Waste-to-Energy (WTE) Options and Solid Waste Export Considerations

Prepared for

King County Solid Waste Division
201 S. Jackson Street, Suite 701
Seattle, WA 98104

Prepared by

Normandeau Associates, Inc.
1904 Third Avenue, Suite 1010
Seattle, WA 98101
www.normandeau.com

in conjunction with

CDM Smith Inc.
14432 SE Eastgate Way, Suite 100
Bellevue, WA 98007

and

Neomer Resources LLC
12623 SE 83rd Court
Newcastle, WA 98056

September 28, 2017

Contents

List of Figures

List of Tables

Acronyms and Abbreviations

2001 Plan	*Comprehensive Solid Waste Management Plan*
AD	Anaerobic Digestion
AMR	Advanced material recovery
APC	Air pollution control
ARC	Advanced Recycling Center
ASTM	American Society for Testing and Materials
ATR	Advanced Thermal Recycling
BNSF	Burlington Northern/Santa Fe
Btu	British Thermal Units
C&D	Construction and Demolition
CFC	Chlorofluorocarbon
CHP	Combined heat and power
CHRL	Cedar Hills Regional Landfill
CMMS	Computerized Maintenance Management Systems
CO_{2e}	CO_2 equivalent emission
DEQ	Department of Environmental Quality
DOE	Department of Energy
ENR	Engineering News Record
EPA	Environmental Protection Agency
EU	European Union
FDEP	Florida Department of Environmental Protection
FGT	Flue gas treatment
GHG	Greenhouse Gas
HHV	Higher Heating Value
HHW	Household Hazardous Waste
HVAC	Heating, Ventilation, and Air-Conditioning
IPCC	Intergovernmental Panel on Climate Change
ISWM	Integrated solid waste management
IWS	Idaho Waste Systems, Inc.
kWh	Kilowatt hour
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
mgd	Million gallons per day
mgy	Million gallons per year
MRF	Material Recovery Facility
MRR	Greenhouse Gas Mandatory Reporting Rule
MSW	Municipal solid waste
MVR	Müellverwertung Rugenberger Damm
MW	Megawatt

MWh	Megawatt hours
MWPF	Mixed Waste Processing Facility
NENMRLF	Northeastern New Mexico Regional Landfill
NO	Nitric Oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O&M	Operational and maintenance
PM	Particulate matter
POTW	Publicly owned treatment works
PPA	Power Purchase Agreement
ppm	Parts per million
ppmv	Parts per million by volume
PTFE	Polytetrafluoroethylene
PURPA	Public Utility Regulatory Policies Act
PV	photovoltaic
RDF	Refuse-derived fuel
REC	Renewable Energy Credits
SCAQMD	South Coast Air Quality Management District
SCR	Selective Catalytic Reduction
SDA	Spray Dryer Absorber
SNCR	Selective Non-Catalytic Reduction
SPU	Seattle Public Utilities
SRM	Secondary Raw Material
SRRL	Simco Road Regional Landfill
SWD	Solid Waste Division
tpd	tons per day
tpy	tons per year
Transfer Plan	*Solid Waste Transfer and Waste Management Plan*
UP	Union Pacific
USDA	US Department of Agriculture
VDI	Verein Deutscher Ingenieure
WARM	Waste Reduction Model
WM	Waste Management of Washington
WSDOT	Washington State Department of Transportation
WTE	Waste-to-Energy
WWTP	Wastewater treatment plant

Executive Summary

Introduction

King County's only active landfill, Cedar Hills Regional Landfill (CHRL), is expected to close in 2028 when the landfill reaches capacity. The County's current policy, as described in the 2007 *Solid Waste Transfer and Waste Management Plan,* is to transition toward exporting its municipal solid waste by rail to a regional landfill when CHRL closes. The King County Solid Waste Division (SWD) is working with its advisory committees to update the *2001 Comprehensive Solid Waste Management Plan*, evaluating long-term disposal strategies and considering options such as energy generation, resource recovery, reuse and recycling, waste-to-energy (WTE) and other conversion technologies in addition to waste export, including partial early export.

The purpose of this *2017 Waste-to-Energy Options and Solid Waste Export Considerations* document is to inform the County's long-range planning efforts. The first part of this report provides an overview of modern WTE technologies currently in use across North America, Asia and Europe, and summarizes the options for WTE facilities. The report presents technological, environmental, and financial criteria to consider in evaluating the feasibility of a WTE facility, and provides a recommendation of the Best Fit for WTE technology and facility sizing options to meet King County's projected solid waste disposal needs. The second part of the report updates solid waste export information presented in the County's 2007 *Solid Waste Transfer and Waste Management Plan,* providing an overview of capacity remaining at regional landfills and potential rail capacity for transporting solid waste.

The report uses the 50-year planning horizon of 2028–2078 to provide context for the scale of future disposal needs. In 2016, the quantity of solid waste requiring disposal was 922,000 tons. The County projects that by 2028, the first year of the planning horizon, the annual quantity of waste requiring disposal will be 1.1 million tons, and by 2078 approximately 2.18 million tons of solid waste will require disposal annually. These waste projections assume the recycling rate to be at 57% in 2018 and remains at 57% through 2078.

Waste-to-Energy Trends

The WTE industry in the US evolved from the early generation of waste incinerators in which wastes were combusted without energy recovery, primarily as a means of volume reduction and waste stabilization. The birth of the modern WTE industry in the US started approximately 42 years ago in 1975 with the construction of facilities in Ames, Iowa, and Saugus, Massachusetts, which are still processing municipal wastes today. There are three general combustion technologies used in North America for reliable and proven processing of municipal solid waste (MSW): massburn, refuse-derived fuel (RDF), and modular massburn.

In North America, there are 85 operating WTE facilities, with 77 facilities in US and 8 in Canada. WTE facilities located on the West Coast of North America include: Vancouver, BC; Spokane, Washington; Portland, Oregon; Stanislaus, California; Long Beach, California; and Commerce, California. The range of WTE facilities varies from 12 tons per day to 3,300 tons per day facilities with typical recovery of the heat of combustion via electricity, combined heat and power, and steam. Typical WTE facilities have demonstrated long-term operational history, with 80 of the WTE facilities currently in operation built prior to year 2000.

Modern WTE facilities continue to advance toward the goals of sustainability, which include significant reductions in emissions (air, water, and solids), reduced use of water, chemicals and reagents, improved recovery of energy, metals and minerals from bottom ash enabling the utilization of the bottom ash as an aggregate, and improved benefits to the local and regional communities that use the facilities.

WTE Options and Evaluation

Waste conversion technologies are typically classified in one of three categories: thermal processes (combustion, gasification, pyrolysis), biological/chemical processes (anaerobic digestion, composting, acid and enzymatic hydrolysis, biological and catalytic fermentation), or physical processes (refuse-derived fuel, or engineered fuel).

The primary focus of this study evaluated eight WTE technologies (four considered proven and four emerging) to identify the potential Best Fit for King County. The study used a set of nine evaluation criteria covering technology, environmental and financial considerations. The results indicated that the most appropriate and Best Fit technology to process King County’s solid waste, given the current waste projections and solid waste composition, is a thermal process that uses grate combustion with a waterwall boiler (also referred to as massburn which is the process of MSW being received and fed unsorted into combustion units), and which includes numerous innovations and design features of advanced thermal recycling (generally practiced in Europe).

WTE Facility Sizing and Plant Configuration

The composition and projected quantity of the County’s solid waste over the 50 year planning horizon was used to help establish the potential number and size of the combustion units needed in a WTE facility. Two strategies were considered in the sizing of the WTE facility: sizing the WTE facility to maximize the available capacity, with future additions to increase capacity as needed, and sizing the WTE facility to minimize bypass waste. The report presents facility scenarios based on a 20, 30-and 50-year planning horizons.

The report recommends that the County consider sizing WTE facilities to minimize the amount of bypass waste from beginning to the end of the planning horizon. This would allow the County to reduce the reliance on alternate disposal methods, reduce the quantity of waste sent to an out-of-county landfill, provide the County the option to fill any unused capacity by accepting waste from other municipalities or special waste programs, and expand the recycling system and opportunities for the County-owned and operated recycling facilities to produce secondary raw materials made in Washington.

Some potential issues with this option include unused capacity at the beginning of the planning horizon, inefficiency of incoming waste being able to meet the efficient operating range of the WTE facility, and frequent shutdowns or operating some of the units at reduced load may be required during periods when waste deliverables are unable to meet the capacity requirements. WTE facilities can be designed to accommodate future expansions (additions of one or more combustion lines) after first commissioning.

The report discusses a number of innovations and features being developed by the WTE industry in the areas of environment, technology, economics, aesthetics and landscaping, and community benefits that provide a wealth of options for achieving desired objectives. The report presents a set of recommended innovation and design features and other options for consideration by King County. These include options for a WTE facility with excess capacity at start and projected to be at full capacity at the end of the financing period ranging from 4,000 tpd to 6,300 tpd, recommended site layout and building systems, and the ability to accommodate future expansion. Other recommendations include electrical systems and mechanical systems, APC/FGT System, process improvements, and operation and maintenance improvements. The report also suggests processes to benefit system users and rate payers and other programs that generate community benefits.

WTE Financial Analysis

Key financial variables necessary to estimate costs and revenues associated with the Best Fit WTE facility include capital and operating costs, estimated sales of electricity to local electric utilities, gross and net electrical energy generation, ferrous and nonferrous metal recovery rates and sale prices, ash and bypassed waste disposal costs. The preliminary financial analysis estimated year 1 (2028) costs at $126.34/ton (20-year analysis), $109.25/ton (30-year analysis) and $119.15/ton (50-year analysis). A number of sensitivity runs were conducted on 20, 30 and 50 year WTE scenarios to help identify options that could improve the financial performance of a WTE facility, which indicated that various combinations of scenarios can result in reducing tipping fee rates to $100/ton or less in 2028.

Elements of a Feasible WTE Project

Key elements of a successful WTE project include: economics, reliability, impact on waste collections, public acceptability, environmental impact, government commitments, and contractual agreements.

WTE Greenhouse Gas Analysis

A preliminary analysis of the greenhouse gas (GHG) emissions of a potential WTE facility was conducted using two different methods: the Waste Reduction Model (WARM) and the Greenhouse Gas Mandatory Reporting Rule (MRR). Each method is designed for different purposes and should not be compared. The WARM assessment determined that the WTE facility may have a lifecycle GHG emissions potential ranging from 12,073 to 125,357 metric tons of CO_{2e}. According to the MRR, total greenhouse gases could range from 1,246,347 to 1,962,997 metric tons of carbon dioxide equivalent at full throughput. Future analysis must be conducted to assess the comparative GHG emissions of various management methods and scenarios.

Advantages & Disadvantages of WTE

The general advantages of the thermal WTE process include reduction of landfill volume, environmental and land usage, air quality, surface and groundwater, economic performance, WTE-derived energy, societal impacts, special programs/opportunities for enhanced community benefits, and integration with other waste management options to understand the full advantages offered by WTE.

General issues/disadvantages of WTE include relatively high capital cost, need for backup/supplemental landfill capacity, limitations on steam and electricity markets, publicly available information on modern WTE capabilities, variability in methods for accounting of GHG emissions, need for consistent, long-term flow as input to WTE facilities, and impact on community recycling goals/performance.

The report presents eight existing WTE facilities that exemplify the technologies and components the county should consider in moving forward. These include Palm Beach County, Florida; Lee County, Florida; Hamburg, Germany; Rothensee, Germany; Copenhagen, Denmark; Brescia, Italy; Giubiasco, Switzerland; and Amsterdam, Netherlands.

Finally, the report presents considerations of integrating a reuse and recycling recovery program to complement the WTE facility.

Solid Waste Export Considerations

The second part of the report updates the County’s 2007 *Solid Waste Transfer and Waste Management Plan* (Transport Plan), providing an overview of capacity remaining at regional landfills and potential rail capacity for transporting solid waste.

The Transport Plan identified seven landfill sites potentially available by rail. Of these sites, 4 remain viable considerations: Columbia Ridge Landfill and Recycling Center, Gilliam County, Oregon; Roosevelt Regional Landfill, Klickitat County, Washington; Finley Buttes Regional Landfill, Morrow County, Oregon; and Simco Road Regional Landfill, Elmore County, Idaho. All of these facilities have remaining capacity to accommodate solid waste disposal from King County, and have the potential to expand their capacities through technology and potential future expansions. The regional rail capacity, however, may be the challenging factor in exporting waste by rail and WSDOT anticipates that additional operational or infrastructure improvements will be required to accommodate the anticipated volumes. The critical rail segment for all of the options is BNSF’s 177-mile Seattle Subdivision, connecting Seattle with Portland, Oregon. It is the most heavily trafficked rail line in Washington State, conveying BNSF and UP trains (the latter via trackage rights) to and from the major Pacific Coast ports.

