Report

Updated Research Study of Alternative Waste Processing Technologies

Scope I.D.: 04R004

Ramsey/Washington County Resource Recovery Project

September 2004

Updated Research Study of
Alternative Waste Processing

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Prepared for

Ramsey/Washington County Resource Recovery Project

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September 2004

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Updated Research Study of Alternative Waste Processing

Executive Summary

Introduction

The Ramsey/Washington County Resource Recovery Project Board (Board) has a service agreement with NRG Energy, Inc. (NRG) to process solid waste from the two counties at the Newport Resource Recovery Facility (Facility). The agreement provided that Northern States Power Company (NSP), the predecessor to NRG, design, construct, and operate the Facility. The Facility began processing solid waste into refuse-derived fuel (RDF) in 1987 and the service agreement extends until 2007.

As part of the preliminary planning process for waste management options after the end of the current service agreement, the Board initiated a research study in 2000 to see what other solid waste processing technologies might have potential merit besides a continuation of the service agreement with NRG to process MSW into RDF. This report in 2004, updates the following technologies:

Mass Burn Waste-To-Energy
Dedicated RDF Combustion Facility
Mixed Waste Processing (Front-end Separation)
Thermo-chemical Processes
Ethanol Production
Anaerobic Digestion

A brief description of each technology follows, along with its perceived advantages/ disadvantages and observations on its applicability to Ramsey/Washington (R/W) counties.

Mass Burn Waste-To-Energy

The waste-to-energy (WTE) industry emerged in the United States in the 1970s due to several factors. The Arab Oil Embargo forced oil and energy prices to increase. There was growing recognition of the risks of groundwater contamination at existing unlined landfills. This led to new regulations requiring the construction of lined sanitary landfills, which increased the cost of landfilling. WTE facilities[1] were considered to be viable alternatives for waste disposal and energy production. In 1980, less than 60 WTE facilities were operating. By 1993, the number of operating facilities reached a peak of approximately 150. From 1993 to present, the number of operating WTE facilities has declined to 98 due to several factors. The decline has been caused by an abundance of landfill space with lower costs than WTE, loss of ordinance based flow control, and implementation of federal air quality standards. Currently, approximately 13 percent of all MSW generated in the United States is processed in WTE facilities.

[1]Berenyi, E.B., and Rogoff, M.S., AIs the Waste-To-Energy Industry Dead?≅ MSW Management, Elements 2000, page 66.

There has not been a significant amount of change in this technology since 2000.

Although many hybrids exist, three basic types of facilities were developed to incinerate and recover energy from solid wastes. They include: (1) refuse derived fuel (RDF), (2) mass burn waterwall, and (3) mass burn modular. RDF facilities shred waste into a homogeneous mixture. This mixture is fed into the combustion facility. Waterwall and modular mass burn facilities do not pre-process waste. Waste is fed directly from a stockpile into the feed chute of the combustion chamber.

For WTE steam customers, the price paid for steam 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 changing. Due to the electric industry's development of gas-fired electric power plants, the demand for natural gas has been increasing, causing higher natural gas prices (perhaps two to three times previous prices). This will increase the cost to produce steam; thereby increasing potential revenues from steam sales. It may be a good time to pursue potential steam customers for a WTE project.

Potential Development in Minnesota

Olmsted County is in the permitting process to add a third combustion line to their facility in Rochester, Minnesota. The current targeted completion date is January 2008. The new combustion line capacity will be 200 tons per day and is estimated to cost $35 to $40 million, including the permitting costs.

AWTE facility has been proposed in Lamberton, Minnesota. Preliminary plans include a 249 ton per day WTE facility at an estimated cost of $37,000,000. The project is under review by several counties in the region.

A pilot project to examine the effectiveness of pre processing waste via autoclaving is being developed south of Shakopee at the transfer station next to the Dem Con Landfill. The autoclaving project is being developed by Specialized Environmental Technologies for NRG.

The autoclave uses heat, pressure, and moisture to process raw municipal solid waste into a homogeneous mix. The mix is then dried, sorted to remove metals and plastics, and will be sent to the Elk River Power Plant for combustion. The goal is for the autoclaved mix to provide a more homogeneous fuel, which increases waste to energy plant efficiencies while reducing emissions.

The project, currently under development, has a two-year demonstration permit to process 50 tons per day of MSW. It is anticipated the process will be operational by September 2004.

Table ES-1 lists some potential advantages and disadvantages of a mass burn facility.

Table ES-1 Potential Advantages and Disadvantages of a Mass Burn Facility

Advantages	Disadvantages
Proven technology	Past, significant public opposition groups make siting/permitting extremely difficult
Capable of handling majority of R/W counties' waste stream	Significant capital and operation costs
Financially stable vendors	Uncertainty around the status of waste-to-energy as a biomass
Past concern for air emissions and ash disposal led to extensive control systems	
Regulators are familiar with the technology	

Advantages/Disadvantages

With over 60 operating facilities in the United States and many more internationally, water wall mass burn is a proven technology capable of handling the majority of the R/W counties= waste stream. The remaining vendors active in the industry have also proven their performance capabilities. Past concerns for air emissions and ash handling led the regulatory community to be familiar with the technologies and led to significant improvements in the environmental performance of mass burn facilities. Mass burn is now perhaps the most regulated/controlled processing technology available.

The disadvantages of mass burn somewhat reflect the Aflip-side≅ of the advantages. There are significant capital and operating costs, some of which are a result of the environmental regulations. The public concern has led to the stagnation of new facilities in the United States. Siting and permitting a new facility in Minnesota will be extremely difficult. There is uncertainty around the status of waste-to-energy as a biomass in Minnesota and thus the potential to receive higher electrical market revenue.

Observations

As an alternative processing technology, mass burn has significant potential. Two variables could improve the potentialXuse of ash in road construction and obtaining an incentive payment for electricity produced. Both of these have potential to improve the economics of a mass burn facility.

Research Feasibility of Dedicated RDF Combustion Facility

This report updated the preliminary estimate of the costs for NRG Energy, Inc. (NRG) to build an RDF combustion facility capable of handling the RDF output from a processing facility handling 2,900 tons per day (tpd) of municipal solid waste (MSW). This report section was a "stand alone" report in 2000 and does not follow the same report content outline as the other updated sections in this report.

The report summarizes the permitting requirements for a Dedicated Combustion Facility adjacent to the NRG Facility in Newport. The primary hurdle will be satisfactory completion of the Environmental Impact Statement (EIS) process. It should be anticipated that any new municipal waste combustion facility will be extremely difficult to permit. One potential advantage to this location could be the fact it is already a major solid waste processing facility with the associated truck traffic. Nevertheless, the permitting process will be lengthy and difficult. For a dedicated combustion facility to be sited at NRG , three unique conditions exist: (1) this site is within an area currently classified as a Anon attainment area,≅ (2) it is near the I-494 bridge, and (3) its proximity to the Mississippi River Valley. Each of these brings significant potential changes to the EIS.

The report also provides a brief review of the electric utility deregulation issue and the potential economic benefit for waste-to-energy to be included in the biomass renewable fuel definition. While the average cost to produce electricity in the Midwest via other technologies was indicated to be 1.5 to 2 cents per Kwh, the estimated cost to produce electricity from RDF in the Dedicated Combustion Facility in this report is 8.8 cents per Kwh. While waste-to-energy is not a cost-effective means to produce electricity, the revenues from electricity can help offset waste disposal costs. It is important that waste-to-energy be included in the definition of biomass renewable fuels in that each cent per Kwh of electric revenue has the potential to reduce break-even disposal costs by approximately $5.20 per ton of MSW.

The advantages and disadvantages of the mass burn technology also apply to the RDF Dedicated Combustion Technology, except that the RDF Dedicated Combustion Facility has the added costs of waste processing to produce the RDF prior to combustion.

Mixed Waste Processing (Front-end Separation)

Mixed waste processing technology can take many different forms and mean different things to different people. Essentially the purpose of a mixed waste processing (MWP) facility is to separate and remove recyclable materials from incoming mixed waste (i.e., divert the recyclable materials from the waste stream). The MWP facility can be a Astand alone≅ facility or it can be part of a Afront-end separation≅ process at a WTE facility, composting facility, transfer station, C&D waste processing facility, balefill, sanitary landfill, or even as part of a recycling facility handling source-separated recyclables. In each case, the MWP facility is tailored to the specific waste streams and goals for the project. Therefore, there are several different approaches to facility design, materials targeted for recovery and costs. Approaches potentially applicable for R/W counties could be a facility targeting commercial waste loads with a high percentage of recyclables or as a front-end of a WTE facility.

MWP facilities may be developed with either relatively low-tech approaches using primarily manual sorting or more high-tech approaches using some mechanical, automated processes combined with relatively less manual labor.

Table ES-2 provides a summary of potential advantages and disadvantages to an MWP facility.

Table ES-2 Potential Advantages and Disadvantages of Mixed Waste Processing

Advantages	Disadvantages
Lower capital and operating costs than other major processing facilities	Not appropriate for the entire waste stream
Can be flexible to adapt to material market changes	A stand-alone facility diverts only 10 to 15 percent of total R/W waste stream. Could not meet a 65 percent recovery requirement to allow remaining wastes to be landfilled
Can focus in on specific waste streams with high recyclable content	
May eliminate the need for separate collection systems for targeted waste generators	Quality of recyclables recovered may be lower than source-separated programs
Can be added to the front-end of other technologies	

Advantages/Disadvantages

A MWP facility is less expensive than other technologies and can be used to focus in on recovery of certain recyclables; thus, operating at a higher level on the waste management hierarchy. MWP facilities are easily adapted to the front end of each of the other processing or landfilling technologies. A common application in Minnesota is on the front-end of a waste-to-energy facility to reduce the total tonnage to be combusted.

A MWP facility cannot meet processing goals for the entire waste stream. Based upon preliminary review, a stand-alone facility may only divert 10 to 15 percent of the entire R/W waste stream. There may be some concern with recovered material marketability, although this can be addressed by actually sorting only recyclables-rich loads while bypassing the remaining wastes delivered.

Observations

Based upon preliminary review, the most promising application of a MWP facility for the R/W waste stream could be a commercial waste material recovery facility (COM-MRF), which targets the recyclables-rich loads currently delivered to the NRG Facility. Loads of commercial wastes tend to be more homogeneous and less contaminated than residential wastes. Such a facility would primarily recover the corrugated cardboard, mixed paper, wood, and ferrous metals present in the commercial wastes. Alternatively, the MWP facility could be front-end processing for a mass burn facility.

Thermo-chemical Processes

Thermo-chemical Processes include pyrolysis, gasification, and plasma pyrolysis/ gasification. Pyrolysis is the thermal decomposition of waste biomass in the complete absence of oxygen. Unlike combustion, incineration, and gasification, pyrolysis uses an external source of heat and does not rely on oxygen to sustain the internal process. In pyrolysis systems, thermal cracking and condensation are used to transform organic substances into gaseous, liquid and solid components.

Table ES-3 summarizes perceived advantages and disadvantages of pyrolysis.

Table ES-3 Advantages and Disadvantages of Pyrolysis

Advantages	Disadvantages
Potential for significant waste diversion—according to some vendors, as much as 90 percent. Potential for producing quantities of usable gas, fuel oil, and/or fuels, as well as front-end recovery of traditional recyclables.	Unproven technology. Pilot and demonstration projects in the United States have documented significant problems in scaling up from very small applications to full-scale, real world projects. High projected capital and operating costs.

Gasification and pyrolysis are similar processes, each converts waste to gases, liquids, and char. However, the gasification process allows a small amount of air, steam or oxygen into the conversion process. This addition of oxygen changes the outputs when compared to pyrolysis and changes the component outputs of gasification.

Table ES-4 summarizes perceived advantages and disadvantages of gasification.

Table ES-4 Advantages and Disadvantages of Gasification

Advantages	Disadvantages
Not incineration	Requires MSW pre-treatment to remove non-organic waste and homogenize the material
Efficient energy production through combustion of gases	Residuals could be hazardous
High temperatures can make the process flexible to other waste streams	Unproven on a commercial scale in the United States
Recycling can be enhanced by up-front separation	System is sensitive to non-organic feedstock
	More expensive than other proven technologies

Plasma pyrolysis with gasification are processes that utilize a plasma reactor to convert waste to inert slag and gases. The gases, called "syngas" can be used as an energy source in a boiler or turbine set up.

The plasma reactor is an enclosed chamber containing plasma torches. These torches heat the gases in the chamber (for pyrolysis, no oxygen is present, nitrogen is typically used; for gasification, oxygen is present in the reaction) to 3,000ºC or higher. These high temperatures convert organic materials into gas and inorganic materials into a glassy slag substance.

Table ES-5 summarizes the perceived advantages and disadvantages of plasma systems.

Table ES-5 Advantages and Disadvantages of Plasma Systems

Advantages	Disadvantages
Superior thermal destruction	High initial investment
Limited pollution	High power requirements
Beneficial use possibilities for gas and ash produced from plasma destruction	High operating costs
Potential to expand waste stream to include other non-MSW streams	May require waste pre-shredding to fit into plasma reactor

Observations

At this time, the basic disadvantages of each of these thermo-chemical processes includes being an unproven technology and high costs. These problems make these unsuitable technologies for serious consideration by R/W counties.

Ethanol Production

The production of ethanol (grain alcohol) from waste products is known by a variety of process descriptions, including Abiomass to ethanol≅ and Aacid hydrolysis.≅ It refers to the process of using Athermo-chemical and enzymatic processing of cellulosic biomass to produce non-petroleum based fuels, fuel cells, and industrial chemicals.≅[2] In layman=s terms, this means turning organic materials, including components of the municipal solid waste stream, into fuel grade ethanol by passing it through a series of refining processes to release, ferment, and distill the available sugars.

Production of ethanol through acid hydrolysis is a technology that has been known and used for over 100 years, with its most extensive use occurring during World War II. Low petroleum prices in comparison to high ethanol production costs kept the process from being adopted for commercial use in the late 1940s. However, ethanol production has received increasing attention in the past decade from agricultural generators seeking additional markets for corn and other farm products or byproducts. Similarly, changes in federal and global environmental policies are driving increased interest in the development of non-petroleum based fuel sources.

Table ES-6 summarizes potential advantages and disadvantages of ethanol production processes.

Table ES-6 Potential Advantages and Disadvantages of Waste-to-Ethanol Processes

Advantages	Disadvantages
Minnesota supports and promotes use of ethanol as a fuel additive	Limited technical application with MSW
	Lack of history with regulators
Use of bioproducts and bioenergy is encouraged by a Presidential Executive Order	Capital/operating cost history is limited, unsettled, and likely high
May offer opportunities to expand the market uses of MSW.	Market demand for ethanol could be met by corn plants
May offer benefits toward sustainable development and resource conservation	Markets for other products need to be developed
	May require separate collection or front-end processing—raising costs

[1]Martin, Kay. AConversion Technologies: The New Frontier.≅ Senior Manager Symposium, SWANA, Amelia Island, Florida, Jan. 15, 2000.

Advantages/Disadvantages

While there appears to be some growing interest in this technology, it simply continues to not be a proven MSW management technology at this time. There is currently very limited technical application to MSW and a lack of history with regulating agencies. Capital and operating cost history is limited and unsettled. To successfully perform using organics from MSW may require source-separated collection of the organics or front-end processing to separate the organic fractionXeither of which will increase the system costs. Markets could develop significantly, but at this point, the ethanol market prices are down and demand could be met with corn plants. Marketing of the by-products is untested.

Observations

With the lack of proven technology and unsettled high costs, this technology may not be considered further by R/W counties at this time. Despite the potential disadvantages, the technology may offer some long-term advantages worth continued observation of its development. If there are waste-to-ethanol plants built that handle MSW successfully and prices for petroleum-based fuels continue to increase, the technology could surface as a viable alternative in the future.

Anaerobic Digestion

Anaerobic Digestion (AD) in the broadest sense is a process to degrade organic material in the absence of oxygen. AD therefore can be used to break down the organic fraction of waste. This includes paper, yard waste, food waste and other organic waste. Microbes that thrive in the absence of oxygen are active. AD is the end result of this microbial activity occurring among multiple microorganisms.

Table ES-7 summarizes the perceived advantages and disadvantages of anaerobic digestion.

In general, anaerobic digestion systems are effective only for the highly organic portion of the wastes and have not been used very effectively for MSW in the United States and may not be considered further by R/W counties at this time.

Table ES-7 Anaerobic Digestion Advantages and Disadvantages

Advantages	Disadvantages
Relatively low capital costs compared to most thermal processes	Uncertainties over the economics and practical applications of AD to treat MSW. AD technology for various homogenous waste streams is widely proven in Europe, but there are no full scale plants in operation in the U.S. on municipal derived wastes.
State-of-the art technology in global use including pollution control technology.	AD of MSW will need to rely on comprehensive pre-processing of the waste or source separation; plastics for example, can cause operational difficulties. Some systems however are designed to operate with mixed municipal type wastes.
Energy recovery potential (methane generation) and possible sale of surplus.	Odor emissions during material handling.
Reduces organic wastes from landfill, which reduces the production of landfill gas and leachate.	Does not treat the whole MSW stream, only the organic fraction, however may be used on residual municipal waste stream with contaminants rejected as part of the process.
Enclosed system reduces environmental impacts.	AD is more capital intensive than composting.
	Materials handling problems with front-end processing can be costly
	Contamination of final product often difficult to avoid; marketing problems.
	Gas handling, storage and cleanup facilities are required, which can be costly.

Comparison of Alternatives

Table ES-8 provides a summary of the technologies covered in this report according to some basic criteria, including whether the technology is proven, the range of break-even costs per ton, ease of permitting, and development time frame.

Proven Technology

Mass burn, RDF, and MWP may all be considered proven technologies for handling MSW. Thermo-chemical processes, waste-to-ethanol, and anaerobic digestion have very limited experience with MSW, and while they could have potential in the future, they do not provide significant opportunity at this time.

Table ES-8 Summary Comparison of Alternatives

	Proven Technology	Break-even Cost/Ton	East of Permitting	Development Period
Mass Burn	Yes	$70 to $90	Extremely difficult	5 years+
RDF dedicated Combustion Facility	Yes	$92 to $107	Extremely difficult	5 years+
MWP	Yes	$40 to $60	Fair	2 to 3 years
Thermo-chemical Processes	Not at this time	Unknown	Unknown	5 years+
Waste-to-Ethanol	Very limited with MSW	Not adequately defined	Unknown	5 years+
Anaerobic Digestion	Very limited with MSW	Unknown	Unknown	5 years+

Break-Even Cost Per Ton

At this conceptual planning level, ranges are provided within which each technology may reasonably be assumed to operate. There are many variables yet to be addressed prior to establishing actual break-even costs. Mass burn may be less expensive than the RDF Dedicated Combustion Facility due to less waste processing costs. MWP appears to have the lowest potential break-even costs per ton (but also provide less overall waste reduction).

Ease of Permitting/Public Acceptance

Understanding that any new waste management facility typically faces difficultyXsome technologies may be simpler than others to permit. Mass burn and RDF Dedicated Combustion Facility will both require an Environmental Impact Statement (EIS), which may take five years and raise considerable controversy. Any of the technologies would be easier to permit at an existing waste management facility.

Development Period

This is an estimate of the time from a decision to pursue the technology until actual commercial operations. The time periods in Table ES8 are for greenfields sites. Siting at an existing solid waste facility typically reduces development time.

Typical Project Schedule

Development of a major new processing facility can be a very lengthy process. Figure ES-1 shows that implementation can take six years or more depending on the final facility type, size and permitting complexing.

The steps shown in Figure ES-1 go sequentially from preliminary planning through procurement, permitting, final design/construction, shakedown/acceptance tests to commercial operations. The biggest variables in schedule occur in permitting (especially if an EIS is required) and the time for construction. For example, if an EIS is required, the permitting period may extend from the two and a half years shown to five years. If everything else held constant, the implementation period prior to commercial operations would extend to nine years.

Project Building Blocks

Consideration of a major waste management processing facility can be quite complex. One convenient way to organize the components and the associated issues is to think of the various components as building blocks to completion of the project. Figure ES-2 shows the key components in a Abuilding block≅ approach.

Building Blocks for a Major Waste Management Facility

The purpose of the facility is to manage solid wastes produced by our society; therefore, waste stream issues provide the base or foundation of the project. What wastes need to be managed or are available for a facility? Can the waste stream be controlled to assure it will be delivered? What type of wastes should be targeted? How much waste needs to be managed and what are the future projections for quantities? Resolution of these questions/issues is the first step in building a major waste management facility.

Selection of the technology and the markets for the technology somewhat go Ahand-in-hand.≅ Without secure markets for the processing facilities end-products, the waste processing facility will not be successful (i.e., Ano marketX no project≅). The selected technology must be capable of meeting the specifications of the targeted markets. Herein lies a key criterium for whether the technology can be considered as a Aproven technology.≅

The facility cannot be built without all the required permits. To gain the permits requires meeting all the regulatory requirements and somehow gaining public acceptance. Solid waste facilities are typically Alocally unacceptable land uses (LULUs).≅ Opposition from site neighbors and organized environmental groups is common. Securing this AProject Building Block≅ is typically the most difficult step in the process.

Somewhere in the process, a decision must be made as to who will own the facility and who will be the operator. Each of the options has advantages and disadvantages. The first basic decision is between public and private. Procurement processes vary depending on owner/operator preferences. Selecting the preferred contractor and negotiating a contract also requires careful consideration.

The site selection is critical to the permitting process. Certain technologies require larger site sizes. Existing solid waste facilities are typically easier to expand than establishing newA green field≅ sites. The use of a AHost Community Benefit Package≅ has become quite common in the solid waste industry.

Figure ES-1

Major Waste Management Facility
Potential Implementation Schedule

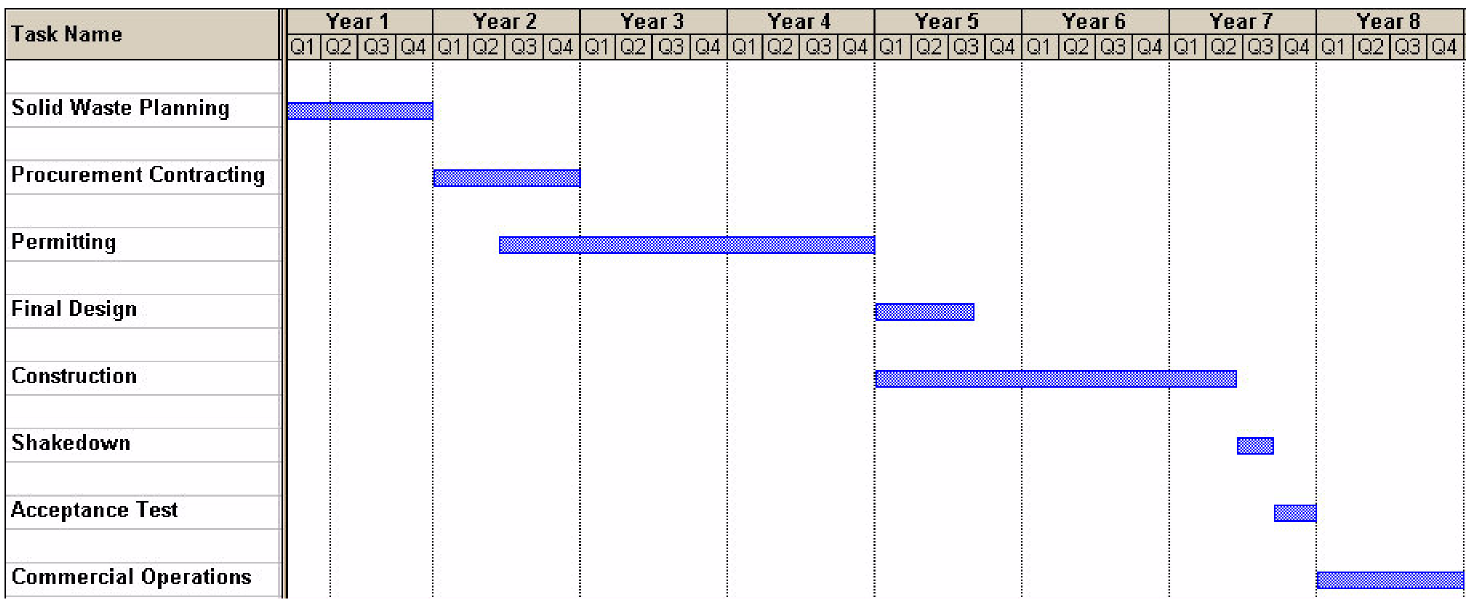


Figure ES-2

Project Building Blocks For a Major Waste Management Facility

Financing
- Bonds
- Loans
- Host Community
- Tip fees

Site
- Location
- Host Community

Residue Disposal
- Quantity
- Disposal Facility Contract

Operator
- Public vs. Private

Owner
- Public vs. Private

Permitting Process

Technology
- Waste-to-Energy
- Mixed Waste Processing
- Waste-to-Ethanol
- RDF Combustion
- Thermo-chemical Processes
- Anaerobic Digestion

Markets/Outlets

End Use for Products

Waste Stream
- Availability
- Waste Assurance
- Sizing (tpd)

All of the technologies have a residue waste stream. The quantities vary along with the characteristics. In any event, arrangements must be made to assure long-term access to a disposal facility.

Financing is the building block that brings all the other project building blocks together. Financing the capital cost may require bond feasibility studies that address the feasibility of success for each of the building blocks. Ongoing revenue generation via tipping fees, market revenues, service charges, or tax support is fundamental to long-term success.

While this explanation of the steps to implement a major processing facility seems simple, the actual process is often times very complicated in that it is very difficult to entirely resolve any one building block issue before moving on to another. Typically, waste stream issues are never fully resolved. Market conditions change with a global economy. New vendors try to enter the process even after a specific vendor is selected. Site selection, the permitting process, and community reaction are all complicated by the adverse image of solid waste facilities.

Updated Research Study of

Alternative Waste Processing

Contents

Contents

Contents

Contents

Contents

Tables

Contents

Figures

Exhibits

Appendices

1. Introduction

The Ramsey/Washington County Resource Recovery Project Board (Board) has a service agreement with NRG Energy, Inc. (NRG) to process solid waste from the two counties at the Newport Resource Recovery Facility (Facility). The agreement began in 1986 and provided that Northern States Power Company (NSP), the predecessor to NRG, design, construct, and operate the Facility. The Facility began processing solid waste into refuse-derived fuel (RDF) in 1987 and the service agreement extends until 2007.

In April 2000, Foth & Van Dyke prepared two reports for the Board—"Research Study of Alternative Waste Processing Technologies" and "Research Feasibility of Dedicated Combustion Facility" (Studies). The Studies included research on mass burn waste-to-energy, source-separated organic composting, mixed waste processing (front-end separation), pyrolysis, ethanol, bioreactors with recovery, and a dedicated RDF combustion plant.

The Board requested an update to the Studies and additional technologies to be reviewed. This report update encompasses the following technologies:

- Mass burn waste-to-energy
- Mixed waste processing (front-end separation)
- Thermo-chemical processes
- Ethanol production
- Methane digestion
- Dedicated RDF combustion

Bioreactors are covered in a separate report. Some technologies have not changed substantially while others have had more research.

The direction provided to Foth & Van Dyke by the Board in 2000 was to conduct a literature search of available information and develop an overview of each technology, including a description, applicability to the R/W counties= waste stream, general concerns/issues, current status, general costs, implementation needs, and potential advantages/disadvantages. It was understood that the technologies are not all equally capable or proven at this point and the information available would vary. Those comments continue to apply to the report completed in 2004. If there was not a significant amount of activity in a t echnology since 2000, this report does not change much from the previous report.

2. Ramsey/Washington County Waste Stream

2.1 Waste Quantity

Table 2-1 provides an historical look at the quantity of MSW delivered to the Facility from R/W counties from 1990 through 2003 and how much of the MSW was made into RDF, recycled, or landfilled. The high point of waste delivered was in 2002. This was a year when several hauling companies signed All Waste delivery contracts at the time R/W counties were considering Public Collection.

Table 2-2 provides a two-year snapshot comparison of the entire R/W counties= waste streams including recycling, processing, landfilling, and other waste management. The total waste stream in 2002 was 996,584 tons. Of this total, approximately 533,000 tons was delivered to the Facility and another 80,981 tons was delivered directly to some sanitary landfill without processing. This provides a total of approximately 614,000 tons that could have been processed.

In 2003, MSW deliveries to Newport were approximately 360,734 tons and another 177,467 tons were delivered directly to a landfill. This provides a total of 538,201 tons that could have been processed.

2.2 Waste Stream Projections

The SWMCB has developed waste stream growth projections as part of the regional/county solid waste master plan. Using the 538,201 tons in 2003 that could have been delivered to the Facility from Ramsey and Washington counties, Table 2-3 provides some projections of the wastes that could be available to a processing facility in the future. The projections coincide with the same percentage growth rates calculated from the SWMCB data for the entire waste stream in the six-county area. As shown in Table 2-3, over 800,000 tons may be available for processing in 2017.

2.3 Waste Composition

The SWMCB completed an MSW Composition Study in the fall of 1999. Table 2-4 shows a comparison of the aggregate (data from residential, institutional/commercial/industrial, and mixed waste streams) waste composition percentage for eight groups of material categories for the NRG Facility versus the Twin Cities Metropolitan Area. While there are differences in the percentages, none appear strikingly different. The Metropolitan Area data represents a larger overall database and, therefore, is used for this preliminary planning report.

As a very preliminary, broad estimate of tonnages available, Table 2-5 shows the Metropolitan Area composition percentages from Table 2-4 applied to the 2003 and 2017 projected tonnages available for processing from R/W counties. These estimates must be considered as very preliminary, broad-based planning quantities. Their purpose is to provide preliminary quantities of MSW that may be suitable for the various alternative processing technologies in this report.

Table 2-1
Management of Waste from Ramsey and Washington Counties
At the Ramsey/Washington County Resource Recovery Facility from 1990-2003

Item	1990	1991	1992	1993	1994	1995 [3]	1996	1997 [4]	1998 [5]	1999	2000	2001	2002	2003
Tons Delivered	409,727	389,461	393,448	388,248	366,861	342,032	349,310	381,768	413,371	392,920	395,459	369,970	532,616	360,734
Ferrous	9,115	3,708	10,863	11,450	11,557	11,267	11,455	12,469	13,077	10,918	11,960	11,128	13,973	11,751
Glass/Stone				115	232	162	61							
Aluminum													1,030	874
Tons Recovered for Recycling	9,115	3,708	10,863	11,565	11,789	11,429	11,516	12,469	13,077	10,918	11,960	11,128	15,003	12,625
% of Tons Del.	2.2%	1.0%	2.8%	3.0%	3.2%	3.3%	3.3%	3.3%	3.2%	2.8%	3.0%	3.0%	2.8%	3.5%
Excess Waste/Bulky Waste Residue [1]	72,012	64,581	58,604	50,543	30,160	19,256	20,282	27,559	34,415	53,616	56,075	49,712	140,615	45,853
Residue [2]	65,562	49,885	30,943	18,264	16,454	9,625	16,329	18,646	27,392	19,012	21,295	19,878	56,227	34,958
Ferrous not Mktd.	4,543	7,947	260	75										
Total Landfill	142,117	122,413	89,807	68,882	46,614	28,881	36,611	46,205	61,807	72,628	77,370	69,590	196,842	80,811
% of Tons Del.	34.7%	31.4%	22.8%	17.7%	12.7%	8.4%	10.5%	12.1%	15.0%	18.5%	19.6%	18.8%	37.0%	22.4%

SOURCE: County Certification Reports, as revised

NOTES:

[1] Waste that does not proceed directly through the processing lines, but is transferred to another waste facility. Generally called BWR or Bulky Waste Residue, this waste stream includes both non-processible waste and excess waste that is processible but is not processed through the processing lines.

