilled.

MSW ash landfills currently exist in Rosemont to support ash disposal from HERC. Given the limited quantity off ash produced from the gasification process, disposal of the ash at a permitted facility is not anticipated to be problematic. Wastewater is also an output from the gasification process. It is anticipated some pretreatment of the wastewater from the gasification process will be required before discharge to the sanitary sewer.

The gasification process also produced CO_2 at about 13 to 30% of the syngas. This gas has market value and would be collected and marketed to users of CO_2, like a refinery. CO_2 sales are not anticipated to generate significant revenue for the gasification plant, but need to be managed to reduce air emissions impacts.

4.4.2.2 Residue Management

Residues from the gasification process would include ash/char, pollution control residue, and wastewater. The ash/char would likely be managed much like the current RDF combustor ash. Ash landfill capacity currently exists in Rosemount at the Waste Connections landfill (formerly SKB Environmental). The landfill currently accepts ash from HERC and also ash from Xcel Energy coal combustion process. Additionally, facilities are available in Red Wing and Mankato that currently dispose of ash from the existing RDF combustion process.

Pollution control residues from air and water pollution treatment systems may have some market value. However, testing of the residues would be required to determine marketability. Additionally, TCLP testing would need to be conducted to determine the disposal practices for the ash residue. It is anticipated the residue would not be classified as hazardous and could be disposed in an MSW landfill that is composite lined and has leachate collection and control systems in place.

Wastewater produced from the gasification to ethanol process will likely require some form of pretreatment prior to discharge into the sanitary sewer. The gasification process typically includes an industrial wastewater pretreatment module to provide treatment of wastewater produced by the process to pretreatment standards required by the wastewater agency.

The MCES would be the regulatory agency responsible for the pretreatment standards for wastewater generated from the gasification process.

The local industrial pretreatment standards adopted by the MCES are provided in Table 4-2[31]:

Table 4-2
MCES Industrial Waste Water Standards

Parameter	Standard (my/l)
Cadmium (Cd)	1.0
Chromium, total (Cr)	6.0
Copper (Cu)	4.0
Cyanide, total (CN)	4.0
Lead (Pb)	1.0
Mercury (Hg)	0.002
Nickel (Ni)	6.0
Zinc (Zn)	6.0

The standards apply to the total facility discharge to the sewer system over a 24 hour period. Additionally, pH must be between 5 and 11 standard units. MCES may also require additional standards for pretreatment depending on the wastewater stream.

Testing of the wastewater stream is required along with permits from the MCES. Foth does not anticipate any challenges in pretreating the wastewater stream from the gasification process to meet the requirements of the MCES.

[31] Waste Discharge Rules or the Metropolitan Disposal System.6.0 Metropolitan Council, February 2013

4.5 Preliminary Economics

4.5.1 Capital Costs

Capital costs presented are estimates based on discussions with gasification and MWP vendors and are provided in ranges. The ranges are dependent on various factors including siting, permitting, throughput tons, markets, etc. The gasification system capital costs were estimated by a leading developer to be between $150 and $200 million. For MWP processing including the equipment and building modifications were estimated between $20 and $25 million. The RDF facility capital costs would be $0 unless the facility is sold. Since the arbitration process resulted in a value of $26.4 million, a range for the Newport facility of $0 to $26.4 million was used. The total capital cost estimate ranges from $170 million to $251.4 million.

Estimates for the annual debt service were developed by Springsted with a summary shown in Table 4-3.

There are four basic debt service projections that help provide a preliminary range of the annual debt service costs for both the $170 million and $251.4 million range of costs. In each of the scenarios, the total dollar amount financed includes 2% issuance costs, two (2) years of capitalized interest, and one (1) year of debt service reserve. The bonds were assumed by Springsted to be "A" credit rated revenue bonds.

Table 4-3
Preliminary Estimated Annual Debt Service Costs

Capital Costs - Gasification	$150,000,000	$150,000,000	$200,000,000	$200,000,000
Capital Costs - MWP	$20,000,000	$20,000,000	$25,000,000	$25,000,000
Capital Costs – RDF	$0	$0	$26,400,000	$26,400,000
Total Capital Costs	$170,000,000	$170,000,000	$251,400,000	$251,400,000
Term (Years)	20	25	20	25
Net Interest Rate	4.40%	4.76%	4.40%	4.76%
Annual Debt Service[1]	$15,405,000	$13,975,000	$22,780,000	$20,665,000
Tons Per Year	400,000	400,000	400,000	400,000
$ Per Ton	$38.51	$34.94	$56.95	$51.66

[1] Debt service cost estimates provided by Springsted Incorporated

The rounded cost per ton for the annual debt service ranges from a low of $35 ($50 million/25 years) to a high of $57 ($60 million/20 years).

4.5.2 Operating Costs

Operating costs for a MWP facility, existing RDF and Gasification facility are summarized in the following section. Operating costs for the RDF facility are based on the existing Newport RDF plant. MWP operation costs are estimates based on the throughput of materials. Gasification costs were estimated by Enerkem.

The single-line MWP schematic provided by BHS includes stations for 18 manual pickers per MWP line. One line would be required for processing the estimated 550 tons per day of commercial waste, with two 10 hour shifts. Therefore a total of 36 manual pickers are required to process the commercial waste. Additional personnel would be required for supervision, scale operation, grapple and equipment operation, yard-trucking, and maintenance. Some of these are already included in the operating cost of the existing RDF system. A total of 100 operating hours per week (5,200 hours per year) is assumed based on the equipment projections provided by BHS over two (2) shifts per day, five (5) days per week. Consistent with other projections provided to the Board, the scale operators includes security personnel and are assumed to work around the clock. The total estimated workforce per shift is of approximately 25 employees for a total of approximately 50 employees. The annual estimated labor cost (with benefits) is $3.5 to $ 4 million, or an estimated $9..00 to $10.00/ton.

Processing the tonnage into RDF would be similar to the current operations at Newport. The estimated labor costs for the RDF production are $9 to $10 million annually. This would be $22.50 per ton to $25.00 per ton

Estimates for O&M for the gasification plant were provided by Enerkem at $20 to $30 million. This would translate to a per ton cost of $50 to $75 per ton for operating the waste to fuels facility.

Table 4-4 provides a summary of the Newport RDF with MWP and Gasification operating costs.