As early as 2008 the segment from Tacoma to Kalama/Longview (both with and without the point defiance bypass) has been operating at 103% of capacity, and it is anticipated that by 2028 demand will continue to exceed capacity with the segment without the bypass surging to 137% of capacity. It is also expected that by 2028, the Kalama/Longview to Vancouver, Washington, segment, without future Passenger Improvements, will reach 143% of capacity. Likewise both the UP and BNSF segments from Vancouver, Washington, to Pasco will be at 100% of capacity in 2028 and the UP segments from Pasco to Spokane and Spokane to Sandpoint, Idaho, will reach 100% of capacity by 2028. The lack of available capacity is likely to cause an increase in unit shipping costs that will need to be accurately modeled in the future, but is beyond the scope of this report.

Next Steps

Based on the WTE Options and Solid Waste Export Considerations of this Report and previous Memoranda, it is recommended that the County consider WTE in their future plans as an appropriate option to address the County's long-term solid waste management needs. The most appropriate and "Best Fit Technology" to process King County's solid waste is an integrated thermal treatment system, which uses combustion on a movable grate with a waterwall boiler to recover heat for production of steam and electricity. The level of integration depends on a number of factors such as site selection, energy use, material recovery and other processes that mutually benefit.

The proposed "Next Steps" are recommended to begin the development process for a public education program and a detailed Feasibility Study. The Feasibility Study will provide an overview of the "Best Fit WTE Option" and key ancillary recycling and disposal components of an Integrated Solid Waste Management (ISWM) system, including a review of existing SWD Infrastructure Systems (e.g., transportation, collection, recycling, reuse, avoidance, landfill), Design/Permitting/Construction Requirements, a Public Outreach Program, Architectural Options, Environmental Opportunities and an Economic/Cost Assessment for the various Project components. In addition, an Implementation Plan, which will be developed to identify the Key Tasks and Schedule for the siting/design/build of the proposed WTE and key infrastructure systems, should be considered as the next step.

1 Introduction

In accordance with the Scope of Work for the King County Solid Waste Department (SWD) Waste-to-Energy (WTE) Study, Normandeau Associates Inc. (Normandeau) and their team members, CDM Smith Inc. and Neomer Resources LLC, have prepared this Task 3—WTE Options and Solid Waste Export Considerations Report (Report).

The purpose of this *2017 Waste-to-Energy Options and Solid Waste Export Considerations Report* is to inform the County's long-range planning efforts. The remainder of Section 1 in this Report summarizes the information presented in the previously completed WTE Memorandum prepared for King County (dated August 16, 2017). This document provided an overview of modern WTE technologies currently in use across North America, Asia, and Europe and summarized the options for WTE facilities. In addition, the documents presented technological, environmental, and financial criteria to consider in evaluating the feasibility of a WTE facility and provided a recommendation of the Best Fit for WTE technology and facility sizing options to meet King County's projected solid waste disposal needs. Section 2 of this Report extends the evaluation conducted in the WTE memorandum to include recommendations for a Best Fit WTE solution for King County, including a description of essential system components. The third section of this report updates the solid waste export information presented in the County's 2007 *Solid Waste Transfer and Waste Management Plan,* providing an overview of capacity remaining at regional landfills and potential rail capacity for transporting solid waste.

Section 4 of this Report summarizes conclusions and provides recommendations for King County's next steps, if the County chooses to move forward with a WTE option in the future.

1.1 Modern WTE Trends and Advancements

A broad overview of the origin and evolution of the WTE industry worldwide was provided for a common understanding of current WTE facilities and recent trends for North America, Europe, and Asia. Section 2 of the Task 2 Memorandum presents the current state of WTE in North America's 85 operating WTE facilities (in terms of technology, capacity, ownership, and heat recovery). The majority (75%) of operating facilities in the US and Canada employ grate combustion with waterwall boiler technologies. Confirmed facility ownership arrangements are evenly divided between public (40) and private (42) entities. WTE facilities are typically operated privately (69, or 81%) with the remaining operated by public entities (16, or 19%). It should be noted that the facilities operated by public entities typically have smaller throughput, with the largest publicly operated WTE facility (Spokane, Washington) being 800 tons per day (tpd). In the case of the Spokane WTE facility, the City assumed operations from Wheelabrator after the initial 23-year operating contract expired. The City essentially hired the Wheelabrator staff and continues to operate the facility.

The range of WTE facilities varies from 12 tpd to very large 3,300 tpd facilities. Typical beneficial recovery of the heat of combustion is most commonly via electricity (76%), followed by combined heat and power (20%) and steam sale only (4%). Typical WTE facilities have demonstrated long-term operational history with 80 of the WTE facilities that are currently in operation built prior to 2000.

Modern WTE facilities continue to advance toward the goals of sustainability, which includes significant reductions in emissions (air, water, solids); reduced use of water, chemicals, and reagents; improved recovery of energy, metals, minerals, and ability to use bottom ash as an aggregate; and improved benefits (e.g., increased jobs and industrial developments) to the local and regional communities that use the facilities.

1.2 WTE Evaluation Criteria

Section 3 of the Task 2 Memorandum summarizes a transparent, collaborative process used to evaluate WTE technologies to identify the Best Fit WTE technology among proven, currently available, and emerging US and International WTE technologies. A ranking and weighting analysis was performed using a set of nine criteria that King County staff had previously reviewed. The intent of this exercise was to provide a snapshot of the current Best Fit WTE technology for King County to be used as the basis for subsequent analysis. However, it was not intended to compare WTE to landfilling or other waste conversion technologies. A practical, preliminary screening criterion was applied (i.e., requiring candidate technologies to be in full-scale operation for at least 3 years processing US-generated municipal solid waste). Eight candidate technologies were evaluated using a transparent, collaborative process that scored each technology across nine weighted, triple-bottom-line criteria, which included four 'Technology;' two 'Environmental;' and three 'Financial/Economic' criteria. The highest ranked WTE technology was a grate combustion with waterwall boiler process that incorporates proven aspects of advanced thermal recycling—this is considered to be the most appropriate (i.e., Best Fit) technology to process King County's current waste projection and composition in accordance with other constraints and assumptions detailed in this Report.

1.3 Preliminary WTE Sizing and Plant Configuration for King County's Waste Projection

Section 4 of the Task 2 Memorandum evaluated the composition and projected quantity of waste in King County over the 50-year planning horizon to establish a basis for the number and size of combustion units that would comprise the Best Fit WTE option. This section is preliminary and will require a detailed Feasibility Analysis to quantify and substantiate the various assumptions to optimize the number, size, and capacity of WTE facilities needed to serve King County.

1.3.1 King County Waste Projections

King County provided the projections for the quantity of waste requiring disposal from the beginning of the planning horizon in 2028 to 2078. King County's annual quantity of waste requiring disposal is projected to increase from approximately 922,000 tons in 2016 to 1.1 million tons in 2028, which is the first year of the planning horizon. By 2078, it is projected that there will be approximately 2.18 million tons per year (tpy) requiring disposal. The waste projection is highly dependent on the recycling rate. The County's recycling rate is assumed to be 57% by 2018 and remains stable at 57% through 2078. It is also assumed that the tonnage will increase 1.5% per year from 2041 to 2078. The County may consider looking at other recycling technologies and ways to collect recyclables to increase the efficiency (see Section 2.2.12 below). If the County's waste projections are modified, the proposed facility configuration, energy generation, and other key performance parameters are subject to change.

1.3.2 King County Waste Composition

The 2015 waste composition report provided by King County indicates that approximately 4.9% of the waste requiring disposal will be non-processable waste, which includes Construction and Demolition (C&D) waste, Gypsum Wallboard, and Electronics. These waste categories were selected because of the ability to identify and remove these items from the waste stream prior to transportation of the processable waste to the facility. The County may consider implementing policies to segregate non-processable waste at the Citizen Drop-Off Facilities and Transfer Stations. These non-processable wastes will require alternate disposal at appropriate C&D landfills or processing at recycling facilities. The quantity of bypass non-processable waste is projected to increase from approximately 54,000 tons in 2028 to approximately 107,000 tons in 2078. The total quantity of non-processable bypass waste from 2028 through 2078 is estimated to be approximately 3.85 million tons. If the County chooses to deliver this waste to the WTE facility, some of the non-processable materials will contain combustible materials and could be accepted by the facility operator. However, objects which may cause plugs in the feed chutes or ash expeller will still need to be removed by the WTE facility operator and disposed of properly. In many WTE projects, this cost is a “pass-through” to the County, or it could be included as the contractor’s responsibility and priced accordingly in their O&M fee.

1.3.3 Waste Heating Value

Based on the expected waste composition of the processable waste to be delivered to the facility, the Higher Heating Value (HHV) of the waste was estimated. Given the estimated HHV for each waste type and the estimated percent of the waste composition, the estimated composite waste HHV was determined to be 5,254 British thermal units (Btu)/lb. As an item of note, the HHV of a community’s waste typically varies on a daily basis (weather dependent) and seasonal basis. Typically, WTE facilities are designed to accept and process waste over a wide range of conditions to account for these changing conditions. Grate combustion units with waterwall boilers can typically accept waste in the range of 3,800–6,000 Btu/lb and be operated in a range of 75% to 110% of their design capacity, this is referred to as their “turndown ratio.”

1.3.4 Options for Size of Combustion Lines

WTE combustion technology has demonstrated the ability to be scaled to meet the needs of the host community (city, county, or several counties) depending on the entities that want to build and operate such a facility. The current range of overall WTE facility capacities varies from 200 tpd to 5,600 tpd. They are typically constructed with multiple combustion lines to maximize their availability to process waste while allowing scheduled maintenance to be performed without taking the entire plant offline. There are plant configurations ranging from two to six combustion lines around the world. For communities expecting growth, WTE facilities can be designed to accommodate future expansions (additions of one or multiple combustion lines) after first commissioning. Several WTE facilities in the US and Europe have been successfully expanded in the past 15 years (examples include Olmstead, Minnesota, 800 tpd expansion; Lee County, Florida, 636 tpd expansion; Hillsborough County, Florida, 600 tpd expansion; and Honolulu, Hawaii, 1,000 tpd expansion).

For the purpose of this study, WTE facility combustion lines ranging from 750 to 1,125 tpd capacity were considered for the preliminary sizing of the WTE facility. The reason for the recommendation for large combustion units is to provide a cost-effective system to accommodate the current and projected large volumes of MSW, while recognizing the lack of existing large landfills in the region. A large WTE facility in the range of 3,000–6,200 tpd overall capacity would likely require 15 to 40 acres, depending on local conditions (site configuration, presence of wetlands, storm water treatment requirements, access to roadways and transmission corridors, etc.). A smaller WTE facility of 1,000 tpd capacity would typically require 10 to 15 acres.

Strategies for Sizing of Combustion Lines

Two strategies were considered in the sizing of the WTE facility:

- Sizing the WTE facility to maximize the available capacity
- Sizing the WTE facility to minimize bypass waste

Sizing the WTE Facility to Maximize Capacity

Sizing the WTE facility to maximize its available capacity in its initial year of operation will have the benefit of meeting the immediate needs of the County and reducing the initial capital costs of the project. However, given the waste projections, there will be a significant increase in the quantity of bypass waste each year that will need to be managed by the County. The County may consider additional recycling initiatives and programs to reduce bypass waste quantity, but given that the current waste projections already consider an increased recycling rate of 57%, the bypass waste may need to be sent to the Cedar Hills Landfill (if permitted for expansion) or an out-of-county landfill for disposal.

Benefits of the Option 1 sizing scenario include:

- WTE facility is at capacity on day 1, thereby ensuring that it is able to operate optimally at its design condition
- WTE facility will be smaller and result in lower capital cost associated with larger facilities compared to larger capacity units
- Smaller WTE facility will present opportunity for alternate forms of recycling to be implemented to process additional waste due to growth

Issues/disadvantages of the Option 1 sizing scenario include:

- Smaller facility will not be able to process all of waste expected due to future growth, and will require alternate disposal methods
- Eliminates opportunity for the County to provide regional waste disposal services to neighboring communities
- Eliminates opportunity for the County to market additional capacity for regional special wastes which command higher tipping fees

Table 1–1 illustrates the required WTE facility sizes and needs for future expansion under this strategy to maximize the available WTE capacity in its first year of operation.

Table 1–1. Combustion Units Sized to Maximize Available Capacity

Planning Scenario: Maximize Available Capacity in its Initial Year of Operation (2028)			
Planning Period	WTE Size in 2028 (tpd)	Additional Capacity (tpd) Needed (Year)	Total Excess Waste (M tons) in Need of Alternate Disposal/Treatment
20-year	3,200	None	3.0
30-year	3,200	800 in 2048	4.4
50-year	3,200	1,600 in 2060	13.5

Sizing the WTE Facility to Minimize Bypass Waste

The second strategy was to initially size the WTE facility to minimize the quantity of bypass waste from the beginning to the end of the planning horizon. This strategy will provide the County the following benefits:

- Reduce the County's reliance, costs, and environmental impacts associated with alternate disposal methods
- Reduce the quantity of waste sent to an out-of-county landfill, or the Cedar Hills Landfill (if permitted for expansion)
- Provide the County the option to accept waste from other municipalities to fill unused capacity (perhaps at a premium tipping fee as the WTE host community)

The potential issues of this strategy include the following:

- There will be unused capacity at the beginning of the planning horizon.
- Incoming quantity of waste may be unable to meet the efficient operating range of the WTE facility (greater than 75%), unless the excess capacity is marketed to other waste generators.
- Frequent shutdowns or operation of some of the units at reduced load may be required during periods when waste deliveries are unable to meet the capacity requirements.