[2] Material remaining after waste proceeds through the two processing lines to produce RDF and recover metals.

[3] Total delivered includes citizen area waste beginning in 1995.

Table 2-2 Summary of Waste Management in Ramsey and Washington Counties, Per 2003 and 2002 SCORE/Certification Reports

2003

	Ramsey	Washington	TOTAL
Recycling	**282,251**	**84,633**	**366,884**
Residential (curbside and dropoff)	69,170	28,050	97,220
Commercial/industrial/institutional	202,757	53,025	255,782
Mechanical (Newport) and hand separated	10,324	3,558	13,882
Processing (RDF as adjusted)	**192,056**	**70,931**	**262,987**
Land Disposal	**228,487**	**34,432**	**262,919**
Residuals and non-processible/excess (from	62,394	23,058	85,452
Unprocessed MSW to MN landfills	25,620	4,725	30,345
Unprocessed MSW to non-MN landfills	140,473	6,649	147,122
Other Waste Management	**13,243**	**5,314**	**18,557**
TOTAL	**716,037**	**196,569**	**911,347**

2002

	Ramsey	Washington	TOTAL
Recycling	**299,807**	**79,377**	**379,184**
Residential (curbside and dropoff)	67,574	26,067	93,641
Commercial/industrial/institutional	220504	49,119	269,623
Mechanical (Newport) and hand separated	11,729	4,190	15,919
Processing (RDF as adjusted)	**235,028**	**86,252**	**321,280**
Land Disposal	**221,804**	**55,782**	**277,586**
Residuals and non-processible/excess (from	143,241	53,364	196,605
Unprocessed MSW to MN landfills	3,580	682	4,262
Unprocessed MSW to non-MN landfills	74,983	1,736	76,719
Other Waste Management	**13,338**	**5,196**	**18,534**
TOTAL	**769,977**	**226,607**	**996,584**

NOTES:

[1] Information provided for SCORE/Certification reports is only for MSW, related recycling, and management of certain problem materials (recycled portion included with recycling and the remainder under Other Waste Management). C&D and other separately managed waste streams, including yard waste, are excluded.

[2] "RDF as adjusted" refers to RDF plus adjustments needed for deliveries to Newport to equal waste managed from Newport; also included are very small quantities of MSW processed at NRG-Empire.

[3] "Other Waste Management" refers to items neither recycled nor processed at a MSW facility; these include the unrecycled portion of several problem materials (major appliances, used motor oil, oil filters, tires, lead acid batteries) and may also include the unrecycled portion of household hazardous waste.

[4] OEA's SCORE report may show slightly different numbers for "Other Waste Management" because their estimates may be based on updated population estimates from those used by the Counties at the time of report submittal.

[5] It appears that with the implementation of the County Environmental Charge in each County, beginning April 2003, some material managed in 2002 as MSW was managed separately as C&D or industrial waste once the CEC was adopted.

Table 2-3 Projections of Waste Quantity Available for Processing Ramsey/Washington Counties

Year	Six-County Tonnage[A]	Growth[B] (%)	R/W Counties Tonnage[C]
2003	3,599,464	--	538,201
2007	4,012,387	14%	613,549
2010	4,332,168	25%	672,751
2017	5,047,768	49%	801,919

[A] Source: Ramsey County Department of Public Health, Environmental Health Section - data from SWMCB.
[B] Percentage change from 2003 to the specific year listed.
[C] Tonnage assuming growth at same percentage rate change as SWMCB data. Totals assume continuing to achieve a 50 percent recycling goal.

Table 2-4 Aggregate Waste Composition Percentages[D]

Material	NRG Newport	Metropolitan Area
Paper	35.1	34.2
Plastic	11.6	11.0
Metals	5.2	4.4
Glass	2.3	2.7
Organic Materials	26.1	27.3
Problem Materials	2.1	1.8
HHW	0.5	0.3
Other Waste	17.2	18.3

[D] Source: Final Report MSW Composition Study for the Solid Waste Management Coordinating Board, March 2000, R.W. Beck.

Table 2-5 Preliminary Application of Composition Percentages to Waste Quantities

Material Category	Composition (%)	2003 Tonnage	Tons Per Day	2017 Tonnage	Tons Per Day
Paper	34.2	184,065	504	274,256	751
Plastic	11.0	59,202	162	88,211	242
Metals	4.4	23,681	65	35,284	97
Glass	2.7	14,531	40	21,652	59
Organic Materials	27.3	146,929	403	218,924	600
Problem Materials	1.8	9,688	27	14,435	40
HHW	0.3	1,615	4	2,406	7
Other Waste	18.3	98,491	270	146,751	402
Total	100.0	538,201	1,475	801,919	2,197

[A] Metropolitan Area aggregate composition.
[B] Material category tons divided by 365 days per year.
[C] Actual total varies due to rounding in percentage data. These totals are the 2003 and 2017 tonnages projected from Ramsey and Washington counties.

3. Mass Burn Waste-To-Energy

The waste-to-energy (WTE) industry emerged in the United States in the 1970s due to several factors. The Arab Oil Embargo forced oil and energy prices to increase. There was growing recognition of the risks of groundwater contamination at existing unlined landfills. This led to new regulations requiring the construction of lined sanitary landfills, which increased the cost of landfilling. WTE facilities[1] were considered to be viable alternatives for waste disposal and energy production. In 1980, less than 60 WTE facilities were operating. By 1993, the number of operating facilities reached a peak of approximately 150. There as not been a significant amount of change in this technology since 2000.

Although many hybrids exist, three basic types of facilities were developed to incinerate and recover energy from solid wastes. They include: (1) refuse derived fuel (RDF), (2) mass burn waterwall, and (3) mass burn modular. RDF facilities shred waste into a homogeneous mixture. This mixture is fed into the combustion facility. Waterwall and modular mass burn facilities do not pre-process waste. Waste is fed directly from a stockpile into the feed chute of the combustion chamber. Characteristics of each type of facility are summarized in Table 3-1.

Table 3-1 Characteristics of Mass Burn, RDF, and Modular Facilities[A]

	Mass Burn	RDF	Modular
Frequency of use (%)[B]	69	18	12
Frequency of steam markets (%)	9.0	9.1	56.5
Frequency of cogeneration (%)	16.4	22.7	17.4
Frequency of electricity markets (%)	74.6	68.2	26.1
Average actual capacity (tpd)	995	960	122
Total throughput (tpd)	23,941,000	10,984,700	997,100
Average ash residue (%)	24.8	11.8	24.1
Average net energy recovery (KWH/ton)	511	597	335
Average adjusted capital cost (cost/design tpd)	$125,528	$174,182	$108,103
Average operating cost without debt service (cost/ton)	$35.27	$36.25[C]	$52.41
Average operating cost with debt service (cost/ton)	$68.97	$56.21[D]	$74.13

[A] Source: Berenyi, E.B. AThe Municipal Waste Combustion Industry In The United States: 1997-1998 Resource Recovery Yearbook and Directory,≅ Governmental Advisory Associates, Inc., 1997.
[B] Frequency of use percentages based on "The 2002 ISWA Directory of Waste-To-Energy Plants," Integrated Waste Services Association, 2002.
[C] Telephone conversation with Eileen Berenyi, Governmental Advisory Associates, March 8, 2000. Data is based on information available from six known facilities.
[D] May not include both processing and combustion facilities. In addition, data may include converted coal-fired combustion facilities.

[1] Berenyi, E.B., and Rogoff, M.S., "Is the Waste-To-Energy Industry Dead?" MSW Management, Elements 2000, page 66.

From 1993 to present, the number of operating WTE facilities has declined to 98 due to several factors[2]. The decline has been caused by an abundance of landfill space with lower costs than WTE, loss of ordinance based flow control, and implementation of federal air quality standards. Currently, approximately 13 percent of all MSW generated in the United States is processed in WTE facilities.

3.1 Process

3.1.1 Waste Feed

Figure 3-1 illustrates a typical mass burn waterwall facility. Waste is delivered to the facility in garbage trucks. The trucks drive onto the tipping floor (1), and unload waste into a pit (2). The waste is mixed and loaded from the pit with a hydraulic crane (3) into a feed hopper (4). Any items that are not processible are removed from the stockpile with the crane. These items, referred to as bypass, may not be processible because they are too large to pass through the feed chute and boiler without risk of plugging, they do not have any heat value (also referred to as non combustibles), or they create problems with air quality standards. Bypass is diverted to a landfill or recycled. These items may include furniture, mattresses, large metal objects, and appliances. After being loaded into the feed hopper, hydraulic ram feeders (not illustrated in figure) provide a controlled flow of waste into the combustion chamber.

MSW also has a moisture content higher than most fuel feedstock for combustion. Typical MSW is 20 to 30 percent water by weight.

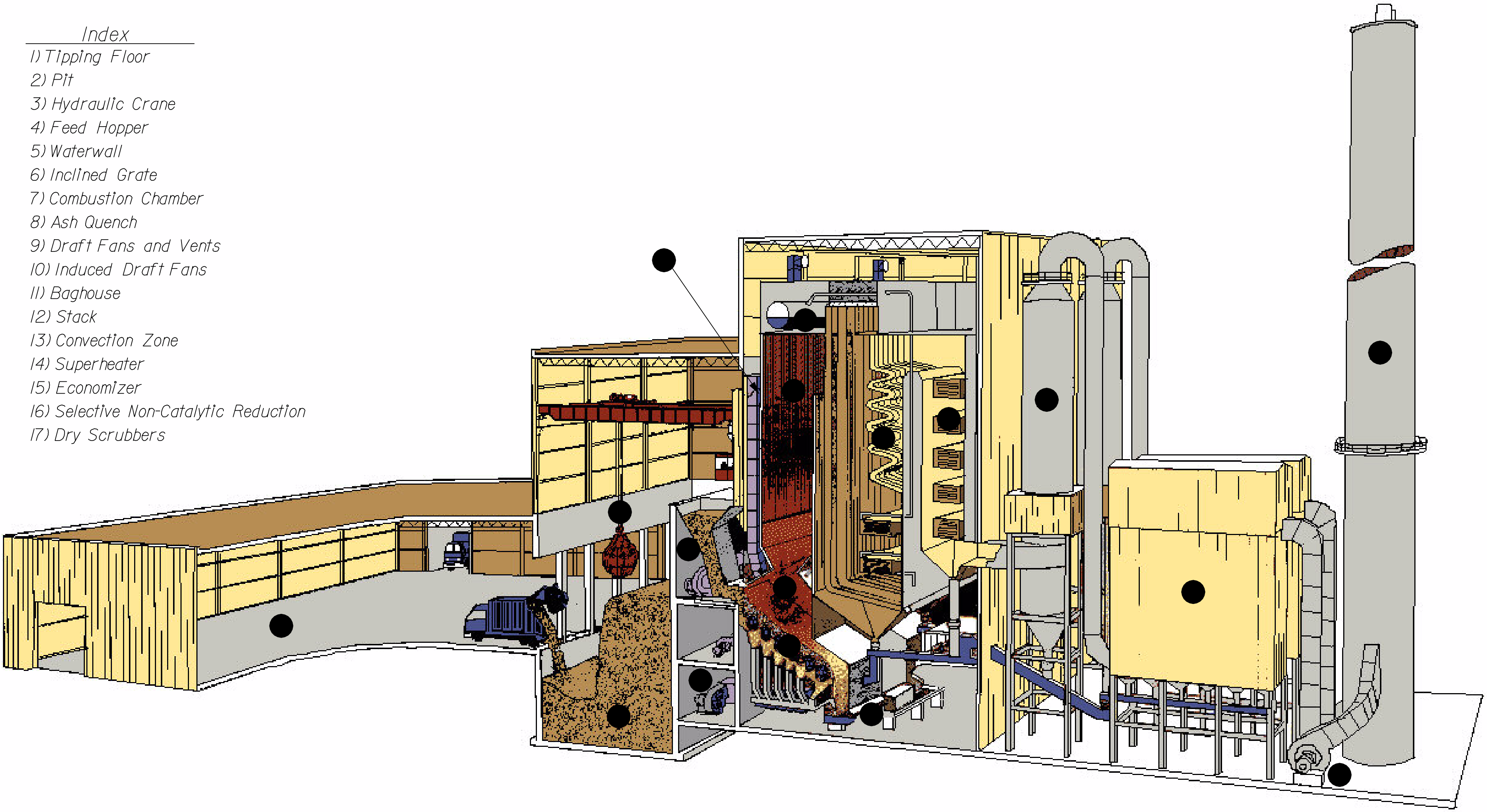
3.1.2 Combustion Chamber[3]

The combustion chamber walls can be either refractory, or waterwall (5). Refractory plants have combustion chamber walls that are constructed of ceramic, silicon carbide or other insulating materials, preventing heat from being lost prior to energy recovery in the boilers. Waterwalls are lined with tubes through which water circulates to absorb the heat of combustion. The water filled tubes contribute to energy recovery.

Waste can be transported through the combustion chamber via an inclined grate (6)Xas shown in Figure 3-1, transfer ram, rotary kiln, or fluidized bed. Each method of transport has different abilities to mix the waste and allow maximum contact with air to improve combustion efficiency. Inclined grates are most commonly used in mass burn waterwall plants. The inclined grates can either be a series of reciprocating grates, rocking grates, or traveling grates. In all cases, the movement of the grates helps mix the waste and deliver it downward through the combustion chamber (7) to the ash quench (8).

[2] Source: Jonathan Kiser and Maria Zannes, "The 2002 IWSA Directory of Waste-To-Energy Plants," IWSA, 2002.

[3] Walsh, P. and O'Leary, P., "Implementing Municipal Solid Waste to Energy Systems," University of Wisconsin – Extension, Madison, Wisconsin, 1986.



Index

1) Tipping Floor
2) Pit
3) Hydraulic Crane
4) Feed Hopper
5) Waterwall
6) Inclined Grate
7) Combustion Chamber
8) Ash Quench
9) Draft Fans and Vents
10) Induced Draft Fans
11) Baghouse
12) Stack
13) Convection Zone
14) Superheater
15) Economizer
16) Selective Non-Catalytic Reduction
17) Dry Scrubbers

Source:
Amercian Ref-Fuel Company
http://www.ref-fuel.com/technology.html
12/17/99

RAMSEY/WASHINGTON COUNTIES			
FIGURE 3-1 TYPICAL MASS BURN WATERWALL FACILITY			
Scale: NOT TO SCALE		Date: APRIL 2000	
Prepared By: **Foth & Van Dyke**		By: JAM3	

Water cooled rams push the waste through the combustion chamber. They do not allow for as much mixing or air contact as the inclined grate design, and are commonly used in modular plants.

The Barlow Group, Inc.[4] developed a combustion technology they refer to as AInclined Fluidized Bed≅ (IFB). The IFB requires no fuel preparation and has no moving parts exposed to combustion. Waste is agitated and moved through the combustion zone via a pneumatic process. The IFB is built in standard size modules, with each module shop fabricated and delivered to the site for final assembly. This technology combines characteristics from both modular plants and larger mass burn technologies.

Rotary kilns utilize an inclined rotating cylinder. As the cylinder rotates, it mixes the waste (burning inside of it) and increases its exposure to air. The incline causes the waste to slowly tumble toward the ash quench. Rotary kilns can be used in refractory or waterwall plants.

Typical fluidized beds burn waste on a Abed≅ of porous, noncombustible media (such as sand) that allows air to travel through it. Air injected through the media literally suspends the waste during combustion, maximizing mixing and air contact. For this reason it is also called suspension combustion. Fluidized beds are most often used in RDF plants. The fluidized bed media is very corrosive. Therefore, it cannot be used in waterwall plants, where the heat recovery tubes located within the combustion chamber walls are vulnerable to the corrosive media[5]. Fluidized beds require refractory walls.

3.1.3 Air Delivery[6]

The amount of combustion air delivered to the combustion chamber is controlled by draft fans (9). The fans deliver air through vents from below and above the burning waste. These are called underfire and overfire air, respectively. The amount of air delivered to each is regulated to complete combustion, maximize efficiency, and minimize hazardous air pollutant emissions.

Air delivery and waste delivery rates through the combustion chamber directly influence combustion chamber temperatures. A properly operating facility typically maintains temperatures in a range above 1,500EF and below 2,000EF to optimize energy recovery efficiency and hazardous air pollutants (HAPs) emissions. Air/waste delivery ratios directly influence combustion. Too much air lowers combustion temperatures below 1,500EF and may cause carbon monoxide (CO) emissions. Too much waste will also decrease temperature and will result in incomplete combustion. Continuous emissions monitoring (CEM) equipment is used to optimize delivery rates and air/waste ratios.

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[4]Barlow Projects, Inc. *The Future in Solid Waste Technology.*

[5]February 9, 2000 tour of Olmsted County WTE Facility, guided by Rob Dunnette.

[6]Olmsted tour, February 9, 2000.

Although draft fans deliver large volumes of air into the boiler, a negative differential pressure exists in the boiler. This means that the pressure in the boiler is lower than ambient air pressure. Negative differential pressure ensures that fumes and exhaust do not exit the boiler, except through the stack. Any breaches in the containment will only allow air to enter, not exit. This keeps odors and dangerous gases produced from incomplete combustion from getting out. To create negative differential pressure, induced draft fans (10) deliver air from the baghouse (11) to the stack (12).

3.1.4 Energy Recovery

The heat of the combusting waste is transferred into water contained in boilers in the convection zone (13), superheater (14) and economizer (15). Each of these are different types of boilers that maximize the transfer of heat at different temperatures. After being heated, temperatures and pressures of steam in WTE facility boilers can exceed 900^{o} Fahrenheit and 900 pounds per square inch gauge (PSIG) pressure.

RDF incinerators are similar in design to waterwall incinerators. As mentioned in Section 3.1.2, if they have a fluidized bed, the combustion chamber must have refractory walls.

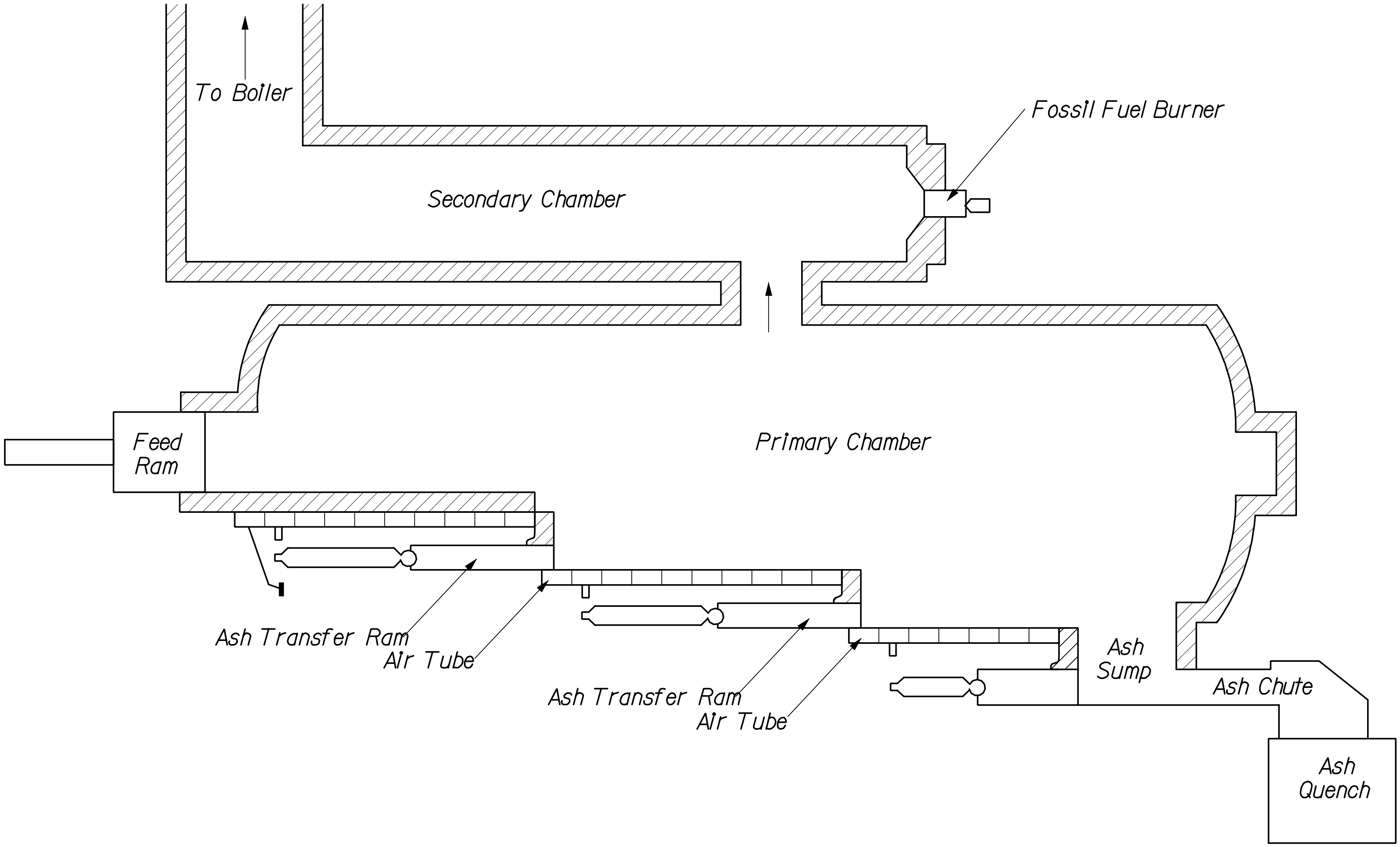
Modular incinerators use a two chamber incinerator. Heat is transferred by convection from the boiler, as shown in Figure 3-2. Modular incinerators are less efficient, do not heat water as hot or build as much pressure, but are easier to build. Additional Amodules≅ are pre-constructed, and can be added to an existing facility with minimal construction.

The superheated steam produced from the boiler is used to power a turbine to generate electricity or is sold as steam to heat, cool or provide energy to a local market; or do both. WTE facilities that generate electricity and sell steam are called cogeneration, or Acogen≅ facilities.

3.1.5 Pollution Control

The air pollution control (APC) equipment on mass burn facilities has changed dramatically. The most dramatic change came with the enforcement of the 1990 Clean Air Act via the 1995 MACT standards. These standards require that WTE facilities use Amaximum achievable control technology≅ (MACT) to control air emissions. Table 3-2 lists the MACT new source standards. With implementation of the MACT standards, the WTE plants in the United States may operate cleaner than coal and oil fired plants, and have similar emissions to natural gas burning plants[7]. To monitor emissions, continuous emissions monitoring (CEM) is also becoming standard in WTE plants. The cleaner air standards required for WTE facilities added a significant cost to waste combustion. Over $250 million were spend in 1991 alone to add air pollution control equipment and retrofit boilers in pursuit of lower emissions[1]. The monitoring and maintenance costs of APC equipment is also significant.

[7]AIMS Coalition, “America’s Newest Energy Source,” 1994.



RAMSEY/WASHINGTON COUNTIES

FIGURE 3-2

CROSS SECTION OF A TYPICAL MODULAR COMBUSTION UNIT

Scale:	NOT TO SCALE	Date:	APRIL 2000
Prepared By:	Foth & Van Dyke	By:	JAM3

Table 3-2 MACT New Source Rules[A]

Emission	MACT Emissions Limits
Dioxins/furans	13 ng/dscm*
Cd (cadmium)	0.020 mg/dscm*
Pb (lead)	0.20 mg/dscm*
PM (particulate matter)	24 mg*
Fugitives	Visible less than 5% of the time
CO (carbon monoxide)	
Modular/mass burn, fluidized bed	100 ppmv*
RDF	150 ppmv*
SO_2	30 ppm* or 80% removal
HCL	25 ppm* or 95% removal
Opacity	10%
VOC	See note on HAPs
Hg (mercury)	0.080 mg/dscm* or 85% removal
NO_x	
First year	180 ppm*
After first year	150 ppm*
Complete:	Siting analysis Materials separation plan Public meetings

[A] Source: Integrated Solid Waste Services Association, "New Clean Air Act Rules for Waste-To-Energy Facilities," Fact Sheet, April 5, 1999.

* Corrected to 7 percent oxygen.

Notes: Emissions Limit applicable for sites greater than 250 tpd. Smaller sites have different rules.
mg = milligrams
ng= nanograms
ppm = parts per million
ppmv = parts per million by volume
dscm = dry standard cubic meters
Single HAP thresholds are 10 tpy, combined HAPs threshold is 25 tpy

The Title V criteria pollutants and hazardous air pollutants (HAPs) emitted by WTE plants are carbon monoxide (CO), dioxins, nitrous oxides (NO_x) sulfur dioxide (SO_2), hydrochloride gas (HCl), particulate matter (PM), solid metals, and mercury (Hg). CO and dioxins are produced by incomplete combustion of the waste. Improved boiler technology and CEM have led to more efficient combustion, and lowered CO and dioxin concentrations. Selective Non-Catalytic Reduction (SNCR) uses ammonia or urea to reduce NO_x into harmless nitrogen and water (16).

Dry scrubbers spray wetted lime to remove acidic SO_2, HCl, and 50 percent of Hg emissions (17). Powdered activated carbon can also be sprayed to control the remainder of Hg emissions.

In order to meet the Title V MACT regulations, APC equipment is shifting away from ESPs. Dry scrubbers and fabric filter baghouses are becoming almost universal. It is expected CEM will become an industry standard; selective non-catalytic reduction for NO_x, and powdered activated carbon for mercury will continue to become more popular.

Mercury emissions in the 1980's were a major concern for WTE facilities. The tonnage of Hg used in manufactured products has been reduced from nearly 1,200 tons per year in 1985 to less than 150 tons per year in 1999[8]. The new APC technology and reductions of Hg used in manufacturing has significantly reduced mercury emissions.

3.1.6 Residue

Once the waste is combusted, it turns into ash. Most of the ash is heavy enough that it remains on the grates or fluidized bed and is termed the bottom ash. The bottom ash is discharged out of the boiler and quenched with water to cool it below combustion temperatures. Air-borne ash, or fly ash, is captured by the air pollution control equipment. Once captured, the fly ash is usually combined with the bottom ash. State-of-the-art facilities often have a ferrous recovery system that removes ferrous metals from the ash. Non-ferrous metals can also be removed at some facilities. Finally, the ash is conveyed to a container where it is most often loaded for transport to an ash monofill. In some cases it is being used for road aggregate, landfill cover material, or cement aggregate.

3.1.7 Redundancy

Mass burn facilities are usually built with a certain amount of redundancy in each facility. This means each facility usually has two combustion chambers, with dedicated waste feed, air delivery, energy recovery, ash collection and pollution control equipment for each. Redundancy makes it less likely that the facility will encounter periods of zero combustion capacity due to scheduled and unscheduled shutdowns.

3.1.8 Typical Markets[9]

WTE 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.

3.1.8.1 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 WTE facility are generally based on the costs that the steam customer

[8] AIMS Coalition, "America's Newest Energy Source," 1994.

[9] Berenyi, E.B., 1997.

can defer by not producing the steam in-house. 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 a "positive" interest in purchasing energy generated from a WTE 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;
- 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);
- Located in an industrially zoned area or within one mile of an area zoned industrial to accommodate the location of the WTE facility (or close enough for a steam line connection).

Steam potentially provides greater revenue than electricity per ton of waste. Based on the average waste processed (320,700 tpy), the average steam production (278,547 pounds per hour) and the average market price of steam ($5.78 per 1,000 lbs), steam generates a revenue of $44 per ton of waste[10].

Only 20 percent of the WTE facilities are dedicated steam producers, and 18 percent are cogen facilities. In contrast, 63 percent are dedicated electricity producers. Table 3-1 shows that approximately 70 percent of Mass burn and RDF facilities are dedicated electricity producers. Approximately 56 percent of modular facilities are dedicated steam producers. Modular facilities tend to favor steam sales, because they usually cannot generate the superheated steam necessary to power electric turbines efficiently or they were more convenient to site next to the potential steam market.

While there may be advantages to having a steam customer, there are also some disadvantages. The WTE facility must be located reasonably close to the steam customer in order to pipe the steam without too much energy loss. Relying solely on a steam customer provides a greater element of risk over the long term should the steam customers' needs change or the business go out of operation. The WTE facility will also need to consider how "firm" a supply of steam the WTE facility can provide. Would back-up natural gas fired boilers be required? Can or should the WTE facility guarantee steam availability and provide for liquidated damages if unable to supply all the steam contracted? Does the steam customer need to keep its boilers in operation to

[10] Berenyi, E.B., 1997.

provide backup? All these potential issues come into play in the steam supply contract and pricing arrangement.

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 changing. Due to the electric industry's development of gas-fired electric power plants, the demand for natural gas has been increasing. According to Casey Whelan, U.S. Energy Services, Inc.,[11] recent natural gas price increases may be here to stay. The reserves of $2 per MMBtu natural gas have peaked and are declining. There are still reserves of natural gas to tap in the world, but the costs will be higher due to the depth to reach the gas or to the added transportatiaon costs to get the natural gas to the United States. These higher natural gas prices (perhaps two to three times previous prices) will increase the cost to produce steam; thereby increasing potential revenues from steam sales (steam prices should be indexed to natural gas prices with some floor price protection[12]). Thus, it may be a good time to pursue potential steam customers for a WTE project.

3.1.8.2 Electrical Markets

A WTE facility=s electric turbine generators are connected to a utility sub-station. From there, the local utility manages the electricity. Electricity generated from waste is sold based on an Aavoided cost≅ value. This is the cost that the utility company saves by using electricity from the WTE plants. Based on the national average, plants sell their electricity for 5.094 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, and are changing due to deregulation of the electric industry. Electricity prices are generally lower in the Midwest than the East Coast, and rates received in Minnesota are therefore lower. HERC (Hennepin County mass burn facility) has a relatively favorable contract for Midwest facilities and receives almost 5 cents per Kwh.

Legislation could be instituted to provide the WTE industry with a better price for its electricity. There are state and federal goals being set to promote the generation of electricity from Arenewable≅ resources. The inclusion of WTE within the definition of Arenewable≅ resources is not clearly agreed upon. In 2003, the State of Minnesota included WTE in the renewable fuels as part of biomass. Unfortunately, price incentives were not included in the Minnesota legislation. The Department of Energy (DOE), Public Utilities Regulatory Policy Act (PURPA), Federal Power Act Amendment (FPAA), and Clean Air Act (CAA) amendments all have different definitions for Arenewable≅ resources. The definitions typically include biomass, wind, solar, and geothermal. WTE plants have been arguably classified as using Arenewable

[11] Natural Gas: Lights On and a Warm Home? Minnesota Air, Water, and Waste Conference, February 26, 2004, Minnesota Pollution Control Agency.

[12] Communication from Sami Kabbani, American Ref-Fuel, February 19, 2004.

resources,≅ since they burn MSW, which is typically 80 percent by mass composed of organic material, or Abiomass[13].≅

Currently, approximately 2 percent of all electricity generated in the U.S. is from renewable resources. There currently is legislation promoting a 4 percent goal[14].

As shown in Table 3-1, RDF generates an average net output of 597 KWH per ton, followed by mass burn at 512 and Modular at 335. Although RDF plants produce more electricity per ton of waste incinerated than mass burn plants, the numbers are subject to interpretation. This increased efficiency is due partly to the fact that non-combustible materials such as metals are included in mass burn facilities. The noncombustibles are included in the KWH per ton output of a mass burn facility, but not in the KWH per ton in an RDF facility. Furthermore, the energy costs of processing RDF is not included in the comparisons.