Table 4-4
Summary Table of O&M Costs for Newport w/ MWP & Gasification

O&M Costs - Gasification	$20,000,000	$30,000,000
O&M Costs - MWP	$3,500,000	$4,000,000
O&M Costs - RDF	$12,500,000	$13,000,000
Annual O&M Costs	**$36,000,000**	**$47,000,000**
+Tons Per Year	400,000	400,000
$ Per Ton	$90.00	$117.50

4.5.3 Revenues

Revenues from the sale of recyclables from MWP and sale of ethanol/methanol from the gasification project are income streams for the Newport with MWP and Gasification option. The sales of recyclable materials from MWP are based 60% recovery of the targeted recyclable materials in the commercial wastes and the waste composition study in Table 2-2. The tons of recyclables projected to be recovered was 21,840 per year in this preliminary analysis. Recycling programs that Foth works with have been receiving a weighted average of $120 to $130 per ton for source separated recyclables the last few years. For purposes of this analysis considering the recyclables are recovered from MSW, an average price of $75 per ton is used. With $21,840 tons at $75 per ton, the total annual revenue is $1,638,000.
Recyclable revenues are estimated to be $4.10 per ton for the 400,000 tons input.

The gasification process will convert RDF into ethanol. The rate of the conversion is from 90 to 100 gallons of ethanol per dry ton of RDF. The RRT plant is expected to produce 324,960 tons (wet) with an anticipated 20% moisture content. This would yield 259,968 tons (dry) that would be sent to the gasification facility. The estimated price range for ethanol including the use of tax credits was estimated by Enerken to be from $2.50 to $3.00 per gallon. For purposes of this preliminary analysis, a range of $2.10 to $2.25 was used.

Table 4-5
Estimated Revenue Table for Ethanol Production

Ethanol Production Rate	90	100	90	100
Dry Tons Processed	259,968	259,968	259,968	259,968
Total Ethanol Produced	23,397,120	25,996,800	23,397,120	25,996,800
Range of Wholesale Ethanol Prices	$2.10	$2.10	$2.25	$2.25
Estimated Range of Revenue	$49,133,952	$54,593,280	$52,643,520	$58,492,800
Revenue Per Gate Ton (400,000)	$122.83	$136.48	$131.61	$146.23

The information provided in Table 4-5 indicates that the ethanol production revenue could be significant.

4.5.4 Breakeven

Using the high and low ranges of the estimated cost per ton for annual debt service, operating costs, and revenues, a range in the break even costs per ton operating at 400,000 tpy is shown in Table 4-6.

Table 4-6
Newport/MWP/RDF/Gasification
Preliminary Estimated Breakeven Cost per Ton

Low Debt Service	$34.94	High Debt Service	$56.95
Low O&M	$90.00	High O&M	$117.50
High Revenue	$146.23	Low Revenue	$122.83
Low Total	($21.29)	High Total	$51.62

In round numbers, the estimated breakeven costs range from $(20) to $50 per ton. The breakeven costs are very dependent on ethanol markets and the final debt and O&M costs which range significantly. Further analysis is needed to provide better estimates, but the potential appears to be positive. The technology is still in the development stage.

4.6 Timeline Needed To Implement Newport with MWP and Gasification

The timeline needed for implementation of a MWP and RDF to fuels facility including permit modifications to the existing Newport permit and new permits for the RDF to fuels process plant are provided below:

- Design 12-18 months
- Permitting, including environmental review (EAW) 18 months
- Construction 24-36 months
- Startup/Commissioning 6-12 months

Total time is expected to be 5-7 years. Additionally, we believe the RDF to fuels process will likely start small and then ramp up over time. A preliminary assumption would be to anticipate the first year of operation the gasification system would accept 100,000 tons of RDF and increase over the next 5-10 years to taking all the RDF produced.

5 Anaerobic Digestion

There are a number of anaerobic digestion (AD) scenarios that could be considered. As the primary AD scenario for this feasibility study, it is assumed all receiving, preprocessing, anaerobic digestion, and residuals management would occur at a stand-alone facility to be developed at a location other than the Newport facility.

The Board would neither purchase nor operate the Newport facility as it is not included in this scenario.

The organic materials could either be converted at an AD facility at the new site or transferred to the a different facility, such as Sanimax AD facility currently under development in South St. Paul, MN (assuming the facility is successfully developed).

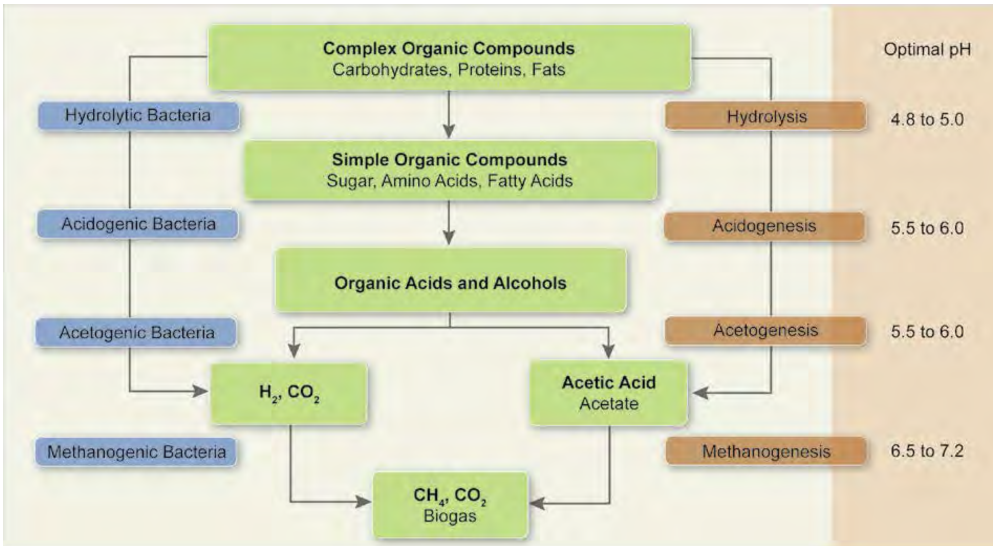
Another key difference in this scenario is that only the organics and recyclables are targeted for recovery, approximately 40% of the total MSW stream.

AD capacity for either of these scenarios is based on 376 tpd of organic materials and a total facility capacity of 1,096 tpd. These figures are derived from an assumed total facility MSW capacity of 400,000 tpd, and the findings of the July 2012 Waste Composition Study, which identified that an estimated 34% of the incoming waste would be suited to processing by anaerobic digestion. The 34% figure includes only organics (28%, less 6% wood) and non-recyclable paper (12%). Due to losses and contamination associated with MSW processing, not all of the separated waste will likely be available for processing by AD. According to BHS, MWP is expected to recover 60% of the organics and recyclables in an MSW waste stream. Therefore, a 226 tpd operating capacity is assumed for the AD-specific system elements of this analysis. This equates to approximately 82,500 tpy on 365 days per year.