Table 1–2 illustrates the required WTE facility sizes and needs for future expansion under this strategy to minimize the amount of excess waste that must bypass the WTE facility over the course of the planning period.

Table 1–2. Combustion Units Sized to Minimize Bypass Waste

Planning Scenario: Minimize Excess Waste that Must Bypass the WTE Facility			
Planning Period	WTE Size in 2028 (tpd)	Additional Capacity (tpd) Needed (Year)	Total Excess Capacity (M tons) Available for Regional Markets
20-year	4,000	None	4.2
30-year	4,500	None	8.5
50-year	4,200	2,100 in 2053	16.0

1.3.5 Final Size of Combustion Lines

The above two approaches for sizing of the WTE facility were presented to the County for review with a recommendation to size the WTE facilities to minimize the amount of bypass waste. This recommendation was made by the County to avoid having to manage the excess waste by other means. As an option, the County could market some or all of the excess capacity to other regional communities to allow the WTE capacity to be fully used. Additionally, the excess capacity could be marketed under a Special Waste Program for "assured destruction" to regional waste generators. These types of programs have proven to be successful at other WTE facilities and can result in additional revenues to help offset costs.

Scenarios 1, 2 and 3 (using the minimize bypass waste strategy) presented above were further analyzed as part of the WTE Memorandum.

1.4 Preliminary Assumptions for WTE Financial Analysis

Preliminary values for key financial variables that were necessary to estimate costs and revenues of the recommended Best Fit WTE facility were identified in Section 5 of the Task 2 Memorandum. These variables will need to be confirmed during a future, detailed feasibility analysis as many of the variables are dependent on local market conditions and may vary by facility, size, type, location, procurement method, and integration with other programs and technologies, etc. Key parameters include WTE facility capital and operating cost, estimated sales price of electricity sold to local electric utility, gross and net electrical energy generation, ferrous and nonferrous metal recovery rates and sale prices, ash (bottom ash and flyash) and bypassed waste disposal cost. It is also possible that bottom ash could be turned into construction aggregate after approval by the appropriate regulating authorities with a corresponding net savings. Technologies are also under development in Europe to recover recyclable metals and salts from flyash in Europe.

Although Renewable Energy Credits (RECs) for electricity derived from WTE is not currently recognized in the State of Washington, it is conceivable that this form of energy could become valid and result in additional revenues to King County.

The opportunity to develop WTE as part of a combined heat and power (CHP) system was discussed in detail, but no financial analysis was performed for this option as this option is highly dependent on the final site selection. Typically, the WTE facility would need to be in close proximity (within 5 miles) to a steam host for a successful CHP project. The County may want to investigate this option and work with local businesses, developers, and property owners to find a Best Fit in the region. There may be opportunities to obtain funds from the US Department of Energy for a feasibility study to explore opportunities for CHP projects. Also included in this discussion was the concept of integrating WTE into a "microgrid" as a way to ensure high reliability and resiliency for the supply of electrical power to critical municipal and industrial infrastructure.

1.5 Preliminary Results of WTE Financial Analysis

Section 6 of the Task 2 Memorandum fully discusses the financial performance of the Best Fit WTE facility derived in the previous sections by estimating costs and revenues for three planning horizons (20, 30 and 50 years). Sensitivity analyses were also completed to help identify key variables, which could improve financial performance of such a WTE project. Several of the sensitivity analysis runs could result in declining performance (sale of power at a lower price, increased O&M inflation factors, increased construction financing interest rate); however, the parameters used in the base-case financial analysis are considered by CDM Smith to be conservative, so the approach was to provide sensitivity analysis for elements that could improve financial performance.

Table 1–3 shows the results of the preliminary financial analysis based on the preliminary values of the preliminary key parameters. The Contractor design and construction management costs are included in the base cost for the WTE capital cost, which is typical for a design, build, operate project. Additionally, a number of inflation assumptions were applied to the financial analysis for both operating costs and costs related to construction. The capital cost inflation factors were based on the Engineering News Record (ENR) indices for the West Coast, which is an industry standard. The ENR estimated costs are widely accepted for financial planning and should prove to be reasonable. The ENR inflation factors were slightly lower than the factors suggested by King County SWD.

Table 1–3. Preliminary Financial Analysis of 20-, 30-, and 50-Year WTE Scenarios

Scenario	Approach	Size (tpd)	Net Income ($/year)*	Required Tipping Fee (Cost/ton)
1: 20-year	Minimize Bypass Waste	4,000	($139,557, 500) (Year 1)	$126.34
1: 20-year	Minimize Bypass Waste	4,000	($52,292,000) (Year 20)	$37.49
2: 30-year	Minimize Bypass Waste	4,500	($120,675,500) (Year 1)	$109.25
2: 30-year	Minimize Bypass Waste	4,500	($147,830,000) (Year 20)	$105.98
2: 30-year	Minimize Bypass Waste	4,500	($89,363,000) (Year 30)	$55.20
3: 50-Year	Minimize Bypass Waste	4,200	($127,633,500) (Year 1)	$118.82
3: 50-Year	Minimize Bypass Waste	4,200	($155,679,000) (Year 20)	$114.19
3: 50-Year	Minimize Bypass Waste	6,300	($156,680,000) (Year 25)	$106.66
3: 50-Year	Minimize Bypass Waste	6,300	($178,443,000) (Year 30)	$112.45
3: 50-Year	Minimize Bypass Waste	6,300	($259,829,000) (Year 50)	$119.15

* These are negative values (costs) and are used to calculate the required tipping fee in the last column.

For the 20-year and 30-year scenarios, it was assumed that the WTE contractor will be under contract for the full duration, and no additional capital replacement costs were anticipated. Historically, WTE service agreements have been executed for 20 to 30 year periods. However, there was an additional assumption for the 50-year analysis, with the contribution to a Repair and Replacement (R&R) Reserve fund. This R&R Reserve contribution was estimated based upon an analysis of a recent WTE project in which the initial 22-year service agreement was extended for an additional ten year period. As part of the extension agreement, the WTE contractor developed a list of capital replacement projects, along with a list of discretionary projects which may or may not be completed during the mid-life extension period. Using this methodology, an equivalent approach to capital replacement was applied to the 50-year alternative, and 0.255 percent of the original capital costs were assigned to the R&R reserve fund, with contributions made from 2028 through 2078. This calculates to an annual contribution of approximately $3.61 million over the entire 50-year service life, which should adequately fund any required capital expenditures.

Another means of analysis for comparing the economic feasibility of the 20-, 30-, and 50-year lifespan options is a net present value analysis. **Figure 1-1** provides a comparison of the three alternative scenarios. It also presents the 30-Year Plan as being slightly less expensive than the other two scenarios. There are economies of scale associated with the construction of larger unit size components for the 30-Year Plan (Scenario 2) configuration. This scenario also benefits from the longer 30-year debt service term and payments rather than 20- or 25-year debt service payments. Net present value analysis, while valuable for comparing options, does not correlate to rate impact. Through the SWD normal operating procedures, they must set rates to have sufficient cash on hand in any given rate period to pay operating costs, debt service, and other obligations.

Nine sensitivity runs were evaluated to help identify options that may improve the financial performance of the WTE facility. A summary of the various sensitivity runs is shown in **Table 1–4** with the net gain in revenues, reduction in base-case cost, and reduction in tipping fee for the first year of the project shown. In addition to the standalone values of the various sensitivity runs, there may be combinations of improved financial parameters with potential benefits to King County solid waste system rate payers. Based on the nine sensitivity runs, there is a wide range in the potential reduction of tipping fees from a maximum of 70.8% to approximately 25%.

This sensitivity analysis provides a list of options that are not all mutually exclusive and a combination of these items may be implemented. For example, the addition of supplemental waste can be implemented by creating a marketing plan to develop this waste source with a 400 tpd addition resulting in a decrease of up to $25/ton in the tipping fee. Additionally, the sale of power internally at $0.06/kWh could provide a substantial reduction in the tipping fee. The provision of an onsite monofill for ash disposal could result in a reduction in the tipping fee of up to $7.43/ton. Further reductions are anticipated when using bottom ash as an aggregate. These options are all possible within the County's control (or ability to negotiate) and could cumulatively lower the tipping fee in 2028 to $100/ton or less.

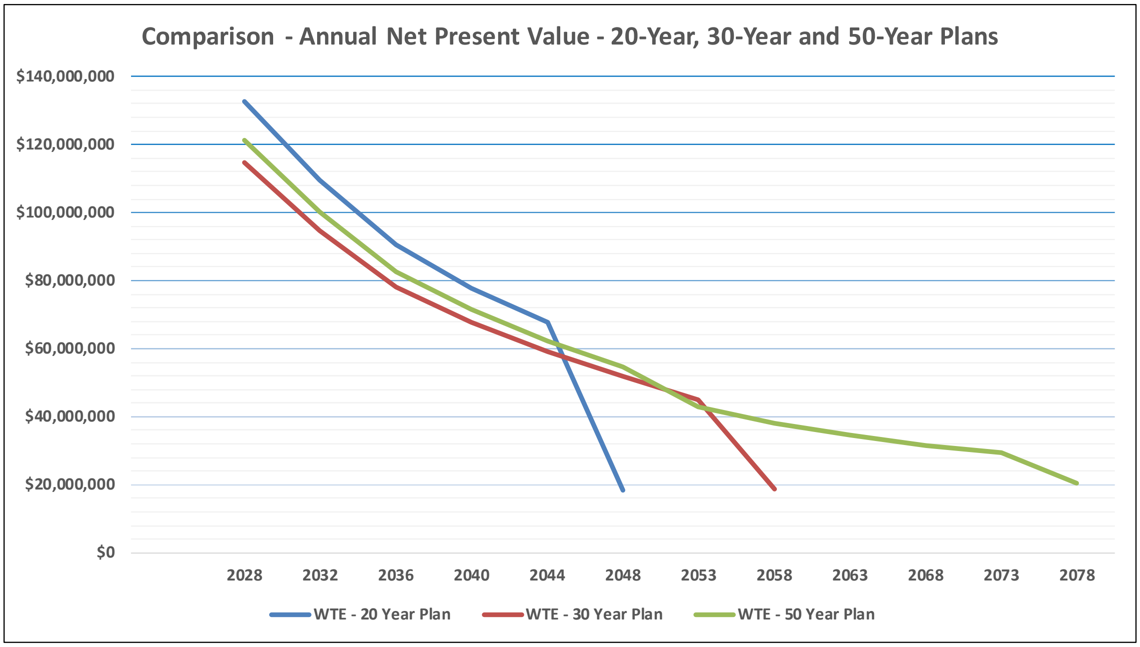

Figure 1–1. Comparison of Net Present Values for the 20-, 30-, and 50-Year Plans

Table 1–4. Sensitivity Analysis

Option	Improved Revenues	Reduced Cost	Standalone Benefit		
			Net Gain ($/year)	Reduction in Base-Case Cost (%)	Reduction in Tipping Fee ($/ton)
Supplemental Waste Revenue (maximized to fill available capacity)	Yes		$56,705,879	40.7	$51.34
Supplemental Waste Revenue (400 tpd, 10% of capacity)	Yes		$27,594,000	19.8	$24.98
Internal use of all electricity (valued at 6 cents/kilowatt hour (kWh) in 2017$)	Yes		$19,178,162	13.7	$17.36
Recycle 75% of bottom ash		Yes	$11,211,129	8.0	$10.15
Disposal of all ash into a King County ash monofill		Yes	$8,204,162	5.9	$7.43
Additional 1 cent/kWh on electric power sales	Yes		$7,903,978	5.7	$7.16
Sale of RECs at $10/REC	Yes		$6,397,356	4.6	$5.79
Reduced O&M Inflation Factors by -0.5%		Yes	$3,226,754	2.3	$2.92
Reduced Construction Financing Interest Rate by -0.5%		Yes	$1,981,800	1.4	$1.79

1.6 Elements of a Feasible WTE Project

Section 7 of the Task 2 Memorandum presented a discussion of various elements that are necessary for a WTE project to be feasible for implementation. It provides specific insights and examples of numerous projects, some of which were not successfully developed and provide useful “lessons learned.” The elements of a feasible WTE project described are those that should be thoroughly addressed in a detailed feasibility analysis if a WTE facility is an option for the County and the Region.

Key elements of a successful WTE project include the following: economics, reliability, impact on waste collections, public acceptability, environmental impact, government commitments, and contractual arrangements and each of the elements were thoroughly discussed in Section 7 of the Task 2 Memorandum. Additionally, examples of successful WTE projects, recent retrofits and expansions, new WTE projects, unsuccessful WTE projects (both those constructed and not constructed) are also discussed in this section.

1.7 Greenhouse Gas Analysis of Best Fit WTE Option

Two methods for estimating impacts of greenhouse gas (GHG) emissions were applied in a preliminary fashion to the Best Fit WTE facility. The two methods were the Waste Reduction Model (WARM) and the Greenhouse Gas Mandatory Reporting Rule (MRR). This analysis is representative only and would need to be refined as part of future evaluation of WTE by King County. The GHG potential results of these two methods for the WTE facility for the 20-, 30-, and 50-year planning scenarios are summarized in **Table 1–5**.