3.2 Residual Materials

The primary residuals to a mass burn facility are bottom ash and fly ash. On average, the wet ash residue from mass burn and modular facilities comprises approximately 25 percent of the weight of the incoming waste. Because the ash is very dense, the ash volume is typically about 10 percent of the original volume. Ash residue from RDF facilities is generally less, averaging 12 percent by mass of the incoming waste. RDF also has the heavy fraction, which is separated in the process. This residue accounts for another 10 to 15 percent of the incoming waste.

The ferrous and non-ferrous metal markets fluctuate. It is not always profitable to recover metals. However, metal recovery has proven to be a dependable and preferred method for managing metals. Although most ash is landfilled, if ash is ever to be marketed as a resource, ferrous and non-ferrous metal recovery will be necessary.

In 1994, a lawsuit, *Chicago vs. Environmental Defense Fund*, the Supreme Court decided that ash generated by WTE plants is subject to hazardous waste regulations. Consequently, WTE ash is tested according to toxicity characteristic leaching procedures (TCLP). The classification of ash as a hazardous waste added liability to reusing it. Currently, approximately 93 percent of ash is landfilled.

Approximately 7 million tons of ash was produced in the U.S. in 1999[15]. Most facilities combine the bottom and fly ash. Landfilling ash is a significant cost in the WTE plant operating cost. For a 1,500 tpd facility, at 85 percent availability, 25 percent by mass ash residual, and transport and

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[13]Integrated Waste Services Association (IWSA), AWaste-To-Energy: A Renewable Energy Source≅ Fact Sheet

[14]Maria Zannes, Integrated Waste Services Association, ATrends - WTE Market Poised for Expansion by 2001,≅ January 1999.

[15]Samuel Lucido, "Utilization of MSW Combustor Ash in Bituminous Pavement Construction," Minnesota Solid Waste Seminar, February 24, 2000.

disposal fees at $25 per ton, it would cost approximately $3 million per year to landfill the ash. Unlike the United States, many European countries use over half of their ash for road aggregate, concrete, asphalt products, and sound barriers[16].

Since 1994, TCLP testing of the ash has proven it to be non-hazardous. Special ash handling processes have been developed. Lime or phosphorous is added to stabilize the ash. Ash is being used on closely monitored projects for road aggregate and cement manufacturing. A road test project in Polk County, Minnesota was conducted using bottom and fly ash mixed from a starved air incinerator. Conclusions from the final report[17] include:

- The use of municipal solid waste combustor (MWC) ash as a partial replacement for aggregate in the production and use of bituminous paving materials is viable;
- The potential for impact to the environment, with a 10 percent replacement rate, is very low (many of the environmental tests that were performed at much higher ash replacement rates also support this conclusion);
- The cost to produce bituminous with 10 percent MWC ash was approximately $3 per ton of bituminous, or an increase of about 13 percent. However, this cost would likely be reduced significantly by process modifications and by improved bituminous performance;
- There is a very distinct possibility that the use of MWC ash results in improved stability, flow and freeze/thaw characteristics;
- While ash amended bituminous was not used in the wear course of the Polk County project, environmental, structural and economic data suggests that this use may also be appropriate; and
- While the environmental safety of the use of ash-amended bituminous is clear, additional production and placement of ash-amended bituminous is necessary to better quantify, economic, production, and short-term and long-term structural issues.

The forecasted shortage of aggregate in the Twin Cities Metropolitan area could also promote the use of ash in road construction. Although there is strong potential for ash markets, they are not yet developed in the United States andremain burdened by the liability that is associated with the potential classification of ash as a hazardous waste.

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[16] National Renewable Energy Laboratory (NREL), "Why Bury It When You Can Use It?" December 1996.

[17] Samuel Lucido (Wenck Associates, Inc.) and Willard Wilson (Polk County Solid Waste Department), "Bituminous Pavement Constructed with Municipal Solid Waste Combustor Ash: Construction, Performance, and Economic Issues," Summary Paper on the Minnesota Office of Environmental Assistance Market Development Grant Project with Polk County, Minnesota, February 2002.

3.3 Environmental Concerns/Permitting Issues

The primary environmental concerns center around air emissions and proper handling of the ash. These concerns have led to air pollution control and ash testing requirements described in previous sections.

Part of the decline of the popularity of WTE facilities is attributable to these environmental issues and the public's concern for them. It is extremely difficult to obtain permits for new facilities due to the public concern and associated opposition groups.

The concern for air emissions and ash handling lead to significant regulatory actions. WTE is likely the most regulated solid waste management option at this time. As mentioned previously in Section 3.1.4, air emissions are required to meet MACT regulations. Consequently, WTE industry proponents believe air emissions from WTE plants are significantly cleaner than other coal and oil fired electric energy plants. WTE facilities that have been started by retrofitting and replacing an existing coal or oil fired plant are reported to improve air quality standards. The diversion of waste from landfills may also improve air quality. WTE facilities prevent the production of approximately 15 million tons per year carbon dioxide and 4 million tons per year of methane.[18]

The EPA estimated that if half of the trash produced in the U.S. was used to generate electricity, 1.4 billion fewer pounds of pollutants would be released into the atmosphere[19].

As mentioned in Section 3.3, ash residue regulations require TCLP testing. However, ash has proven itself to have inert and non-hazardous characteristics.

3.4 Applicability to R/W Waste Stream

Mass burn technology is suitable for the current R/W counties= waste stream delivered to the existing RDF facility. A waterwall facility would be more appropriate than modular due to the size of the potential waste stream.

3.5 Current Status

As mentioned earlier, loss of ordinance based flow control, low cost landfilling, lower fuel prices, increased environmental regulation on air pollution control (APC) and ash have been the major barriers to economically feasible WTE facilities. Although the number of facilities has been reduced to 98, WTE facilities still process about 13 percent of the MSW generated in the U.S. To make WTE more competitive, the industry has been pursuing alternative uses for ash.

[18]IWSA website: www.wte.org/waste.html.

[19]Zannes, Maria, ARenewable Energy in the (Trash) Can≅, IWSA, May, 1996.

3.5.1 Existing Operating Facilities – Including Hennepin Energy Resource Company (HERC)

There are 98 operating WTE facilities in the nation at this timeXdown from a high of 150 in 1993. Although the WTE industry has not grown nationally, development has continued internationally. For example, Covanta Energy (formerly Ogden Martin), who had developed 28 of the operating facilities in the U.S., has developed over 200 facilities worldwide. Ogden Martin had started over 50 facilities worldwide alone after 1993[20]. There are also predictions that there will be additional growth in WTE facility use in Europe due to organic waste bans[21] at landfills.

The HERC facility, located in downtown Minneapolis, is a mass burn facility operated by Covanta Energy under a contract with Hennepin County. HERC began processing waste in January 1990. The plant produces a constant 34 megawatts of electricity, which is enough power to provide electricity to approximately 23,500 homes. The County and Covanta Energy share in the revenues from the sale of electricity to Xcel Energy while the County is responsible for ash disposal. HERC is designed to burn 1,212 tons of MSW per day, but is legally permitted to burn only 1,000 tons of MSW per day.

HERC receives waste seven days per week and operates under stringent environmental regulations. To meet air quality standards, HERC uses atomizing dry scrubbers; high efficiency baghouse collectors; ammonia injection to control nitrous oxides and an activated carbon injection system to control mercury. The mercury control was the first application of this technology at a mass-burn facility in the United States. In addition, emissions from the plant are continuously monitored 24 hours a day.

The ash from the HERC facility is disposed of in privately owned landfills with specially designed ash monocells.

3.5.1.1 Location[22]

WTE facilities are most common in Florida and the East Coast. In Florida, the groundwater elevation is very close to ground surface. This has made landfill siting very difficult. Florida, and the East Coast both are highly populated. Due to population densities, the value of land is much more expensive, and there are fewer eligible locations to site a landfill.

Although WTE facilities often service cities with high population densities, they cannot be sited in some large cities due to air permitting restrictions. California, for example, has very stringent air emissions limits, making WTE facilities more difficult to permit there.

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[20] AThermal Waste Treatment Facilities Using the Martin7 System,≅ March 29, 1999.

[21] John Skinner presentation at Solid Waste Association of North America (SWANA) breakfast Meeting, February 24, 2000.

[22] Phone Conversation with Lyle Hanna, American Ref-Fuel Company, February 7, 2000.

Incinerating waste at small facilities was at one time attractive for small communities. Due to the new MACT air emissions regulations, the cost of APC has made small plants less feasible.

3.5.1.2 Size

As shown in Table 3-1, approximately 69 percent of the operating facilities are mass burn waterwall, 12 percent are Modular, and 18 percent are RDF. Based on tonnage of waste capacity, the proportions are significantly different. Mass burn facilities burn 77 percent of the waste, RDF burns 21 percent, and Modular burns 2 percent. These different distributions reflect the fact that RDF and mass burn plants typically burn just under 1,000 tpd, while modular facilities usually burn slightly more than 100 tpd.

3.5.1.3 Owner/Operator/Procurement[23]

About 50 percent of WTE facilities are publicly owned, and 50 percent privately owned. More of the small modular facilities are publicly owned, and more of the mass burn and RDF facilities are privately owned. Twenty years ago, 73 percent of WTE facilities were publicly owned.

Approximately 75 percent of the WTE facilities are privately operated. Operators currently have an average total contract life of 20.5 years. Most of these contracts will expire between 2007 and 2010.

Nationwide, full service operators are most common (58 percent), providing design, construction, and operation of the plant. Exceptions to this trend occur in the Midwest, where turn-key represents 40 percent of the facilities; and nationwide, 40 percent of the RDF facilities are run by merchants (completely independent of the local public entity). Companies providing such services and their share of the market are listed in Table 3-3. The Integrated Waste Services Association (IWSA) representing the industry lists their Board members to include American Ref-Fuel Company; Covanta Energy Corporation; Montenay Power Corporation; and Wheelabrator Technologies, Inc.[24]

3.5.1.4 Regulatory History/Status[25]

Siting of a new mass burn facility, especially in a highly populated area such as the Twin Cities Metropolitan area, would require a lengthy permitting process. The primary regulatory agency is the Minnesota Pollution Control Agency (MPCA), but several other agencies will be involved. This process would include an Environmental Impact Statement (EIS), Title V air permit, Water Appropriations permit, NPDES Permit, city and county Conditional Use Permits (CUPs), and a county solid waste license. Public hearings and public notices will be required. Host fees and/or payments-in-lieu of-taxes (PILOT) may need to be negotiated. The Permitting process would

[23] Berenyi, E.B., 1997.

[24] Jonathan Kiser and Maria Zannes, "The 2002 IWSA Directory of Waste-To-Energy Plants," IWSA, 2002.

[25] Berenyi, E.B., 1997.

require as much as five or more years, and several million dollars. The permitting process is discussed in more detail in Section 4.

Table 3-3 Major Developers of WTE Facilities[A] – Mass Burn and RDF

Name	Total tpd Process in U.S.	Market Share by Design tpd (%)	Total Facilities Operating in U.S.	Market Share by Number of Facilities (%)
Ogden Martin[B]	35,920	34.2	28	23.9
Wheelabrator	23,475	22.4	15	12.8
American Ref-Fuel	9,772	9.3	5	4.3
Montenay	6,448	6.1	6	5.1
Westinghouse	5,248	5.0	5	4.3
Foster Wheeler	3,654	3.5	5	4.3
Xcel/NRG	2,994	2.9	3	2.6
Other	17,483	16.7	50	42.7
Total	104,994	100%	117	100%

[A] Source: Berenyi, E.B., "The Municipal Waste Combustion Industry in the United States: 1997-1998 Resource Recovery Yearbook and Directory," Governmental Advisory Associates, Inc., 1997.
[B] Ogden Martin is now under Covanta Energy Corporation.

3.5.1.5 Funding Sources[26]

There is a wide variety of funding sources used to acquire the capital funding necessary for a WTE plant. At least two sources are usually used for each plant. As shown in Table 3-4, private investment was used 50 percent of the time as one of the funding sources. Tax-free revenue bonds and industrial revenue bonds were the next most common sources. It is expected that tax-free bonds will occur less frequently.

3.5.1.6 Waste Assurance[27]

A wide variety of waste assurance methods are also used. Again, usually at least two methods are used for each plant. Table 3-5 summarizes the frequency of use of different waste assurance methods. Long term (greater than one year) and short term (equal to or less than one year) contracts are the most common, each being used about 50 percent of the time. Interlocal agreements (such as joint powers or contracts between municipal entities) are the next most popular, being used about 40 percent of the time. Residential collection contracts, and public residential collection follow, each being used about 23 percent of the time.

[26] Berenyi, E.B., 1997.

[27] Berenyi, E.B., 1997.

Table 3-4 Methods of Capital Financing[A]

Financing Mechanism	Number of Projects Using Methods	% of Projects Using Method
Private Investment	58	50.4
Tax-Free Revenue Bonds	51	44.3
Industrial Revenue Bonds	37	32.2
State Grants	19	16.5
General Obligation Bonds	19	16.5
Taxable Revenue Bonds	15	13.0
Local Revenues	8	7.0
Leverage Lease	7	6.1
County Revenues	7	6.1
Other	16	13.8
Total	237	206.1%

[A] Source: Berenyi, E.B., "The Municipal Waste Combustion Industry in the United States: 1997-1998 Resource Recovery Yearbook and Directory," Governmental Advisory Associates, Inc., 1997.

Table 3-5 Methods of Waste Assurance[A]

Financing Mechanism	Number of Projects Using Methods	% of Projects Using Method
Interlocal Agreement (Joint Powers or municipal agreement)	43	38.4
Residential Collection Contract	25	22.3
Commercial Collection Contract	11	9.8
Public Residential Collection	27	24.1
Public Commercial Collection	3	2.7
Short-Term Contract (# 1 year)	53	47.3
Long-Term Contract (> 1 year)	61	54.5
Ordinances still in-place	23	20.5
Other	14	12.5
Total	260	232.1%

[A] Source: Berenyi, E.B., "The Municipal Waste Combustion Industry in the United States: 1997-1998 Resource Recovery Yearbook and Directory," Governmental Advisory Associates, Inc., 1997.

Sixty-five (65) percent of the facilities only accept waste from within one county. Twenty-nine (29) percent accept waste from outside of the county.

3.5.2 Potential Development in Minnesota

3.5.2.1 Olmsted County Expansion

Olmsted County is in the permitting process to add a third combustion line to their facility in Rochester, Minnesota. The current targeted completion date is January 2008. The new combustion line capacity will be 200 tons per day and is estimated to cost $35 to $40 million, including the permitting costs (an estimated $175,000 to $200,000 per daily design throughput ton).

3.5.2.2 Lamberton

AWTE facility has been proposed in Lamberton, Minnesota. Preliminary plans include a 249 ton per day WTE facility at an estimated cost of $37,000,000 (approximately $150,000 per daily design throughput ton). The project is under review by several counties in the region.

3.5.2.3 Autoclaving Pilot Project

A pilot project to examine the effectiveness of pre-processing waste via autoclaving is being developed south of Shakopee at the transfer station next to the Dem Con Landfill. The autoclaving project is being developed by Specialized Environmental Technologies for NRG.

The autoclave uses heat, pressure, and moisture to process raw municipal solid waste into a homogeneous mix. The mix is then dried, sorted to remove metals and plastics, and will besent to the Elk River Power Plant for combustion. The goal is for the autoclaved mixto provide a more homogeneous fuel, which increases waste to energy plant efficiencies while reducing emissions.

The project, currently under development, has a two-year demonstration permit to process 50 tons per day of MSW. It is anticipated the process will be operational by September 1, 2004.

3.6 Site Needs

A mass burn facility in the range of 1,500 tpd. needs approximately 20 acres for the entire facility. An electrical substation would be necessary to properly control the electricity produced. Unless there is one nearby, this would have to be constructed.

Water requirements are dependent on methods of cooling for the facility. Except for cooling, approximately 250,000 gpd of water would be needed. This water would be used for the dry scrubbers, ash quench, boiler make up, and potable water[28].

The steam exiting the energy recovery system needs to be cooled and condensed before it is re-circulated through the boilers. If river water is used, without a cooling tower, 10 million gph would be required. If the steam is cooled with air cooled condensers, no water is required.

[28] Telephone conversation with James Schneider, Ogden Waste To Energy, March 8, 2000,

3.7 Typical Capital Costs

As shown in Table 3-1, the national average capital cost per daily design throughput ton for existing facilities is $108,000/tpd for a modular facility, $125,000/tpd for mass burn, and $174,00/tpd for RDF. Vendors have suggested that $125,000/ tpd would be a conservative high estimate for a 1,000 to 2,000 tpd mass burn facility, not including site acquisition and development, which is site dependent. Including site related costs and permitting could bring the total to $150,000 per daily design throughput ton. For a 1,500 tpd mass burn facility for the R/W waste stream, this yields a capital cost of $225,000,000.

Although the typical capital costs have risen significantly in the past 15 years, the driving forces that spurred these increases may have leveled off. Air pollution control equipment and ash treatment systems are not expected to become more costly in the next 15 years. Currently, recent increases in steel costs could increase construction costs.

3.8 Typical Break-Even Cost Per Ton

Table 3-1 compares annual operation and maintenance (O&M) cost per ton with and without debt service. The costs compare facilities with Modular, Mass Burn, and RDF incinerators. Including debt service, the costs range from $56.21 to $74.13 per ton.

The numbers given in the table do not indicate size of facility, geographic location, or capital costs. Capital costs may or may not have included RDF processing prior to incineration[29]. Capital costs for RDF may be reduced by converting existing coal or oil fired plants. Although RDF is shown to be less expensive in Table 3-1, statistics show capital costs for RDF facilities are more than mass burn when building the processing and combustion facilities as greenfield facilities. Vendors have indicated that in addition to the extra capital costs of an RDF facility, O&M costs without debt service are also usually higher for an RDF facility due to the additional processing of the waste stream.

The price comparisons do not distinguish size of facilities. Modular facilities are generally smaller. Consequently, they are more expensive per ton of waste processed.

The greatest expense for most facilities is labor. The actual site specific operating costs will be influenced by labor. Statistics show modular facilities to require the most labor per ton of waste processed. Vendors claim that RDF facilities require approximately 250 percent more labor per ton of waste processed as is needed for mass burn, if the labor required to process RDF is included[30].

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[29]Telephone conversation with Gloria Mills, Executive Vice President, Odgen Waste-To-Energy, February 15, 2000.

[30]Gloria Mills telephone conversation, Feburary 15, 2000.

Unlike capital costs, the O&M costs are much more unpredictable. They are more dependant on market values of labor, electricity, and ash disposal fees. The debt service costs are also variable. For a 1,500 tpd facility, break-even costs could range from $70 to $90 per ton.

3.9 Implementation Needs/Time Lines

Vendors typically budget 27 months for construction of a new facility[31]. This time period will be extended by shortened work seasons and abbreviated if parts of the facility already exist (such as a retrofitting an existing coal fired plant). The environmental permitting process, as mentioned in Section 3.4 will likely require several years.

Combining construction, environmental permitting, and financing, it is recommended that WTE facility planning start six to eight years before the desired start-up date.

3.10 Advantages/Disadvantages

Table 3-6 lists some potential advantages and disadvantages of a mass burn facility.

Table 3-6 Potential Advantages and Disadvantages of a Mass Burn Facility

Advantages	Disadvantages
Proven technology	Past, significant public opposition groups make siting/permitting extremely difficult
Capable of handling majority of R/W counties' waste stream	Significant capital and operation costs
Financially stable vendors	Uncertainty around the status of waste-to-energy as a biomass
Past concern for air emissions and ash disposal led to extensive control systems	
Regulators are familiar with the technology	

3.10.1 Advantages

With over 60 operating facilities in the United States and many more internationally, mass burn is a proven technology capable of handling the majority of the R/W counties= waste stream. The remaining vendors active in the industry have also proven their performance capabilities. Past

[31] Gloria Mills telephone conversation, Feburary 15, 2000.

concerns for air emissions and ash handling led the regulatory community to be familiar with the technologies and led to significant improvements in the environmental performance of mass burn facilities. Mass burn is now perhaps the most regulated/controlled processing technology available.

3.10.2 Disadvantages

The disadvantages of mass burn somewhat reflect the Aflip-side≅ of the advantages. There are significant capital and operating costs, some of which are a result of the environmental regulations. The public concern has led to the stagnation of new facilities in the United States. Siting and permitting a new facility in Minnesota will be extremely difficult. There is uncertainty around the status of waste-to-energy as a biomass and thus the potential to receive higher electrical market revenues.

3.10.3 Observations

As an alternative processing technology, mass burn has significant potential. Two variables could improve the potentialXuse of ash in road construction and defining mass burn WTE as a renewable fuel technology and obtaining an incentive payment for the electricity produced. Both of these have significant potential to improve the economics of a mass burn facility.

4. Research Feasibility of Dedicated RDF Combustion Facility

4.1 Introduction

The Ramsey/Washington County Resource Recovery Project Board (Board) has a service agreement with NRG Energy, Inc. (NRG) to process solid waste from the two counties at the Newport Resource Recovery Facility (Facility). In conjunction with the alternatives research project initiated in 2000, NRG agreed to provide the Board with information on how they could approach development of a combustion facility to handle RDF at or near the existing Facility in Newport. Foth & Van Dyke was directed to utilize the information provided by NRG to prepare a written report entitled AResearch Feasibility of a Dedicated Combustion Facility.≅

Foth & Van Dyke and Ramsey/Washington County staff met to outline what NRG would address, which included information on RDF characteristics; site needs; electric utility market rates and interconnections; existing processing facility conditions and expansion capability; a general description of their approach to the new combustion facility; and preliminary economic information on capital and operating costs. Foth & Van Dyke also met with NRG to update this section in March 2004.

In addition to assembling the information supplied by NRG in this report, Foth & Van Dyke was tasked with describing the permitting needs for the combustion facility, calculating the break-even tipping fee, and identifying implementation steps and time frames.

4.2 Information from NRG

NRG provided a letter addressing the requested information. Foth & Van Dyke clarified some items and summarized the information in this section of the report with updates based on the 2004 discussion.

4.2.1 RDF Characteristics

The current maximum plant permitted capacity is 500,000 tons per year (tpy) of municipal solid waste (MSW) processed. Deliveries in 2002 were over 565,000 tons, of which 425,620 tons were processedXyielding 348,447 tons of RDF (82 percent RDF of tons processed). Not all the waste delivered was processed due to lack of combustion capacity. The 2002 deliveries were an all time high and were atypical of ongoing tonnages.

The Btu content of the RDF varies throughout the year based on seasonal fluctuations in the type of MSW received and the moisture content. Generally, the Btu content is between 5,700 and 5,800 Btu=s per ton. NRG indicated they have never done a chemical analysis of the RDF.

Currently the ash percentage is 16 percent by wet basis (i.e., the ash enters a water quench tank after combustion, which causes the ash to retain moisture and weigh more than it would dry).

NRG indicated they would continue to transport RDF from the processing facility to the new combustion facility via transfer trailers.

4.2.2 Site Selection

Ten to 15 acres would be required to accommodate the combustion facility. The current processing facility includes 14 acres (some area was lost in the recent bridge reconstruction). There should be room for construction of a combustion facility at the site. NRG anticipates using NSP=s nearby electrical substation. If the existing substation can be used, connection costs were estimated at $150,000. In the event a new substation is required, NRG estimated the cost to be over $1 million. In addition, a 115 KV electrical lead would be required from the combustion facility to the substation.

4.2.3 Electric Utility

NRG indicated the demand for electricity in the upper Midwest is increasing while plans to construct facilities to meet these demands are limited. NRG believes the result is that the value of electricity will increase. NRG estimates that in 2004, the flat value of electricity may be $35 per megawatt (MW), but that peak value for electricity may be as high as $110 per MW. NRG indicated that $35 per MW may be a conservatively low value.

Power sales contract terms and interconnection requirements will depend on to whom the electricity will be sold. NRG indicated each customer has their own issues and concerns. Fuel prices and environmental issues will have a major impact on the completion of a power sales agreement. NRG indicated another potential issue may be formation of an ISO, a central marketer for electricity. This is not currently in place in the area, but is common on the East Coast of the United States.

NRG believes given future expectations for the value of electricity, it may be more advantageous to use the utility industry market rather than sell to a dedicated electrical customer (i.e., a large, local industrial customer).

4.2.4 Technologies

4.2.4.1 Existing Processing Facility

The current processing building is approximately 129,000 square feet. Although there is a permit processing limit of 500,000 tpy, NRG indicated the current equipment can process between 1,700 and 2,000 tons per day (tpd). NRG would add a third processing line in the area of the removed aggregate processing line. The addition of a third line rated at 100 tons per hour (tph) rather than the 50 tph of each of the existing lines would double the processing capacity. NRG indicated that between the processing lines, approximately 150 tph would actually be processed. If operated over two shifts (18 hours per day), this would provide processing capacity of 2,700 tpd.

NRG indicated the cost for the processing capacity expansion would be between $10 million and $12 million.

4.2.4.2 Dedicated RDF Combustion Facility

A combustion facility capable of handling 900,000 tpy of RDF was requested to be addressed by NRG. This equates to 2,465 tpd of RDF. At an RDF production rate of 85 percent, it would take 1,058,500 tpy (2,900 tpd) of MSW to produce the RDF. That is more than what is available from Ramsey and Washington counties but was requested by Ramsey/Washington counties staff to provide information for the Metro region as a whole.

NRG indicated the receiving and fuel handling system for the Dedicated Combustion Facility will include a barn capable of storing 1,000 tons of RDF. The RDF will be transferred into fuel bins and metered into the boiler bin via a scalping conveyor.

For purposes of this generic analysis, NRG used a fluidized bed boiler with steam turbines. A hopper with a conveyor will be used to load out ash for disposal at a contracted ash monofill. NRG intends to use state-of-the-art equipment for air pollution control, including air-cooled condensers, active carbon injection, scrubbed baghouse, carbon monoxide (CO) catalysts, and NO_x controls.

The combustion facility would produce approximately 70 megawatts (MW) of electricity (net for sale). As points of comparison, Red Wing and Wilmarth (existing RDF combustion facilities) are each rated at 25 MW. The King plant is rated at 550 MW, and Sherco is approximately 1,800 MW.

4.2.5 Preliminary Economics

NRG estimated the total capital cost for the Dedicated Combustion facility to be $130 million to $150 million.

NRG indicated RDF processing costs of $60 to $75 per ton of MSW, including debt service for a $10 million expansion, operating costs, and transport of RDF.

The Combustion Cost was estimated by NRG to be $55 per ton of RDF. NRG estimates 400 tpd of ash will need to be landfilled at a cost of $25 per ton of ash.

Without an added economic incentive for renewable energy, NRG estimates $35 per MW at a 70 MW net output and 90 percent availability.

These costs are summarized on an annual basis and converted to the break-even cost per ton in Table 4-1.

4.3 Permitting Needs

This section summarizes (1) the regulatory agencies involved in permitting; (2) the required permits; and (3) the expected regulations applicable to construction and operation of a dedicated combustion facility in Minnesota. Site specific variables for a new dedicated combustion facility permitted at the existing NRG Resource Recovery Facility (NRG) are also discussed.

Table 4-1 Dedicated RDF Combustion Facility Cost Summary

Category	Rate/Ton	Tons/Year	Annual Cost
RDF processing	$75[A]	1,058,500	$79,387,500
Combustion	$55	900,000	49,500,000
Ash disposal	$25	146,000	3,650,000
			Subtotal = 132,537,500
Energy Revenues[B]			
$35/MW x 70 MW x 365 days/year x 24 hours/day x 90% availability =			($19,315,800)
			TOTAL = $113,221,700
			÷ 1,058,500 tons per year
			BREAKEVEN COST = $106.96/ton

[A] NRG=s estimate was $60 to $75 per ton. This is the high end. Using $60 per ton results in a per ton break-even of $91.96.

[B] Represents the conservatively low rate for all the electricity. A portion may sell for more, which would increase energy market revenues and lower the break-even cost per ton.

As explained below, most of the permitting process is coordinated with the Minnesota Pollution Control Agency (MPCA). Siting a dedicated combustion facility at NRG, or anywhere in the state, historically has required from 18 months to five years and several million dollars. Factors that increase the time line from 18 months to five years are site specific. These factors include limitations of emissions to the Mississippi River, 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, waste combustion facilities have faced significant public opposition. It should be anticipated that the permitting process for this potential combustion facility will take several years for completion, with no assurance of success.

4.3.1 Regulatory Agencies

In addition to the MPCA, several other agencies may be involved, including:

- United States Environmental Protection Agency (EPA)
- United States Army 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)
- Washington County
- City of Newport

Brief descriptions of these agencies= involvement is included in Appendix A.

4.3.2 Studies and Permit Requirements

Due to the size and complexity of a dedicated combustion facility, several permits must be obtained prior to construction and operation. The permits come from several regulatory agencies. The following sections summarize the permitting requirements for constructing and operating a dedicated combustion facility. Table 4-2 lists the individual permits required and the agencies from whom they are obtained.

Table 4-2 Required Permitting; Dedicated RDF Combustion Facility

Permit	Agency
EIS	MPCA
Title V Air Permit	MPCA
NPDES	MPCA
Water Appropriations Permit	DNR
CUP	County and City
FAA form 7460-1	FAA

4.3.2.1 Environmental Impact Statement (EIS)[32]

The Minnesota Environmental Policy Act of 1973 established a formal process for permitting major facilities. Following this process, an EIS for a typical dedicated combustion facility will take 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 facility. A summary list of the items that the EIS must contain (an EIS Preparation Notice) is published in a local newspaper. The EIS is then prepared by the RGU. The RGU 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 notice is published in a local newspaper and is open to review and comment by the public. The RGU will respond to comments on the EIS. The response may include additional studies. A series of comments and responses may occur. After review and comment, the Draft EIS is revised into final form. At this point, the RGU decides if the EIS is adequate and publishes their impending decisions. Ten days after publication, their decision is final.

As part of an EIS for a dedicated combustion facility:

- Air modeling will be performed to predict how parameters such as air temperature, visibility, humidity, and pollutant concentrations will be impacted;

- If water is pumped from, or discharged into the Mississippi River, impacts to the river will be evaluated;

[32] MPCA AQ Doc. #2.08, April 1998.

- Potential for impact to critical habitat, protected wetlands, or archaeological sites will be examined; and

- A health risk assessment, including an Air Toxics Review will be performed to determine human exposure through inhalation, skin, food consumption, drinking and surface water.

- 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.

The cost of an EIS varies widely. The level of effort requested by the RGU, the public response, and the difficulty in attaining compliance all directly affect the cost and complexity of the EIS. An EIS could cost from $1 million to $5 million depending on the complexity of the facility and the thoroughness of the investigation.

For a ddicated combustion facility to be sited at NRG , three unique conditions exist: (1) this site is within an area currently classified as a Anon-attainment area,≅ (2) it is near the I-494 bridge, and (3) its proximity to the Mississippi River Valley. Each of these brings significant potential changes to the EIS. The time period for the EIS will be on the long end of the range (i.e., closer to five years than 18 months).

4.3.2.1.1 I-494 Bridge

There is an I-494 bridge located less than one mile south of NRG. It is likely that the EIS will identify the potential for black ice to form on the bridge if a water cooled condenser is used for the facility. A water cooling system for the condenser would need to have a tower roughly the same height as the I-494 bridge. An alternative to water-cooled condensers is air-cooled condensers, which are more costly.[33] The air-cooled condenser is included in the NRG capital cost estimate in Section 2.