5.1 Brief Technology Description

Anaerobic digestion (AD) is the process of decomposing organic materials in a controlled oxygen-deficient (anaerobic) environment. The stages of AD are illustrated on Figure 5-1. In the first stage, microorganisms secrete enzymes that hydrolyze polymeric compounds (carbohydrates, proteins, fats) to simpler organic compounds. These simple organics (sugars, amino and fatty acids) are further degraded by the processes of acidogenesis and acetogenesis; first into organic acids and alcohols, and subsequently into short chain volatile fatty acids and hydrogen. In the final stage, these simple compounds are converted by anaerobic, methanogenic bacteria into methane and carbon dioxide (biogas).

Figure 5-1
Stages of Anaerobic Digestion



Source: Technical Document on Municipal Solid Waste Organic Processing, Government of Canada, Minister of the Environment, 2013.

Anaerobic digestion is generally conducted in large digesters where moisture content, temperature, and pH are measured and controlled to maximize biogas generation and waste decomposition rates. Commercial AD processes are often classified according to the total solids (TS) content of the slurry in the digester reactor, the temperature range they operate in, and by the number of stages (one or two) of the operation.

Low solids systems (LS) typically contain less than 10 % solids, medium solids (MS) typically range from 15%-20% solids, and high solids (HS) processes typically range from 22% to 40%.

Mesophilic digesters operate at temperatures between 68ºF and 104ºF and thermophilic typically operate at temperatures between 122-149ºF. In a typical mesophilic application, the digestion process occurs during a two- to six-week period[32]. In thermophilic operations, digestion can be completed in as little as 3-5 days.

In two-stage systems, the first stage is operated within the lower pH range favored by the organisms responsible for hydrolysis of larger organic compounds. The second stage is operated at a higher pH favoring the methanogenic bacteria that produce biogas. Most MSW digesters are single-stage, with all biological processes occurring in the same reaction vessel.

[32] Environment Canada, 2013, p. 4-7

The advantages and disadvantages of each of these categories are summarized in Table 5-1, reproduced from Environment Canada's 2013 "Technical Document on Municipal Solid Waste Organics Processing."[33]

Table 5-1
Main Characteristics of Different Digester Designs

High-Solids (slurry and stackable) AD systems	Wet (low solid) AD systems
• Requires less energy • More energy available for export • Stackable systems require bulking agents to provide adequate porosity for percolation • Stackable systems must operate as batch systems—requires purging and opening the digester • Slurry systems require special pumps • Cannot handle liquid wastes as well as wet digesters	• More energy needed to heat and pump water • More energy needed to dewater digester contents • More suited for co-digestion with animal manures or biosolids • Can remove plastic from incoming waste stream • Requires more water • Loss of volatile solids and potentially lower gas yields
Single-stage AD Systems	**Two-stage AD Systems**
• Lower capital cost • Easier to operate • Fewer technical failures • Conditions for two stages are not optimized • May lead to somewhat lower biogas yields	• Higher capital cost • More technical complexity • More technical failures • Potentially higher gas yields • More decomposition of biodegradable material under optimal conditions
Mesophilic digestion systems	**Thermophilic digestion systems**
• Bacterial populations more robust and adaptable to changing conditions • Lower energy input to maintain temperature • Lower rates of gas production • Lower throughput rates	• Higher construction costs for heat-resistant materials • Higher energy input to heat to thermophilic temperatures • Higher rates of gas production • Higher throughput rates

Technical Document on Municipal Solid Waste Organic Processing, Government of Canada, Minister of the EnvironmentEnvironmenta, 2013.

Descriptions of three recently developed or developing large-scale AD facilities, two of them in Minnesota, are described in the following sections.

5.1.1 Sanimax/SaniGreen – South St. Paul, Minnesota

Sanimax and SaniGreen BioEnergy are in the process of permitting an AD facility for processing of organic materials from Sanimax's adjacent rendering operation in South St. Paul, Minnesota. The facility also anticipates accepting organic materials from off-site sources.

The system is designed as a plug flow reactor using the GEP group/Big Ox Energy design and will have an operating capacity of 150,000 tpy (410 tpd based on 365 days). The facility will be able to handle both solid and liquid wastes and is designed to allow flexibility to address input variabilities. The adjacent rendering facility alone generates approximately 300,000 gallons of effluent per day. Biogas from AD is anticipated to be cleaned/scrubbed to pipeline quality and injected in the area natural gas distribution system. Electricity produced will be either sold or used at the Sanimax rendering facility. Liquid wastes from the digesters will be disposed in the sanitary sewer. Solid wastes from the digesters, estimated by Sanimax at 50-60 tpd, will be

[33] Environment Canada, 2013, p. 4-3

dewatered, dried, and pelletized for RDF. The current capital cost estimate for development of the operation is $35 million (approximately $96,000 per daily design throughput ton based on 365 days). SaniGreen anticipates breaking ground for the facility in mid to late 2014 and be operational by the end of 2015 or early 2016.

Figure 5-2
Sanimax/SaniGreen – South St. Paul, Minnesota

Source: SaniGreen BioEnergy website

5.1.2 Minnesota Municipal Power Agency (MMPA) – Le Sueur, Minnesota

A December 22, 2013 article in the Minneapolis Star Tribune Sunday Business Section provides background on the "Hometown Bioenergy Project," a recently-constructed AD facility in Le Seuer, Minnesota that processes a combination of corn silage and manure into electricity. The facility is owned by MMPA, which is a partnership of twelve municipal utilities around the State of Minnesota, and was developed by Avant Energy of Minneapolis, which manages the MMPA. The project is intended to help the twelve municipal utilities meet state-wide renewable energy requirements.

Two anaerobic digesters produce methane from trucked-in corn silage, manure, and potentially other waste. Biogas from the digesters is stored in three fabric domes until it is needed for electrical production, which is produced in four internal combustion engine/generator sets. The plant design includes a total plant output of 8 megawatts generated 12-15 hours per day during peak demand. The cost of the facility was $45 million, which was 50% higher than MMPA's $30 million initial estimates. The plant will process about 45,000 tpy (125 tpd based on 365 days) of agricultural residuals, including corn silage, potato waste and chicken manure. The current plan is to generate additional revenue from the sale of post-digestion liquids as fertilizer and dried solids (digestate) as boiler fuel or animal bedding.

Figure 5-3
MMPA – Le Sueur, Minnesota

Source: MMPA Hometown Community Updates November 2013 as published in the Le Sueur News Herald

5.1.3 Zero Energy – San Jose, California

The City of San Jose, California recently completed construction on a 90,000 tpy (250 tpd based on 365 days) thermophilic dry AD facility utilizing Kompoferm technology; the first of three planned phases to process pre- and post-consumer source separated food waste, MRF residuals from processing wet and dry materials, and yard wastes. The facility was constructed on a former landfill site.