Table 1–5. GHG Analysis Summary

Scenario	WTE Facility Design Capacity (tpd)	Tonnage Processed (tpy)	WARM Mixed MSW (metric tons CO_{2e} per year)	WARM Material Categorization (metric tons CO_{2e} per year)	MRR (metric tons CO_{2e} per year)
20-Year (Year 2048)	4,000	1,350,500	79,592	12,073	1,246,347
30-Year (Year 2058)	4,500	1,519,313	89,541	13,583	1,402,141
50-Year (Year 2078)	6,300	2,127,038	125,357	19,016	1,962,997

Notable conclusions can be drawn from the summary table.

- According to WARM, depending on the categorization of the waste materials and the scenario selected, the WTE facility may have an annual equivalent GHG emissions potential from 12,073 to 125,357 metric tons of CO_{2e}.
- According to GHG MRR, annual greenhouse emissions, depending on the scenario selected, may range from 1,246,347 to 1,962,997 metric tons of carbon dioxide equivalent at full throughput.

Although the CO_{2e} results are presented in one table, the results between WARM and MRR should not be compared directly. The WARM provides a lifecycle assessment and is meant to be a planning tool for solid waste managers and planners. The MRR provides an estimate of direct emissions and determines the regulatory obligation of the WTE facility owner in regards to GHG emissions.

These results also do not account for the GHG potential of the waste that bypasses the WTE facility due to the processable waste quantity exceeding the capacity of WTE facility. The GHG potential of the non-processable waste is also excluded from this analysis.

Further analysis of the potential CO_{2e} from alternative solid waste management may be considered to obtain an assessment of the comparative GHG emissions potential between the management methods and scenarios. Further analysis will allow solid waste managers to better decide on which management scheme would be more appropriate to fulfill the goals and policies of the solid waste management system. Some additional parameters that may be considered are as follows:

- Potential GHG emissions from the current waste management practices
- Potential GHG emissions of the bypass and non-processable wastes
- Potential GHG emissions from the long hauling of waste to out-of-county landfill
- Potential GHG emissions decrease if ash (bottom ash and flyash) recovery systems are considered
- GHG emissions accounting between biogenic and anthropogenic (human-generated environmental impacts) sources from the WTE process via reporting from current WTE facilities
- Potential GHG emissions decrease if a CHP project is developed

  The focus of the work to date has been on the potential GHG emissions from a standalone massburn WTE facility and not on a comparative basis with other waste disposal methods or specific WTE technologies. An additional topic of research may be to evaluate the impact to GHG emissions if the WTE facility is designed with CHP technology to maximize the energy output from the integrated facilities. Considerations for this option that may impact the GHG emissions co-benefits include the location of the CHP user of the energy and the source of energy this technology would replace (e.g., carbon-intensive v. renewable fuel).

2 WTE Options

2.1 Summary of WTE Industry

2.1.1 Summary of the US and International WTE Industry

A broad overview of the origin and evolution of the WTE industry worldwide was previously provided in Section 2 of the Task 2—WTE Existing Conditions Memorandum for a common understanding of current WTE facilities and recent trends for North America, Europe, and Asia.

This section discussed the current state of WTE in North America's 85 operating WTE facilities (in terms of technology, capacity, ownership, and heat recovery).

The WTE industry in the US evolved from the early generation of waste incinerators in which wastes were combusted without energy recovery, primarily as a means of volume reduction and waste stabilization. The birth of the modern WTE industry in the US started approximately 35 years ago in 1975 with the construction of facilities in Ames, Iowa, and Saugus, Massachusetts. These two facilities are still processing municipal wastes today. However, the WTE industry in Germany started more than 120 years ago[1] with the first waste incineration facility operating in Hamburg. It produced electricity to cover parasitic consumption, and surplus energy was used to power a barge for transportation of waste from the city of Hamburg to the facility. It also helped prevent many diseases that are affiliated with contaminants contained in waste.

In North America, there are 85 operating WTE facilities with 77 facilities in the US and 8 in Canada. Three general combustion technologies are used in North America for reliable and proven processing of MSW, which includes massburn, refuse-derived fuel (RDF), and modular massburn. Massburn is the most commonly implemented combustion technology with 64 installations (60 in US, 4 in Canada), followed by RDF (12) and modular (7). Two facilities have a combination of massburn and one other combustion technology (Honolulu and Tulsa). Recent expansions and additions in the US include one retrofit, three expansions, and two new WTE facilities. One new WTE facility was added in Canada (2015), and one new large WTE facility was recently announced for Mexico City.

Currently operating WTE facilities located on the West Coast of North America include:

- Vancouver, BC (850 tpd massburn)
- Spokane, Washington (800 tpd massburn)
- Portland, Oregon (Marion County, 550 tpd massburn)
- Stanislaus, California (800 tpd massburn)
- Long Beach, California (Southeast Resource Recovery facility, 1,380 tpd massburn)
- Commerce, California (Los Angeles County, 360 tpd massburn)

Confirmed facility ownership arrangements are about equally divided between public (40) and private (42) entities. WTE facilities are typically operated by private (69) entities, while operation by public entities (13) has been gaining traction. It should be noted that the facilities operated by public entities typically have smaller throughput, with the largest publicly operated WTE facility being 800 tpd (Spokane, Washington).

The capacity of WTE facilities do range widely from 12 tpd to 3,300 tpd. **Table 2–1** summarizes the number of WTE facilities by capacity.

[1] 100 Years Waste Incineration in Hamburg (1896–1996). Published by the City of Hamburg Sanitation Department (Stadtreinigung), November 1996.

Table 2–1. WTE Capacities by Size

Country	WTE Capacity (tpd)				
	0 to 500	501 to 1,000	1001 to 2,000	2001 to 3,000	>3,000
US	22	19	19	14	3
Canada	6	2	0	0	0
Total	28	21	19	15	2

Typical beneficial recovery of the heat of combustion is most commonly via electricity (63) followed by CHP (17) and steam sale only (3).

Typical WTE facilities have demonstrated long-term operational history with 80 of the WTE facilities that are currently in operation built prior to year 2000.

Although there are only 3 facilities in the US that are larger than 3,000 tpd, it may be helpful to understand the apparent limitation. The reason that most large WTE facilities in the US are less than 3,000 tpd is because of the Public Utility Regulatory Policies Act (PURPA) legislation, which obligates investor owned utilities to purchase power from independent power producers, up to a limit of 80 MW electrical. This is the approximate amount of electric power produced from a WTE facility sized in the range of 3,000–3,300 tpd. However, there are several WTE projects worldwide that are larger than 3,000 tpd capacity, including three US facilities (Pinellas, Florida: WTE at 3,150 tpd; Detroit RDF WTE facility: 3,300 tpd; and Delaware Valley, Pennsylvania: WTE at 3,510 tpd), one European facility (Amsterdam at 4,170 tpd), and one Asian facility (Shenzhen China at 5,512 tpd). The maximum size of a WTE facility is highly dependent upon the availability of MSW and the ability to market the net electrical generation.

Modern WTE facilities continue to advance toward the goals of sustainability, which include significant reductions in emissions (air, water, and solids), reduced use of water, chemicals and reagents, improved recovery of energy, metals and minerals from bottom ash and utilization of the bottom ash as an aggregate, and improved benefits to the local and regional communities that use the facilities. A list of the advantages and benefits associated with WTE facilities is provided in Section 1.8 above and in Sections 2.2.9 and 2.2.10 below.

2.1.2 Summary of the Trends Advancing the Industry Toward Greater Levels of Sustainability

North American WTE Industry

Recent trends in the North American WTE industry include:

1. Addition and upgrade of existing metal recovery systems with advanced ferrous and nonferrous metal recovery systems using high strength magnets and eddy current separator technology

   In conjunction with greater recovery of metals from WTE bottom ash, the opportunity for beneficial bottom ash reuse includes aggregates for road base and construction products along with the partial inclusion as feedstock in the production of Portland cement. For clarification on the potential use of WTE bottom ash in manufacturing of Portland cement, bottom ash does not typically exhibit toxic properties and future uses such as this would likely involve further washing and sizing of the bottom ash materials to meet the requirements of the cement kiln. The cement manufacturing industry is concerned both with the technical performance (structural properties) of their Portland cement products and the environmental performance (leaching potential) along with potential emissions from the high-temperature cement kiln process. Consequently, they would need to perform trial production runs under an approved test protocol and submit data to the permitting agencies prior to any approval being granted for using bottom ash as a mineral feedstock. Using bottom ash in this application will be a lot less problematic than using RDF waste as a supplemental fuel in the cement kilns, which is currently being done in a few locations in both the US and Europe.

2. Advanced combustion controls that result in reduced combustion air, improved combustion and burnout of waste, and reduced emissions that require downstream treatments

   WTE facilities have also demonstrated the ability to operate in full compliance with more stringent regulatory emission limits.

3. Advanced air pollution control systems for reduced use of reagents and chemicals used in treatment processes for reduction of emissions of acid gases, nitrogen oxides, dioxins, heavy metals, and particulates

   The new WTE facility in Palm Beach County, Florida, is the first WTE facility in the US to employ Selective Catalytic Reduction (SCR) technology for reduced emissions of NO_x compounds.

4. Improved operation and maintenance techniques (nondestructive testing for predictive and preventive maintenance such as monthly vibration tests, quarterly oil sampling, infrared thermography, ultrasonic testing for metal thickness, acoustic data, and motor electrical signature tests)

   Included in this category is the use of Inconel and other alloy materials for overlay on various boiler and heat transfer surfaces in the boilers. These best management practices result in higher boiler and turbine-generator availability and gross and net electric generation. Additionally, there has been a trend in the WTE industry to increase both gross and net electrical generation, primarily by the increase of steam conditions (pressure/temperature). In a few installations, the use of high pressure boilers have been recently deployed.

5. Use of reclaimed water for cooling systems, when available, or in many cases, use of air cooled condensers to minimize need for makeup water and eliminate visible plumes from wet cooling towers

6. In the US, the HHV of MSW appears to be holding steady, or slightly increasing, with many WTE communities processing MSW at greater than 5,000 Btu/lb. This may be primarily related to the growing presence of plastics and other high British thermal unit (Btu) fuels present in MSW (used tires, asphalt shingles, and rigid plastics). In Germany, it has been reported that there has not been a remarkable change in the waste heating value during the past years because higher recycling rates in plastic and/or paper are offset by higher recycling rates of organic wastes (lower heating value

materials). However, modern combustion systems are designed to process MSW with HHVs over a wide range (typically from 3,800 Btu/lb to 6,000 Btu/lb)

7. Increase in number of WTE facility expansions and additions to existing WTE campuses

   Recent expansions and additions in the US and North America include:

   a. One retrofit (1,000 tpd WTE in the City of Tampa, Florida [2000])
   b. Three expansions (636 tpd WTE unit in Lee County, Florida [2006]; 600 tpd WTE fourth unit in Hillsborough County, Florida [2007]; and 200 tpd unit in Olmsted, Minnesota [2010])
   c. Two new WTE facilities (1,000 tpd unit in Honolulu, Hawaii [2013] and 3,000 tpd WTE in Palm Beach County, Florida [2015])
   d. One new WTE facility was added in Canada (436 metric tpd [480 tpd] WTE in Durham York, Ontario [2015]) and one new large WTE facility was recently announced for Mexico City (5,500 tpd [2020]).

8. Evolution of WTE facilities as key components of an integrated solid waste management (ISWM) systems

   These include combinations of landfills (ash monofills, C&D, and Subtitle D landfills); organic waste composting systems; material recycling facilities; collection facilities for used tires, oils, and Household Hazardous Waste (HHW); and C&D recycling. Additionally, the concept for the integration of ISWM with recycling and manufacturing industries in an eco-park have been proposed in a number of locations in North America. The new WTE facility in Palm Beach County, Florida, is located on a 1,320-acre campus that has two WTE facilities, two landfills, a biosolids drying facility powered by landfill gas, and a material recovery facility for processing single stream recyclables.

9. Increase in energy and cost efficiencies by the synergistic use of the energy (both heat and power) of publicly owned WTE facilities for the community's own utilities (water, wastewater) and public works and institutional facilities

10. Development of project as a microgrid may also prove to be of value in securing improved revenues

    Microgrids are being promoted by the US Department of Energy (DOE) to ensure greater reliability of electric power to critical municipal services (utilities, emergency response, power, etc.), may also prove to be of value in securing improved revenues. As an example, Hillsborough County, Florida, is currently operating one of its wastewater treatment and water treatment plants with electricity generated by its 1,800 tpd WTE facility. They are also currently evaluating additional "behind the meter" uses for their internal use of power to include an adjacent public works campus. CDM Smith is aware that DOE is promoting CHP projects and trying to help communities in the first step in finding a use for CHP by funding the community's initial feasibility study.

11. Greater attention to aesthetics, LEED® standards, and innovative host community programs, such as mercury bounty collection programs, marine debris collection, out of date pharmaceuticals, and other special programs to more properly manage local wastes

    This includes the co-combustion of biosolids (80,000 wet tpy, or up to 10% of the processed waste) from wastewater treatment plants and used tires in the new WTE facility in Honolulu. Several other WTE facilities in Florida are permitted to co-combust up to 5% of their waste as biosolids.