4.3.2.1.2 Mississippi River

The NRG site is located adjacent to the Mississippi River. The valley that follows the river can create unique wind patterns. Wind patterns are quantified by wind row data. Wind rows characterize frequency of wind direction and intensity. Wind row data are very important in air modeling as they influence how quickly emissions from a proposed facility would be dispersed. Wind row data for most of central Minnesota does not change from site to site. However, the Mississippi River Valley creates a localized change in wind patterns. At NRG, the valley tends to cause wind to travel in the direction of the valley. Site specific wind row data may need to be collected for one year for air modeling purposes. Wind rows in valleys tend to retard dispersion of air pollutants.

[33]DNR Website.

4.3.2.2 Title V Air Permit[34]

The Clean Air Act (CAA) of 1990 gave the EPA the responsibility and authority to issue permits for facilities that have the potential to emit threshold quantities of criteria pollutants in excess of 100 tpy and hazardous air pollutants (HAPs) in excess of 10 tpy individually, or 25 tpy collectively. Nitrogen oxides (NO_x), sulfur dioxide (SO_2), ozone/volatile organic compounds (VOCs), particulate matter less than 10 microns in size (PM_{10}), CO, and lead (Pb) are criteria pollutants. There are approximately 188 HAPs. Because municipal waste combustors are also highly likely to be subject to the New Source Review Prevention of Significant Deterioration (PSD) standards, Title V permits must also contain requirements resulting from a preconstruction review. The federal Standards of Performance for New Stationary Sources (NSPS, 40 CFR 60) set Maximum Achievable Control Technology (MACT) standards for emissions from new dedicated combustion facilities. These are summarized in Table 3-2.

To meet MACT requirements, the waste-to-energy (WTE) industry has begun to use flue gas desulfurization (dry scrubbers that spray lime into the exhaust) to remove SO_x and HCl; Selective Non-Catalytic Reduction (sprays urea or ammonia) to remove NO_x; activated carbon injection to remove mercury; bag houses (fabric filter bags) to remove particulates, metals, dioxins/furans, and dry scrubber fallout; and combustion controls that rely on continuous emissions monitoring (CEM) to improve combustion efficiency and minimize CO.

Although the federal and state regulations only require compliance with MACT standards, the EIS may conclude that Lowest Achievable Emissions Rate (LAER) standards are necessary to protect human health and the environment. To meet the LAER standards, air pollution control (APC) equipment may include Alow NO_x technology≅ and CO and mercury emissions controls. A circulating fluidized bed, or Astarved air≅ furnace, with selective catalytic reduction APC equipment can be used to provide the low NO_x technology. Catalytic CO reduction can reduce CO. Activated carbon injection can be used to control mercury emissions. Some of these technologies, such as fluidized beds and activated carbon injection are already being used voluntarily by dedicated combustion facilities. OthersXsuch as selective catalytic reductionXare more difficult and costly to use effectively and are rarely used.

There are site specific permitting requirements that go beyond the preliminary scope of this report. Currently, the NRG facility has an existing state ARegistration≅ Permit. This permit is classified as a Asynthetic minor.≅ Permitting a dedicated combustion facility at the NRG facility would have different requirements than permitting at an unpermitted site. Additional site specific factors include the Potential To Emit (PTE) thresholds of the facility and site specific air quality status (attainment or non-attainment area).

[34] MPCA website: www.pca.state.mn.us/air/aboutpermits.html.

4.3.2.3 SIP Non-attainment Area[35]

The CAA of 1990 required Minnesota to implement a State Implementation Plan (SIP). The Minnesota SIP has monitored air quality in Minnesota to determine areas that exceed National Ambient Air Quality Standards (NAAQS). Areas that exceed NAAQS are called Non-attainment areas. Modifications to existing facilities or permitting of new major sources in non-attainment areas are subject to New Source Review (NSR).

Attainment areas follow different requirements. Modifications to existing facilities, or permitting of new major sources in attainment areas, must follow the prevention of significant deterioration (PSD) program.

NRG is located in a non-attainment area for particulate matter less than 10 microns (PM_{10}). The non attainment area is bounded on the north by Interstate I-94, on the east by Highway 61, on the south by Interstate I-494, and on the west by the Mississippi River. The MPCA has currently collected three consecutive years of PM_{10} data that are below the NAAQS. The MPCA is now able to submit to the EPA for redesignation to remove this area from non-attainment classification for $PM_{10.}$ Once the MPCA does this, the EPA=s redesignation process will require about 18 months to achieve attainment classification. CO has recently been reduced to within the air standards in the NRG area and removed from the non-attainment status following a similar process.

In non-attainment areas, modifications to major facilities, modifications to synthetic minor facilities, and construction of new facilities is allowed, provided that the potential to emit (PTE) is below thresholds specified by the MPCA. The PTE would be determined by the company designing and constructing the combustion facility. Major new sources, permit modifications, and synthetic minors have different thresholds. If they are not below the threshold PTE, they must follow the New Source Review (NSR) Program to reduce emissions.

In the NSR program, a facility may use LAER technology, Anetting of offsets≅ to stay below the PTE thresholds. LAER, unlike MACT described in Section 4.3.2.2, refers to air pollution control equipment that does not need to be cost effective (i.e., the top-of-the-line must be used). It is usually significantly more expensive and technically difficult to achieve. ANetting≅ refers to Anet≅ change in facility emissions. A facility may acquire a modification that increases emissions above the PTE thresholds if it can demonstrate that reductions to emissions of the same pollutant in other parts of the facility make the Anet≅ change in emissions less than the PTE threshold.

If a facility cannot reduce its emissions adequately with LAER and netting, it would need to obtain offsets from an existing source within the non-attainment area. According to the Minnesota AOffset≅ rule, found in Minnesota Rules, Chapter 7007.4000-4030, a facility may exceed the limits if it can obtain emissions reductions (offsets) from an existing emitter of the same pollutant. The dedicated combustion facility would then be allowed to emit a fraction (less

[35] 1997 State Implementation Plan, MPCA website: www.pca.state.mn.us/air/pubs/97sipmem.pdf.

than 100 percent) of the offset emissions. Although regulations exist to allow for offsetting, it has never been done in the state of Minnesota. Furthermore, it is possible that none of the contributors are willing to sell offsets. If offsets are used, the facility would also be required to use LAER technology.

There is no separate permit that is required for operation in a non-attainment area. This issue is reviewed as part of the Title V permitting process.

4.3.2.4 NPDES[36]

The 1993 Minnesota Legislature revised the MPCA=s responsibilities in Minnesota Statutes Section 115.03, subd.1(e)(10) Arequiring that applicants for wastewater discharge permits evaluate in their applications the potential reuses of the discharged wastewater.≅

Based on this statute, if any water is discharged to the Mississippi River, a NPDES permit must be issued by the MPCA. It takes approximately one year to receive an NPDES permit[37].

A combustion facility may have two types of water discharge. If water cooled condensers are used, non-contact cooling water would be discharged into the Mississippi River. During the steam generation process, as steam is lost, the concentration of contaminants in the remaining steam increases in concentration. When the concentrations get large enough, the water needs to be removed from the system. This wastewater may be sent to the local Waste Water Treatment Plant (WWTP) or discharged directly into the Mississippi River.

4.3.2.5 Mississippi River/Water Appropriations Permit[38]

If water is pumped from or discharged into the Mississippi River, these activities must comply with Minnesota Rules, Chapter 7056.0040 and Chapter 7050.0222.

Minnesota Rules, Chapter 7056.0040, mandates water quality standards for waters discharged to the Mississippi River. Part of the requirements are that discharge waters not reduce the dissolved oxygen content of the river below 5 mg/liter; increase temperature above 93 degrees Fahrenheit; increase taste, odor, color, or turbidity above natural levels; or cause water quality at water supply intake locations to exceed drinking water standards after Class IV treatment.

Minnesota also has a non-degradation policy. Water discharged in excess of 200,000 gpd to the section of the Mississippi River near NRG, known as Pool 2, must comply with the non-degradation policy, summarized in Minnesota Rules, Chapter 7050.0222[39]. These rules are more stringent than the Chapter 7056.0040 rules. The rules include over 60 water quality standards,

[36]MPCA website: www.pca.stae.mn.us/water/permits/index.htm.#industrial.

[37]DNR website.

[38]MPCA AQ Doc. #2.08, April 1998.

[39]Phone Conversation with Dave Maschwitz, MPCA, March 2, 2000.

including mandates that water hardness not exceed 400 mg/liter, the temperature of the river not increase more than 5 degrees or exceed 86 degrees Fahrenheit, turbidity not exceed 25 nephelometric turbidity units (ntu), or the average monthly dissolved oxygen not be reduced below 5 mg/liter.

If the Mississippi River is used as a water source, water use must comply with the regulations listed above. As explained in Section 3.1.2.3, a Water Appropriations Permit must be obtained from the DNR if more than 10,000 gpd or 1 million gpy are appropriated from the Mississippi River.

4.3.3 History and Current Projects

A historical review of sites that have pursued permitting is helpful to see what has been successful or unsuccessful.

Sites that were permitted in the past may not be permitted with the same facility conditions as those under current environmental regulations. All of the dedicated combustion facilities operating in Minnesota were permitted prior to the implementation of the CAA in 1990, Title V rule revisions made in 1993, and the 1995 MACT rules. (The Hennepin Energy Resource Company and the Elk River Resource Recovery Project incinerators start-up dates were both in 1989, with early dates of permit acquisition.) Consequently, these facilities were grandfathered into compliance with policies such as the non-attainment areas (e.g., HERC). Existing facilities typically have less stringent standards thamew sources. Old facilities burning less than 250 tpd had no MACT standards as of 1999. Permitting a new facility will likely be more difficult.

Proposed facilities in Winona and Dakota County were not successfully permitted. Title V rules required that the Winona facility submit air modeling data. Modeling showed that emissions from the Winona facility were confined by the Mississippi River Valley, causing inadequate dispersion. Consequently, the Winona facility lost support and was not permitted. Dakota County spent several years attempting to permit a new WTE facility. Ultimately, the health risk assessment portion of the EIS raised questions and the project lost support.

Olmsted County is currently in the process of seeking regulatory approvals to add to their WTE facility combustion capacity (adding a third line). Olmsted County staff noted that their current permitting process with the MPCA is an overwhelming process in which everything is project specific. Olmsted County is working with the MPCA on a multi-risk pathway called an Air Emissions Risk Analysis (AERA) as part of the EIS. Olmsted County indicated that the MPCA establishes teams to address each project and each team may treat the permitting project differently. Hence, any project pursued in Ramsey/Washington counties will likely face extensive, but somewhat different circumstances than even Olmsted County.

Olmsted County started the current permitting process in June of 2003. Based on various assumptions in the schedule and the MPCA holding to the required review timelines, the County anticipates receiving a construction air quality permit in June 2006 and the operating air quality permit in January 2008 (having passed initial air emission testing).

4.3.4 Conclusion

The above information summarizes the agencies involved in permitting, the required permits, and the expected regulations. Permitting a dedicated combustion facility in Minnesota requires an EIS, Title V Air Permit, Certificate of Need, NPDES Permit, Water Appropriation Permit and special water and air pollution control equipment. These measures are taken to insure that human health and the environment are not harmed by the construction or operation of the dedicated combustion facility. The MPCA is the primary regulatory agency involved in the permitting process. Other regulatory agencies will make comments on the EIS relating to their special interests.

Public response to the EIS has historically been a major stumbling block in permitting combustion facilities. Significant concern and opposition should be expected, which will affect the outcome These issues and how the dedicated combustion facility design is proposed for compliance will determine the time and money required to obtain permits, as well as the ultimate success of the permitting process.

4.4 Observations on Electric Utility Deregulation

Deregulation, or restructuring, of the electric utility industry was occurring in the United States in 2000. Over twenty states enacted some type of law related to restructuring. The federal government was taking a proactive stance on it as well. Subsequent to some difficulties with large energy companies (such as Enron), deregulation activity has halted[40].

While some consumers may choose to purchase Agreen≅ energy on the competitive market, the magnitude of supply relative to such demand is not yet known. Many states, including Minnesota, have required utilities to meet minimum levels of renewable resources to meet customer demand. The Minnesota Renewable Energy Objectives adopted by the Legislature in 2003 include waste-to-energy under the biomass renewable fuel definition. By 2010, 1 percent of the electric generation must be generated by biomass. While existing facilities (except for HERC) are included, there is still some room for additional waste-to-energy based electric generation. Unfortunately, there was no specific economic incentive included in the Minnesota legislation in 2003. Whether utilities will provide a better rate than the estimated 3.5 cents per kilowatt hour included in this section is unknown. There may be efforts to include higher rates, but it is not included at this time.

Waste-to-energy is typically an expensive form of electric generation. Unless special provisions are made, there is little incentive to produce electricity by processing waste.

An example of the competitive disadvantage faced by waste-to-energy illustrates the impact that some economic incentives could have. The average cost of producing baseload electricity with coal in the Midwest is about 1.5 to 2.0 cents per kilowatt hour (Kwh). The cost of producing electricity using RDF from the Dedicated Combustion Facility in this report is 8.8 cents per Kwh (based on the combustion and ash disposal cost in Table 2-1). The revenue from electricity

[40] Personal conversation, Gary White, NRG Energy, Inc., March 5, 2004.

($19,315,800) in Table 2-1 is based on 3.5 cents per Kwh. For every additional one cent per Kwh, the break-even cost per ton for the combustion facility may be reduced by $5.20.

5. Mixed Waste Processing (Front-end Separation)

Mixed waste processing technology can take many different forms and mean different things to different people. Essentially the purpose of a mixed waste processing (MWP) facility is to separate and remove recyclable materials from incoming mixed waste (i.e., divert the recyclable materials from the waste stream). The MWP facility can be a Astand alone≅ facility or it can be part of a Afront-end separation≅ process at a WTE facility, composting facility, transfer station, C&D waste processing facility, balefill, sanitary landifll, or even as part of a recycling facility handling source-separated recyclables. In each case, the MWP facility is tailored to the specific waste streams and goals for the project. Therefore, there are several different approaches to facility design, materials targeted for recovery, and costs.

5.1 Process

MWP facilities may be developed with either relatively low-tech approaches using primarily manual sorting or more high-tech approaches using some mechanical, automated processes combined with relatively less manual labor.

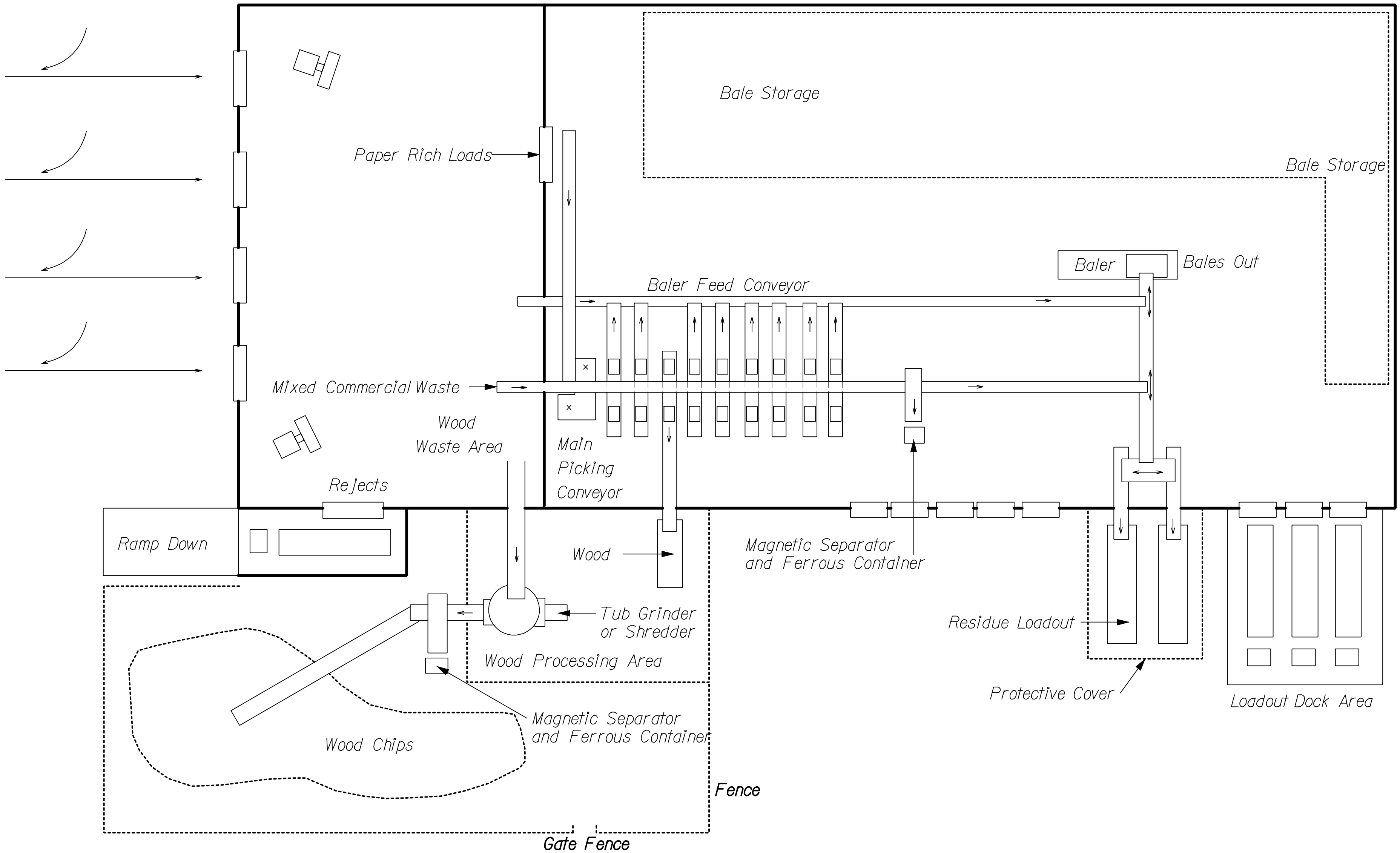
5.1.1 Low-Technology MWP Facilities

The simplest type of MWP facility may be referred to as a Adump and pick≅ operation. Waste materials are delivered on the tipping floor and recyclable materials are manually pulled from the waste. There may be some equipment such as a grapple, which can separate and lift heavy objects such as white goods, wood, scrap metal, etc. A front-end loader may be used to help move materials around the tipping floor to help separate larger items. This simple approach is sometimes used at a transfer station.

The next step up in relatively low-technology approaches incorporates a conveyor system with manual sorting stations. The mixed waste stream is conveyed up an incline conveyor to an elevated sorting platform, which may be enclosed in a separate room. Sorters pick the targeted recyclables out of the waste stream, deposit the recyclables through chutes into dedicated bunkers, bins, or roll-off containers for each material. The remaining waste materials discharge off the sorting conveyor to be handled via whatever the next technology may be (landfill, balefill, WTE facility, etc.). The sorted recyclables are typically densified (baled, crushed, etc.) for transport to the end markets.

MWP facilities often limit the types of wastes they receive in order to target certain materials. For example, a MWP facility may target wastes from commercial businesses who tend to have higher concentrations of corrugated cardboard, high-grade paper, wood, or other recyclables. By targeting certain types of waste deliveries, the MWP facility is able to recover a higher percentage of the wastes and the recovered materials may have less contamination.

Figure 5-1 provides a schematic of a generic, low-technology MWP facility.



RAMSEY/WASHINGTON COUNTIES			
FIGURE 5-1 GENERIC LOW-TECH MWP FACILITY			
Scale: NOT TO SCALE		Date: APRIL 2000	
Prepared By: **Foth & Van Dyke**			By: JAM3

5.1.2 High-Technology MWP Facilities

High-technology MWP facilities are more elaborate than low-technology operations, but still incorporate some manual sorting labor. Sorting of the different recyclables has not evolved to the point that sorting is fully automated. Also, as with the low-technology facilities, the extent of automation can vary widely depending on the specific waste stream handled and the project goals.

A high-technology MWP facility may include automated debaggers, finger screens, trommel screens, disc screens, air classifiers, magnetic separators, eddy current separators, pneumatic conveyors, balers, hammer mills, or tub grinders to separate and densify the recyclable materials.

Debaggers perform the function inherent in the nameXopening and removing wastes from plastic bags. Different types of screens (finger, trommel, and disc) are used to size-separate the materials, often times into three or more sizes: (1) Afines,≅ which may be residue or material too small to be recyclable; (2) Amiddlings,≅ which may contain recyclable containers; and (3) Aovers,≅ which may contain recyclable paper or wood.

Air classifiers separate materials by weight into lighter and heavier fractions. For example, aluminum and plastic containers are lighter than glass containers. A magnetic separator removes ferrous items from the rest of the materials. An eddy current sytem separates aluminum.

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 from a sorting station to a bunker or bin to await baling.

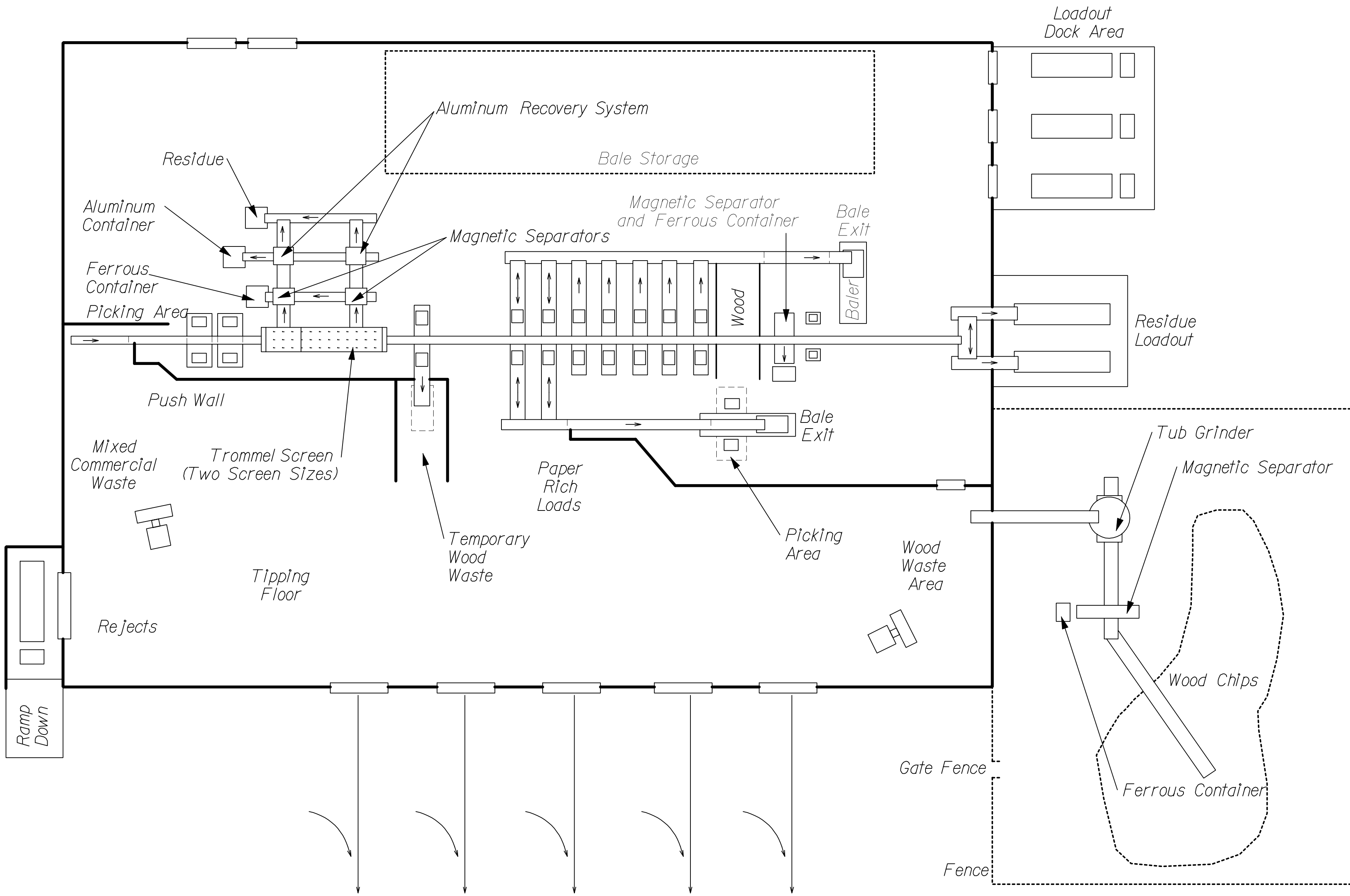
There is typically still some manual sorting of various recyclables such as various grades of paper (newsprint, office paper, magazines, etc.) or different plastic resins such as HDPE and PETE. The extent of manual sorting depends on several factors such as the actual type of waste delivered (select commercial loads versus mixed residential wastes); the market specifications (mixed paper versus a #8 news), and the follow-up technology and overall project goals.

Figure 5-2 provides a schematic of a generic high-technology MWP facility.

5.1.3 Comparison and Typical Applications

Low-technology and high-technology approaches each have their advantages and disadvantages or more suitable applications.

The low-technology Adump and pick≅ approach is quite limited in effectiveness and the application may only be suitable for low-volume transfer stations or to target a limited type of bulky recyclable on a tipping floor (such as bulky metal objects). The low-technology approaches that incorporate sorting conveyors and balers have broader applications.



RAMSEY/WASHINGTON COUNTIES

FIGURE 5-2

GENERIC LARGE HIGH-TECH
MWP FACILITY

Scale: NOT TO SCALE | Date: APRIL 2000

Prepared By: **Foth & Van Dyke** | By: JAM3

The major advantage of low-technology facilities is that equipment requirements are low, minimizing capital, fuel, and maintenance expense. Equipment downtime is not a significant factor in the rate of waste flow through the facility.

The disadvantages of low-technology facilities include worker safety issues (i.e., bending, repetitive motions, danger from sharp and protruding objects, and general exposure to hazardous materials). The amount of material recovered is highly dependent on the number of laborers, the speed of the conveyors, and the extent of contamination (especially moisture). Hand sorting is most efficient on dry, homogeneous wastes.

A low-technology hand-sorting operation may be applicable for the dry fraction of a two-stream wet/dry collection program; select commercial waste, which contains minimal amounts of wet contamination; or construction waste and light demolition debris. Relatively high labor costs versus the quantity of material recovered would make it more difficult to address mixed waste streams such as residential waste.

Some construction and demolition processing facilities have incorporated mechanical screens (commonly finger screens) and hammer mills into the manual sorting process. The fines from the screens are mixed with the non-sorted materials entering the hammer mill. The resulting product is a material used as "alternative daily cover" (ADC) at sanitary landfills.

The advantages of high-technology facilities may include higher recovery rates of recyclables, as well as higher throughputs of waste per worker, which reduces labor cost per ton.

The disadvantages of high-technology facilities include the increased capital and maintenance costs for equipment and potential equipment related downtime. Contamination may still be a problem.

The high-technology approach can be applied to more types of waste streams and process a larger daily volume. However, clean and dry loads will result in higher recovery rates.

5.2 Typical Markets

The material products that typically can be recovered by a MWP facility include corrugated cardboard, office paper, mixed paper, newsprint, containers (aluminum, glass, tin cans, plastic, etc.), wood and ferrous metals. The mix of products depends on the incoming waste stream. As noted in the introduction, a MWP facility can be a Astand alone≅ facility or on the front-end of other processing technologies. These other processing technologies (many covered elsewhere in the report) can recover other materials such as energy or compost. This section only addresses the recyclable materials recovered Aupfront.≅

The markets for the recyclables include the Astandard≅ markets utilized by source-separated recycling programs. These include paper mills, insulation manufacturers, aluminum mills, glass manufacturing, metal mills, and plastic recyclers. Wood markets include mulch and wood fuels.

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 from source-separated programs.

5.3 Residual Material

An 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 will be largely unchanged from the state it was delivered (as opposed to ash from a WTE facility or screenings from a compost facility).

The recovery rate in a MWP facility will vary significantly depending on the composition of the waste stream delivered. For facilities handling the entire waste stream, less than 10 percent is likely to be recoveredXleaving over 90 percent to be disposed or otherwise processed. For facilities targeting commercial wastes with high recyclable content and relatively dry, recovery rates may be at or above 40 percentXleaving approximately 60 percent of the incoming wastes for disposal. A MWP handling only construction/demolition wastes and producing an acceptable ADC product could recover over 90 percent of incoming construction/demolition materials.

5.4 Environmental Concerns/Permitting Issues

MWP facilities have similar potential environmental impacts as transfer stations and source-separated recyclables processing facilities (commonly referred to as MRFs). In particular, dust and particulate matter may be created from the processing operations, especially from any wood grinding equipment. The dust and particulate matter will be minimal and controlled by air handling and filtering equipment if necessary.

Wash water or moisture from loads must be handled via the municipal waste water treatment system.

Noise, litter, and odors could be problems but are easily controlled by fully enclosing receiving and processing areas. An MWP facility would be regulated by the Minnesota Pollution Control Agency (MPCA) and county environmental departments.

5.5 Applicability to Ramsey/Washington Counties Waste Stream

In general, MWP facilities are more applicable for commercial waste streams than non-separated residential waste streams because the materials in commercial wastes tend to be more homogeneous and less contaminated than residential wastes. Commercial waste loads tend to be from a single generator (delivered in a roll-off container) or grouping of like generators delivered by a front loader running a route in a shopping mall. Some of these loads are Arich≅ in paper or wood wastes that would be relatively easy to process with an MWP facility sorting system.

For example, there are approximately 1,500 tpd of wastes to be processed, of which approximately half is from commercial/industrial sources. A COM-MRF (MWP facility targeting commercial wastes) sized at roughly 750 tpd could process this waste stream. Loads rich in targeted recyclables could be sent through the sorting process. Contaminated loads could be by-passed. A preliminary review of waste composition data indicates approximately 40 percent of the commercial/industrial waste stream delivered to the NRG Facility is potentially targeted recyclables. If 75 percent of these recyclables could be successfully sorted from the commercial wastes via the COM-MRF, there would be approximately 225 tpd of recyclables recovered (750 tpd x 40% x 75% = 225 tpd). This represents 15 percent of the entire 1,500 tpd available.

5.6 Current Status[41]

MWP facilities grew from six in 1991 to 63 in 1997. Most of the increase came in the early 1990s with the overall growth in the recycling industry. A larger increase for MWP facilities was predicted due to the advantage of the lower collection related costs over source-separated Material Recovery Facilities (MRFs) (avoiding the duplicate collection system required for source-separated MRFs). By 2000, the number of MWP facilities dropped to 52, with there now being only 46 noted[42]

More than half the MWP facilities are located in the West (mainly California) where they handle yard debris and C&D debris, which count toward their waste reduction goal. MWP facilities have been added to some Minnesota waste-to-energy facilities (Polk County and Pope-Douglas counties) as front-end separation processes to remove recyclable cardboard, metals, and glass. This may improve the overall fuel quality and reduce the size of the combustion facility required (saving some capital costs while increasing operating costs).

The number of private companies developing MWP facilities has decreased along with the consolidation in the solid waste industry. Despite the potential to achieve recycling goals without additional separate collection, higher capital costs coupled with less than projected recovery rates hindered growth of MWP facilities.

In the approximate 14-year period from 1991 to present, MWP facilities and MRFs in general have become a more mature technologyXfocused on addressing industry issues such as efficiency, performance, and market volatility.