The design features 16 AD digesters and 4 in-vessel composting (IVC) tunnels per phase. Each of the three phases is expected to produce 6.28 MM Btu/hour of heat, 1.6 MW of power, and 30,000 tons of finished compost per year. The compost generated from the post-AD digestate will be used to enrich local soils. The biogas will provide both on-site power for the operation and power for sale to local users of renewable energy. The cost for development of the AD elements alone, not including land or landfill closure costs was reportedly $20 million (approximately $55,000 per daily throughput ton).

5.1.4 Mixed Waste Processing

Under any of the AD scenarios described, MWP would proceed consistent with the description provided in Section 4.1.1, with the potential for additional processes to be added at the front end of the operation to separate and size organic materials for processing by AD. For the AD scenario, both commercial and residential-sourced MSW would be subject to MWP. Using the 30 to 35 ton per hour MWP system described and illustrated by BHS in Section 4.1.1 would require a second MWP line to be provided. Under the primary stand-alone AD scenario, MWP residuals, representing as much as 68% of the MSW input, would be landfilled, rather than burned as RDF.

5.1.5 Plastics-to-Fuel

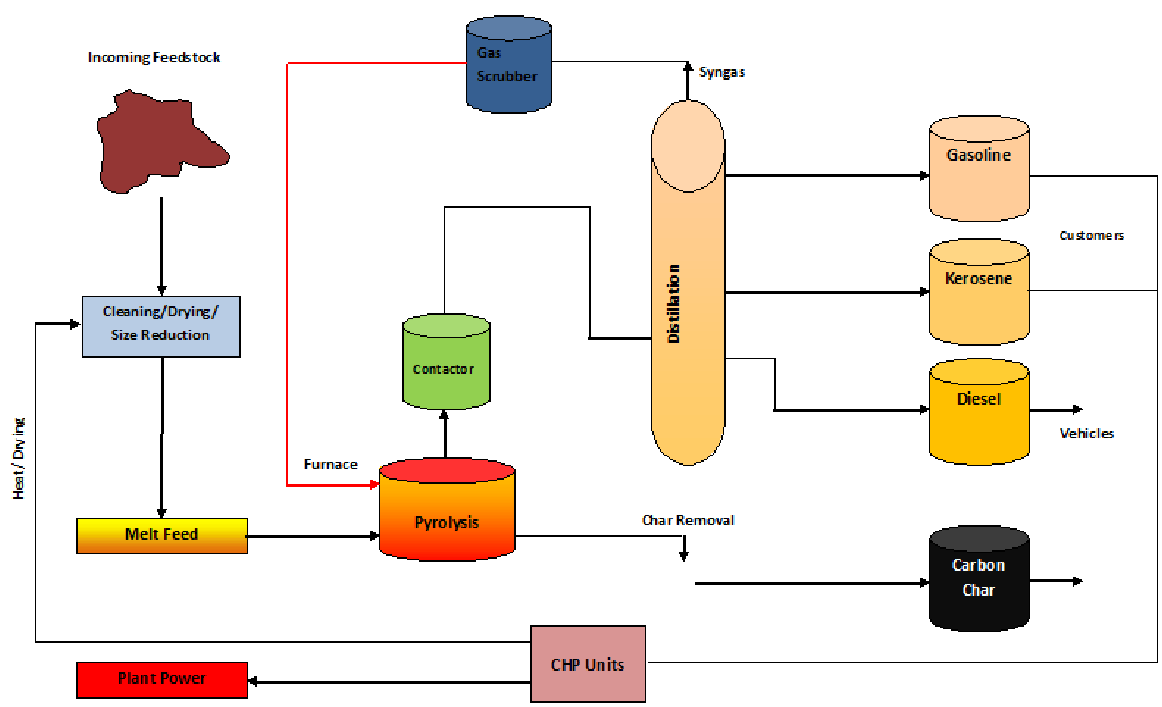
This preliminary feasibility analysis recognizes that the potential could exist to sort non-recyclable plastics that could be processed with emerging plastics-to-fuel technology. While this technology is not yet proven, there is extensive work occurring, vendors promoting systems, and some commercial operations in start-up. Therefore, plastics to fuel is included in this preliminary feasibility as a “placeholder” for future consideration.

Plastics to fuel (PTF) systems use a pyrolitic process coupled with depolymerization/distillation components to convert recovered plastics into oil[34]. Due to well established markets for numbers 1 and 2 plastics, numbers 2, 4, and 5 plastics are considered the best feedstock for plastic to oil production. Process technologies vary from vendor to vendor with each having unique features and performance claims, but most share the same basic processes including;

- Some level of pretreatment –this could be as minor as size reduction or as involved as cleaning and moisture removal.
- Conversion – pyrolytic processes are used to convert the plastic to a syngas.
- Distillation – the syngas is converted to liquid form.
- Acid removal process – removal of acids that form in the breakdown of some scrap plastics. These acids require removal because they can be corrosive to the PTF systems as well as the engines that will consume the fuel.
- Separation/refining/final blending – the final steps required to make this product consumer ready can either be done on site or by a third party, depending on the system design.

Figure 5-4 is a general schematic of the plastics to fuel process:

Figure 5-4
Plastics to Fuel Flow Schematic



[34] 4R Sustainability Inc. 2011. Conversion Technology: A Complement to Plastic Recycling, Prepared for American Chemistry Council Washington D.C.

The process flow for a typical plastics to fuel starts with the receipt of plastics from various sources. This could be from a material recovery facility, mixed waste processing facility as considered in this analysis, or a specific producer that may have "off spec" plastic from a manufacturing process. The plastics are received in a receiving area and may be sorted or graded depending on the process.

Plastics are then sized by shredding or other methods to provide a uniform size of plastic chip. Plastic sizing preparation is critical to the pyrolysis process to maximize the surface area exposed and to provide a uniform size of material entering the chamber. Typically, some form of cleaning or other contaminant removal process is part of the sizing process. Limiting contaminants and unwanted plastics (like PVC) is needed to ensure the syngas produced has limited contamination.

Once sized, a select quantity of plastic material is placed into a specially designed container. For batch technologies using batch systems, the container is made to effectively operate in a pyrolysis environment and contain enough volume to support an efficient process. Since the pyrolysis process uses external heat to convert the plastic to syngas, the container must be able to efficiently transfer heat from the exterior to the interior of the container. Once the container has the correct amount of plastic material inside, the container is moved into a pyrolysis active zone. Air is removed from the container and is then heated externally and the plastic is converted in syngas. The heating and conversion process can take several hours to complete, depending on the size of the container and the amount of plastics in each batch.

Syngas is harvested from the container, cooled and purified to form a basic crude oil. Since most plastics contain hydrocarbons, the conversion of plastics to oil can be completed effectively as long as there are not contaminants in the plastic mix that would require further treatment to the oil. This can be the case when too much PVC is part of the process.