European WTE Industry

Recent trends in the European WTE industry are described below.

1. The majority of the new WTE facilities use massburn technology
2. Implementation of numerous advanced systems for online cleaning and operation and maintenance practices for optimization of annual availability
3. Extensive innovative technologies for maximizing recovery rates of metals, minerals, and glass from bottom ash as well as the utilization of bottom ash as an aggregate in, for example, lieu of gravel and concrete
4. Incorporation of extensive air emissions control technology, some far more rigorous than the regulatory requirements
5. Expansion and additions to WTE facilities have also been completed, similar to the experience in the US
6. Production of RDF and combustion of the RDF in fluidized bed combustion units, cement kilns, and grate fired boilers to allow displacement of fossil fuels

   However, the use of RDF fuels in fluidized bed combustion units have more stringent specifications of the fuel with regard to impurities (metals, chlorides, inert materials, C&D waste, etc.).
7. Co-generation or CHP generation has been widely deployed

   It is a way of increasing the overall thermal efficiency from 20% to 30% to more than 85% by using waste heat from the production of electricity. In traditional power plants with electricity production only, the efficiency is approximately 20% and the excess heat is discharged to the atmosphere via the cooling system. CHP can create various forms of energy including electricity, heat for district heating purposes, steam for process use, cooling for air-conditioning, or energy for water treatment (desalination, and other alternate supply sources). By also extracting energy from the flue gas by condensation and heat pumps, it is possible to achieve up to 100% energy efficiency (based on the net calorific value).

Asian WTE Industry

Recent trends in the Asian WTE industry are described below.

1. The lack of land, stringent landfill regulations, environment concerns, and loss of resources has caused a rapid growth in WTE facilities.

2. Most of the recent WTE facilities (last 20 years) are massburn and most technologies are of European or Asian origin (often Japanese).

   Today more are Chinese as they are building an average of 50 new WTE facilities every year and now have over 400 with about 40 massburn under construction. The world's largest WTE facility (until the Mexico WTE facility is built) is currently being designed for the city of Shenzhen and will include six processing lines with a total capacity of 5,000 metric tpd (5,512 tpd). This plant is essentially two plants located side by side and under a common roof. It will also provide electricity for the production of 125 million gallons per day (mgd) of desalinated potable water and build in connection with solar panels to cover the entire roof to make best use from an integrated system maximizing benefits.

3. Many of the Asian WTE facilities have special energy recovery facilities that allow feeding of MSW with a higher moisture content.
4. There are a few WTE facilities that incorporate gasification and other emerging technologies; most can be found in Japan.
5. The Asian WTE facilities follow the more stringent of North American or European air emissions requirements.

2.1.3 Summary of WTE Advancements

Worldwide, there have been many advancements for WTE facilities, primarily in massburn WTE technology, such as:

1. Technical evolution of the entire process continues to advance from introduction of the MSW fuel to the FGTs. These improvements include advanced combustion controls, water and air cooling of the high wear zones of the grates and boiler, improved boiler metallurgy and refractories, improved operation and maintenance techniques (such as online boiler cleaning), and optimized FGT.
2. Widespread use of distributed heating including use of hot water for community benefits (such as heating community centers, pools, greenhouses) and adding community-specific unique architectural features that offer new economic opportunities (such as the ski slope/hiking trail feature that was constructed over much of a new WTE facility in Copenhagen, Denmark)
3. Incorporation of enhanced materials separation systems to maximize the amount of recyclables available for sale, both from the raw MSW stream and from the inert bottom ash
4. Utilization of the bottom ash as an aggregate in lieu of gravel, cement, and other construction materials/aggregates with tangible economic and ecologic benefits
5. Incorporation of higher heat recovery boiler pressures to increase the amount of energy recovered from the MSW
6. Facilities in Spain and Finland produce much more power by combining a natural gas fired turbine-generator with a WTE steam water cycle, raising the overall efficiency to more than 40% compared to 22%–25% of a conventional WTE facility

However, this is most economical in countries with low prices for natural gas or high prices of electricity, which is currently the case in the US. It is also possible to use landfill gas in conjunction with WTE to operate the gas turbine. This concept may be of interest to local utilities that are retiring coal units and will likely replace them with natural gas fired combustion generators/combined cycle plants. The above-cited example is an innovative way to configure WTE with other base load power generating technologies to provide local benefits. The co-location of these two types of power generation facilities could be explored as a local opportunity on a single suitable site. If the local utility has an interest, they may have an existing power plant site that could host a future WTE facility.

2.2 WTE Technologies/Facilities Evaluation

In Section 3 of the Task 2—WTE Existing Conditions Memorandum, a transparent, collaborative process was used to evaluate WTE technologies to identify the Best Fit WTE technology among proven, currently available and emerging WTE technologies. A ranking and weighting analysis was performed using a set of nine criteria that King County staff had previously reviewed and commented on. The intent of this exercise was to provide a snapshot of the current Best Fit WTE technology for King County, which is used as the basis for subsequent analysis; it was not intended to compare WTE to landfilling or other waste conversion technologies.

A practical, preliminary screening criterion was applied (i.e., requiring candidate technologies to be in full-scale operation for at least three years processing US-generated MSW). Eight candidate technologies progressed to a transparent, collaborative scoring process that scored each technology across each of nine, weighted, triple-bottom-line criteria, which includes four ‘Technology;’ two ‘Environmental; and three ‘Financial/Economic’ criteria. The highest ranked WTE technology was a thermal process (grate combustion with waterwall boiler) that incorporates proven aspects of advanced thermal recycling—this is considered to be the most appropriate (i.e., Best Fit) technology to process King County’s current waste projection and composition in accordance with other constraints and assumptions detailed in the Memorandum.

2.2.1 WTE Candidate Technologies

Waste conversion technologies are typically classified in one of three categories: thermal processes (combustion, gasification, pyrolysis, plasma arc), biological/chemical processes (anaerobic digestion, composting, acid and enzymatic hydrolysis, biological and catalytic fermentation), or physical processes (RDF, engineered fuel). A detailed evaluation of waste conversion technologies was not part of this study. The primary focus of this study evaluated eight WTE technologies: four considered proven and four emerging technologies currently under development.

Proven Thermal WTE Processes

1. **Grate combustion with waterwall boilers (massburn) WTE**: this technology has successfully been implemented for decades in Europe, Asia, and North America. The term “massburn” (also known as “thermal treatment”) relates to MSW being received and fed unsorted to the combustion units. Heat recovery boilers recover energy from the hot combustion gases to create high pressure steam, which in the US is most often sent to a turbine to generate electric power for sale. The new European Commission’s

R1 criteria emphasizes efficiency and depend upon location and the type of waste used. It also grants special credits to higher efficiency uses often in the form of steam, for example over 80% of Copenhagen, Denmark and over 50% of Paris are heated by WTE. Combustion gases exiting the boiler are cleaned in an air pollution control (APC) system before being dispersed by a stack. Metals and, in some cases, minerals are removed from the bottom ash from the combustion chamber and flyash from the APC are landfilled.

2. **Advanced Thermal Recycling (ATR)**: this is very similar to grate combustion thermal WTE except that enhancements have been added to increase its ability to achieve governmental and public support. The enhancements can include MSW sorting prior to combustion of the remaining waste to maximize materials recycling and the incorporation of advanced systems for recovery of metal and minerals and the ability to utilize the bottom ash in construction along with advanced APC systems to exceed emissions requirements. In Europe over the last 20 years, the enhancements typically associated with ATR are now applied to most massburn WTE facilities such that these two technologies are now the same.

3. **RDF WTE**: although not as prevalent as massburn WTE, RDF technology has been used worldwide at many facilities. The MSW is first sorted to remove toxic materials, metals, inorganic materials (which are typically landfilled) and wet wastes (organics, including food wastes) that are often used in bio digesters or composted. The remaining material, composed mainly of paper, plastic and other organics, are re-sized as a “fluff type” fuel, or in some cases the resultant material is formed into small pellets. These RDF pellets can be combusted onsite to generate electric power or exported to other users where they are combusted to recover the energy content.

4. **RDF to Cement Kiln**: the RDF to Cement Kiln WTE process is the same as the RDF WTE process described above except that the RDF pellets are sent to a cement kiln where limestone and clay are converted to Portland cement. The RDF pellets are an energy source and used to augment (to about 25%) the total energy demand of a cement kiln, which is typically fueled by coal. There are operating facilities (one in North America and several in Europe) where RDF is sent to a cement kiln. These projects have all been implemented for monetary reasons to take advantage of the lower cost of RDF fuel v. coal on a Btu/lb basis. While creating many benefits (lower GHG and no flyash), the facility depends on the cement plant remaining viable over the long-term.

Alternative WTE Processes

1. **Thermal Gasification WTE**: thermal gasification WTE uses a process similar to how charcoal is made and MSW is sorted and heated to a high temperature to drive off gases (called syngas) that can be combusted to generate electric power. Thermal gasification is viewed by its proponents as being “cleaner” because the MSW is not directly combusted, but the proof is missing due to lack of operating data and the process is used at only a few facilities worldwide because the costs are significantly higher and the availability much lower than massburn technology. Depending on the gasification vendor, the MSW feed must be sorted minimally or extensively to remove impurities that might damage the gasification system.

2. **Plasma Arc Gasification WTE**: plasma arc gasification WTE requires extensive preprocessing of the MSW to remove impurities. The remaining material is then subjected to the heat provided by an electric arc to convert the organics into syngas, which can be combusted on site to generate electric power or purified and sent off site. This technology is rarely used. This is due to the high cost and, to date, has only been commercially applied at relatively small capacities due to upscaling problems.
3. **Biochemical Waste-to-Biofuels**: after extensive preprocessing to remove materials contained in the heterogeneous MSW that are not suited for the process, MSW can be subjected to chemical decomposition and/or conversion to produce a biofuel that can be exported for use at other locations. Different chemicals and processes can produce different biofuels such as alcohol, methanol, synthetic diesel and gasoline, and aviation fuel. Some materials are not broken down or converted by the chemical processes (lignin[2] and inorganics) and these materials need to be handled according to regulation. In countries like Germany, the remaining waste has to be thermally treated for inertization so it will no longer react with the environment; some might be able to be recycled or landfilled.
4. **Thermochemical Waste-to-Biofuels**: thermochemical to biofuel WTE is similar to biochemical to biofuel WTE except that heat is applied to some of the processes to enhance the conversion process. This process can also produce a wide range of biofuels (noted above).

The Association of German Engineers, Verein Deutscher Ingenieure (VDI), has developed a five stage process to evaluate the status of development for emerging technologies (VDI # 3460), which is helpful for comparing WTE technologies. It is summarized below.

1. **First stage**: Concept of a new process structured in a logical order from a process-engineering perspective prior to the operation of an experimental plant; may include the performance of tests on a laboratory scale
2. **Second stage**: Operation of an experimental plant including all process components at different operating modes and loads
3. **Third stage**: Stationary operation of an experimental plant or a commercial-scale laboratory pilot plant at nominal load over an extended period of time (at least 4 weeks) accompanied by a measurement and analysis program
4. **Fourth stage**: Stationary operation of a commercial-scale plant over a period of 1 or 2 years (approximately 10,000 operation hours) on the scale required for waste management, including a key assessment of operational safety, environmental relevance, usable operational time, and cost
5. **Fifth stage**: Demonstration of commercial-scale application over many years in permanent operation as a waste management plant at least 80% of annual usable operational time

[2] Lignin is a class of complex organic polymers that form important structural materials in the support tissues of vascular plants and some algae

Current trends in alternative technologies indicate that actual operating facilities that meet stage 5 are not expected in the near future. The number of large scale failures in worldwide gasification and waste to biofuel projects is indicative of the difficulties that must be overcome to commercialize new processes. The learning curve is steep and costly, but the promise is for reduced carbon emissions. Although they have been successfully making syngas from coal in South Africa for over 60 years, using MSW (or processed MSW) is a different material with highly variable properties of the heterogeneous waste.

2.2.2 Technology Evaluation Criteria

A detailed list of questions and issues were considered for each of the nine categories in the WTE criteria matrix. For the King County project, a public–private partnership with a design-build contractor is assumed. A brief summary of these major criteria follows.

- **State of Technology**: The state of technology review addresses the documented track record of the vendor(s) with both pilot and commercial facilities. The operational history of all process steps, from waste receipt through energy conversion to management of material side streams and residuals, are considered under the state of the technology. Specific factors assessed include waste types and quantities processed, demonstrated operational reliability, predictable and steady gross and net electricity generation, and the existence of operational facilities demonstrated over multiple years.
- **Technical Performance**: This criterion addresses the ability of the proposed waste conversion process to focus on the full spectrum of the potential needs of the users and rate payers of the solid waste management system. Also addressed is whether the proposed process can safely and efficiently process the types of wastes that are generated by the system users, the need for source separation and/or pretreatment (removal of items, sorting, and size reduction). The percentage of waste bypassed to the landfill or other waste disposal options is also of importance.

Of particular concern for King County is the effect of their increased diversion goals, its impact on the quantity of materials available for use as a fuel, and the possible decline in HHV. A future sensitivity analysis on this parameter may be considered and is one of the recommendations for future analysis.