5.7 Site Needs

An MWP facility in the range of 500 to 750 tpd would require approximately 10 to 15 acres for the entire facility. Typical utility needs would include three-phase electrical service, natural gas, water, and sewer. As with all the processing facilities, adequate truck access to major highways and zoning for heavy commercial or light industrial is advisable.

[41] Brenyi, E.B., "Whether MRF-based Recycling?", *Resource Recycling*, April 1999; and "State of MRF's: 2001," *Resource Recycling*, January 2001.

[42] Source: Governmental Advisory Associates Website.

5.8 Typical Capital Costs

Capital costs for MWP facilities can vary widely depending on the throughput and degree of automation. For example, a survey completed for the West Cook County Solid Waste Agency (suburban Chicago area)[43] indicated that the capital cost per design capacity ton for nine large (400 tpd and higher) facilities ranged from $7,625 to $89,846, with an average of approximately $32,000. The higher-cost facilities tended to include additional processing (such as composting or RDF production). Capital cost of a 650 tpd COM-MRF for the Des Moines Metropolitan Area Solid Waste Agency in an April 1993 study[44] was estimated at $22,715 per daily design capacity ton.

As a very preliminary estimate, for conceptual discussions, assuming a capital cost of approximately $25,000 per daily design capacity ton and a 750 tpd facility, capital cost for a COM-MRF targeting only commercial/industrial wastes would be $18,750,000.

5.9 Typical Break-even Cost Per Ton

Operating costs will be dependent on several factors, with labor and residue disposal being the largest. Another factor affecting a Abreak-even≅ cost will be the revenues received from the recyclables. At this conceptual stage, operating cost estimates of $50 to $70 per ton (including debt service) minus material revenues (approximately $30 per recovered ton and 30 percent recovery) provides a break-even cost per ton in the range of $40 to $60 per ton.

5.10 Implementation Needs/Timelines

Construction of an MWP facility could be completed in approximately a year. Permitting is not anticipated to be as difficult as other technologies such as mass burn, RDF, or waste-to-ethanol. Depending on the procurement approach and financing method, an MWP facility could be operational within three years of a decision to utilize the technology.

5.11 Advantages/Disadvantages

Table 5-1 provides a summary of potential advantages and disadvantages to an MWP facility.

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[43] *Feasibility Analysis of Alternative Technologies, Volume X.* ADevelopment of Mixed Waste Processing Facilities to Enhance Collection and Processing of Recyclables,≅ prepared for West Cook County Solid Waste Agency by Patrick Engineering, September 1997.

[44] *Options Analysis for a Major Waste Reduction Facility*, prepared by GBB Solid Waste Management Consultants, April 1993.

Table 5-1 Potential Advantages and Disadvantages of Mixed Waste Processing

Advantages	Disadvantages
Lower capital and operating costs than other major processing facilities	Not appropriate for the entire waste stream
Can be flexible to adapt to material market changes	A stand-alone facility diverts only 10 to 15 percent of total R/W waste stream. Could not meet a 65 percent recovery requirement to allow remaining wastes to be landfilled
Can focus in on specific waste streams with high recyclable content	Quality of recyclables recovered may be lower than source-separated programs
May eliminate the need for separate collection systems for targeted waste generators	
Can be added to the front-end of other technologies	

5.11.1 Advantages

A MWP facility is less expensive than other technologies and can be used to focus in on recovery of certain recyclables; thus, operating at a higher level on the waste management hierarchy. MWP facilities are easily adapted to the front end of each of the other processing or landfilling technologies. This has occurred in Minnesota WTE facilities, and is included in planning stages such as the proposed Lamberton project.

5.11.2 Disadvantages

A MWP facility cannot meet processing goals for the entire waste stream. Based upon preliminary review, a stand-alone facility may only divert 10 to 15 percent of the entire R/W waste stream. There may be some concern with recovered material marketability, although this can be addressed by actually sorting only recyclables-rich loads while bypassing the remaining wastes delivered.

5.11.3 Observations

Based upon preliminary review, the most promising application of a MWP facility for the R/W waste stream could be a COM-MRF, which targets the recyclables-rich loads currently delivered to the NRG Facility. Such a facility would primarily recover corrugated cardboard, mixed paper, wood, and ferrous metals. Alternatively, the MWP facility could be front-end processing for a mass burn facility. Another potential emerging use is for construction/demolition waste processing, but that is not part of the MSW stream covered by R/W counties in this analysis.

6. Thermo-chemical Processes

6.1 Definitions

Several terms that may be new to some and not entirely clear to others are used in this section and again in the next section on Ethanol Production. The following definitions are drawn from multiple sources to aid in clarification of processes and feedstocks.

Biomass: Matter produced through photosynthesis consisting of plant materials and agricultural, industrial and municipal wastes and residues.

Biomass fuel: Liquid, solid, or gaseous fuel produced by the conversion of biomass.

Combustion: Burning. The transformation of biomass fuel into heat, chemicals, and gases through chemical combination of hydrogen and carbon in the fuel *with oxygen in the air* [emphasis added].

Distillation: The process to separate the components of a liquid mixture by boiling the liquid and then recondensing the resulting vapor.

Gasification: A chemical or heat process to convert a solid fuel to a gaseous form. *(Gasification systems use air or oxygen to aid combustion.)*

Gasifier: A device for converting solid fuel into gaseous fuel. In biomass systems, the process is referred to as pyrolitic distillation.

Plasma Gasification: A process like plasma pyrolysis, but the arc is used to heat oxygen rather than nitrogen.

Plasma Pyrolysis: The process uses a plasma arc to heat nitrogen to high temperatures. This results in melting or vitrifying inorganic material (slag) and gasifying the organic fraction.

Pyrolysis: The thermal decomposition of biomass at high temperatures (greater than 400º F or 200 C)*in the absence of air* [emphasis added]. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Thermal Depolymerization: A process to reduce organic material into light crude oil. The process uses temperature and pressure to convert the material followed by a rapid pressure change to drive off water.

6.2 Technology Explanation

6.2.1 Pyrolysis

6.2.1.1 Process

Pyrolysis is the thermal decomposition of waste biomass in the complete absence of oxygen. Unlike combustion, incineration, and gasification, pyrolysis uses an external source of heat and does not rely on oxygen to sustain the internal process. In pyrolysis systems, thermal cracking and condensation are used to transform organic substances into gaseous, liquid and solid components.

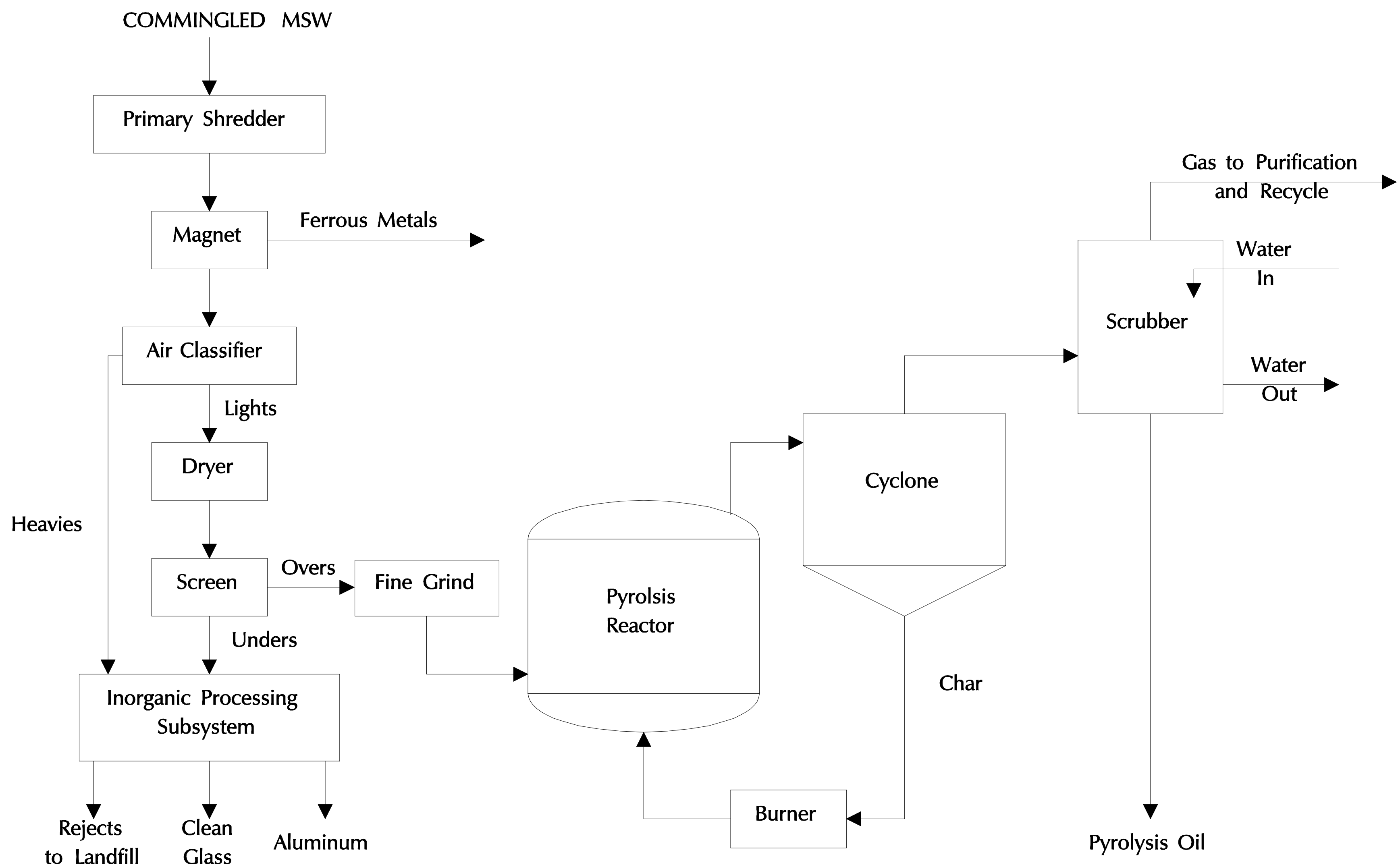
Based on descriptions of several United States based projects, most at the pilot level, managing MSW through pyrolysis appears to require several process steps:

- Pre-processing, which typically includes a bag opener, a sorting or screening system to separate non-organic recyclables, and a shredding or size reduction process.
- Drying, which involves evaporation of moisture from the waste feedstock. This typically occurs through heating the feedstock before it enters the pyrolysis system. A second opportunity for drying, quenching, occurs late in the pyrolysis system and refers to rapidly cooling materials to stop the thermal pyrolysis process.
- Pyrolysis, in which feedstock is placed in a vacuum chamber and rapidly heated, then rapidly cooled to decompose (e.g., vaporize) waste into a mixture of gas, liquids, and solids.
- Recovery and refinement of oils, gases, and solids.
- Power generation or gas combustion, typically to support on-site processes.

Pilot and demonstration projects also note the need to clean the output gases, possibly through an electrostatic precipitator (ESP) or wet scrubbing process.

Figure 6-1 shows a schematic diagram of a demonstration project.

The result of these processes is intended to be the transformation of MSW into pre-separated recyclable materials and three process componentsXgas, liquid, and solid.



Source:
Integrated Solid Waste Mangement, Engineering Principles and Management Issues, Tchobanoglous/Thiesen/Vigil

RAMSEY/WASHINGTON COUNTIES

FIGURE 6-1
SCHEMATIC DIAGRAM OF THE OCCIDENTAL FLASH PYROLYSIS SYSTEM FOR THE ORGANIC PORTION OF MSW

Scale: NOT TO SCALE		Date: APRIL 2000	
Prepared By:	Foth & Van Dyke	By: JAM3	

6.2.1.2 Recovered Products

6.2.1.2.1 Gas

The gas stream contains hydrogen, methane, carbon dioxide, carbon monoxide, and lesser amounts of other gases. The quantity of gases produced is dependent on the temperature reached during pyrolysis with greater quantities reached at higher temperatures. Table 6-1 shows gas composition by percentage as produced from 100 pounds of MSW at various temperatures.

Table 6-1 Gas Production from Pyrolysis[A]

	% by Volume			
	900ºF	1,200ºF	1,500ºF	1,700ºF
Hydrogen	0.69	3.09	6.76	7.91
Methane	1.53	2.97	3.25	2.55
Carbon monoxide	4.13	5.68	8.08	8.59
Carbon dioxide	5.52	5.92	4.88	4.46
Trace gases	0.46	0.98	0.72	0.85
Totals	12.33	18.64	23.69	24.36

[A] Source: Tchobanoglous, George; Theisen, Hilary; and Vigil, Samuel; *Integrated Solid Waste Management Engineering Principles and Management Issues*: pp. 627-630.

If pyrolysis is conducted to maximize gas production (i.e., at high temperatures), the gas produced is projected to have a heating value of 700 Btu per cubic foot (Btu/ft;). In comparison, landfill gas produced from waste decomposition has a heating value of 400 to 550 Btu/ft;.

In theory, the gas from a pyrolysis process could be used to produce electricity or provide heat to support additional processing. However, operation of facilities in California (San Diego and El Cahon, California) indicate that recovered gas contained large amounts of particulate material and chemicals that interfered with ongoing processing efforts and made the gas a questionable fuel source.

6.2.1.2.2 Liquid

The liquid fraction of the pyrolysis process is projected to contains tars and oils composed of acetic acid, acetone, methanol, and complex oxygenated hydrocarbons. The production of this liquid fraction decreases minimally as pyrolysis temperature increasesXfrom about 61 percent at 900 F to 58.7 percent at 1,7001 F.

If the liquid fraction is refined, it can be used in the production of No. 6 fuel oil. However, moisture content is critical in trying to generate a marketable fuel oil. Facilities in California intended to use pyrolysis to generate a fuel oil with a moisture content of no more than 14 percent and a heating value that reached 64 to 77 percent of that of conventional fuel. In practice, the Apyro oil≅ produced by the demonstration project, Occidental Flash Pyrolysis, had an average moisture content of 52 percent and heating values of 27 percent that of No. 6 fuel oil.

6.2.1.2.3 Char

The final product of the pyrolysis process is a solid, char, which consists of pure carbon and inert materials from the MSW feedstock. According to an editorial from a Regional Director of system vendor, Union Nature Company, Inc. in Coram, NY., char is typically a non-toxic, non-hazardous product with a heating value of 7,000 to 8,000 Btus per pound and value as a fuel source or soil additive.[45]

6.2.1.3 Previous Experiences

6.2.1.3.1 San Diego Flash Pyrolysis Facility, Occidential Research Corporation[46]

A full-scale MSW pyrolysis facilityXthe 200 tpd San Diego Flash Pyrolysis FacilityX has been constructed in the United States. The San Diego facility was intended to be operated as a demonstration project only prior to development of a much larger 1,000 to 2,000 TPD facility . The facility was constructed and operated by the Occidental Research Corporation (Occidental) under a turnkey contract with San Diego County and some financial support ($4.2 million) from the EPA.

Construction on the facility began in February 1976. Following a seven-month shakedown period, a planned third party, one-year testing and evaluation phase began in August 1977. The facility was closed in July 1978.

The facility was intended to run waste receiving and pre-processing operations eight hours per day, six days per week (2,496 hours per year) with all other operations intended to run 24 hours per day, six days per week (7,488 hours per year). Despite this planned schedule, during the eleven months between the start of the third party evaluation and facility closure, the pyrolysis system operated only 140 hours. The facility never was able to complete EPA=s requirement for 72 hours of consecutive operations.

The limited amount of operating time was attributed to Aexcessive mechanical problems and breakdowns experienced throughout the plant, especially in the pyrolysis system..≅ Operating problems were reported to occur at all stages of the processing, including an inability to dry feedstock to design specifications, an inability to replace outside heating fuel sources with internally produced pyrolytic gas, and problems separating solids and gases that led to blockages in a variety of waste handling and material delivery systems. Taken as a whole, the problems led to the production of a pyrofuel, the intended facility output, that did not meet market specifications for moisture content and thus, heating values.

[45] Doble, Bill; "Pyrolysis for Low Cost Waste Disposal and Generation of Electricity," http://eco-web.com/editorial/03280.html.

[46] Harrison, Brenda P.; and Vesilind, Aarne; *Design and Management for Resources Recovery. Volume 2: High TechnologyXA Failure Analysis*. 1980: AThe San Diego Flash Pyrolysis Project,≅ pp.61-84.

6.2.1.3.2 Georgia Institute of Technology Mobile Agricultural Pyrolysis System[47]

This pilot system was intended to process 200 tpd of wet wastes (50 percent moisture) into 45 tons of a char-oil fuel mixture. Based on two to three semi-trailers, its designers planned to move the system to the wastes rather than bring the wastes to the processing facility. (Pyrovac International, one of the current system vendors, describes a similar mobile capability for treating contaminated soils via pyrolysis in their equipment literature.)

Operating assumptions included:

- 272 to 336 working days per year, of which 238 to 294 would be spent on production and the remainder for travel and maintenance
- Between 17 and 21 sites per year
- Approximately eight employees plus a supervisor
- The need to pay $5 per ton to receive the agricultural wastes
- An ability to market the fuel produced for $28 to $35 per ton.

Conclusions from the study noted that the proposed pyrolysis system appeared to be technologically sound but lacked research or data in the areas of the mobile concept, drying feedstock, and identification of potential problems related to mixing char and the pyrolitic oil.

6.2.1.3.3 Andco-Torrax Pyrolysis System[48]

The Andco-Torrax System (Andco) System was intended to convert MSW into a usable gas, which could be burned to produce heat and generate steam. It was demonstrated in Eric County, New York, beginning in 1972. Additional commercial (full-scale applications) facilities were reported as under construction in Europe in 1977 and 1978.

The Andco system report provided design and operating assumptions and cost projections for facilities at three sizesX331 tpd, 992 tpd, and 1,653 tpd. At the 992 tpd design throughput level, a facility was assumed to have a utilization factor of 85 to 90 percent per year and some system redundancy (i.e., back-up systems) necessary for production reliability.[49] Site requirements were estimated at 8 acres for staging, buildings, load-out, and traffic flow.

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[47]Wilson, E. Milton; Leavens, John M.; Snyder, Nathan W.; Brehany, John J.; Whitman,, Richard F.; The Ralph M. Parsons Company; Engineering and Economic Analysis of Waste to Energy Systems. U.S. EPA: May 1978, pp. 99-132.

[48]Wilson, et al., pp. 133-166.

[49]One of the major design flaws reported in the Occidental system in San Diego was the lack of system redundancy. In that facility, almost no processes had back up systems.

The 992 tpd facility was projected to produce 2,449 tpd of steam at 493 pounds per square inch (psia) and 234 tpd of potentially reusable slag. Emissions includes hydrochloric acids, sulfur oxides, nitrous oxides, carbon dioxide, and hydrocarbons. Use of an electrostatic precipitator for cleaning air emissions was recommended as a means to meet federal air quality standards for CO_2 existing at the time.

The study concluded that the system was likely to be competitive with oil-based steam generators where tipping fees of approximately $10 per ton (approximately $29.56 in 1999$) were charged on incoming MSW.

6.2.1.3.4 SWERF®

A facility using pyrolysis for energy recovery was constructed in Wollongong, New South Wales, Australia. The facility, called the Solid Waste Energy Recovery Facility (SWERF®) was developed by Brightstar Environmental.

The following excerpts from the Brighstar web site (www.brighstarenvironmental.com) describes the Wollongong project.

> "The SWERF® at Wollongong is a staged project. The first and current stage allows for 30,000 tonnes per annum of household waste to be processed in line with current EPA license provisions. The key deliverable for the Company to move forward with Stage 2 is the successful completion of performance testing of the plant.
>
> At full capacity, the Whytes Gully SWERF® is expected to provide electricity for around 24,000 homes, while achieving a 80% reduction in waste to landfill by weight.
>
> The key changes in the plant to upgrade it to handle all of Wollongong City Council's waste per annum are additional autoclaves, pulp washing, drying and storage equipment, gasifiers and associated gas conditioning modules and power generation units."

The SWERF® technology begins by first autoclaving the waste. The waste is then separated using mechanical methods into recyclables (25 percent), residue (5 percent), and organic pulp (70 percent). The organic pulp is washed to remove sand and glass then dried before being converted in a pyrolysis process. The pyrolysis process returns about 4 to 7 percent residue, though the plant has reported residue as high as 40 percent.

The pyrolysis process converts the dry organic pulp into synthetic fuels and solid residue. Drying the organic pulp aids in better fuel development and overcomes some of the previous problems in other pyrolysis processes. The SWERF® processes use the synthetic fuels generated, after cleaning, for power generation. The char remaining is a solid residual that can be landfilled,though the company claims other options exist for the material, including uses as a soil amendment and mulch.

As of August 2001 (six months after initial start-up), the facility was still not fully operational and operating well below the 91 tons per day permitted capacity.

The Brightstar web site also indicates development of pyrolysis projects in Derby and Shelford, United Kingdom. The initial environmental assessments indicate the plants would process 50,000 tpy at Derby and 110,000 tpy at Shelford. Both plants are in the planning stages with expected start-up in 2005.

Brightstar did propose a SWERF® system for Collier County, Florida, during a proposal process to determine feasibility of pyrolysis/gasification processes in the United States. After a four-month review of proposals from Interstate Waste Technologies (IWT) and Brightstar, the county concluded IWT's had the experience and superior technical package but was cost prohibitive. Brightstar offered limited experience in a more experimental technology but was cost competitive to current tipping fees. At this time, Collier County is not considering either option and does not foresee any development of these options in the near future.[50]

6.2.1.3.5 Toups Technology Licensing, Inc. (Toups)[51,52]

Toups has developed and is marketing a pyrolitic carbon extraction (PCE) system. The company claims their process converts 40 percent of the waste into carbon black and the rest into a clean burning gas called Phoenix 777. The process is advertised to have a capacity of 10 tons per day. The Phoenix 777 gas is said to provide one megawatt per 16 tons of waste.

The PCE system only works on hydrocarbon waste so an extensive recycling and sorting system would be required to remove glass and metals.

Toups indicated in 1999 that a complete system is under development in La Caleta, Dominican Republic. Efforts to reach Toups were not successful. Phones were disconnected and their web site is no longer available.

6.2.2 Gasification[53, 54]

6.2.2.1 Process

Gasification and pyrolysis are similar processes, each converts waste to gases, liquids and char. However, the gasification process allows a small amount of air, steam or oxygen into the

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50 Kevin Dugan, Environmental Compliance Manager, Collier County, Florida. Phone interview April 13, 2004.

51 "U.S. Firm to help Build Sustainable Community," http://www.enn.com, July 15, 1999.

52 "Pyrolitic or 'Burning Without Air' Technology Uses Municipal and Industrial Waste to Create Clean-Burning Gas and Carbon Black," http//www.prnewswire.com, June 21, 1999.

53 Klein, Alexander, "Gasification: An Alternative Process for Energy Recovery and Disposal of Municipal Solid Waste," M.S. Thesis, Columbia University, May 2002.

54 "Waste Gasification Impacts on the Environment and Public Health," A Blue Ridge Environmental Defense League Report, April 1, 2002.

conversion process. This addition of oxygen changes the outputs when compared to pyrolysis and changes the component outputs of gasification.

Gasification with air results in a nitrogen-rich low Btu fuel gas. Gasification with pure oxygen results in a higher quality gas (no nitrogen). Gasification with steam produces syngas, a combination of hydrogen and carbon dioxide.

Gasification processes are usually conducted in fixed bed or fluidized bed reactors. Fixed bed gasifiers are common due to their ease of design and operation. Fluidized beds offer the best reactor for MSW due to the uniform bed conditions, which support efficient reactions of the various components in the solid waste. The two main types of fluidized bed gasifiers are bubbling and circulating. Circulating fluidized bed gasifiers would be used for large applications.

6.2.2.2 Recovered Products

6.2.2.2.1 Gas

The gas stream from gasification consists primarily of carbon monoxide, hydrogen and carbon dioxide. The amounts of each gas depends on the amount and quality of air, oxygen or steam used in the process. More air or oxygen brought into the system tends to increase the carbon monoxide and carbon dioxide amounts and can produce acid gases. Increases in steam tend to increase hydrogen quantities. The gas composition is usually dictated by the end user of the gas; however, most commercial products tend to try to balance gas output at 30 to 35 percent each for carbon monoxide, carbon dioxide and hydrogen.[55]

6.2.2.2.2 Liquid

Liquids from a gasification process tend to be in the form of tars. The amount and composition of tars is dependent on the operating condition of the gasifier. Elliot[56] classified tars into three primary categories depending on the temperature in the process the tars form. Table 6-2 provides the categories of tars formed.

Table 6-2[57] Categories of Tars

Category	Formation Temperature	Constituents
Primary	400-600°C	Mixed Oxygenates, Phenolic Ethers
Secondary	600-800°C	Alkyl Phenolics, Heterocyclic Ethers
Tertiary	800-1000°C	Polynucleic Aromatic Hydrocarbons

55 www.interstatewastetechnologies.com.

56 Elliott, D.C. "Relation of Reaction Time and Temperature to Chemical Composition of Pyrolysis Oils," ACS Symposium Series 376, *Pyrolysis Oils from Biomass*.

57 Evans, R.J., Milne, T.A. "Chemistry of Tar Formation and Maturation in the Thermochemical Conversion of Biomass," Developments in Thermochemical Biomass Conversion, Vol. 2, 1999.

The primary tars are mixed oxygenates and are a product of pyrolysis. As gasification takes over at higher temperatures, the primary products thermally decompose to lesser amounts of secondary and tertiary products and a greater quantity of light gases. Tertiary products are the most stable and difficult to crack catalytically. Provided that there is adequate gas mixing, primary and tertiary tars are mutually exclusive in the product gas. Both lignin and cellulose in the fuel result in the formation of tertiary tar compounds. However, lignin rich fuels have been shown to form heavier tertiary aromatics more quickly[61]

6.2.2.2.3 Ash

With a gasification process and the introduction of oxygen into the process, some materials will burn and ash is formed. The amount of ash and its composition is dependent on feedstock, oxygen availability and temperature of the process. Primarily the ash contains heavy metals remaining from the gasification process. The ash is estimated to be 8 to 15 percent[58] of the original volume of material. Constituents of concern in the ash would be lead, cadmium and mercury. The ash from gasification would need to be managed like the ash from incineration of MSW.

6.2.2.3 Previous Experience

6.2.2.3.1 Collier County, Florida[59]

Collier County, Florida, in developing an integrated waste management program, solicited long-term waste management solutions from private companies. The companies were to be capable of processing a majority of the municipal solid waste in the County (in FY 2002, estimated to be 580,000 tons; by 2010, 730,000 tons). Three proposals were received in April 2002. Proposals were received from Interstate Waste Technologies (IWT), Brightstar Environmental, LLC (Brightstar) and the Slane Company. The Slane Company was initially eliminated since they did not meet the initial technical and financial requirements outlined in the request for proposals. Brightstar and IWT were further evaluated based on their experience, technical approach, business management and cost. The selection committee concluded IWT offered the best experience and technical approach, but the cost for the technology was prohibitive for the County. Brightstar offered lower cost but an experimental process. The committee's final recommendation was to solicit a best and final offer from IWT. In further discussions with the Solid Waste Division staff, IWT could not obtain the financing needed to fulfill the requirement of Collier County. Discussions with Brightstar indicated technology problems have hampered their ability to meet the requirements of Collier County.

[58] "Waste Gasification Impacts on the Environment and Public Health," A Blue Ridge Environmental Defense League Report, April 1, 2002.

[59] Schwarz, S.C. and Dieteh, D.E., "Collier County, Florida, Consideration of Gasification as a Long-Term Waste Management Solution," NAWTEC 11, April 20-30, 2003.

6.2.2.3.2 Interstate Waste Technologies (IWT)[60]

Interstate Waste Technologies is marketing a gasification technology called "Thermoselect." The technology uses a combination of high temperature and long-residency time to convert organic material to synthesis gas. Information regarding the various plants and processes depicted on their web site is limited. The company does indicate their process produces 100 percent recycling. The company reports an input of 2,000 pounds of waste plus 978 pounds of oxygen and 60 pounds of consumables; has an output of 1,790 pounds of synthesis gas, 460 pounds of minerals, 698 pounds of water and 90 pounds of other materials. There are currently no IWT plants operating in the Untied States. The company reports fully operational plants in Karlsruhe, Germany (792 tpd) and Chiba, Japan (330 tpd). However, details on these plants are not readily available.

The steps and principles of the Thermoselect® process as described by IWT are as follows[61]

1. Waste Compaction
   Unprocessed municipal solid waste has a low density and requires a great deal of space. The Thermoselect® process uses standard in-line scrap metal presses to compress the waste and increase its overall density. To accomplish this, presses which have been thoroughly tried and tested in over 30 years of industrial operation are used. The refuse is compacted to about 10 percent of its original volume. The compacting results in highly compressed packets of co-mingled waste where the moisture that is naturally contained in the refuse becomes evenly distributed. The packets are estimated to be 2 inches in diameter As a result, the residual air content in the compressed refuse packets is reduced to a minimum.

2. Degassing
   The highly compressed refuse packets are pushed directly to a pressure-resistant channel to form a gas-tight "plug." In this channel, the refuse is intensively heated by conduction. The heat (350°C/660°F) vaporizes the volatile portion of the waste, which is primarily water. The hot gas molecules, especially those of water vapor, transfer energy to further heat the waste packets. These hot gases flow through the heated channel and enter the next stage, the high temperature chamber (HTC). The organic part of the compressed packets is degassed and converted into carbon; the inorganic mineral and metal matter are entrapped in the carbonized material. The hot carbon packets, with the entrapped inorganic components, are continuously moved forward to the next stage by feeding new refuse packets into the degassing channel. The gaseous components: water, carbon monoxide, carbon dioxide, hydrogen, and hydrocarbon gases, are moved continuously from the degassing channel into the high temperature chamber (HTC).

3. High Temperature Gasification
   The carbon packets break apart as the carbon and inorganic portions enter the high temperature gasification chamber (HTC). Oxygen is introduced, providing a high

[60] www.interstatewastetechnologies.com.
[61] Ibid.

temperature gasification medium. Oxygen, in the presence of steam, ensures that all chemical reactions occur rapidly. The essential processes are:

a. All organic compounds are completely destroyed and are decomposed (cracked) to atomic levels.

b. A synthesis gas is formed as carbon, oxygen, hydrocarbon gases, and water combine. Degasification in the absence of air produces a continuous flow of carbon into the high temperature oxygen based gasification process, resulting in a raw synthesis gas volume of about 800 Nm^3 (25,000 cubic feet) per ton of waste input, depending on the heat content of the waste. This process for forming synthesis gas has been utilized for more than 60 years. Significant industry experience assures the integrity and safety of the design and operation of gasifiers at various temperatures and pressures.

c. Minerals and metals in the waste are liquefied and refined by oxidation, resulting in the total conversion of all entrapped carbon. The metal/mineral product is recovered in the form of an inert and non-toxic material that meets US Environmental Protection Agency Toxic Characteristics Leaching Procedure test standards. The metallurgy and glass industries have developed methods for converting these materials into useful products.