Once the pyrolysis process is completed, the container is removed from the pyrolysis area and cleaned. Part of the pyrolysis process is the formation of char. In the plastics to fuel process, the char forms on the sides of the containers and must be cleaned after each use. The char is essentially carbon that did not convert to syngas. The char is an effective insulator and if not cleaned from the sides of the container, can limit the pyrolysis process because the heat is not effectively transferred from the exterior to the interior of the container. Typically, a large wire brush is used to scrub the inside of the container. The char is then collected and disposed.

Some vendors are attempting to develop continuous process systems rather than batch fed systems. This will increase throughout and improve production efficiency.

5.1.6 AD Process Flow

As noted in the introduction to this section, there are a number of AD scenarios that could be considered. For the primary AD scenario, it is assumed that all receiving, preprocessing, anaerobic digestion, and residuals management (primarily composting of digestate) would occur at a new site not yet identified. The separated organic materials would be managed at an on-site

stand-alone AD facility developed in conjunction with receiving facility and MWP system or potentially transferred to an off site existing facility such as the Sanimax AD facility currently under development in South St. Paul.
For applications involving MSW feedstocks, AD operations would be expected to include four major processes: preprocessing, anaerobic digestion, biogas recovery/utilization, and residual handling/processing.

For the primary, stand-alone scenario, MSW would be received in a building to control odor and windblown litter. The building would be sized to handle the expected daily waste input with additional waste storage to provide two to three days of capacity to assure a continuous waste input, should an interruption of the waste processing occur. Preprocessing would include MWP consistent with the processing described Section 4.1.1, but with the addition of second line to provide the capacity to remove organics from both the commercial and residential waste streams. An estimated 122 tons per day of recyclables are recovered by the MWP lines. The removal of plastics for plastics-to-fuel technologies could also occur in this process if that technology reaches commercial viability. The separated organic materials estimated at 226 tons per day would likely be shredded or ground to a size that would optimize the efficiency of the AD process. Based on the waste composition data and projected recovery rates from the MWP lines, there will still be an average of 748 tpd sent to a landfill.

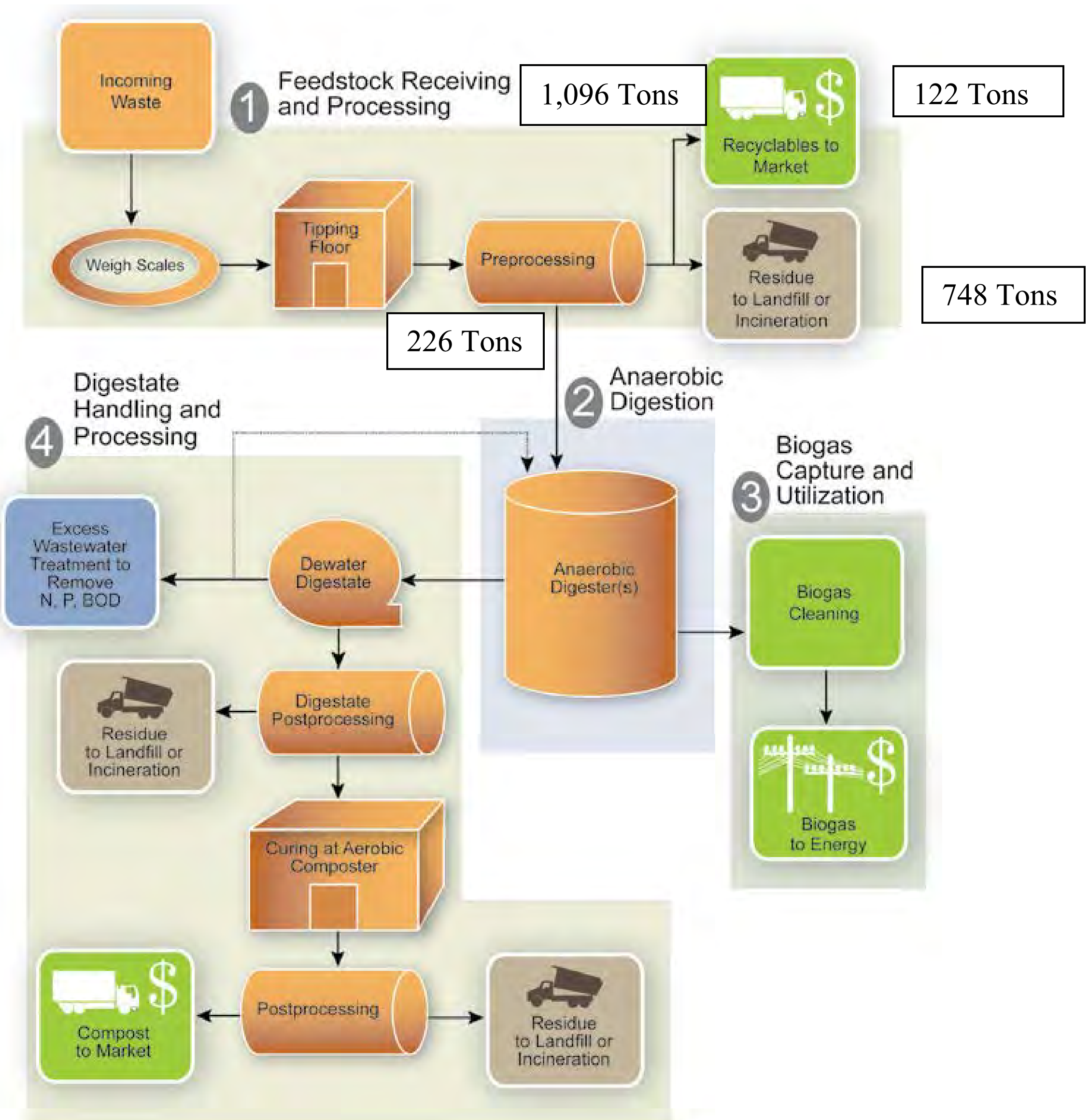
The AD-produced biogas could be used directly in engines for Combined Heat and Power (CHP), burned to produce heat, or cleaned and used in the same way as natural gas, as a vehicle fuel, or in sufficient quantities in an engine or gas turbine to produce electricity.

The residues from the AD process itself would include both liquid (effluent) and solid (digestate) components. Excess liquid (effluent) from AD processes, if generated, has been used as a fertilizer, especially on non-food crop applications, or could be discharged to the municipal sewer for additional treatment. The batch thermophilic AD facility being marketed by Zero Waste Energy, LLC reports that it is a net user of water and produces no excess liquid requiring disposal.

The solid digestate would likely be composted, or for drier operations, such as the facility being constructed at Sanimax, it could be converted to RDF. A typical AD process flow diagram is provided in Figure 5-5.[35] Additional residues would be generated during MWP, as discussed previously and will be part of the wastes assumed to be landfilled in this option.