- **Technical Resources**: The vendor must demonstrate that its organization has the local resources (on a continuing basis) to provide technical support to the project, including a key project leader with a track record of conducting similar assignments. Emerging technologies often will have one “key project leader,” whereas the preferred case would be for the vendor to have a broader team that can sustain the project if one or more of the project leaders are not involved in the future.
- **Facility Siting and Public Acceptance**: Siting a WTE facility is complex and in many cases, a lengthy multi-dimensional process. There is no single successful siting process that exists and various steps may occur simultaneously. After a genuine need for the WTE facility has been determined and the community has decided to seriously explore the development of a WTE facility, the following major siting considerations will need to be addressed:

- o environmental and health risks, including potential groundwater and air quality impacts (local, sub-regional, and regional), and transportation concerns;
- o economic issues, including the facility's effect on neighboring property values, construction and operating costs and its impact on local residents and industry, including employment opportunities for area residents (both union and non-union) and opportunities for small and minority businesses during construction and operation phases of the project;
- o social issues, such as equity in site choice, the effect on host community image, aesthetics and future land uses; and
- o political issues, such as local voting districts and representation, elections, non-governmental organizations and community groups' vested interests, site management responsibility and local governmental control.

Decisions about the siting of WTE facilities should be made in the context of sound overall land-use planning. WTE facilities should be located as close as possible to electric load centers to take advantage of existing substations and transmission corridors; to encourage conservation and pollution abatement by linking the environmental burdens of renewable power generation with its local benefits; and where possible, maximize efficient use of energy through utilization of waste heat for beneficial purposes. Ideally, WTE facilities should be located on land that has little other productive value, be sited in such a way as to be compatible with and encourage the use of waste heat and reclaimed wastewater and the development of renewable energy resources.

A geographic information system based map should be developed to help narrow the field of acceptable sites. A list of unacceptable site categories of land should be identified and excluded from consideration by the SWD and the WTE siting committee based on federal, state and local laws.

Exclusionary siting factors for WTE facilities include airports, floodplains, wetlands, fault areas, seismic impact zones and unstable areas. Other exclusionary siting factors include current and anticipated incompatible land uses, presence of threatened and endangered species; local zoning restrictions or lack of transportation access.

A list of siting criteria for evaluating and ranking potential sites should also be developed. Sites that meet the most criteria should receive the highest ranking. General siting criteria for WTE facilities may include:

- o compatibility of the proposed facilities with the project site; including proximity to schools, churches, hospitals and other public facilities, and environmental equity (not concentrating MSW facilities in minority and low income areas)
- o existence of natural buffers between the public and the facility
- o ability to mitigate potential impacts associated with visual impacts to neighboring properties, including:
    - ▪ minimizing height and enhancing aesthetics of stack
    - ▪ appropriate control of emissions of odors, noise, and dust

    - enhanced architectural designs and other host benefits could be proposed, similar to that done in many other WTE communities.
- ability to minimize transportation to minimize hauling distance to the facility
- ability to minimize traffic problems via access to appropriate transportation routes and ability to schedule waste deliveries to avoid rush hours
- preventive measures to minimize accumulation of debris and litter along truck delivery route and plan for appropriate cleanup
- minimizing impacts due to number, type and hours of waste delivery trucks
- fill and grading required to implement the facility
- availability of required utilities (water, sewage, natural gas)
- capacity for storm water treatment for ground and surface water protection
- nearby access to electrical substation for import and export of electric power
- present and future population density and the need to relocate residents
- cultural and historic impact
- perceived impact on property values, and
- perceived risk

The issues noted above are the minimum criteria that need to be addressed and mitigated for facility siting and public acceptance. There will always be additional local issues that need to be addressed during a public education campaign. Local issues may be diverse, ranging from. However, since no site has been specifically identified, it is difficult to identify the local issues at this time.

Most new WTE facilities are sited in urban and suburban settings in close proximity to population and the source of waste generation. Host communities often receive special benefits, amenities or services in exchange for locating a WTE facility within its geographic boundaries. Local residents and elected officials should be involved in identifying and approving host community benefits.

Examples of locations for WTE facilities that have been successfully sited include:

- closed, active or future landfill sites
- integrated solid waste and recycling campuses
- industrial areas (brownfields and greenfields)
- adjacent to wastewater treatment facilities
- adjacent to water resource facilities and other public works sites
- retired or active electric power plant sites
- co-located near a steam host (district heating and cooling system, manufacturing facilities, and process industries)

- marine ports looking for new economic development and able to accept waste via barge
- populated areas, including downtown districts (common and accepted in many European and Asian towns)

Successful WTE project development requires early and continuous public involvement for a credible siting process and to inform local officials of residents' perceived risks. Citizens often mistrust government and solid waste contractors, especially if past solid waste management decisions were made by a few people behind closed doors. An open, two way communication process that maximized public participation has been shown to have the best chance for success. Public involvement should serve two main purposes:

1. determine the most suitable WTE facility site and,
2. ensure that the public completely understands the process, any possible problems and all potential solutions

It has been shown that public involvement can be enhanced by creating a siting committee. The committee may include local citizens, politicians, public works officials, industry and business leaders, non-governmental organization representatives, and environmental groups. The committee should be an integral part of the decision-making loop, involved early and until the end. It should have specific responsibilities such as research, siting criteria development, preliminary site evaluation and reviewing consultant recommendations. Independent Consultants (technical and legal) can serve as advisors and also be neutral participants in the siting process, providing research of environmental constraints, legal requirements, costs and other relevant siting issues. All consultant recommendations must be clearly presented to the public.

Key elements of a successful siting campaign include the following:

- General approach
    - Recognize that it may take three to five years to site disposal facilities
    - Establish a diverse siting committee with representatives from the public and private sector, non-governmental organizations, County staff and elected officials under the direction of an experienced facilitator
    - Present case history information and testimonials from spokespeople of similar successful facility siting processes
    - Develop specific criteria to help narrow potential sites to a small number
    - Identify current and proposed future environmental regulations that are intended to protect the community’s quality of life
    - Conduct an open evaluation and ranking process of the candidate sites
- Public involvement and transparency
    - Involve citizens and community leaders early and throughout the siting process
    - Earn and maintain the support of non-elected community leaders

        - Anticipate negative reactions and misconceptions at the onset of the project, and work diligently to determine the true concerns underlying those expressed
        - Be prepared to respond to legitimate public concerns about negative aspects
        - Do not hide negative aspects such as potential hazards and valid community issues
        - Make all information available to the siting committee and general public through public workshops, web sites, and local press releases
        - Demonstrate that the public authority has the resources to manage the project, and that the procurement process will result in the safe management and operation of the facility for the project's life
    - Political involvement and support
        - Encourage a local official to personally guarantee the success of the project
        - Maintain contact with all involved politicians
        - Conduct workshop to inform newly elected officials of prior siting activities and keep them informed throughout the remainder of the process
    - Host community issues
        - Address the host community's concerns

Establish appropriate benefits or compensation for the host community for the use of the site for the benefits of the system users and rate payers

2.2.3 Environmental Criteria

- **Environmental Emissions**: All waste conversion technologies will generate emissions in solid, liquid, and gaseous phase that represent some impact to the environment. The intent of this criterion is to assess the nature of this impact. Specific information evaluated includes the quantity and types of emissions with specific consideration of the technology contributions to GHG. However, it should be noted that by designing the facility accordingly, some of these emissions can be reduced to zero or near zero. For example, facilities in Germany are not allowed to discharge wastewater from the combustion and flue gas treatment (FGT) process, and the amount of solid wastes can be reduced by treating them accordingly to recover reusable materials (this is also a requirement of German regulations). Additionally, many European countries require that WTE facilities be designed to maximize the recovery of energy and resources (e.g., electricity, steam, hot water, and chilled water). A WTE plant that at the start only produces electricity does not lose its ability to produce heat for beneficial purposes because it can be refurbished with the equipment to extract heat from the steam turbine at the appropriate level later on. Additionally, it is a question of the quality of the energy (exergy [usable energy]) produced. Electricity, for example, is a high quality energy that can be used for just about any foreseeable task at high efficiency; whereas, steam or hot water can usually be used only for heating (and cooling) or processing. Unfortunately, thermodynamics has not been able (up to now) to define the efficiency of a process to include the quality of the energy produced. Accordingly, the fuel efficiency includes electricity and heat as equal usable energies produced and relates this to the energy input. This criteria is used in Europe as part of their underlying philosophy of maximizing both energy and material recovery from the processing of waste.

- **Environmental Sustainability**: The intent in applying the sustainability criterion is to assess the proposed technologies' contribution to the local community's overall environmental goals and regulatory compliance requirements. For example, key factors considered include conformance with local community waste objectives, economic development through the creation of "Clean Tech" jobs, and promotion of healthy natural habitats and communities.

2.2.4 Financial/Economic Criteria

- **Financial Resources**: The primary aspect of this criterion is whether the WTE contractor has the financial resources to continue to provide additional capital and operating expenses to resolve technical and operational and maintenance (O&M) problems to fully achieve performance goals for the project. Other components of the financial resources criterion relate to the Respondent's financial capability to make the project owner whole from any investments made by the agency and the resources to dismantle and remove the facilities in the event of a "failure" to meet performance standards. Also, included in this category is whether the proposed technology would attract competitive proposals.
- **Project Economics**: The economic analysis incorporates the operating expenses associated with a technology (labor, power, chemicals, etc.) and estimated revenues obtained from the sale of power and byproducts. In addition, the economics of a given technology is significantly influenced by the municipality's requirement to commit to participation in capital investment and commitment of the feedstock delivery at a specified price. The overarching assumption for this project is that the County will finance the project to obtain tax free municipal interest rates (corporate rates are higher). A project of this size could be financed by a private contractor and this is not unusual and has been done in the past, but essentially what happens is the public rate payers and users of the system pay off the debt service and the contractor may or may not reduce their processing fee (depending on the agreement) after the debt is retired. The low cost and low risk option is for public finance and private operation under a long-term Service Agreement. Although the local fuel (and electricity purchase prices) are key parameters, there may be options to improve revenues beyond the sale of electricity, such as steam/hot and chilled water sales (CHP), implementation of special waste programs, and other incentives via grants from federal government (USDA, DOE, DOI, or possibly future Infrastructure Reinvestment programs).
- **Overall Project Risks Criteria**: These criteria summarize many of the above noted criteria to address the economic realities, overall technical risk, any unique or problematic procurement issues, presence and identification of any fatal flaws, duration of time to reach full commercial operation, and contractual terms and risk.

2.2.5 Evaluation and Recommendation for Best Fit WTE

Evaluation Results

Each of the above criteria was assigned a specific value (weight) as shown in **Table 2–2**.