4. Synthesis Gas Treatment
The synthesis gas and other components of the gas steam exit the HTC at a temperature of 1,200°C (2,200°F) and are shock-cooled to below 90°C (194°F) using a water flush. Melted mineral particles and, in some circumstances, traces of carbon that can be carried along with the gas are precipitated in water, separated, and recycled back into the thermal process. The rapid cooling of the hot gas stream in the absence of oxygen prevents a “de-novo” synthesis (new formation) of dioxin and furan compounds. The multi-stage alkaline wash assures the separation of sulfur compounds. The synthesis gas is separated prior to this second gas washing stage and separately cleaned and cooled to reduce its residual moisture. The purification of the synthesis gas is concluded by passing the gas through an activated coke filter. The use of activiated coke filters for the final purification of oxygen-free synthesis gases at temperatures far below 80°C (176°F) is a process and safety advantage.

5. Water Treatment
The aqueous acid washing solutions generated during the gas cleaning process are subjected to conventional chemical material separation processes. Products from the gas cleaning and water recovery process include industrial grade sodium chloride (salt), elemental sulfur, and a separate precipitate containing the heavy metals from the input waste. The precipitate is concentrated to produce a material that is rich enough in zinc and lead to be processed in smelters to recover these two metals. All of the remaining water from this process is recovered and reused within the system. No process water is discharged from the plant.

6. Electricity Generation
The clean synthesis gas is transformed directly into electrical energy using generators driven by high efficiency, low speed gas engines. The energy in the engine exhaust gas is used to heat the degassing channel and to provide heat for the evaporation stage of the water treatment process.

6.2.2.3.3 TPS – Termiska

TPS Termiska is a Swedish research and development company that specializes in gasification technology. The company has two gasifiers operating in Italy processing 200 tpd of RDF[62]. Each gasifier has a 15 MW fuel capacity. The gasifiers operates under atmospheric pressure at 850°C using air as the gasification agent. The gas produced is used in either the adjacent cement furnaces or a boiler. The boiler is used to drive a 6.7 MW steam turbine. Significant repairs and upgrades have been conducted to this plant. Due to boiler fouling and the need for a gas clean-up line, an additional $10 million was needed for upgrades[63]. Most recently, the company has installed a wood-fueled combined cycle gasifier in the Uited Kingdom [64]. This gasifier uses wood as a feedstock (mostly poplar trees) in an atmospheric pressure circulating fluidized bed gasifier coupled to a tar cracking vessel. The gas produced is converted to energy using a gas turbine to produce 8 MW of electricity.

6.2.3 Plasma Pyrolysis and Gasification

6.2.3.1 Process

Plasma pyrolysis with gasification are processes that utilize a plasma reactor to convert waste to inert slag and gases. The gases, called "syngas" can be used as an energy source in a boiler or turbine set up.

The plasma reactor is an enclosed chamber containing plasma torches. These torches heat the gases in the chamber (for pyrolysis, no oxygen is present, nitrogen is typically used. For gasification, oxygen is present in the reaction) to 3,000°C or higher. These high temperatures convert organic materials into gas and inorganic materials into a glassy slag substance.

6.2.3.2 Recovered Products

6.2.3.2.1 Gas

Gas from plasma based processes typically include carbon monoxide (CO), hydrogen (H_2) and carbon dioxide (CO_2). Other gases may also form (SO_x, HCL, HF) but are usually neutralized in a gas scrubber. The gas has a typical heat value of 300 Btu/scf, similar to coal gas[65].

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[62] Morris, Micheal, "Electricity Production from Solid Waste Fuels Using A Chemical Gasification Technology," SWANAs Waste Conference, Charlotte, North Carolina, October 26-29, 1998.

[63] Granatstein, D., "Fluidized Bed Gasification as a Means of Converting Waste to Energy," presented at the IEA Bioenergy Agreement Joint Task Meeting, Tokyo, Japan, October 28, 2003.

[64] Morris, M. and Waldheim, L., "Update on Project Arbre, UK – A Wood Fueled Combined Cycle Demonstration Plant," www.tps.se/gasification/publ-gas-en.htm.

[65] "Processing of Waste Materials," http//maven.gtri.gatech.edu/geoplasma/processing.htm

6.2.3.2.2 Vitrified Residue

The inorganic fraction of the waste stream is converted to a silicate based slag. The slag is formed from the glass, soil, minerals and metals in the MSW. In a plasma pyrolysis process, the lack of oxygen causes metal, halogen and sulfur atoms to bond with the silicate. This atomic bonding makes leaching of the materials difficult.

6.2.3.3 Previous Experience

6.2.3.3.1 Yoshii, Japan[66]

A plasma arc facility was commissioned in 1999 located in Yoshii, Japan. The plant, a pilot plasma gasification process, was designed to convert 24 tpd of MSW in a single train. The system uses external torches and produces syngas for a waste heat boiler. This facility does not generate electricity. The project successfully demonstrated the viability of plasma arc gasification and provided the groundwork for a commercial size plant in Utashinai City, Japan.

6.2.3.3.2 Utashinai City, Japan[67]

Based on the research and success of the Yoshii, Japan, plant, the Japanese government certified the construction of a commercial size plasma gasification plant in Utashinai City. The plant is used to dispose of auto shredder residue (ASR) at a rate of 165 tpd. However, the plant can accept up to 300 tpd of 100 percent MSW. The plant uses the syngas to produce about 8 MW of electricity. The plant began full operation in 2003.

6.2.3.3.3 Mihama-Mikata, Japan[68]

In December 2002, the twin cities of Mihama and Mikata, Japan, commissioned an MSW and sewage sludge treatment plant using plasma gasification. The plant is reported to process 24 tpd of MSW and 4 tpd of sewage sludge.

6.2.3.3.4 Kinuura, Japan[69]

The plant in Kinuura, Japan, is an ash vitrification plant using plasma torches to melt the ash produced from a 240-tpd MSW incinerator. The torches require 180 kWhr per ton of ash. The plant has been operating since 1995.

6.2.3.3.5 Ukiah, California[70]

The National Defense Center for Environmental Excellence (NDCEE) was tasked by the Department of Defense to evaluate plasma arc technology to treat complex military wastes. The program, conducted in 1997, evaluated the Plasma Arc Centrifugal Treatment (PACT) system

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[66] http://www.westinghouse-plasma.com/gasif.htm

[67] http://www.westinghouse-plasma.com/utashinai.htm

[68] http://www.westinghouse-plasma.com/mihama.htm

[69] http://www.westinghouse-plasma.com/ihi.htm

[70] "Plasma Arc Technology," http://p2library.nfesc.navy.mil/p2_opportunity_handbook/2-II-10.htm

designed and built by Retech, Inc. of Ukiah, California. Several systems were evaluated in the pilot program using various wastes (medical waste, sludge, soil, waste paint, etc.)

The pilot program evaluated the cost of using PACT for four different system compared to disposal of hazardous waste materials. Results concluded PACT may not be feasible when compared to conventional hazardous waste disposal costs.

6.2.3.3.6 Startech Environmental Corporation[71]

Startech Environmental Corporation (Startech) is marketing a plasma system including the plasma vessel, gas polisher, computer control system and power supply system. A "turnkey" type of system, Startech is currently seeking investors and opportunities to sell their system for MSW processing.

6.2.3.3.7 Other Studies[72]

Plasma arc technology has been studied for possible application in Ireland, Honolulu, Hawaii, and Sanpete County, Utah.

The Ireland study examined plasma arc technology as a method to further reduce the toxicity and volume of ash from MSW incineration. The study also suggested the plasma arc technology may replace incineration[73].

In Honolulu, Hawaii, their study[74] examined the applicability of plasma arc gasification and vitrification technology for waste disposal. Of primary concern was the dwindling space for landfilling and the desire to look at other technologies for MSW management. Ultimately, the report concluded the challenges to financing such a system and the risk the city may have to take would require a complete RFP process. The city has not chosen to pursue an RFP for plasma technology at this time.

The Sanpete, Utah, study is more of a "sales pitch" for Creative Energy Systems[75]. They propose to use a plasma arc technology similar to the Japanese sites to treat up to 120 tons of waste per hour. At this time, investors are being sought for such a system in various locations, including Sanpete County, Utah; Rochester, New York; and Boise, Idaho.

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[71] www.startech.net.

[72] "City of Honolulu Review of Plasma Arc Gasification and Vitrification Technology for Waste Disposal," R.W. Beck, January 23, 2003.

[73] Farrell, P. and LeGray, P.R., "Using Plasma Pyrolysis Vitrification (PPV) to Enhance Incineration Waste Ash Reduction in Ireland," NAWTEC 10 Proceedings, May 6-8, 2002.

[74] "City of Honolulu Review of Plasma Arc Gasification and Vitrification Technology for Waste Disposal," R.W. Beck, January 23, 2003.

[75] Meyers, Welton and Allen, S., "Landfill Association Hears Proposal for Turning Waste into Electricity," August 5, 2002, press release found at http://www.remnantsaints.com/alternativeutilities/ waste_energy/sanpetel.htm

6.2.4 Thermal Depolymerization Process

6.2.4.1 Process

Thermal depolymerization is a process of converting complex organic material into light crude oil. The organic feedstock is usually ground in the first stage to small chunks of material. The material is placed in a vessel where it is subjected for 15 minutes to temperatures of 250°C and pressure of 600 psig. The pressure is then released rapidly, which causes the remaining water to evaporate. The result is a mix of crude hydrocarbons and solid minerals[76].

6.2.4.2 Recovered Products

6.2.4.2.1 Light Crude Oil

The light crude oil created from the organic material subjected to the thermal depolymerization process requires further refining. The light crude oil is sent to a second reaction chamber and heated to 500°C. This process further breaks the long hydrocarbon chains down and the output is an oil that can be refined using conventional processes.

6.2.4.2.2 Solid Minerals

Solid minerals are also a product of the thermal depolymerization process. These solid minerals are dependent on the feedstock but typically have little value. Most of the solid consists of minerals and carbon black, which can be used as a soil amendment.

6.2.4.3 Previous Experience

6.2.4.3.1 Changing World Technologies (CWT)[77]

CWT has been the leader in the thermal depolymerization process. Their original pilot plant was constructed in a warehouse in Philadelphia in 1999. The original reactor started at 1 ton per day, then was increased to 7 tons per day. The first commercial plant was developed at Carthage, Missouri, for Con-Agra. This plant converts 200 tpd of turnkey offal and waste grease into a medium Btu fuel gas, oil, carbon and fertilizer. The approximate mass breakdown for the Carthage plant is reported to be[78]:

Input

108 tpd	Water
92.9 tpd	Organics
8.2 tpd	Minerals
1.0 tpd	Ammonia

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[76] http//www.sciencedaily.com/encyclopedia/thermal_depolymerization.

[77] http://www.changingworldtech.com.

[78] Adams, T.N., Appel, B.S. and Roberts, M.J., "Converting Turnkey Offal Into Bio-derived Hydrocarbon Oil with the CWT Thermal Process." Presented at the Power-Gen Renewable Energy Conference, Las Vegas, Nevada, March 1-3, 2004.

Output

7.5 tpd	Fuel gas
69.8 tpd	TDP-40 oil
6.7 tpd	Carbon
79.7 tpd	Distilled water
33.6 tpd	Water, glycerol and $(NH_4)2S0_4$
8.2 tpd	Dry minerals

At this time, the only full-scale thermal depolymerization plant operating is in Carthage, Missouri. Future plants are being planned but are dependent on feedstock (must be highly organic) and funding (the Con-Agra plant was estimated to cost $15 million; the EPA supplied a $5 million grant for the project).

CWT has also received funding (approximately $500,000) from a partnership between the Vehicle Recycling Partnership and the American Plastics Council to apply thermal depolymerization technology to auto shredder residue. Currently, the research on the application of the technology to ASR (which contains plastics, metals and other non-organics) is being conducted at CWT's Philadelphia facility[79].

6.3 Costs

6.3.1 Pyrolysis

Table 6-3 summarizes process costs for the Occidental, Georgia Institute of Technology, and Andco (two sizes) processes. Costs are generally reported as valued at the time of project completion; however, unit costs are reported both in historic costs and as they may exist in year 1999 if escalated at an average rate of 4.62 percent per year from 1976 or 4.86 percent per year from 1975. The average escalation rate is drawn from the change in the Consumer Price Index for all Urban Consumers from 1975 through 2003.

No additional cost data is available on full-scale pyrolysis systems. Brightstar has stated they would be able to build, own and operate a facility compared to SWERF in the United States for between $35 an $45 per ton. However, they caution that individual economic analysis would be needed for each particular application[80] However, when Brightstar proposed their system in Collier County, Florida, they were reluctant to fully guarantee performance and identified numerous exceptions to various contract principles, including project development and financing[81].

[79] Johnson, Jim, "Carmakers Push Residue Recycling," Waste News, March 1, 2004, p. 10.

[80] Federal Remediation Technologies Roundtable, "Pyrolysis," October 1997.

[81] Schwarz, S.C. and Dietch, D.E., "Collier County, Florida – Consideration of Gasification as a Long-Term Waste Management Solution," NAWTEC 11, Tampa, Florida, April 28-30, 2003.

Table 6-3 Pilot and Demonstration Project Costs

Measures	G.I.T.	Andco-Torrax		Occidental
Base year for costs	1976	1976	1976	1975
Facility size	200 tpd	331 tpd	992 tpd	200 tpd
Feedstock	Ag wastes	MSW	MSW	MSW
Capital costs				
Total	778,900[A]	$12,760,000	$30,630,000	$14,470,000
Annual costs				
Operations	$207,680 - $270,680	$1,493,000	$2,740,000	
Annual debt service	$121,936	$1,584,000	$3,692,000	
Total annual cost	$329,616 - $392,616	$3,077,000	$6,432,000	
Net cost/ton projections [B]	$6.08 cost to $1.57 profit	$5.75/ton cost	$4.00/ton cost	$13.42/ton cost[C]
Capital cost (2003$)	$2,430,877	$39,822,815	$95,593,482	$49,916,927
Capital per daily design throughput ton	$12,154	$120,310	$96,364	$249,584
Annual costs (2003$)	$995,248 - $1,185,471	$9,290,746	$19,420,892	$6,863,370

[A] If base assumptions were proved incorrect, capital had potential to be at least $100,000 low

[B] Assuming sales of recovered materials and energy or fuel sources but no incoming tipping fee.

[C] Per MSW ton delivered. Excludes front end recovery and processing of aluminum

6.3.2 Gasification

Capital and operational costs for gasification plants are difficult to obtain due to the proprietary nature of gasification systems. These systems are highly dependent on feedstock. In order to provide some indication of relative costs for gasification systems, the following data are provided:

Project Name: TPS – Termiska gasifier with tar cracker[82]
Material: RDF (200 tpd)
Capital Costs: $170,675,000
Annual Operating Cost: $1,500,000 to $2,000,000
Annual Electric Revenue: Approximately $1,040,000 (assumed $0.04/Kwh)

Project Name: Battelle indirectly heated gasifier[83]
Material: Wood, biomass and RDF (10 tpd)
Capital Costs: $80,532,000

[82] Klien, Alexander,"Gassification: An Alternative Process for Energy Recovery and Disposal of Municipal Solid Waste," M.S. Thesis, Columbia University, May 2002.

[83] Ibid.

Annual Operating Cost: $48.00 per ton
Annual Electric Revenue: $25.00 per ton (assumed $0.04/Kwh)

Project Name: Zeltweg coal boiler[84]
Material: Biomass (woodchips, bark, sawdust) 8% and polish coal 92%
Capital Costs: $4,300,000
Operating Cost: $14.00 per hour
Electric Production Cost: $0.016/Kwh
This plant has not operated since April 2001 due to the high cost of generated electricity.

Project Name: Kymijarui Power Station[85]
Material: Biomass, coal, natural gas
Capital Costs: $10,000,000
Operating Cost: Not provided
Electric Production Cost: $0.017- $0.025/Kwh
This project was used to extrapolate the cost of a 20MW biomass gasifer. The following are estimated annual costs for such a plant
Capital Cost: $2,300,000
O&M Cost: $1,260,000
Electric Cost to Product: $0.0245/Kwh

Project Name: Greve In Chianti, Italy[86]
Material: RDF (100 tpd)
Capital Costs: $29,700,000
Operating Cost: Unavailable
Electrical Cost: $4,666/KW

Project Name: ARBRE, U.K.[87]
Material: Wood fuel (43,000 tpy)
Capital Costs: $17,000,000
Operating Cost: Unknown – began operation in 2002
Electrical Cost: Unknown

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[84] Granatstien, D.L., "Fluidized Bed Gasification as a Means of Converting Waste to Energy," Natural Resources Canada, 2003.

[85] Ibid.

[86] Ibid.

[87] Morris, M. and Waldheim, L., "Update on Project ARBRE, UK – a Wood Fuelled Combined Cycle Demonstration Plan," 1999.

Project Name: TPS[88]
Material: RDF (25,000 tpy)
Capital Costs: $14,000,000
Operating Cost: $1,800,000
Revenue: $775,000 (fuel gas and heat sales)
This is a hypothetical economic case assembled by a gasification developer.

6.3.3 Thermal Depolymerization[89] [90]

Thermal depolymerization is exclusively done by Changing World Technologies (CWT). CWT has one plant operating in Carthage, Missouri for Con Agra. This plant processes turkey offal and grease at a rate of 200 tpd. Private investors have provided $40 million to develop the thermal depolymerization process and the USEPA has provided an additional $12 million in funding. The plant in Carthage, Missouri, has been estimated to cost $20 million to construct.

6.3.4 Plasma Pyrolysis/Gasification

Plasma pyrolysis/gasification plants have been primarily developed by Westinghouse-Plasma. Dan Lazzara of Westinghouse Plasma in 2002, estimated the capital cost for a plasma reactor at $200/KW of thermal capacity[91]. The city of Honolulu report on Plasma Arc Gasification[92] concluded plasma facility economics are too variable and existing plants lack proper scale for comparison.

NOCEE was asked by the Department of Defense to evaluate plasma arc technology to treat complex military waste. They concluded plasma disposal costs ranged from $415 per ton for agricultural-based medium to $6,360 per ton for waste paint. The study examined four different plasma arc systems. Of the four systems, the PACT-8 system with two torches yielded the least average cost of $931 per ton[93].

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[88] Morris, M., "Electrical Production from Solid Waste Fuels Using Advanced Gasification Technology," SWANA WASTECON 1998, Charolette, N.C.

[89] Lemley, B., "Anything Into Oil," Discover, Vol. 24, No. 5, May 2003.

[90] Adams, T.N., Appel, B.J. and Samson, P.J., "Converting Turkey Offal into Bio-Derived Hydrocarbon Oil with the CWT Thermal Process," Power-Gen Renewable Energy Conference, March 1-3, 2004, Las Vegas, Nevada.

[91] R.W. Beck, "City of Honolulu Review of Plasma Arc Gasification and Vitrification Technology for Waste Disposal," January 23, 2003.

[92] Ibid.

[93] "Plasma Arc Technology," http://p2library.nfesc.navy.mil/P2_Opportunity_Handbook/2-II-10.htm.

6.4 Environmental Concerns and Permitting Issues

6.4.1 Pyrolysis

Pyrolysis systems permitting is difficult due to the lack of long-term data on a full-scale (or beyond pilot scale) facility. This is further complicated by variables in pyrolysis processes and inputs. Plants proposed for siting in the United Kingdom were required to complete an environmental impact analysis, which examined traffic, air emissions and health risk.

Brightstar has been leading the way in permitting new pyrolysis plants. Two plants were proposed in England. One in Shelford and another in Sinfin Lane, Derby. Both plants required an environmental impact statement. Brightstar relied on their SWERF plant data to comply with the requirements. For reference, the SWERF plant air emissions data is provided in Table 6-4.

The health risk assessment conducted on the plant on Sinfin Lane indicated a cancer risk due to all plant emissions of 1 in 35,335, which is below the acceptable lifetime risk of 1 in 14,285. The report on the Sinfin Lane facility further examined traffic, nuisance (dust, odor and noise), visual impact and ecology, which are site specific.

With the available data, it would still be likely a pilot or demonstration project would be needed for granting approval for a project in the United States.

Table 6-4 Summary of SWERF Air Emission Test Results

Pollutant	Units of Measure	Proposed NSWEPA License Limits for Combined Stack	Emissions Test Results Sample Date: March 1-2, 2001	Emisison Test Results Sample Date: July 3, 4, & 18, 2001
Carbon Dioxide	%		6.1-10.3%	10.1-10.9%
Carbon Monixide	Mg/Nm^3		440-625	681-692
Chlorine	Mg/Nm^3	200	1.0-1.4	<15
Dioxins and Furans Cogeners (Total I-TEQ)	ng/Nm^3 11% O_2	0.1	0.0331	0.0039
Hexachlorobenzene	Mg/Nm^3 11% O_2	0.005	0.000009	<0.0004
Hexachlorocyclohexane	Mg/Nm^3 11% O_2	0.005	Not analysed due to sample contamination	<0.00005
Hydrogen Chloride	Mg/Nm^3	100	<1.0	0.38
Hydrogen Floride	Mg/Nm^3	50	0.59	<0.2
Hydrogen Sulfide	Mg/Nm^3	5	<2	<1.5-2.1
Metallic Compounds	Mg/Nm^3			
Antimony (Sb)	Mg/Nm^3		0.00082	0.0003
Arsenic (As)	Mg/Nm^3	0.008	0.0051	0.013
Beryllium (Be)	Mg/Nm^3		<0.0002	<0.0002
Cadmium (Cd)	Mg/Nm^3	1	<0.0002	0.011
Chromium (Cr)	Mg/Nm^3		0.013	0.039
Chromium VI (CrVI)	Mg/Nm^3	0.0003	<0.0008	<0.0002
Cobalt (Co)	Mg/Nm^3		<0.0002	0.0016
Lead (Pb)	Mg/Nm^3		0.0051	0.0064
Manganese (Mn)	Mg/Nm^3		0.008	0.0037
Mercury (Hg)	Mg/Nm^3	1	0.0029	0.0006
Nickel (Ni)	Mg/Nm^3		0.016	0.0019
Selenium (Se)	Mg/Nm^3		<0.0002	<0.0002
Tellurium (Te)	Mg/Nm^3		<0.0002	<0.0002
Tin (Sn)	Mg/Nm^3		0.021	0.022
Vanadium (V)	Mg/Nm^3		<0.0002	0.01
Total Metals	Mg/Nm^3	5	0.072	0.11
Nitrogen Oxides		500	40-96	190-300
Oxygen ($)_2$)			8.6-8.8	8.0-9.5[a] 9.2-10.3[b]
Particulate matter		28	1.6-10	0.91
Polycyclic Aromatic Hydrocarbons (PAH's)			0.0267	<0.05
Benzene		2.3	0.0027-0.0039	0.0016
Sulphur Dioxide		36	<0.1	11
Volatile Organic Compounds (VOCs)		98% destruction efficiency	0.05	2
Sulphuric Acid mist And/or Sulphur Trioxide			190	<0.23

Source: Schwarz, S.C. and Dietch, D.E., "Collier County, Florida – Consideration of Gasification as a Long-Term Waste Management Solution." NAWTEC 11, Tampa, Florida, April 28-30, 2003.

6.4.2 Gasification

Permitting and environmental concerns for a gasification process would be similar to those discussed in the pyrolysis section. This is because pyrolysis and gasification have some of the same process components and have similar histories in as far as large-scale operating plants. The plant in Greve in Chianti, Italy, reports air emissions of[94]:

SO_2: less than 50 mg/Nm^3
HCl: less than 10 mg/Nm^3
Particulates: less than 10 mg/Nm^3
Dioxins: Approximately 10 mg/Nm^3

Blue Ridge Environmental Defense League reports theoretical emissions from a 100 tpd starved air combuster as shown in Table 6-5[95].

Table 6-5 Blue Ridge Environmental Defense League Air Pollutants from Starved-Air Combustion/Gasification

Pollutant	Uncontrolled	Electrostatic Precipitator
Particulate matter	125,195 pouns	12,702 pounds
Sulfur dioxide	117,895 pounds	*
Nitrogen oxides	115,340 pounds	*
Hydrochloric acid	78,475 pounds	*
Carbon monoxide	10,913 pounds	*
Mercury	204 pounds	*
Nickel	201 pounds	37 pounds
Chromium	121 pounds	22 pounds
Lead	103 pounds	--
Cadmium	88 pounds	17 pounds
Arsenic	24 pounds	4 pounds
Dioxins/furans	0.11 pound	0.14 pound

* Same as uncontrolled.

[94] Granatstein, D., "Fluidized Bed Gasification as a Means of Converting Waste to Energy," IEA Bioenergy Agreement Joint Task Meeting, Tokyo, Mapan, October 28, 2003.

[95] "Waste Gasification, Impacts on the Environment and Public Health," A Blue Ridge Environmental Defense League Report, April 1, 2002.

6.4.3 Plasma Pyrolysis and Gasification

Permitting and environmental concerns for a plasma system would be similar to pyrolysis and gasification. However, plasma systems require a tremendous amount of electricity to support the plasma arc. The need for large amounts of electricity would limit where a plant could be sited and how the needed power demand would affect existing loads. Significant study on power availability would be needed.

6.4.4 Thermal Depolymerization

Since this technology is highly experimental, environmental impact data is not readily available. It is likely a pilot plant would need to be developed before a full-scale plant would be considered.

6.5 Applicability to Ramsey/Washington Counties Waste Stream

6.5.1 Pyrolysis

A pyrolysis process in a system beginning with pre-separation theoretically has the potential to handle a majority of the R/W counties= waste stream.

6.5.1.1 Current Status

No full-scale pyrolysis facilities using MSW as a feedstock are currently known to be operating within the United States. Several companies, both in the United States and international, claim in their promotional materials to have developed processes applicable to MSW feedstock. Among these are the Canadian company, Pyrovac International (Pyrocycling9); the French company, Serpac Environnement (Pyroflam7); and in the United StatesXVanguard Research, Inc. (PEPS9), Lorton, Virginia; and Union Nature Company, Inc., Coram, New York.

Pilot plants in Quebec and France have demonstrated small-scale success with pyrolysis in controlled studies using limited quantities of homogeneous feedstock over a limited testing period. Additionally, some industrial applications in the United States may continue using coal and heavy petroleum fractions as feedstocks.[96]

6.5.1.2 Site Needs

Based on the pilot and demonstration project data reviewed, as well as current vendor materials, a site to house a pyrolysis system would need to be at least 15 to 20 acres in size and be located in an industrial area. Co-location with one or more facilities capable of using the gas, oil, or electricity produced would be advantageous.

6.5.1.3 Implementation Needs and Timelines

If pyrolysis is a technology that R/W counties wish to pursue, implementation should include:

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[96] Tchobanglous, George; Theisen, Hilary; and Vigil, Samuel; *Integrated Solid Waste Management Engineering Principles and Management Issues*. 1993: pp. 627-630.

- Large and binding financial commitments from multiple federal, state, and local agencies as an investment in demonstrating what is still an unproven waste management technology.

- A turnkey contract with a system vendor, preferably one with one or more reference projects, and that requires the vendor to achieve set financial, operating, and market specification performance standards prior to turning the facility over to R/W counties.

After a site is found and available for use (after facility siting is completed), there should be a minimum of two to three years for facility start-up, shakedown, and test runs. This recommendation is based on the results of the Occidental project where the following conclusion was drawn:

> "One might argue that an experimental facility of such a multiunit, interdependent and nonredundant nature as the San Diego plant warrants a long shakedown period. Total plant operation, including shakedown, was for a little more than 1.5 years. The pyrolysis system was only operated over half this time period. Such short operational time before the closing of a plant may be unfair to the system."

6.5.1.4 Advantages and Disadvantages

Pyrovac International, one of the international companies proposing the use of pyrolysis as a waste treatment technology, has identified several potential technology advantages:[97]

- No dust, toxic emission, or secondary pollution
- Wastes are transformed into oils and useful solid residues
- A small amount of clean gas is produced
- Products and by-products can be sold
- No need for expensive gas scrubbing system

Among the disadvantages identified by researchers in the mid to late 1970s were:

- Difficulties in scaling up the complete pyrolysis process from a pilot project to full-scale operations.

- Design inadequacies, including:

  - Labor intensive pre-separation systems that did not perform at design levels

  - Less recovery of marketable recyclables, particularly aluminum, than anticipated

  - Dryers unable to dry feedstock to necessary moisture levels when operated at greater than 50 percent of design capacity

[97] Pyrovac International, Inc. website: www.enviroaccess.ca/fiches_4/F4-03-95a.html

- Shredders that, because of moisture levels, didn=t produce waste feedstock meeting particle size specifications

- Excessive breakdowns

- Difficulty in meeting market specifications and reusing output components as intended

These might be summarized best as shown in Table 6-6. At this time, the basic disadvantage of it being an unproven technology, with documented significant problems in previous pilot projects, makes pyrolysis an unsuitable technology for serious consideration by R/W counties.

Table 6-6 Advantages and Disadvantages of Pyrolysis

Advantages	Disadvantages
Potential for significant waste diversion—according to some vendors, as much as 90 percent. Potential for producing quantities of usable gas, fuel oil, and/or fuels, as well as front-end recovery of traditional recyclables.	Unproven technology. Pilot and demonstration projects in the United States have documented significant problems in scaling up from very small applications to full-scale, real world projects. High projected capital and operating costs.

6.5.2 Gasification

Like pyrolysis, gasification has the potential to process all of the Ramsey/Washington County waste stream. However, current gasification systems used for MSW have demonstrated operational problems and considerable pre-preparation of MSW to ensure a proper gasification process.

6.5.2.1 Current Status

Interstate Waste Technologies (IWT) appears at this time to be the current leader in gasification technologies. Their "thermoselect" process is being used in plants in Germany and Japan. During the Collier County, Florida, proposal process, IWT was the firm of choice, but had difficulty finding investors. This leads us to believe their process may not be as advanced or reliable as touted.

TPS – Termiske, the Swedish R&D firm, has an MSW gasifier operating in Italy and is working to market the technology. The gasifiers in Italy process 200 tpd of RDF. Future developers appear to be focusing on uniform feedstocks (mostly organic) to produce energy.

6.5.2.2 Site Needs

A project in Germany required 15 acres for a 225,000 tpy facility[98]. We anticipate a 15- to 20-acre site would be needed for R/W counties. Sites in industrial areas are preferred and close to a power grid for sale of power generated from the process. Some residual wastes in the form of carbon char and ash would need to be shipped to a landfill or a beneficial end use identified.

6.5.2.3 Implementation Needs and Timelines

If gasification is a technology that R/W counties wishes to pursue, implementation would include the same criteria as pyrolysis. Furthermore, a lengthy discussion with Collier County, Florida, staff would be recommended to understand the process they went through to select a gasification process and why the project was not successful. We would further recommend tours of existing facilities to determine the applicability of the process to R/W counties waste stream. Assuming a site is available for a gasification plant, we anticipate a two to three year start-up procedure to ensure long-term viability of the technology.

6.5.2.4 Advantages and Disadvantages

The basic advantage to gasification technology is it is not incineration; thus, can be perceived as a "cleaner" process. However, MSW requires extensive pre-treatment to remove wastes not suitable for gasification. A summary of the advantages and disadvantages is provided in Table 6-7.

Table 6-7 Advantages and Disadvantages of Gasification

Advantages	Disadvantages
Not incineration	Requires MSW pre-treatment to remove non organic waste and homogenize the material
Efficient energy production through combustion of gases	Residuals could be hazardous
High temperatures can make the process flexible to other waste streams	Unproven on a commercial scale in the United States
Recycling can be enhanced by up-front separation	System is sensitive to non-organic feedstock
	More expensive than other proven technologies

[98] "Pyrolysis and Gasification," found at http://www.mbt.landfill-site.com/pyrolysis_gasification.html.