[35] Environment Canada, 2013, p. 4-2

Figure 5-5
Typical AD Process Diagram



Source: Technical Document on Municipal Solid Waste Organic Processing, Government of Canada, Minister of the Environmenta, 2013.

5.2 Site/Utility Needs

Development of a stand-alone process facility for processing 1,096 tpd of MSW and 200-300 tpd of organics by anaerobic digestion would likely require 10 - 20 acres of contiguous land, depending on support systems, roads/access, security needs, set-backs, the type of AD facility constructed (wet/dry, batch/plug-flow/continuously mixed), the quantity and characteristics of the digestate and effluent generated, and the method of digestate management or disposal.

The process area itself (not including setbacks, wastewater or stormwater treatment, roads, scales, or digestate handling or processing) would likely require 4 acres[36]. Receiving operations (security, scales, turn-around area, etc.) would likely require about 0.5 acres. MWP would likely require 2-3 acres under roof. Facility and process support functions, such as offices, maintenance shop, equipment storage garage and shed, utilities/boiler house (small chiller, water softener, boiler, compressor, associated storage tanks and controls), a QC laboratory, restroom/shower/locker facilities, spare/replacement parts, lay-down yard, access for fuel delivery and waste pickup, would likely require an additional 2 acres. Again, depending on the operation selected, wastewater pretreatment, stormwater treatment, and setback/buffer areas may require an additional 2 to 4 acres.

If a dry, plug-flow AD system (e.g. Sanigreen/Sanimax) is selected, digestate would most likely be processed on site into RDF, limiting the required footprint to less than or equal to 10 acres. If, however, a dry batch system is constructed, as much as 10 acres would likely need to be provided for management of digestate by composting on site. Compost mixing would likely require at least 1.0 acre under roof, plus access, an area for exhaust controls (scrubbers, etc), and other support facilities, plus run-off management, for a total of about 1.5 acres. If a conventional windrow compost system were utilized, at least 5 acres of land would be required for compost windrows, assuming a 21-day compost cycle in windrows 10 feet high and 20 feet wide, separated by at least 10 feet. Additional land would need to be provided for setbacks/buffers to reduce the potential for odor complaints. A smaller footprint would likely be required if in-vessel composting technology were utilized, but likely at a higher cost.

If the separated organics can be sent off-site, such as to the planned AD facility by Sanimax in South St. Paul, the area for AD processing would not be required.

Utilities needed for AD processing typically include electricity, 15 psi steam, chilled water (to about 35°F), and 90 psi compressed dry, oil-free air (for some valve actuators). Additionally, instrumentation, and a sewer connection or alternative means of wastewater transportation and disposal is needed. Additional steam may be needed for start up in winter. Fuel for the compressor/dryer, heavy equipment and other vehicles may be either diesel or recovered methane. If methane is used as a fuel for onsite use, conditioning of the biogas to pipeline quality would be required.

Site security would include perimeter fencing, cameras, and lighting. Some of the cameras can also be used for process support, especially at the receiving and weighing areas.

5.3 Permitting and Public Acceptance

Sanimax has been in the process of permitting an AD operation at its South St. Paul location across the river from the Newport Facility for the past several years. The list of permits, licenses, and approvals required include Federal, State and local permits, as summarized in the following sections.

[36] Personal correspondence with Zero Waste Energy

5.3.1 Environmental Review

As discussed in the June 2009 Source Separated Organics Materials Anaerobic Digestion Feasibility Study[37], an Environmental Assessment Worksheet (EAW) would likely be required for an AD facility based on the mandatory environmental review categories listed in Minnesota State Statutes 4410.4300. It is believed that the facility would fall under subpart 5 (Fuel conversion facilities) which would require an EAW with the MPCA as the regulated government unit (RGU).

It should be noted that if the facility were to have the capacity to utilize 250,000 dry tons or more per year of input (for fuel conversion) an Environmental Impact Statement (EIS) would be mandatory (per Minn. Statue 4410.4400). If an EIS is a mandatory, an EAW is still required as a scoping tool for the EIS.

5.3.2 Environmental Permitting

Under the primary alternative, the facility would be required to obtain a solid waste operating permit from the MPCA. The permit would likely require a year or more to process, including the required public notice and comment period. A number of SSO-related permits have been issued in recent years and separation and processing of organics is favored by the MPCA, so the the process should be getting more streamlined. However, concern for odors associated with both the AD and compost operations will likely be raised as issues during both the environmental review and permit public notice/comment periods.

Federal air quality permits for AD facilities are required only if a combustion device is present and operating above federal thresholds. For its air permit, the Sanimax facility, includes its rendering operations and does revisions nearly every year due to changing equipment for scrubbing air, boilers, and other equipment. For the anaerobic digester component, the MPCA completed a predetermination, but Sanimax subsequently engineered a slightly larger unit for electricity which required them to submit changes. Sanimax has not yet submitted the changes as they are re-evaluating the digester size.

The Agency's approach to permitting AD systems that process manure and other organic waste is to include the solid waste requirements in an individual permit that also includes the water permit information. For the water permits, it will require an individual industrial NPDES permit and a wastewater discharge permit.[38] A State Demolition permit may be required if existing buildings are present on the development site. Additionally, written assurances may be sought from the MPCA if the development occurs on a brownfield site.

It is anticipated that some local permitting and/or approvals will also be required. The scope of permitting and/or approvals required would be determined during environmental review.

[37] Foth Infrastructure & Environment, LLC, June 2009.
[38] http://www.epa.gov/agstar/tools/permitting.html#mn

However, it is anticipated that local review may include:

- ♦ County solid waste processing permit
- ♦ Site development plan review
- ♦ Conditional use permit
- ♦ Building and zoning permits
- ♦ Grading and utility permits.

Depending upon the volume of biogas generated and the end use selected, a permit may also be required from the Public Utilities Commission (PUC). If the biogas is used for the production of electricity, it is not anticipated that action by the PUC will be required for the anticipated capacity that could be generated by a facility of this size. If, however, the biogas will be cleaned to pipeline quality for transport to an off-site user via a high pressure pipeline, PUC involvement may be required. As noted in the 2009 feasibility study, it may be desirable to limit the scope of any gas pipeline to reduce potential PUC permitting requirements.

5.4 Technical Application to R/W Wastes

In 2009, Foth completed a study on the feasibility of a source separated organic materials AD facility to be constructed in St. Paul. The 2009 AD study concluded that AD would be a good conversion technology for the organic waste stream in R/W Counties. For a 100,000 tpy facility, tipping fees at that time were estimated to range from $55 to $60 per ton.