Table 2–2. Summary of Evaluation Matrix Scores

Criteria Number	Criteria Description (Major / Minor)	Score (points)	WTE Evaluation Matrix: Massburn WTE	Refuse-Derived Fuel (RDF) WTE	Advanced Thermal Recycling (ATR)	Thermal Gasification WTE	Plasma Arc Gasification WTE	Biochemical Waste-to-Biofuels	Thermochemical Waste-to-Biofuels	Refuse-Derived Fuel (RDF) to Cement Kiln	Questions/Comments
1.0	State of Technology	15	15	15	15	5	3	5	3	12	
	Degree to which entire system has been proven on a commercial scale		Commercially proven over past 50 years	Commercially proven over past 25 years at numerous plants	Commercially proven in Europe since 1999 at MVR facility in Hamburg Germany	Limited commercial experience with MSW in Asia over past 10 years	Pilot scale experience with RDF only	Pilot scale with select waste feedstocks only, Ineos Facility in Florida shutdown end of 2016	Pilot scale with select waste feedstocks only, Enerkem facility in Canada in startup phase for 2 yrs.	One cement plant using RDF (SpecFUEL) in the US since 2015 and several in Europe	Identify status of technology: Bench Scale, Pilot Scale , Demonstration Scale (0-3 years), or Commercially Proven (+ 3 years)
	Operating history / availability		Yes, well proven at > 60 plants in US and over 1,000 plants world wide	~ 5 RDF processing and 5 RDF processing / WTE plants in US	Two EU facilities. ATR is in essence the same as WTE	No commercial experience with MSW in the US	No commercial experience with MSW in the US	No commercial experience with MSW in the US	No commercial experience with MSW in the US	One cement plant using RDF (SpecFuel) as a fuel in the US since 2015 and several in Europe	Identify the number of operational plants and years of successful operation
	Freedom from high risk failure modes		Yes, mature industry has fully addressed high risks via design codes and operational procedures	High potential for shredder explosions has been observed	Yes. Same as WTE, with additional processes to improve energy recovery and residual efficiencies.	Potential for release of carbon monoxide syngas is dependent on successful operation of bypass flares	Uncertain, molten materials inside reactor present some degree of risk	Uncertain, liquid fuels must be safely stored	Uncertain, liquid fuels must be safely stored	Fully dependent on the financial viability of the cement plant	Identify problem areas with mitigation measures implemented to prevent high risk failure modes
	Demonstrated reliability of entire system		Yes, > 90% typical plant availability, many facilities 20-25 years old available 92-95%	Yes, high reliability (87.5%) has been demonstrated	Yes, high reliability in the EU with 18 years of operations, 92 - 95 percent annual availability	Uncertain, no commercial experience in US	No commercial experience with MSW in the US	No commercial experience with MSW in the US	No commercial experience with MSW in the US	One cement plant using RDF (SpecFUEL) in the US since 2015 and several in Europe	Identify the capacity and throughput (small, medium, large), and historical system and component annual availability (0-100%)
2.0	Technical Performance	10	9	7	9	4	4	4	5	7	
	Compatibility with full spectrum of King County waste tonnage (volume and composition)		Yes, with limited percentage of tires and WWTP biosolids (although not currently considered by King County), except, e-waste, HHW, treated lumber, mercury containing devices	Yes, except numerous non-processable materials removed prior to combustion and disposed of in landfill and/or send to WTE facility	Yes, with limited percentage of tires and WWTP biosolids (although not currently considered by King County), except, e-waste, HHW, treated lumber, mercury containing devices	No - Process requires substantial amount of pretreatment. Process does not work with Heterogeneous waste - needs to be homogenized / presorted	No - Process requires substantial amount of pretreatment. Process does not work with Heterogeneous waste - needs to be homogenized / presorted	No - Process is limited to cellulosic wastes (paper, cardboard, vegetative, and wood wastes)	No - Process prefers dry wastes, primarily limited to cellulosic wastes (paper, cardboard, vegetative, and wood wastes) and plastics	No - RDF processing prefers dry wastes, primarily limited to cellulosic wastes (paper, cardboard, vegetative, and wood wastes) and plastics	Is the process compatible with the full spectrum of potential needs (residential, commercial, and industrial MSW; household hazardous waste, construction and demolition waste, medical wastes, electronic wastes, WWTP biosolids, special wastes (asbestos, carpet, shingles, tires, used oils, etc.)?
	Ability to produce marketable byproducts		Yes, gross electricity (+600 kWh/ton), steam, hot water, ferrous and nonferrous metals, aggregates which can be used as daily LF cover (although not currently permitted in WA)	Yes, electricity, steam, hot water, ferrous and nonferrous metal, and aggregates which can be used as daily LF cover (although not currently permitted in WA)	Yes, electricity, steam, hot water, ferrous and nonferrous metal, chemicals, minerals, gypsum, hydrochloric acid, bottom ash (separate from fly and boiler ash) proven uses as an aggregate, permitting expected in WA State	Very limited information available	Very limited information available	Limited, electricity, liquid fuels, and chemicals	Yes, electricity, liquid fuels, and chemicals	The RDF produced becomes part of the fuel for a cement kiln (reduces coal use)	Does the process produce a viable commodity that can be sold to a large local or regional market? What type of other marketable by-products are produced?
	Need for preprocessing		No, other than removal of a small percentage of bulky, and non-processable items (typically < 1% of waste delivered, but could be as high as 4.9 percent in King County)	Yes, the RDF process has to extract metals, glass, PVC and inert materials then creates a RDF for combustion, with typical 30% sent to landfill	No, other than removal of bulky and non-processable items	Yes, gasification typically requires pre-sorting for removal of metals, glass, and inerts, although Thermoselect process can process MSW less than 2' dimension	Yes, gasification process is not well suited for high moisture materials, and generally prefers removal of metals, glass, and inerts	Yes, process will require select wastes which are reduced in size and screened of inerts	Yes, process will require select wastes which are reduced in size and screened of inerts	Yes, process will require select wastes which are reduced in size and screened of inerts	Does the process require source separation, sorting, or sizing, and what % of waste is bypassed to landfill?
3.0	Technical Resources	5	5	4	5	1	1	1	1	3	
	Proven contractor experience in waste processing		Yes, 3 major, 3 minor, domestic private firms, and 9 public in US (B&W, Covanta and Wheelabrator)	Yes, 3 major domestic, 3 minor firms, and 1 public in US (Covanta, B&W, Xcel Energy, Great River)	Yes - Contractor has proven experience with underlying technology though not one contractor and vendor in the US with proven experience in the advanced efficiency technologies	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	One cement plant using RDF (SpecFUEL) in the US since 2015 and several in Europe	Does the proposer have direct and applicable experience in the receipt, storage, handling, and processing of MSW?
	Proximity of technical support		US based vendors, often located regionally at WTE facilities with industry crossover	US based vendors, often located regionally at WTE facilities with industry crossover	Uncertain, pilot scale (advanced metals recovery) only.	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Fair technical support for RDF processing and fair support for using RDF in a cement kiln	Does the proposer have local resources to provide ongoing technical support of the process, or will the support be located in the US or Offshore?
	Availability to provide support on continuing basis		US based vendors, often located regionally at WTE facilities with industry crossover	US based vendors, often located regionally at WTE facilities with industry crossover	Uncertain, no one primary vendor with experience in managing ATR	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Fair technical support for RDF processing and fair support for using RDF in a cement kiln	Is there one "key project leader" without whom the project may fail, or does a broader team exist that can sustain the project if one or more project leaders leave?

Criteria Number	Criteria Description (Major / Minor)	Score (points)	WTE Evaluation Matrix								Questions/Comments
			Massburn WTE	Refuse-Derived Fuel (RDF) WTE	Advanced Thermal Recycling (ATR)	Thermal Gasification WTE	Plasma Arc Gasification WTE	Biochemical Waste-to-Biofuels	Thermochemical Waste-to-Biofuels	Refuse-Derived Fuel (RDF) to Cement Kiln	
4.0	Facility Siting and Public Acceptance	5	4	4	4	4	4	3	3	5	
	Acceptable site		Yes, typically located in urban settings, at landfills, adjacent to WWTP facilities, or within industrial areas	Yes, typically located at landfills, adjacent to WWTP facilities, or within industrial areas	Yes, location as any other WTE facility: located in industrial areas, urban settings, at landfills, adjacent to WWTP facilities, near district heating systems	Yes, typically located at landfills, adjacent to WWTP facilities, or within industrial areas	Yes, typically located at landfills, adjacent to WWTP facilities, or within industrial areas	May require special zoning for refinery process	May require special zoning for refinery process	May require special zoning but may not be required if the RDF plant is located at the cement plant	Is there adequate acreage, adequate buffer, acceptable zoning, ability to be rezoned, or is the proposed process better suited for an alternate location?
	Synergy with adjacent activities		Yes, use of reclaimed water, and sale of steam and electricity is common, internal use of electricity may be possible	Yes, use of reclaimed water, and sale of steam is common, internal use of electricity may be possible	Yes, use of reclaimed water, and sale of steam and electricity is common, internal use of electricity may be possible	Yes, use of reclaimed water, and sale of steam, internal use of electricity may be possible	Yes, use of reclaimed water, and sale of steam, internal use of electricity may be possible	Yes, use of reclaimed water, and sale of steam, internal use of electricity and biofuels may be possible	Yes, use of reclaimed water, and sale of steam, internal use of electricity and biofuels may be possible	Excellent integration of the RDF plant with the cement plant	Is the process able to take advantage of adjacent activities in a synergistic way, such as sale of electric hot water, or steam?
	Adequate utilities		Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Site specific, typically requires potable, process, sanitary / wastewater, and natural gas (if available)	Are adequate water, wastewater, reclaimed water, and natural gas utilities available to the existing site, or will new or increased capacity be required?
	Adequate / affordable electric interconnection		Site specific, facility generally within 3 miles of utility substation	Site specific, facility generally within 3 miles of utility substation	Site specific, facility generally within 3 miles of utility substation	Site specific, facility generally within 3 miles of utility substation	Site specific, facility generally within 3 miles of utility substation	Site specific, facility generally within 3 miles of utility substation, if electricity is to be sold	Site specific, facility generally within 3 miles of utility substation, if electricity is to be sold	Site specific, facility generally within 3 miles of utility substation but may not be an issue if the RDF plant is located at the cement plant	Does the proposed site allow acceptable electric interconnection to a nearby utility substation, or will new transmission lines and switchgear be required?
	Synergy with local infrastructure		Yes, requires accessible via major highways, occasionally served by rail service	Yes, requires accessible via major highways, occasionally with rail service	Yes, requires accessible via major highways, occasionally with rail service	Yes, requires accessible via major highways, occasionally with rail service	Yes, requires accessible via major highways, occasionally with rail service	Yes, requires accessible via major highways, occasionally with rail service	Yes, requires accessible via major highways, occasionally with rail service	Yes, requires accessible via major highways, occasionally with rail service	Will the local roads be adequate for the project, or will new transfer stations, transfer trucks, or other infrastructure improvements be required?
	Public acceptance		Yes, many modern WTE with advanced combustion and flue gas controls are located in urban areas close to population centers. Some were originally rural areas, and neighboring development came later.	Yes, requires greater buffer area due to odors, unless odor treatment system is employed	Uncertain. While the underlying technological premise is similar to massburn. There has been no US experience in ATR.	Uncertain, requires greater buffer area due to odors from RDF process, and perceived issues with carbon monoxide gas and potential explosions	Uncertain, requires greater buffer area due to odors from RDF process, and perceived issues with carbon monoxide gas and potential explosions	Uncertain, odors and storage of ethanol	Uncertain, odors and storage of ethanol	Yes, requires greater buffer area due to odors, unless odor treatment system is employed	Will the process be acceptable to local residential, business, environmental and civic groups?
	Local economic impacts		Positive, well-paying construction, O&M jobs, positive economic ripple effect over long-term operation	Positive, well-paying construction, O&M jobs, positive economic ripple effect over long-term operation	Uncertain. While the underlying technological premise is similar to massburn. There has been no US experience in ATR.	Positive, well-paying construction, O&M jobs, positive economic ripple effect over long-term operation	Positive, well-paying construction, O&M jobs, positive economic ripple effect over long-term operation	Positive, well-paying construction, O&M jobs, positive economic ripple effect over long-term operation	Positive, well-paying construction, O&M jobs, positive economic ripple effect over long-term operation	Positive, well-paying construction, O&M jobs, positive economic ripple effect over long-term operation (may make the cement plant more economically viable)	Will the process / project create well-paying construction jobs, operation and maintenance jobs, and have a significant annual economic ripple effect on the local / regional economy?
5.0	Environmental Criteria	15	15	12	15	5	5	4	4	12	
	Data to support ability of control technology for air emissions		Credible database, permits grow more restrictive over time	Credible database, permits grow more restrictive over time	Credible database, though it is the European experience	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Credible database, permits grow more restrictive over time	Is there qualified data to allow permitting agencies to regulate major and minor air pollutants?
	Data to support ability of control technology for residues		Credible database, ash residue generally land filled	Credible database, ash residue generally land filled	Potential to significantly reduce solid	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Credible database, no ash residue (becomes part of the cement)	Is there qualified data to allow permitting agencies to regulate residues and non-processable wastes bypassed to the landfill?
	Data to support ability of control technology for liquid discharge		Credible database, some facilities are zero water discharges	Credible database, some facilities can be zero water discharges	Liquid discharges should be similar to massburn and RDF	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Credible database, some facilities can be zero water discharges	Is there qualified data to allow permitting agencies to regulate wastewater quantities and quality?
	Data to support ability of control technology for odor emissions		Credible database, massburn WTE has almost no odors escaping buildings	Credible database, possible odor control needed in the MSW processing building.	Credible database, the underlying massburn WTE has almost no odors escaping buildings	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Uncertain, no commercial experience with data in US	Credible database, possible odor control needed in the MSW processing building.	Is there qualified data to allow permitting agencies to regulate odorous compounds and ability to escape project boundary/ buffer zone?
	Data to support ability of control technology for noise		Credible database, very little noise outside of building walls	Credible database, very little noise outside of building walls	Credible data base, very little noise outside of building walls	Uncertain, but mitigating measures can be provided (enclosures, sound barriers, noise attenuation)	Uncertain, but mitigating measures can be provided (enclosures, sound barriers, noise attenuation)	Uncertain, but mitigating measures can be provided (enclosures, sound barriers, noise attenuation)	Uncertain, but mitigating measures can be provided (enclosures, sound barriers, noise attenuation)	Credible database, very little noise outside of building walls	Is there qualified data to allow permitting agencies to regulate noise levels during daylight and nighttime conditions?
	Reduction in greenhouse gases		Credible database, ongoing debate over biogenic versus anthropogenic emissions	Credible database, ongoing debate over biogenic versus anthropogenic emissions	Credible data base, ongoing debate over biogenic versus anthropogenic emissions	Uncertain, ongoing debate over biogenic versus anthropogenic emissions	Uncertain, ongoing debate over biogenic versus anthropogenic emissions	Uncertain, ongoing debate over biogenic versus anthropogenic emissions	Uncertain, ongoing debate over biogenic versus anthropogenic emissions	Will be a significant reduction in GHGs due to the cement plant using RDF and reducing their dependence on coal	Will there be a net reduction in GHG compared to local sources of electric power or comparable energy generation; compared to current landfill disposal option; compared to future landfill option with landfill gas collection and destruction?