6.5.3 Plasma Pyrolysis and Gasification

The existing technology indicates a plasma system could be developed that could process all of R/W counties waste. However, the expense of such a system in construction and operation would be extensive.

6.5.3.1 Current Status

Westinghouse – Plama is the leader in plasma technology applied to waste streams. The plants in Yoshii, Utashinai, Mihami-Mikata and Kinuura, Japan, all use Westinghouse – Plasma technology to process MSW, autoshredder residue, sewage sludge and MSW incinerator ash. Other, smaller companies (Retech, Inc. and Startech) are seeking investors for their plasma-based systems.

6.5.3.2 Site Needs

Site needs will vary depending on the pre-processing of waste that will occur and the need for storage sapace for waste. The existing plants in Japan are estimated to be 5 to 10 acres in size but process less than 300 tpd. A site to support R/W counties' waste stream may be as large as 25 acres.

6.5.3.3 Implementation Needs and Timeline

Given the relatively new technology of plasma arc for MSW processing, implementation of plasma technology for the R/W counties' waste stream would likely follow the example in Japan. In Japan, the Yoshii facility was used as a pilot plant for two years prior to commercialization. Then a larger plant was constructed to handle the waste stream. We would anticipate a similar process would be required for a plasma system to be utilized for R/W counties.

6.5.3.4 Advantages and Disadvantages

The primary advantage of the plasma technology is the reduction in waste volume. A 200 tpd MSW facility would produce 50 tpd of ash[99]. It is likely the ash could have a beneficial reuse (aggregate or cement production) and the system would have minimal waste. The primary disadvantage is cost and power consumption. The estimate for capital cost is difficult to predict given the limited nature of MSW plasma processes.

The reported costs range from $900 to $8,000 per ton processed depending on the feedstock and capacity of the system. Energy consumption has been estimated to be 100 Kwh per ton of material[100].

A summary of the advantages and disadvantages is provided in Table 6-8.

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[99] "City of Honolulu Review of Plasma Arc Gasification and Vitrification Technology for Waste Disposal," R.W. Beck, January 23, 2003, pg. 24.

[100] Dean Lazzara, Westinghouse Plasma Corporation, September 19, 2002.

Table 6-8 Advantages and Disadvantages of Plasma Systems

Advantages	Disadvantages
Superior thermal destruction	High initial investment
Limited pollution	High power requirements
Beneficial use possibilities for gas and ash produced from plasma destruction	High operating costs
Potential to expand waste stream to include other non-MSW streams	May require waste pre-shredding to fit into plasma reactor

6.5.4 Thermal Depolymerization

Thermal depolymerization is an industry with limited scope and applicability. For R/W counties to pursue this technology for use with MSW would require an extensive pilot program to confirm the ability of the process to convert MSW or RDF to usable products.

6.5.4.1 Current Status

Currently, the only operating thermal depolymerization plant is processing highly organic turkey offal and grease for Con Agra in Missouri. This plant, made by Changing World Technologies, processes approximately 200 tpd.

6.5.4.2 Site Needs

The site in Carthage, Missouri, is estimated to be about 4 to 5 acres. It is anticipated a thermal depolymerization plant capable of processing the R/W counties' waste would require 20 to 40 acres at a minimum. Furthermore, storage of process products, primarily the oil for further refining, may be substantial.

6.5.4.3 Implementation Needs and Timeline

Implementation would require a pilot plant to operate on a limited scale for one to two years before a large-scale plant would be warranted. If the pilot process is successful, a full-scale plant would be constructed within five to ten years.

6.5.4.4 Advantages and Disadvantages

The primary advantage of the thermal depolymerization process is the efficient conversion of organic waste into refinable oils. The disadvantages include high costs due to the experimental nature of the process and the lack of operational experience with heterogeneous feedstocks like MSW or RDF.

7. Ethanol Production

7.1 Definition and Overview

The production of ethanol (grain alcohol) from waste products is known by a variety of process descriptions, including Abiomass to ethanol≅ and Aacid hydrolysis.≅ It refers to the process of using Athermo-chemical and enzymatic processing of cellulosic biomass to produce non-petroleum based fuels, fuel cells, and industrial chemicals.≅[101] In layman=s terms, this means turning organic materials, including components of the municipal solid waste stream, into fuel grade ethanol by passing it through a series of refining processes to release, ferment, and distill the available sugars.

Production of ethanol through acid hydrolysis is a technology that has been known and used for over 100 years, with its most extensive use occurring during World War II. Low petroleum prices in comparison to high ethanol production costs kept the process from being adopted for commercial use in the late 1940s. However, ethanol production has received increasing attention in the past decade from agricultural generators seeking additional markets for corn and other farm products or byproducts. Similarly, changes in federal and global environmental policies are driving increased interest in the development of non-petroleum based fuel sources. Among recent drivers are:

- The Kyoto, Japan, Treaty on global warming
- The United States= Presidential Executive Order that calls for tripling national use of bio-products and bioenergy by 2010[102]
- California=s state requirement that state agencies examine the potential to use ethanol in place of the gasoline additive MTBE[103]

7.2 Targeted feedstock

The California Energy Board completed an extensive review of potential biomass resources (e.g., feedstock) suitable for use in the production of ethanol. These can be summarized in three categories[104], of which only the third is applicable to the waste-to-ethanol process under review here:

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[101]Martin, Kay. AConversion Technologies: The New Frontier.≅ Senior Manager Symposium, SWANA, Amelia Island, Florida, Jan. 15, 2000.

[102]Clinton, William J., Presidential Executive Order 13134, ADeveloping and Promoting Biobased Products and Bioenergy,≅ Aug. 12, 1999.

[103]California Energy Commission, AEvaluation of Biomass to Ethanol Fuel Potential in California,≅ December 1999.

[104]California Energy Commission, pg. III-1.

- Sugar, including sugar cane and sugar beets
- Starch, including grains like corn and wheat
- Cellulose, including trees, paper waste, agricultural residues, etc.

The cellulose category is typically referred to as Abiomass.≅ Several components of the municipal solid waste stream, including paper, wood waste, yard waste, and food processing wastes were identified as suitable waste biomass feedstock. Additionally, animal wastes and sludges are also considered suitable feedstock materials.

7.3 Process Steps

Although specific activities within each process step may vary, a review of several approaches to ethanol production reveals four to five sequential processes that appear common to each:

- ***Feedstock preparation:*** Within this process, the feedstock is received, separated, dried, shredded (usually to a uniform size of 2-4 inches), and otherwise prepared for processing. This usually includes some aspect of a material recovery facility (MRF) to remove non-organic components and any household hazardous waste (HHW) that may be in the waste stream. Outputs of feedstock preparation are:

  - Feedstock, including cardboard, newsprint, and other organics typically used in production of refuse-derived fuel

  - Non-organic recyclable materials including aluminum, steel, other metals, glass, plastics, styrofoam and bulky waste

  - Non-organic special wastes like batteries, fluorescent lights, tires, leather, etc..

- ***Decrystallization***During this process, which is also known as Aacid hydrolysis,≅ sugars within the organic feedstock are released and captured through the use of heat and/or chemicals. The resulting acids and sugars are separated, with the acids recaptured or mixed with lime to produce gypsum.

- ***Fermentation***: The sugars released in the previous process are converted to ethanol through the use of either heat or yeasts. The outputs of this process are ethanol and carbon dioxide. With appropriate equipment, the carbon dioxide can be recovered, purified and liquified, thus producing another marketable product.

- ***Distillation***: Ethanol is refined by boiling and recondensing the vapor. The distilled ethanol is mixed with unleaded gasoline to produce vehicle fuel.

- ***Combustion of residue for energy production***: This final process, which turns an otherwise unusable residue into a value added byproduct provides the essential step to make waste-to-ethanol a closed loop system. Although the waste-to-ethanol process works without combustion of residue, economic feasibility is enhanced by including it.

Although not listed above, a viable waste-to-ethanol process seems likely to also include both a waste collection step, in which targeted organic wastes are collected separately of other components of the municipal solid waste stream, and an intensive marketing effort to ensure that the products produced are distributed.

Three exhibits from potential vendors show their process flows. Exhibit 7-1 shows a material flow diagram for Arkenol=s concentrated acid hydrolysis process. Exhibit 7-2 shows a process flow diagram for the TVA=s demonstration projects in Muscle Shoals, Alabama.

7.4 Products, By-Products, and Markets

Although researchers of waste-to-ethanol have historically not found uses for the process by-products and residues, current proponents report it to be a Aclosed system, zero discharge≅ process[105] that produces usable products and by-products:

- Non-organic recyclables, separated from MSW deliveries
- Acids, which can be mixed with lime to produce hydrated gypsum
- Carbon dioxide, produced during the fermentation process and marketable to industrial gas companies[106]
- Ethanol, marketed as a fuel additive
- Part of the residue remaining after hydrolysis, lignin has a reported energy value of 8,500 to 11,000 Btu per dry pound and is said to be usable as a boiler fuel for production of steam or electricity[107]
- Specialty products (furfural, furans, glycols, etc.) used in industrial chemicals

The California Energy Commission=s report includes calculations to establish the quantity of ethanol potentially produced from waste feedstocks. Selected theoretical yields from those calculations are shown in Table 7-1.

[105]Martin, pg. 2.

[106]Tennessee Valley Authority, AMunicipal Solid Waste and Waste Cellulosics Conversion to Fuels and Chemicals, Volume V: Product Markets,≅ March 1993.

[107]TVA, Volume V: Product Markets, pg. 10.

Exhibit 7-1

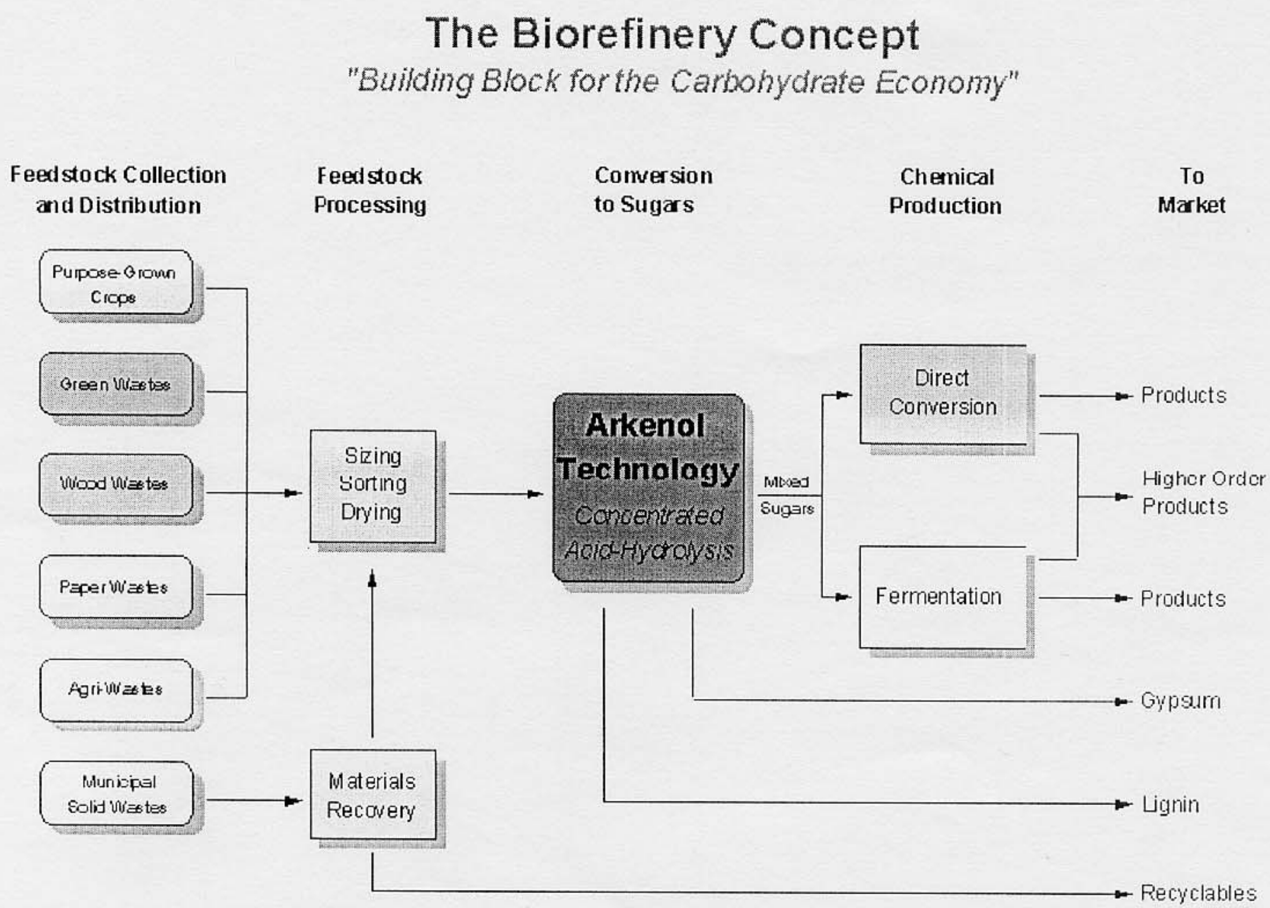
The Biorefinery Concept
"Building Block for the Carbohydrate Economy"
Feedstock Collection and Distribution
Feedstock Processing
Conversion to Sugars
Chemical Production
To Market
Purpose-Grown Crops
Green Wastes
Wood Wastes
Paper Wastes
Agri-Wastes
Municipal Solid Wastes
Sizing Sorting Drying
Materials Recovery
Arkenol Technology
Concentrated Acid-Hydrolysis
Mixed Sugars
Direct Conversion
Fermentation
Products
Higher Order Products
Products
Gypsum
Lignin
Recyclables

Exhibit 7-2

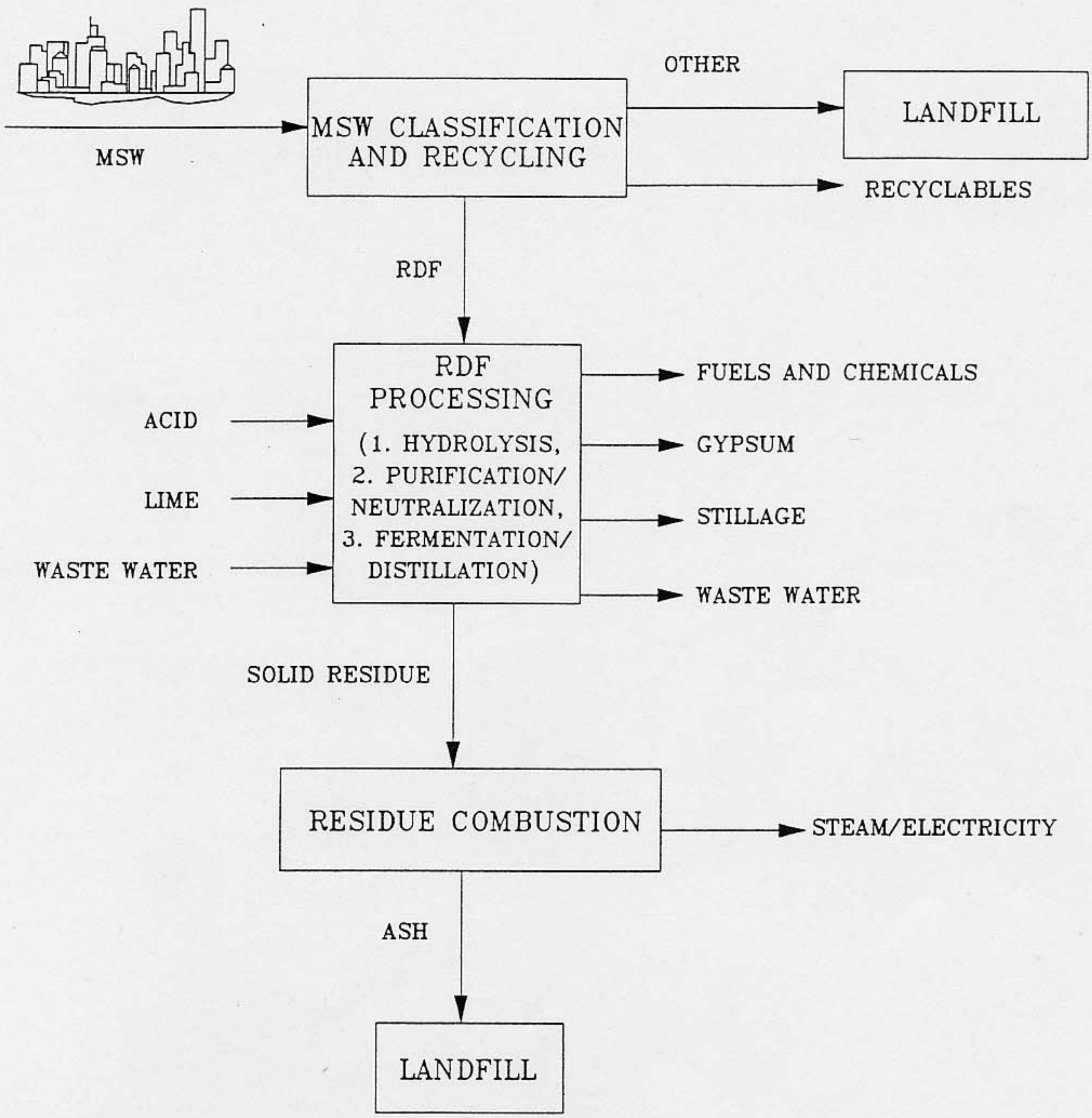

Figure 1. Integrated MSW conversion process.

Source: TVA Biotechnical Research Department, "Municipal Solid Waste and Waste Cellulosics Conversion to Fuels and Chemicals," Volume 1: Summary Report, March 1993.

Table 71 Theoretical Ethanol Yield from Selected Feedstocks[A]

Feedstock	Theoretical Ethanol Yield (gallons/bone dry ton)[B]
Packaging papers	133.4
Corn Stover	113.3
MSW (35% fir, 20% almond tree pruning, 20% wheat straw, 12.5% office paper, 12.5% newsprint)	109.0
Coated paper	98.2
Newspaper	96.1

[A] AEvaluation of Biomass-to-Ethanol Fuel Potential in California,≅ California Energy Commission, December 1999, and AEthanol Industry Outlook: 1999 and Beyond,≅ Renewable Fuels Association, February 1999, Table VIA-A-1, Appendix VI-A.
[B] Bone dry ton is the equivalent of 0 percent moisture content.

Ethanol from a waste-to-ethanol facility typically competes with gasoline produced from crude oil or ethanol produced from other feedstock. The primary current market for ethanol is as a fuel additive in gasoline. Ethanol is also considered an appropriate fuel for fuel cell vehicles, which are being tested as replacements for traditional automobiles powered by internal combustion engines.[108] Ethanol can also be further refined for use in the industrial chemical market.

Ethanol from al sources supplies about 1.2 percent of the highway motor vehicle fuel market in the United States. The Department of Energy expects ethanol consumption to grow to 2.6 billion gallons per year in 2005 and 3.3 billion gallons by 2020. The increase in consumption will increase the ethanol market share to 1.5 percent by 2005. The market share for ethanol is expected to remain at 1.5 percent through 2020. Most is used in a 10 percent blend with gasoline (gasohol).[109] Minnesota, has replaced nearly 10 percent of all gasoline consumption with ethanol. Minnesota also is the second largest consumer of ethanol blended fuels.[110] However, the available capacity to produce ethanol significantly exceeds demand. In Minnesota, 14 existing ethanol plants have the capacity to produce 400 million gallons of ethanol per year.

The MASADA Resource Group, a company actively trying to develop waste-to-ethanol plants, indicates that during the past 20 years, ethanol prices have averaged about $1.36 per gallon while ranging from $1.05 to $1.75 per gallon. Reviewing MASADA=s data shows that the highest recorded revenues occurred prior to 1986. Between 1986 and 1999, prices appeared to range between $1.00 and $1.39 per gallon and to average about $1.15 per gallon. The price has continued to trend downward since 1996, with the 1999 price appearing to be about $1.01 per

[108]DOE, EIA, Annual Energy Outlook 2001, December 22, 2000.

[109]California Energy Commission, pg. II-2.

[110]California Energy Commission, pg. II-10.

gallon. Such a trend would appear to be consistent with a market in which supply exceeds demand.

In assessing factors driving economic viability of biomass-to-ethanol processes, the California Energy Commission noted that biomass to-ethanol=s more established market competitors (AMidwest corn-to-ethanol and Mideast crude oil≌) rely on refineries that produce multiple usable products, rather than a single product, for market viability. Similarly, it wrote, a facility producing ethanol from waste feedstock must seek to maximize the use and marketability of all process outputs, not just ethanol.

7.5 Environmental Concerns/Permitting Issues

Environmental and permitting issues are noted in four areas:

- **Air emissions[111].** Ethanol plants were originally believed to have limited air emissions of ethanol and methanol. In 2001, the MPCA conducted a comprehensive study of emissions from ethanol plants in the St. Paul area. The findings were far reaching and impacted ethanol plants nationwide. The MPCA discovered significant amounts of other VOCs, including acetaldehyde, acrolein, formaldehyde, 2-furaldehyde, acetic acid and lactic acid. Total VOC emissions were measured at ten times what was originally estimated. Further studies conducted at other plants outside Minnesota indicated significant carbon monoxide emissions and higher than predicted particulate matter emissions.

  The study findings resulted in a civil settlement, including installation of advanced pollution control equipment in existing ethanol plants, and penalties ranging from $19,000 to $39,000 for violations to the Clean Air Act.

  As would be expected, a waste-to-ethanol plant would require extensive emissions monitoring and increased emission controls to ensure compliant operations.

- **Wastewater management.** Management processes and permits are likely to be required in the areas of process water management and stormwater discharge. From Genesyst process on MSW fluff conversion to alcohol, a system taking 277 tpd can expect to discharge 100 gallons of waste water per day. However, that analysis assumes a secondary market for the 9,500 pounds per day of acetic acid and 1,800 pounds per day of urea.

- **Solid waste management.** Although the intention may be to create a closed loop process, an ethanol production facility using MSW feedstock must be prepared to manage process residues such as non-marketable recyclables, grit, ash, and scrubber sludges. Depending on the infeed material and success of the individual management components, capacity

[111] Minnesota Pollution Control Agency, "Air Emissions From Ethanol Plants," Air Quality General Bulletin 1.21, October 2002.

may be required at either an MSW or industrial waste landfill. The Genesyst process for 277 tpd MSW fluff conversion process is estimated to produce 63 tons per day of plastics, 28.8 tons of carbon dioxide as acid and 40 tons of inert solids as lime.

- According to 40 CFR Part 79: Registration of Fuels and Fuel Additives as quoted within a TVA report, cellulosic residue and ethanol must be registered with the EPA as new fuel or additives.

The TVA notes that separation of hazardous materials from the feedstock is an Aessential≅ part of a processing operation because of potential effects on Amost, if not all, effluent and product streams.≅[112]

Additionally, regulations of the Bureau of Alcohol, Tobacco, and Firearms should be reviewed because of the creation of a regulated product: ethanol (grain alcohol).

7.6 Applicability to R/W Waste Stream

7.6.1 Capacity/Flexibility

The waste-to-ethanol technology is suitable for the organic fraction of the waste stream. Other processes can be added to a facility to separate recyclables or inorganics and handle the entire waste stream.

Reviewing the preliminary waste quantities in Table 2-5 shows that504tons per day of paper and 403 tons per day of organic materials were projected in the 2003 tonnages. These quantities are projected to grow to 751 and 600 tons, respectively, in 2017.

Using the Genesyst system for ethanol production, mass balance results are based on a waste input of (all percentages by weight):

Paper and paper products	50%
Food wastes	38%
Plastics	7%
Yard wastes	2%
Metals	2%
Other	1%

[112]TVA, Volume IV: Environmental Considerations, p. 35.

The outputs included:

Plastic	22%
Carbon dioxide as acid	10%
Inert solids with lime	14%
Alcohol	16%
Carbon dioxide as gas	7%
Yeast	0.4%
Furfural	1%
Acetic acid	2%
Urea	0.3%
Waste water discharges	0.4%
Water	26.9%

Given the relatively high organic content of the Genesyst mass balance and the R/W waste stream given on Table 2-5, some pre-processing of the waste would be needed to achieve maximum ethanol production for the R/W waste stream.

7.6.2 Minnesota Policies

The Minnesota Ethanol Program is administered by the Minnesota Department of Agriculture. The Department provides the following summary of the Minnesota Ethanol Program[113].

7.6.2.1 Background

The 20-cent ethanol producer payment legislation initially provided the security required by lenders to invest in these small farmer-owned ethanol facilies. In addition to opposition from the petroleum industry, bankers were concerned that these plants could not compete in the market with large agribusiness processors. At the time, most ethanol production occurred in large mills outside the state. Minnesota corn prices were among the lowest in the country, which was advantageous to local processing by farmers.

Although these ventures have been successful to date, margins have been squeezed by periods of record high corn prices and low ethanol prices. It is hoped that ten years of payments will allow plants to retire debt, increase efficiency and to develop new products so they can survive the competition and price fluctuations in agricultural and petroleum markets. Unique aspects of the ethanol industry made these incentive payments necessary, but the ethanol industry will contribute over $350 million in net annual benefit to the state.

Since low farm commodity prices are common, these new corn plants may represent a new strategy for the long-range profitability of farmers and farm communities. Vertical integration from the bottom up could allow farmers to participate in the more profitable end of agriculture. Promoting farmer investments in the processing and marketing of other crop or livestock enterprises may not require the high level of state funding as did ethanol. It is hoped that such

[113] Minnesota Department of Agriculture, Marketing Services Division – Revised January 2002.

initiatives can reduce the need for continual funding of farm financial crisis measures allowing farmers to make it on their own.

7.6.2.2 Main Components

- Oxygenated fuel statute that requires state-wide oxy-fuel (ethanol blend) use;
- The 20-cent per gallon ethanol producer incentive provides payment for ethanol produced, plus
  - $550 million was spent for total corn/ethanol plant construction and start-up costs.
  - $370 million in private sector financing was contingent on local equity capital.
  - $180 million in local equity capital was raised by over 8,000 farmer and business members.
  - $300 million worth of corn is committed for processing annually by local farmers.

7.6.2.3 Goals

- To build a new market for the state's largest crop (corn).
- To develop corn processing/ethanol production facilities in Minnesota.
- To increase the number of New Generation Farmer Coops (NGCs). These businesses were designed to provide farmer members greater direct cash return for their crops.
- To replace 10 percent of imported petroleum we use for gasoline ($100 million annual savings).
- To help the Twin City Area meet US EPA standards for carbon monoxide.

7.6.2.4 Results

- 160 million bushels of corn (20 percent of Minnesota's crop) is made into ethanol and other products.
- Minnesota's 14 plants can produce over 300 million gallons of ethanol per year.
- Twelve of Minnesota's 14 ethanol plants were organized as NGCs.
- Nearly 10 percent of our gasoline is being replaced by ethanol each year.
- The Twin Cities Area met US EPS's carbon monoxide standard and has recently achieved "attainment" status. The continued use of ethanol was required to keep emissions low.

7.7 Current Status

7.7.1 Ethanol Facilities

Reports from the Ohio Corn Marketing Program identify 62 existing or under construction ethanol production facilities in the United States. Table 7-2 summarizes the concentration of facilities by feedstock and current production status.

Of the 62 ethanol facilities described above, Minnesota hosts 14 existing plants, which account for 325.6 million gallons per year or 20 percent of the annual national production capacity. Thirteen of the 14 facilities process corn; one handles cheese whey.

Table 7-2 U.S. Ethanol Production Facility Status[A, B]

Feedstock	No. of Facilities Operating	No. of Facilities Under Construction
Corn and other grains[C]	40	19
Ag waste & residues[D]	6	0
Process wastes[E]	5	0
Sugars and starches	2	0
Paper waste	1	0
MSW	0	0
Wood waste	0	0
Total facilities	54	19
Capacity (gpy) by Facility Status	1.6 billion	413 million

[A] Ohio Corn Marketing Program, "U.S. Ethanol Production Facilities," www.ohio corn.org/ethanol_about_usfacilities.htm.
[B] Bryan and Bryan Inc., "Iowa Ethanol Plant Pre-Feasibility Study," for the Iowa Ethanol Sub-Committee, January 2000.[C] Other grains used as feedstock include barley, milo, and wheat.
[D] Agricultural wastes and residues include potato waste, bagasse and rice hulls, rice straw, and forest residues.
[E] Process wastes include brewery wastes, beverage wastes, and whey.

As can be seen in Table 7-3, two facilities nationwide target or will target components of the municipal solid waste stream. For this report on alternative municipal solid waste processing, it is most appropriate to review results from the limited number of facilities that target strictly MSW components.

Table 7-3 Facilities Targeting MSW Components[A]

Owner	Location	Feestock	Capacity (gpy)	Status
Georgia Pacific	Bellingham, WA	Paper waste	7 million	Existing
MASADA	Middletown, NY	MSW	6.6 million[B]	Proposed

[A] AEvaluation of Biomass-to-Ethanol Fuel Potential in California,≅ California Energy Commission, December 1999.
[B] In a 11 Feb. 2000 interview, MASADA Project Manager David Webster indicated production is likely to be 9 million GPY.

7.7.2 Waste-to-Ethanol Facilities

7.7.2.1 Tennessee Valley Authority, Muscle Shoals, AL

For several years in the late 1980s and early 1990s, the Biotechnical Research Department of the Tennessee Valley Authority (TVA) conducted a pilot project on converting MSW and waste cellulose to ethanol. In 1990, researchers recommended that the TVA conduct a research and development project to provide data for designing a commercial MSW conversion facility. The study was completed for two facilities: one a demonstration facility with a 400 tons per day (tpd) capacity and the other, a commercial facility with a 2,000 tpd capacity.[114]

The study concluded that waste-to-ethanol processing is technically and economically feasible for facilities "processing over 500 tpd of MSW."[115]

Table 7-4 shows projected mass balances for the two facilities (400 tpd and 2,000 tpd).[116]

Table 7-5 summarizes projected capital costs, which were reported in the study as mid-1992 and estimates an equivalent year 2003 value of $263 million for the 2,000 tpd facility[117]. The capital cost averages $131,594 per daily design throughput ton.

Table 7-6 summarizes projected operating costs and also estimates equivalent year 2003 values.[118] The projected $36 million operating cost equates to a gross facility cost of approximately $50 per ton, with an additional $36.0 per ton required to cover annual capital costs (debt service and depreciation).

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[114]Tennessee Valley Authority Biotechnical Research Department, "Municipal Solid Waste and Waste Cellulosics Conversion to Fuels and Chemicals, April 1990 to September 1992 Final Report." March 1993.

[115]TVA, Volume 1: Summary Report, pg. 14.

[116]TVA, Volume 1: Summary Report, pg. 13.

[117]TVA, Volume VI: Technical and Economic Evaluation, pg. 29.

[118]TVA, Volume VI: Technical and Economic Evaluation, pg. 31.

Table 7-4 Process Inputs and Outputs for 400 tpd and 2,000 tpd Facilities[A]

	Demonstration Plant (tpd)	Commercial Plant (tpd)
Input		
MSW	400	2,000
Outputs		
Recyclables	96	477
Ethanol (@ 25 gallons/dry ton of RDF)	15	72
Carbon dioxide	14	71
Cellulosic Residue (@ 50% moisture)	224	1,122
Gypsum (@ 50% moisture)	40	201
Furfural	8	40
Total outputs[B]	397	1,983

[A] Based on 24 hour per day operation and 96 percent plant availability.
[B] Differences between the input and output totals were attributed to moisture loss and incomplete capture (92.6 percent) of furfural.