To capture organic materials from the current waste stream from R/W Counties would require either a source separated organic material (SSOM) collection program or installation of MWP as covered in this analysis to target organics removal from the current waste stream. Organics could then be sent to an AD process for conversion to methane for electrical generation or alternative fuel products as discussed below. Residuals from the process (solids and liquid, if generated) could be managed via composting and existing waste water treatment plants. Based on discussions with a MWP vendor, up to 60% recovery of both the targeted organics and targeted recyclables would be anticipated (34% of the targeted organics and targeted recyclables along with wastes not targeted would not be recovered).

5.4.1 Inputs and Outputs

The primary inputs to a stand-alone AD facility with pre-processing of MSW and on-site composting of digestate would be MSW and water. Source separated organics from external sources could also be potentially be received, although such deliveries are not addressed here.

Typical outputs from an AD process with pre-processing of MSW and on-site composting of digestate would include biogas (methane and CO_2), recyclables, finished compost, solid residuals for disposal, and liquid residuals, also for disposal. The biogas from an AD process can be cleaned and injected into a natural gas pipeline; burned in an engine/generator set to produce electricity; burned in a boiler to produce steam for district heating or to be used in a steam turbine to generate electricity.

Zero Waste Energy provided an estimate of 1.6 MW of power being generated from a 300-tpd AD facility processing organics separated from MSW. A 30% generator efficiency is typically assumed, with 30% of the electricity consumed by the system. Cogeneration heat would also be available, estimated at 1.13 kWh of thermal energy per kWh of available electrical energy.[39]

A typical quantity of digestate for all digester types is 0.85 ton of dewatered digestate for each ton of wet source separated organic (SSO) added to the digester[40]. Thus, for a 200 to 300 tpd operation, an estimated 170 to 255 tpd of digestate would initially be generated. According to Zero Waste Energy, LLC and additional sources (e.g. Biocycle, 2001 [41], City of Palo Alto), the quantity of final mature compost from AD is typically 35-40% of incoming SSO feedstock and 20-25% of all material delivered to a mixed waste facility. For this scenario, an estimated 70 to 120 tpd of finished compost is anticipated to be generated.

Referring to the process flow diagram (Figure 5-5), Table 5-2 summarizes the anticipated daily inputs and outputs for the standalone AD scenario. The energy outputs are based upon an assumed biogas generation rate of 3 ft^3 of biogas, containing 60% methane by volume, per pound of municipal organic waste. If plastics to fuel were implemented, the diverted quantities would come out of the residuals to landfill output.

Table 5-2
Anticipated Daily Inputs and Outputs for
the Stand-Alone AD Scenario Summary

Inputs	Daily Input	Final Outputs	Daily Output
MSW	1,096 tons		
Targetable Organics	376 tons	Biogas Energy Potential (60% recovery) @ 30% engine efficiency	79,350 kWh
		Cogeneration Energy Potential @ 30% engine efficiency	89,700 kWh
		Compost to Market	70-120 ton
Targetable Recyclables	205 ton	Recyclables to Market @ 60% recovery	122 tons
Process Water	TBD	Wastewater	TBD
Other Wastes	515 ton	Residuals to Landfill including organics & recyclables not recovered	748 ton

5.4.1.1 Markets for Outputs

The primary marketable outputs from a stand-alone AD facility with pre-processing of MSW and on-site composting of digestate would be recyclables; electricity, cogeneration heat, or pipeline quality natural gas, compressed natural gas (CNG) for vehicles, and finished compost. The markets for recyclables and electricity are well-established. The markets for cogeneration heat,

[39] City of Palo Alto (CA) web page.
[40] Environment Canada, 2013, p. 4-11.
[41] Biocycle, October 2001 "A Rough Guide to Anaerobic Digestion Costs and MSW Diversion."

pipeline quality gas, and CNG depend primarily on the location of the facility in relation to an a end users and/or pipeline, which is unknown at this time. The market for finished compost derived from SSO is reportedly good at this time. However, the volume of SSO-derived compost is increasing and may have an impact on both available outlets and pricing for finished compost.

5.4.1.2 Residue Management

Residues from a stand-alone AD facility with pre-processing of MSW and on-site composting of digestate will include rejects from both pre-processing and further processing of separated organics, and excess water (if generated) from both the AD process and runoff from the compost curing pad. Depending on the AD technology selected, there may not be excess water from the AD operation and contact water from the compost curing pad may be used to supplement the water needs of AD. Whether discharged or not, runoff from the compost curing pad would need to be contained. Excess water would likely be disposed at an area wastewater treatment plant. For this analysis, an assumption has been made that all process water will be consumed or used on site.

5.5 Preliminary Economics

Foth obtained preliminary financial information from two AD facility developers and operators in the U.S. with on-going or developing interests in Minnesota. Zero Waste Energy, LLC recently completed construction of a 90,000 tpy dry, thermophilic AD facility in San Jose, CA[42]. The San Jose facility is the first large-scale commercial facility of its kind in the U.S. and is expected to generate approximately 1.6 MW of renewable energy. The other developer, Sanimax anticipates initiating construction on its planned 150,000 tpy plug flow AD facility in St. Paul in Spring 2014. That facility will complement an existing rendering operation and is expected to have some excess capacity and could potentially handle separated organics from R/W Counties. Sanimax has also expressed some interest in discussing development of a stand-alone facility for management of organic materials separated from R/W Counties waste using their plug-flow AD technology.

5.5.1 Capital

A dry fermentation AD facility, similar to Zero Waste's San Jose facility, scaled to digest 90,000 tpy of organic wastes is estimated to cost $30 million. The current estimate of the costs for the plug flow system designed for the Sanimax St. Paul facility is $35 million, but with a design capacity of 150,000 tpy. Both estimates are consistent with the estimates reported in Foth's June 2009 SSOM Anaerobic Digestion Feasibility Study. These costs would include all permitting, engineering, construction, start-up commissioning of facility systems, building, roadways, etc, for AD operations, but would not include MWP, site acquisition costs, procurement/legal/ consulting costs, or any financing costs. These costs calculate to approximately $85,000 to $120,000 per daily throughput ton of organic waste. Based on the recent experience of MMPA

[42] Correspondence from Jeff Draper, Zero Waste Energy, LLC.,Vice President, Business Development , November 2013

in Le Seuer, Minnesota, a $100,000 to $120,000 estimate per daily throughput ton of organic material input to the facility is reasonable.