Table 7-5 TVA=s Capital Investment for 2,000 tpd Waste-to-Ethanol Facility

Cost Breakdown	Total Cost (1992$)	Estimated Cost (2003$)[A]
Direct costs		
MSW classification component	$42,866,400	$56,154,984
Hydrolysis component	$25,410,728	$33,288,054
Purification/neutralization component	$8,687,254	$11,380,303
Fermentation/distillation component	$34,495,266	$45,188,798
Product handling component	$602,601	$789,407
Direct investment	$112,062,249	$146,801,546
Indirect costs		
Engineering and supervision	$8,964,980	$11,744,124
Construction and contractor fees	$16,809,337	$22,020,231
Contingency	$11,206,225	$14,680,155
Indirect costs	$36,980,542	$48,444,510
Other		
Allowance for startup	$11,923,423	$15,619,684
Interest during construction	$14,904,279	$19,524,605
Land	$2,679,760	$3,510,486
Working capital	$22,356,419	$29,286,909
Other costs	$51,863,881	$67,941,684
Total – all costs	**$200,906,672**	**$263,187,740**

[A] Based on the CPI for all Midwest urban consumers from 1992 through 2003.

Table 7-6 TVA's Projected Operating Costs 2,000 tpd Waste-to-Ethanol Facility

Cost Breakdown	Total Cost (1992$)	Estimated Cost (2003$)[A]
Direct costs		
Raw Materials (supplies)	$5,361,351	$7,023,370
Operating labor and supervision	$207,300	$2,760,563
Utilities	$2,103,346	$2,755,383
Waste disposal	$3,569,621	$4,676,204
Waste treatment	$343,876	$450,478
Maintenance	$5,961,712	$7,809,843
Analysis	$316,095	$414,084
Supplies	$894,257	$1,171,477
Direct operating	$20,657,558	$27,061,402
Indirect costs		
Plant overhead	$1,053,650	$1,380,282
Administration overhead	$421,460	$552,113
Marketing overhead	$2,094,425	$2,743,697
Taxes and insurance	$3,569,535	$4,676,091
Indirect operating	$7,139,070	$9,352,183
Total annual operating	**$27,796,628**	**$36,413,585**
Annual capital (debt & depreciation)	**$19,420,978**	**$25,441,481**
Total annual costs	**$47,217,606**	**$61,855,066**

[A] Based on the CPI for all Midwest urban consumers from 1992 through 2003.

Table 7-7 reports assumed revenue credits in both 1992 dollars and estimated 2003 dollars.[119] Note that the estimated 2003 dollars are escalated from TVA assumptions, rather than reported based on current market conditions. The final column in Table 7-7 pulls current market data from a variety of sources including the May 10, 2003,Waste News Commodity Pricing Report. If the current market values were used in place of the TVA=s assumptions, the economic feasibility of a waste-to-ethanol plant decreases from that projected by the TVA researchers.

[119]TVA, Volume VI: Technical and Economic Evaluation, pg. 28.

Table 7-7 Summary of Assumed and Updated Revenue Credits

Revenue Item	$/Unit (1992$)[A]	Escalated $/Unit (2003$)[B]	Typical Value from 2003[C]
MSW tipping fees	$45/ton	$58.95/ton	$40.00/ton
Ethanol	$1.50/gallon	$1.97/gallon	$1.23/gallon[E]
Carbon dioxide	$10/ton	$13.10/ton	--
Furfural	$620/ton	$812.20/ton	--
Cellulosic residue	$0.95/mmBtu	$1.24/mmBtu	--
Aluminum	$900/ton	$1,179.00/ton	$760/ton
Glass	$10/ton	$13.10/ton	$0 to $30/ton
HDPE	$140/ton	$183.40/ton	$300/ton
PET	$140/ton	$183.40/ton	$340/ton
Ferrous metals	$50/ton	$65.50/ton	$102/ton
Non-ferrous metals	$20/ton	$26.20/ton	--

[A] Table 19. Summary of Revenue Credits. TVA: Volume VI: Technical and Economic Evaluation.

[B] Based on the CPI for all Midwest urban consumers from 1992 through 2003.

[C] Unless otherwise noted, based on Aaverage≅ values for Chicago (Midwest region) as reported in Waste Commodity Pricing Report, Waste News, May 10, 2004.

[D] Price is drawn from data supplied by MASADA Resource Group and discussed in Section 7.4.

[E] Price is taken from the Minnesota Department of Agriculture, Market News Report, 2002/2003 Average Price, December 2003.

7.7.2.2 MASADA, Middletown, NY

The MASADA Resource Group of Birmingham, Alabama, is working to open the Orange County Recycling and Ethanol Production Facility on 22 acres adjacent to the Middletown, NY, wastewater treatment facility. Construction on the proposed waste-to-ethanol facility is to begin in late 2004, with waste acceptance beginning in 2006 at full scale operation.[120]

Unless otherwise noted, the following information is drawn from a February 11, 2000, personal interview with MASADA Project Manager David Webster. When open, the Orange County facility is projected to:

- Have an annual capacity of 230,000 tons of MSW and 49,000 tons of biosolids.[121]

- Have permitted capacity of 800 tpd, with an actual working capacity of 650 tpd over a 52 day working week

[120] In a May 21, 2004, interview with MASADA.

[121] AMSW and Biosolids Become Feedstocks for Ethanol,≅ *Biocycle*. August 1999.

- Have a capital cost of approximately $130 million (annual capacity of 230,000 tons) 365 days/year = approximately 630 tpd. $130 million) 630 tpd = $206,000 per daily design throughput ton).

- Have annual operating costs of approximately $38 million per year,[122] which includes:
  - $2 to $5 per MSW ton in host community benefits and payments in lieu of taxes
  - 30 to 40 unskilled or low skilled sorters
  - 90 to 100 skilled to highly trained operators

- Produce 9 million gallons per year of ethanol. Webster noted that new vendor tests caused the production estimate to increase from earlier estimates, including those used by the California Energy Commission (source of Table 7-3).

- Divert 90 percent of the waste delivered through recycling or beneficial conversion.

Exhibit 7-3 shows MASADA as projecting total direct manufacturing costs of $1.37 per gallon of ethanol produced, which is 32 to 42 times more expensive than producing ethanol from corn. However, a facility would pay for corn feedstock but would expect to be paid a tipping fee to accept MSW. At an estimated 2003 ethanol price of $1.23 per gallon, MASADA appears to expect to make up a net cost of approximately $0.14 per gallon from tipping fees and/or the sale of other by-products.

As shown in the pro forma, MASADA has assumed tipping fee revenues equivalent to $1.47 to $3.42 per gallon of ethanol with a facility reported to have an annual production of 6 to 7 million gallons. If annual production is assumed to be 6.6 million gallons as reported by the California Energy Commission, equivalent tipping fee requirements can be calculated to range from $42 to $98 per ton of MSW delivered.[123]

Webster noted that MASADA has a 20-year "put or pay" contract with the City of Middletown, which has additional individual waste delivery agreements with 20 other area communities. Under the contracts, each community pays $60 per ton for the first 10-year period, with an increase to $69 per ton for the second 10 year period.[124] Webster indicated that the contract with Middletown requires MASADA to arrange for independent financing and accept all risk. The contract does not allow for gain sharing or reductions in the minimum delivery requirements, though it does allow for increases in minimum deliveries.

It may be important to note that the MASADA facility has been delayed approximately four years from the schedule reported in the 2000 report prepared for R/W counties.

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[122] Waste News, 17 Jan. 2000.

[123] Calculated as: 6.6 mm GPY x $1.47/gallon = $9,702,000) 230,000 tpy = $42.18/MSW ton
6.6 mm GPY x $3.42/gallon = $22,572,000) 230,000 tpy = $98.14/MSW ton

[124] *Waste News*, 17 Jan. 2000.

7.8 Implementation Assumptions for Ramsey/Washington Consideration

7.8.1 Site Needs

MASADA=s Webster noted that a site size of approximately 30 acres would be optimum for the planned 230,000 tpy operation in Middletown, NY.

A facility would preferably be co-located with a landfill, recycling center, or other waste handling facility to increase access to feedstock. It may also be co-located with an energy user to provide a market for non-ethanol by-products.

7.8.2 Typical Capital Costs

Webster indicated he believes the threshold for economic viability to be a facility with the capacity to handle at least 500 tpd of MSW and 150 to 200 tpd of bone dry (0 percent moisture) sludge. Assuming the host municipality is supportive of the process, he indicated capital costs are likely to range from $100 million to $150 million ($200,000 to $300,000 per daily design throughput MSW ton and $145,000 to $215,000 per daily design throughput ton of MSW and sludge) for the threshold facility.

The TVA studies showed a capital cost of approximately $131,600 per daily design throughput ton. For a facility processing at least 500 tpd, which TVA also reported to be the economically and technically viable level, this would reflect capital costs of roughly $66 million.

There does not appear to be a track record established for capital costs. Experience with other solid waste technologies indicates that capital costs rise as experience is gained (problems arise and are addressed with facility improvements). For purposes of estimating capital costs, a cost of $200,000 per daily design throughput ton may be used.

7.8.3 Typical Break-even Cost Per Ton

Webster indicated that tipping fees to support capital and operating costs for a threshold facility would be likely to range from Athe high $40s to the mid-$60s per ton,≅ exclusive of the costs of waste collection and transfer. Using an estimated market price for ethanol of $1.01 per gallon, MASADA=s pro forma appears to indicate facility tipping fee could range from $42 to $98 per ton of MSW delivered.

TVA=s studies indicated a gross facility operating cost of approximately $50 per ton, with an additional $36.50 per ton required to cover annual capital costs (debt service and depreciation).

There is not a significant track record of operating costs to provide a typical break-even cost per ton. Until there is more operating data, it is safer to assume break-even costs on the high sideXperhaps $80 to over $100 per ton.

7.8.4 Implementation Needs and Timeline

Among implementation needs for a waste-to-ethanol facility are likely to be development of a collection system to accommodate source-separated organic wastes and facility siting in proximity to one or more existing waste management facilities. Additionally, work may be needed on existing Minnesota state policies supporting ethanol production and use to ensure their support of waste-based ethanol, as well as corn-based ethanol.

Based on comments and data on the existing and proposed facilities, implementation is likely to require a minimum of five years from the date a decision is made about technology use to beginning operations.

7.9 Advantages and Disadvantages

Table 7-8 summarizes several advantages and disadvantages of the waste-to-ethanol technology.

7.9.1 Comparison of Advantages/Disadvantages

While there appears to be some growing interest in this technology, it simply is not a proven MSW management technology at this time. There is currently very limited technical application to MSW and a lack of history with regulating agencies. Capital and operating cost history is limited and unsettled. To successfully perform using organics from MSW may require source-separated collection of the organics or front-end processing to separate the organic fractionXeither of which will increase the system costs. Markets could develop significantly, but at this point, the ethanol market prices are down and demand could be met with corn plants. Marketing of the by-products is untested.

7.9.2 Observations

Despite the potential disadvantages, the technology may offer some long-term advantages worth continued observation of its development. If there are waste-to-ethanol plants built that handle MSW successfully and prices for petroleum-based fuels continue to increase, the technology could surface as a viable alternative in the future.

Table 7-8 Potential Advantages and Disadvantages of Waste-to-Ethanol Processes

Advantages	Disadvantages
Minnesota supports and promotes use of ethanol as a fuel additive	Limited technical application with MSW
Use of bioproducts and bioenergy is encouraged by a Presidential Executive Order	Lack of history with regulators
May offer opportunities to expand the market uses of MSW.	Capital/operating cost history is limited, unsettled, and likely high
May offer benefits toward sustainable development and resource conservation	Market demand for ethanol could be met by corn plants
	Markets for other products need to be developed
	May require separate collection or front-end processing—raising costs

8. Anaerobic Digestion

8.1 Definition and Overview

Anaerobic Digestion (AD) in the broadest sense is a process to degrade organic material in the absence of oxygen. AD therefore can be used to break down the organic fraction of waste. This includes paper, yard waste, food waste and other organic waste. AD naturally occurs in landfills over a long period of time. However, rapid AD will be reviewed in this section.

The following sections will examine AD feedstocks, processes, products/by-products, environmental issues, current facilities, and applicability to the R/W counties waste stream.

8.2 Feedstock

As discussed, the AD process is limited in applicability to only organic wastes. For AD processes, feedstocks are grouped as follows[125].

8.2.1 Energy Crops

The potential for energy crop digestion is similar to that of bioethanol and biodiesel. Selecting crops over wastes will increase the biogas production, as crops generally have lower lignin levels than the residues that have traditionally been treated using anaerobic digestion. Studies have been carried out on a wide range of substrates, including oats, maize, grasses and hay – with much better gas production rates than have been achieved with wastes.

8.2.2 Agricultural Wastes

The largest sources of wastes are the manures and crop residues that are derived from food production. Currently these wastes are either disposed of or applied to the land with further treatment. Anaerobic digestion can prove to be beneficial in the management of these wastes by reducing the environmental impact and the pathogen levels and by improving the utilization of the nutrients and the humus-forming organics fraction.

8.2.3 Industrial Process Wastes

The main sources of organic wastes will be the food and drink industrial wastewaters, and anaerobic digestion is currently used extensively for treating these wastes. However, there are many more food and drink residues, in particular the solid residues such as vegetable packing, abattoir waste and oilseed wastes, that could also be treated. Other industries will have lower overall quantities of suitable feedstocks, but there are opportunities for residues from the pharmaceutical, paper and rubber production industries, for example.

[125] "Commercial and Strategic Perspectives of Anaeorobic Digestion," Wheeler, Patrick, www.jxj.com/wmw/yearbook/anaerobic-chtml, 2000.

8.2.4 Municipal Solid Waste

Municipal waste covers both sewage and garbage. Sewage treatment using anaerobic digestion is widespread and will not be considered further here. Solid domestic waste can be treated either as a source separated feedstock or as a mixed waste.

8.3 Process[126]

Anaerobic biodegradation of organic material occurs without oxygen and includes microorganisms that thrive in the oxygen free environment. AD is the end result of a series of metabolic interactions that occur among multiple microorganisms. The first group of microorganisms break down materials to glucose and amino acids. The second group further reduces the glucose and amino acids to volatile fatty acids, hydrogen, and acetic acid.

The third group of microorganisms convert hydrogen, carbon dioxide, and acetate to methane. The AD process is usually carried out in large vessels, called digesters, and is conducted at 30°C to 65°C.

For a full-scale AD process for MSW, four distinct stages are common to all systems. Stage 1 is pretreatment of the waste. Most AD processes require pretreatment of the feedstock to increase homogeneity, separate out non-digestible material and shredding to have a uniform particle size.

Stage 2 is waste digestion. Digestion can either be a wet or dry process. Wet processes include wet single-step and wet multi-step. Dry processes include dry continuous, dry sequencing batch and dry multi-step.

The wet single-step process is where waste is slurried with water (either fresh water, waste water or recycled water from the process) to make a 10 to 15 percent total solids slurry. The slurry is fed into a mix tank digester. In the digester, the mixture is continuously stirred.

In the wet multi-step process, the MSW is slurried like the single-step process, but then allowed to ferment to release fatty acids. The released fatty acids are converted to biogas in an anaerobic digester. A new percolation system is also a wet multi-step process. In a percolation system, the waste is anaerobically percolated. The result is an organic-rich liquid that is further digested to make biogas.

The dry continuous process is not totally dry. Waste is slurried to obtain a mixture of 25 to 40 percent total solids. The slurry then enters a vertical or horizontal mixer and is digested anaerobically.

In the dry sequence batch system, three tanks or vessels are used. Each vessel contains digested materials at different stages. The approach is to inoculate feedstock with liquid from the

[126] Verma, Slefali, "Anaerobic Digestion of Biodegradeable Organics in Municipal Solid Waste," MS Thesis, Columbia University, 2002.

previous cycle. This activity speeds the process of anaerobic breakdown and provides a vessel for each group of microorganisms.

The dry multi-step process is where the waste first enters a hydrolysis reactor followed by three separate reactor vessels. Each vessel treats the waste at a specific degradation point.

Stage 3 is gas recovery and treatment. In this stage, the methane recovered from the AD process is scrubbed, or cleaned, to produce pipeline quality gas. Much like landfill gas, AD produced gas from MSW will be saturated and contain approximately 50 percent methane and 50 percent carbon dioxide with some trace gases. The trace gases, carbon dioxide and moisture must be removed. Table 8-1 shows the typical biogas composition.

Table 8-1[127] Typical Biogas Composition

Item	Quantity
Biogas	100-200 m^3/ton organic MSW
Methane	55-70% by volume
Carbon dioxide	30-45% by volume
Hydrogen sulfide	200-4,000 ppm by volume
Energy content	20-25 MJ/standard m^3
Energy content clean methane	167-373 MJ/ton MSW

Stage 4 is residue treatment. When digestion is complete, the water is removed and the remaining solid materials are cured aerobically in compost piles. The compost product is usually screened to remove deleterious materials (glass, plastic, etc.) and marketed.

The quality of the compost will depend on the waste composition entering the AD process. With good pre-treatment of the waste, a marketable product may be achievable. The Minnesota Pollution Control Agency has established the following requirements for Class I and Class II (restricted use) compost derived from MSW.

Contaminant	Maximum Concentration (Mg/Kg)
Arsenic	41
Cadmium	39
Copper	1,500
Lead	300
Mercury	5
Molybdenum	18
Nickel	420
Selenium	100
PCBs	6
Zinc	2,800

[127] Regional Informational Service for Southeast Asia, November 1998.

Inert material may not be greater than four millimeters in size or 3 percent (dry weight) of the compost.

Class II Compost Loading Rate

Contaminant	Loading Rate (lb/acre) Cumulative	Annual
Arsenic	37	1.8
Cadmium	34	1.7
Copper	1,338	66.8
Lead	267	13.3
Mercury	5	0.25
Molybdenum	16	0.5
Nickel	374	18.7
Selenium	89	4.5
Zinc	2,497	124.6

PCB concentration cannot exceed 6 mg/Kg. Compost can not contain more than 4 percent inert material (dry weight) or have a particle size greater than 4 millimeters.

Most MSW derived compost does not meet the requirements for Class I compost due to the metals loading.

8.4 Previous Experience

8.4.1 RefCom

Using research conducted at the University of Illinois, the first full-scale AD was built in Pomparo Beach, Florida, in the early 1980s. The system, called RefCom, consisted of two continuous stream wet reactors of 44,100 cubic feet capacity. The original design was for 110 tons per day. The system was not successful due to the lack of adequate pretreatment.

8.4.2 European Experience

Worldwide, there is an estimated 130 large AD plants that digest the organic portion of MSW or industrial waste. All but five of the plants are located in Europe. Table 8-2 provides a summary of the large facilities.

Table 8-2 Large AD Facilities Operating with Digestion

System	Country	City	Type of Waste	Ton/Year	Start-up
BTA/Roediger	Poland	Pulawy	MSW	24,200	2001
BTA	Italien	Villacidro	MSW	38,500	2001
Citec	Finland	Vaasa	MSW, Biowaste	16,500	1994
Citec/Vagron	Holland	Groningen	Grey Waste	253,000	2000
Dranco	Germany	Gassum	Grey Waste	14,850	1997
Dranco	Germany	Kaiserslautern	Grey Waste	22,000	1999
Dranco	Italy	Rome	MSW	44,000	2002
Dranco	Spain	Alicante	MSW	33,000	2002
ISKA	Germany	Buchen	Grey Waste	27,500	2000
Ionics Italbia	Italy	Bellaria	MSW	4,400	1988
Linde	Spain	Barcelona Ecoparc	MSW	165,000	2002
Snamprogetti	Italy	Verona	MSW	55,000	1998
Valorga	Belgium	Mons	MSW	41,250	2001
Valorga	France	Amiens	MSW	93,500	1988
Valorga	France	Varennes-Jarcy	MSW	110,000	2001
Valorga	Italy	Bassano di Grappa	MSW, Biowaste, SS	60,500	2002
Valorga	Spain	Cadiz	MSW	126,500	2001
Valorga	Spain	La CoruZa	MSW	156,200	2001
Wehrle Werk	Germany	Kahlenberrg	MSW	22,000	2001

Each plant in Europe uses one of the basic processes described previously. The major AD suppliers have potential processes to generate the biogas and compost from the organic waste. Centralized source separation is also a critical component to the process.

Performance of the plants varies by process and feedstock. To provide a general overview of plant performance, Table 8-3 shows general performance for some European plants.

Table 8-3 Performance Data of AD Plants

Location	Waste Type*	Waste Tons/Yr	Ft3 Digester	Ft3 Gas Production	Ft3 Biogas/Ton	Ft3 gas/Ft3 Digester/Day	lbs./Day/ Ft3 Digester
Aarburg	Yard	12,128	52,973	28,605,150	2,359	1.48	1.25
Baar	Yard	4,410	16,951	13,419,700	3,043	2.17	1.43
Bachenbηlach	Yard & Food	9,482	18,364	30,017,750	3,166	4.48	2.83
Baden-Baden	Food & Kitchen	7,166	211,890	51,206,750	7,146	0.66	0.19
Braunschweig	Kitchen	17,640	59,329	60,035,500	3,403	2.77	1.63
Buchen	MSW	110,250	141,260	141,260,000	1,281	2.74	4.28
Geneva	Yard	13,230	35,315	42,378,000	3,203	3.29	2.05
Grindsted**	Biosolids & Food	38,036	98,882	22,954,750	603	0.64	2.11
Holsworthy**	Manure & Food	160,965	282,520	137,728,500	856	1.34	3.12
Karlsruhe	Yard & Kitchen	8,820	47,675	30,935,940	3,507	1.78	1.01
Lemgo	Yard & Kitchen	37,485	90,053	134,197,000	3,580	4.08	2.28
Mηnchen	Yard & Kitchen	27,563	84,050	52,972,500	1,922	1.73	1.80
Niederuzwil	Yard	11,025	31,784	30,724,050	2,787	2.65	1.90
Otelfingen	Yard	13,781	29,665	38,846,500	2,819	3.59	2.55
Rηmlang	Yard & Food	7,718	16,245	28,252,000	3,661	4.76	2.60
Samstagern	Yard & Food	8,489	18,364	28,958,300	3,411	4.32	2.53
Average		30,512	77,207	54,530,774	2,922	2.65	2.10

*When there is more than one type of waste, the higher percentage feedstock is provided first.
**While not a part of the survey, sufficient information was gathered to make consistent comparisons.

As Table 8-3 indicates, large variabilty in production of biogas can be expected depending on the quality and quantity of the feedstock.

Cost data for the plants is provided in Table 8-4. The table indicates large variation in the installed cost per ton. This variation can be attributed to the type of waste to be processed.

Table 8-4 Investment Data of AD Plants

	Type	Provider	Waste Tons/Year	Installed Cost $	Installed Cost $/Ton	Remarks
Baar	Dry	BRV	4,410	14,000,000	3,175	w/8,800 tons/yr composting
Baden-Baden	Wet	BTA	7,166	3,470,000	484	Cogen added
Braunschweig	Dry	Kompogas	17,640	10,200,000	578	w/post-composting
Buchen	Wet	ISKA	110,250	15,500,000	141	Earlier work cost
Geneva	Dry	Valorga	13,230	5,100,000	385	
Grindsted	Wet	Kruger	38,036	8,860,000	233	
Holsworthy	Wet	Farmatic	160,965	8,000,000	50	
Lemgo	Dry	BRV	37,485	15,600,000	416	w/building
Mηnchen	2-Stage	BTA	27,563	10,500,000	381	w/pretreatment & planning
Niederuzwil	Dry	Kompogas	11,025	4,100,000	372	w/o air treatment
Otelfingen	Dry	Kompogas	13,781	5,350,000	388	
Average			40,141	9,152,727	228*	

*Weighted average,

8.5 Advantages and Disadvantages

Advantages and disadvantages of AD systems are presented in Table 8-5. In general, AD systems are effective for processing the organic portion of MSW but ineffective at non-organic waste. Thus, expensive pre- and post-processing activities are usually required to eliminate contamination.

Table 8-5 AD Advantages and Disadvantages

Advantages	Disadvantages
Relatively low capital costs compared to most thermal processes	Uncertainties over the economics and practical applications of AD to treat MSW. AD technology for various homogenous waste streams is widely proven in Europe, but there are no full scale plants in operation in the U.S. on municipal derived wastes.
State-of-the art technology in global use including pollution control technology.	AD of MSW will need to rely on comprehensive pre-processing of the waste or source separation; plastics for example, can cause operational difficulties. Some systems however are designed to operate with mixed municipal type wastes.
Energy recovery potential (methane generation) and possible sale of surplus.	Odor emissions during material handling.
Reduces organic wastes from landfill, which reduces the production of landfill gas and leachate.	Does not treat the whole MSW stream, only the organic fraction, however may be used on residual municipal waste stream with contaminants rejected as part of the process.
Enclosed system reduces environmental impacts.	AD is more capital intensive than composting.
	Materials handling problems with front-end processing can be costly
	Contamination of final product often difficult to avoid; marketing problems.
	Gas handling, storage and cleanup facilities are required, which can be costly.

8.6 Applicability to Ramsey/Washington County Waste Stream

Currently, organic waste comprises 61 percent of the waste stream in R/W counties. This equates to about 920 tons per day of organic solid waste suitable for an AD process. The remaining estimated 580 tons perday would be required to be separated or somehow removed either prior to or post the AD process.

An AD process to handle current and future waste loads would need to be about two to three times the largest plant in Europe (see Table 8-2). This plant would need to be constructed in addition to the current RDF process since front-end separation of non-organics would be needed.

8.7 Estimated Process Outputs and Costs[128]

Based on a daily throughput of 920 tons per day, the following output is estimated from an AD type process:

Biogas	65 – 92 tons
Water vapor	110 tons
Fugitive emissions	19 tons
Waste water	165 – 207 tons
Non-organics to landfill	46 – 185 tons (depends on pre-process)
Digested material	185 – 460 tons

The biogas produced would require further scrubbing to produce a saleable quality of gas. The digested material, depending on composition, may have marketing potential as compost. However, Class I compost is difficult to achieve from MSW using an AD process.

[128] Adapted from information provided at http://www.mbt.landfill-site.com/AD/ad.html

Appendix A

Regulatory Agency Descriptions

Regulatory Agency Descriptions

Federal

(1) United States Environmental Protection Agency (EPA)

Federal environmental regulations are handled by the EPA. State regulatory agencies are allowed to adopt their own regulations, but typically these must be equal to or more stringent than federal regulations. The Minnesota Pollution Control Agency (MPCA) has adopted regulations for Minnesota that have been reviewed and approved by the EPA. Although Minnesota regulations reflect federal regulations, the EPA is not directly involved in permitting dedicated combustion facilities in Minnesota. The MPCA manages the permitting process.

EPA regulations that apply include the Standards of Performance for New Stationary Sources (NSPS) and New Source Review (NSR), which includes Prevention of Significant Deterioration (PSD).

(2) United States Army Corps of Engineers (USACE)[1]

The Rivers and Harbors Acts of 1890 and 1899 authorized the USACE to prevent unauthorized obstruction or alteration of any navigable water of the United States. This includes the construction, excavation, or deposition of materials in, over, or under such waters, or any work that could affect the course, location, condition, or capacity of those waters. These Acts give the USACE authority over the construction of intake structures, discharge structures, dredging, and filling of the Mississippi River. If water is pumped from or into the Mississippi River, the USACE is authorized to issue or deny issuance of a permit to construct the intake and discharge structures. Although the USACE does not have authority over pumping to or from the Mississippi River, they will make comments on the Environmental Impact Statement (EIS), discussed in Section 3.2.1.

(3) United States Fish & Wildlife Service (USF&WS)

The USF&WS may make comments on the EIS. If any unknown USF&WS compliance issues exist, the USF&WS will clarify them in their comments on the EIS.

(4) Federal Aviation Administration (FAA)[2]

Any facility constructing a stack within a 6-mile radius of an airport must submit a Proposed Construction Alteration Form (Form 7460-1). The same form is required for stacks 200 feet in height or greater and located more than 6 miles away from an airport. With Form 7460-1, the FAA will perform an Air Space Review. The FAA will decide if the stack can be built and if the stack requres lighting. NRG is located less than 4 miles from the St. Paul Downtown Airport.

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[1]USACE website www.usace.army.mil/inet/functions/cw/cecwo/reg/oceover.htm.

[2]Phone conversation with Mike Pinkley, FAA Airport Program Analyst, March 8, 2000.

State

(5) Minnesota Pollution Control Agency (MPCA)

Most of the permitting process for dedicated combustion facilities is done through the MPCA. Permits required by the MPCA include a Title V Air Permit and a National Pollution Discharge Elimination System (NPDES) Permit. Each of these permits will be discussed in Section 3.2.

A dedicated combustion facility is classified by the MPCA as a major facility. Major facilities may require preparation of an EIS. An EIS determines if a project may have "potential for significant environmental effects." It also determines the economic and sociological impacts of the proposed permit. An Environmental Assessment Worksheet (EAW) can be completed to determine if an EIS is necessary. Since Minnesota State Rules, Chapter 4410.4400, Subp.13, require that dedicated combustion facilities perform an EIS, an EAW is not necessary.

(6) Minnesota Public Utilities Commission (PUC)

The PUC requires that any new electricity generators obtain a Certificate of Need. If the additional generation of electricity is not needed, this certificate is not issued. Since this facility would generate approximately 60 to 80 megawatts (MW) and be located near St. Paul, it is expected that the need to obtain a Certificate of Need from the PUC will be a possibility. This is usually a one-year process.

(7) Minnesota Department of Natural Resources (DNR)[3]

The Minnesota DNR will make comments on the natural resources portion of the EIS. If any natural resource related compliance issues exist, the DNR would clarify them.

Minnesota Statutes, Chapter 103G.265, and Minnesota Rules 6115.0620 require that any facility appropriating more than 10,000 gallons per day (gpd), or 1 million gallons per year (gpy) must obtain a Water Appropriation Permit from the DNR.

There are wetlands located north of NRG on adjacent property. If there was a need for construction on this area for part or all of the dedicated combustion facility, the DNR would likely be involved in mitigating these wetlands.

(8) Minnesota Legislature (Legislature)

The Minnesota Legislature passed a law regulating the construction and operation of incinerators. 1984 Minn. Laws ch. 654, art. 2, sec. 29, limits the capacity of a waste combustor built in large cities. Minnesota Statute 116.85 has specific requirements for incinerators, including (a) a monitor for good combustion, indicating dioxin destruction, (b) mercury testing frequency, and

[3]**DNR website: www.dnr.state.mn.us/waters/programs/plu_section/approprirations/progdesc.html.**

(c) mandatory shutdown if emission exceedances cannot be corrected within a given amount of time. The MPCA waste combustor rules were written to incorporate this statute.

Local

(9) County

Counties typically require a Conditional Use Permit (CUP) for construction and operation of a dedicated combustion facility. The CUP usually requires a commitment to noise control, odor control, and aesthetic landscaping of the facility[4]. Earth berms, constructed walls, and proper equipment maintenance are used to comply with noise requirements. Since dedicated combustion facilities can only be sited in industrially zoned areas, hours of operation are typically not a problem. Indoor storage of waste prior to incineration, differential negative pressure maintained in the incinerator, and proper design of stack height are used to comply with odor control. Professional landscaping, tree planting, and regular lawn maintenance are used to comply with aesthetic requirements.

(10) City

Cities also may require a CUP, and issues covered are generally similar to those addressed in the county CUP.

[4] DNR website.