BHS has provided a preliminary estimate of approximately $5 million dollars per MWP line (30-35 tph capacity). Two lines would be required to process the entire 400,000 tons of incoming commercial and residential waste targeted for the facility. Based on the MWP configuration provided by BHS, a 100,000 square foot building would likely be required for receiving and processing of waste prior to AD. The estimated cost for a warehouse/factory building is $80 to $100 per square foot based on R.S. Means 2013 estimated project costs, or $8 to $10 million for this project. A 5-6 acre asphalt compost curing pad and lined pond would likely be required for management of contact water and precipitation. The estimated cost for these facilities is $1.5 to $2 million. The overall capital cost for development of a MWP AD facility for processing of 1,096 tons per day of MSW, exclusive of site acquisition costs, procurement/legal/consulting costs, or any financing costs but including a 10% contingency, would be $50 to $60 million.

Estimates for the annual debt service were developed by Springsted with a summary shown in Table 5-3. There are four basic debt service projection that help provide a preliminary range of the annual debt service costs for both the $50 million and $60 million range of costs. In each of the scenarios, the total dollar amount financed includes 2% issuance costs, two (2) years of capitalized interest, and one (1) year of debt service reserve. The bonds were assumed by Springsted to be "A" credit rated revenue bonds.

Table 5-3
MWP & AD Facility
Preliminary Estimated Annual Debt Service Costs

Capital Cost	*$50,000,000*	*$50,000,000*	*$60,000,000*	*$60,000,000*
Term	20 Years	25 Years	20 Years	25 Years
Net Interest Cost	4.40%	4.76%	4.40%	4.76%
Annual Debt Service[1]	$4,530,000	$4,110,000	$5,439,000	$4,934,000
Tons per Year	400,000	400,000	400,000	400,000
$ per Ton	$11.32	$10.28	$13.60	$12.34

[1] Debt service cost estimates provided by Springsted Incorporated

The rounded cost per ton for the annual debt service ranges from a low of $10 ($50 million/25 years) to a high of $14 ($60 million/20 years).

5.5.2 Operating Costs

Operating costs for an AD facility processing 100,000 tpy of SSO were evaluated in the 2009 AD study and resulted in a broad range of costs from $10.00/ton to $100/ton. A rate of $53/ton - $60/ton was suggested in 2009, the actual figure depending on the intended use for the biogas. Direct use would be expected to have a lower operating cost than conversion to electricity. In 2013 dollars, those costs would be roughly $60 – $68/ton.

Sanimax estimated operating costs at $2.5 – 4 million/year, or $25-40/ton, depending upon the technology and end uses chosen. Zero Waste Energy provided a preliminary operating cost estimate of $1.2 million/year, or $12/ton of organics processed for the the AD portion of the project. Additional operating costs would be realized for the MWP labor, recycling, and residue transportation and disposal.

The single-line MWP schematic provided by BHS includes stations for 18 manual pickers per MWP line. As two lines would be required for processing the entire 1,096 tons per day, 36 pickers are assumed. Additional personnel would be required for supervision, scale operation, grapple and equipment operation, yard-trucking, and maintenance. A total of 100 operating hours per week (5,200 hours per year) is assumed based on the equipment projections provided by BHS over two (2) shifts per day, five (5) days per week. Consistent with other projections provided to the Board, the scale operators includes security personnel and are assumed to work around the clock. The total estimated workforce per shift is approximately 50 employees for a total of approximately 100 employees. The annual estimated labor cost (with benefits) is $7 to $8 million, or an estimated $17.50 to $20.00/ton.

Under the baseline AD scenario, as much as 68% of the commercial and residential MSW processed at the facility would be disposed as residual at an area landfill. Because the facility would not be meeting the State of Minnesota's processing requirement of 85%, the waste would be subject to taxation at normal rates, rather than as process residual. A tipping of fee of $50/ton is therefore assumed. With transportation, the estimated annual disposal costs for MSW residue would be approximately $16.3 million, or $40.80 per ton of MSW processed.

Insurance, taxes, and operational contingencies could amount to an additional $1 million, or $2.50 per ton of MSW processed. Thus, a total annual estimated operating cost of $65.00 to $85 per ton of MSW processed, averaging $75/ton, would be anticipated.

5.5.3 Revenues

In the Foth 2009 AD study for SSOM in the seven county metro area, estimated tip fees for an AD facility were $55-$60 per ton.

There will be potential revenues associated with the sale of electricity and finished compost produced from the digestate, as well as recovery of recyclables. At the design capacity of 90,000 tpy, Zero Waste Energy estimates that 1.6 MW of power will be produced. Foth estimates biogas production at approximately 942 cubic feet per minute (cfm) from 226 tpd of processed organics.

As summarized in Table 5-2, Foth anticipates a daily biogas energy potential of 79,350 kWh assuming 60% recovery of digestable organics and 30% engine efficiency. This equates to 3.3 MW of available electricity. Typically, engine sets produce 1.6 to 1.8 MW per 500 cfm of landfill gas @ 50% methane. Therefore, we anticipate operating one to two engine sets with a combined power output of 1.6 to 3.3 MW. Based on a sales price of $0.04-0.06 per kWh, the estimated range of annual revenue (365 days), assuming a 90% availability factor for the operation, would be approximately $500,000-$1,500,000/year at the 1.6 to 3.3 range of MW production rates. On a per ton of separated organic waste basis, and 82,500 tons of organics per year before processing and AD, electrical revenues at that same rate would be projected at $1.25 to $3.75 ton.

For this scenario, an estimated 70 to 120 tpd of finished compost is anticipated to be generated. A recent study by Eureka Recycling[43] reported regional wholesale prices of $8.50-13.00 per cubic yard for compost. Retail prices of $12.00-18.00 per cubic yard were also reported. Assuming a bulk density of 1,000 pounds per cubic yard for the finished compost, revenues from compost sales could amount to $434,350 to $1,138,800 on a wholesale basis.

On a per ton of processed waste basis, and assuming 400,000 tons of MSW per year pre-processing, revenues from compost sales would be projected at $1.09 to $2.85/ton of MSW processed. Note that these compost sales figures exclude transportation-related expenses and assume the availability of a wholesale market for all compost produced from the digestate.

Recyling revenue would be consistent with the other technologies discussed in this feasibility study, estimated at a weighted average of $75 per ton for all the recyclables. With the estimated 44,640 tons per year, this approximately $3,350,000 per year or approximately $8.37 per total ton received.

5.5.4 Breakeven

Using the high and low ranges of the estimated cost per ton for annual debt service, operating costs, and revenues, a range in the break even costs per ton operating at 400,000 tpy is shown in Table 5-4.

Table 5-4
MWP & AD System
Preliminary Estimated Breakeven Cost per Ton

Low Debt Service	$10.00	High Debt Service	$14.00
Low O&M	$65.00	High O&M	$85.00
High Revenue	$10.71	Low Revenue	$14.97
Low Total	$64.29	High Total	$84.03

In round numbers, the estimated breakeven costs range from $64 to $84per ton.

[43] Zero-Waste Composting-2013