Criteria Number	Criteria Description (Major / Minor)	Score (points)	WTE Evaluation Matrix: Massburn WTE	Refuse-Derived Fuel (RDF) WTE	Advanced Thermal Recycling (ATR)	Thermal Gasification WTE	Plasma Arc Gasification WTE	Biochemical Waste-to-Biofuels	Thermochemical Waste-to-Biofuels	Refuse-Derived Fuel (RDF) to Cement Kiln	Questions/Comments
6.0	Environmental Criteria—Sustainability	10	8	8	9	7	7	9	7	8	
	Impacts on local resources		Requires potable and clean process water, can use reclaimed water and/or other alternate sources for cooling	Requires potable and clean process water, can use reclaimed water for cooling	Requires potable and clean process water, can use reclaimed water for cooling,	Requires potable and clean process water, can use reclaimed water for cooling,	Requires potable and clean process water, can use reclaimed water for cooling,	Requires potable and clean process water, can use reclaimed water for cooling, if power is co-produced	Requires minor potable and clean process water, can use reclaimed water for cooling, if power is co-produced	Requires potable and clean process water, can use reclaimed water for cooling	Does the process minimize use of local water resources (potable, wastewater, and reclaimed water); minimize fossil fuel (natural gas, coal, oil) and fossil powered electricity, and maximize local recycling / energy recovery?
	Impacts on neighboring communities		With adequate buffer and aesthetic treatment, WTE facilities are compatible with industrial and institutional locations, many have been located near population centers	With adequate buffer and aesthetic treatment, WTE facilities are compatible with industrial and institutional locations	With adequate buffer and aesthetic treatment, ATR facilities are compatible with industrial and institutional locations, many have been located near population centers	With adequate buffer and aesthetic treatment, WTE gasification may be compatible with industrial locations	With adequate buffer and aesthetic treatment, WTE gasification may be compatible with industrial locations	With adequate buffer and aesthetic treatment, waste Biofuel facilities may be compatible with industrial locations	With adequate buffer and aesthetic treatment, waste Biofuel facilities may be compatible with both industrial locations	With adequate buffer and aesthetic treatment, RDF facilities are compatible with industrial and institutional locations, especially if the RDF facility is located at the cement plant	Are there any significant or potential issues (positive or negative) on the neighboring communities (visual, traffic, litter, property values)?
	Impacts on natural habitats		Minor, typically much smaller sites than landfills with well-developed mitigation strategies	Minor, typically much smaller sites than landfills with well-developed mitigation strategies	Minor, typically much smaller sites than landfills with well-developed mitigation strategies	Minor, typically much smaller sites than landfills where mitigation strategies can be employed	Minor, typically much smaller sites than landfills where mitigation strategies can be employed	Minor, typically much smaller sites than landfills where mitigation strategies can be employed	Minor, typically much smaller sites than landfills where mitigation strategies can be employed	Minor, typically much smaller sites than landfills where mitigation strategies can be employed	Are there any significant or potential issues (positive or negative) on the local, sub-regional, or regional habitat (litter, emissions, noise, and lighting)?
	Compatibility with local environmental goals		Complies with the EPA waste management hierarchy of energy recovery over landfill disposal.	Complies with the EPA waste management hierarchy of energy recovery over landfill disposal.	Complies with the EPA waste management hierarchy of energy recovery over landfill disposal.	Complies with the EPA waste management hierarchy of energy recovery over landfill disposal.	Complies with the EPA waste management hierarchy of energy recovery over landfill disposal.	Uncertain GHG emissions due to limited commercial applications,	Uncertain GHG emissions due to limited commercial applications	Complies with the EPA waste management hierarchy of energy recovery over landfill disposal.	Does the process fully meet all of the local community's environmental goals, such as reduction in pollutants, and greenhouse gases on a lifecycle basis?
	Compatibility with local waste reduction goals		Recovered and recycled metals help meet local recycling goals, WTE may qualify for recycling goals in some states	Recycled metals help meet local recycling goals, WTE may qualify for recycling goals in some states	Recycled metals, residues, and minerals maximizes the waste reduction goals. Over 99% landfill diversion possible	Recycled metals help meet local recycling goals, gasification may qualify for recycling goals in some states vitrification can minimize residues	Recycled metals help meet local recycling goals, gasification may qualify for recycling goals in some states vitrification can minimize residues	Waste conversion to biofuels may count toward recycling	Waste conversion to biofuels may count toward recycling	RDF facility can include enhanced recycling	Does the process fully meet all of the local community's waste reduction and recycling goals?
	Synergistic with municipal utilities and recycling processes		Yes, electricity from WTE can be used for other public works and municipal utilities if co-located	Yes, electricity from WTE can be used for other public works and municipal utilities if co-located	ATR maximizes the recovery of energy and material resources and process efficiencies	Yes, electricity from WTE can be used for other public works and municipal utilities if co-located	Yes, electricity from WTE can be used for other public works and municipal utilities if co-located	Less impact than WTE renewable electricity, but biofuels could be internally used for fueling fleets	Less impact than WTE renewable electricity, but biofuels could be internally used for fueling fleets	Yes, there will be no ash stream produced	Does the process afford the opportunity to provide additional benefits to community's public works programs and processes?
7.0	Financial Resources	10	10	10	10	3	3	3	3	8	
	Ability of vendor to finance project without public money		Yes, however, most WTE is typically publically owned, unless tax laws are favorable for private ownership	Yes, however, most WTE is typically publically owned, unless tax laws are favorable for private ownership	The underlying technology is typically publically funded. No US demonstrated facility	Lack of commercial development may not allow projects to be suitable for public finance	Lack of commercial development may not allow projects to be suitable for public finance	Lack of commercial development may not allow projects to be suitable for public finance	Lack of commercial development may not allow projects to be suitable for public finance	Lack of commercial development may require a guarantee from the public	What % of public money is at risk?
	Ability to endure and achieve performance goals during prolonged startup and testing phases		Startup easily achieved based on historical performance	Startup easily achieved based on historical performance	Uncertain, no commercial experience for the enhanced efficiency processes in the US.	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Startup easily achieved based on historical performance	Does the developer have the financial resources and access to additional funds and resources to make the system fully functional during prolonged startup?
	Ability to make municipality whole from their investments and costs if technology fails		Historically demonstrated via long-term operation and maintenance service agreements with performance guarantees	Historically demonstrated via long-term operation and maintenance service agreements with performance guarantees	Uncertain, no commercial experience for the enhanced efficiency processes in the US.	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Historically demonstrated via long-term operation and maintenance service agreements with performance guarantees	Does the developer have the financial resources and willingness to accept liquidated damages causes to cover costs and impacts to the public?
	Financial reserves in escrow to dismantle and remove in event of failure		Yes, performance guarantees typically included in O&M service agreement	Yes, performance guarantees typically included in O&M service agreement	Uncertain, no commercial experience for the enhanced efficiency processes in the US.	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Uncertain, no commercial experience in US	Yes, performance guarantees typically included in O&M service agreement	Does the developer have the financial resources and willingness to place adequate funds, insurance, or financial backup to dismantle system in event of failure?
8.0	Project Economics Score	20	20	18	20	10	7	7	7	10	
	Requirement for Public capital investment		Typically 100% publically financed with municipal bonds, unless tax laws are favorable for private ownership	Typically 100% publically financed with municipal bonds, unless tax laws are favorable for private ownership	Uncertain. No commercial experience for the enhanced efficiency processes in the US	Lack of commercial development may not allow projects to be suitable for public finance	Lack of commercial development may not allow projects to be suitable for public finance	Lack of commercial development may not allow projects to be suitable for public finance	Lack of commercial development may not allow projects to be suitable for public finance	Typically 100% publically financed with municipal bonds, unless tax laws are favorable for private ownership	What % of commitment is required from local municipality to participate in capital investment?
	Commitment for delivery of wastes		Typically require commitment for minimum delivery of wastes on a daily, weekly and annual basis	Typically require commitment for minimum delivery of wastes on a daily and annual basis	Typically require commitment for minimum delivery of wastes on a daily and annual basis	Likely to require commitment for minimum delivery of wastes on a daily and annual basis	Typically will require commitment for minimum delivery of wastes on a daily and annual basis	Typically will require commitment for minimum delivery of wastes on a daily and annual basis	Typically will require commitment for minimum delivery of wastes on a daily and annual basis	Typically require commitment for minimum delivery of wastes on a daily and annual basis	What is the commitment of required waste delivery (tons per day, contract years)?

Criteria Number	Criteria Description (Major / Minor)	Score (points)	WTE Evaluation Matrix								Questions/Comments
			Massburn WTE	Refuse-Derived Fuel (RDF) WTE	Advanced Thermal Recycling (ATR)	Thermal Gasification WTE	Plasma Arc Gasification WTE	Biochemical Waste-to-Biofuels	Thermochemical Waste-to-Biofuels	Refuse-Derived Fuel (RDF) to Cement Kiln	
	Acceptable contract terms and conditions		Yes, historically demonstrated as normal practice	Yes, historically demonstrated as normal practice	Uncertain. The underlying technology will have historically demonstrated as normal practice, except for the enhanced efficiency processes.	Uncertain, but likely to adopt as normal practice	Uncertain, but likely to adopt as normal practice	Uncertain, but likely to adopt as normal practice	Uncertain, but likely to adopt as normal practice	Yes, historically demonstrated as normal practice	Does the project allow acceptable put or pay contract terms; base service fee plus excess waste processing fee; method of determining annual escalation; revenue sharing of energy production, recyclables, and other co-products?
	Economic costs and benefits to the community		Yes, stabilizes solid waste rates over long-term, especially after facility debt is retired, lowest cost of WTE technologies	Yes, stabilizes solid waste rates over long-term, especially after facility debt is retired, costs higher than massburn	Uncertain. The cost effectiveness of the enhanced efficiency processes is unknown	Uncertain, but likely to adopt as normal practice	Uncertain, but likely to adopt as normal practice	Uncertain, but likely to adopt as normal practice	Uncertain, but likely to adopt as normal practice	Yes, stabilizes solid waste rates over long-term, especially after facility debt is retired, costs higher than massburn	Does the process provide any long-term revenue potential for the host municipality, or other benefits such as renewable energy to the local service area?
	Realistic estimate of project revenues / incomes		Yes, long-term electric power purchase agreements cover bulk of revenues, market fluctuations for recycled metals	Yes, long-term electric power purchase agreements cover bulk of revenues, market fluctuations for recycled metals	Uncertain. The long-term electric power purchase agreement cover bulk of revenues. The cost effectiveness of the enhanced efficiency processes is unknown	Yes, long-term electric power purchase agreements cover bulk of revenues, market fluctuations for recycled metals	Yes, long-term electric power purchase agreements cover bulk of revenues, market fluctuations for recycled metals	Uncertain, market risk for biofuels, long-term PPA if electricity is sold	Uncertain, market risk for biofuels, long-term PPA if electricity is sold	Yes, long-term RDF purchase agreement covers bulk of revenues; market fluctuations for recycled metals	Are the assumptions reasonable for estimating income from sale of power, by-products, or processing of special wastes in comparison with other similar industries and processes?
	Realistic assumptions for estimation of operation and maintenance expenses		Yes, long history of successful operations and data base	Yes, long history of successful operations and data base	Uncertain. The cost effectiveness of the enhanced efficiency processes is unknown	Uncertain, no commercial experience and data in US	Uncertain, no commercial experience and data in US	Uncertain, no commercial experience and data in US	Uncertain, no commercial experience and data in US	Limited history of successful operations and data base	Are the assumptions reasonable for estimating expenses (labor, wage rates, power use, cost of chemicals, fuels, and equipment) in comparison with other similar industries and processes?
	Costs to commercial, industrial, or institutions?		No additional cost, system users pay set fees per ton	No additional cost, system users pay uniform fees per ton	Uncertain. The cost effectiveness of the enhanced efficiency processes is unknown	No additional cost anticipated	No additional cost anticipated	No additional cost anticipated	No additional cost anticipated	Cost of RDF to the cement plant is limited to the energy value content of the coal displaced	Is the impact of implementation of the process acceptable to the commercial, industrial, and institutional community?
9.0	Overall Project Risks	10	9	7	8	3	3	3	5	7	
	Economic realities		Cost effective approach when evaluated over 45–50 life cycle, stabilizes disposal rates	Less competitive than WTE, stabilizes disposal rates	Uncertain. No commercial experience in the US, but should be similar to massburn WTE	Uncertain, no commercial experience and data in US, more costly than WTE	Uncertain, no commercial experience and data in US, more costly than WTE	Uncertain, no commercial experience and data in US, Biofuel revenues may be significant, but cost of production is uncertain	Uncertain, no commercial experience and data in US, Biofuel revenues may be significant, but cost of production is uncertain	Much lower capital cost compared to WTE, but dependent on the economic viability of the cement plant	What is the process cost differential compared to landfill disposal and other competing technologies? Will the process help stabilize solid waste rates over long-term?
	Technical risk		Low risk, proven technology, experienced contractors	Moderate risk, proven technology, high O&M, potential shredder explosions, few experienced contractors	Low risk, proven technology, experienced contractors	Uncertain, no commercial experience and data in US, technically riskier than WTE and RDF	Uncertain, no commercial experience and data in US, may be technically riskier than WTE and RDF	Uncertain, long learning curve anticipated, feedstock pretreatment, process (wastewater, effluents, odors) concerns anticipated	Uncertain, long learning curve anticipated, feedstock pretreatment, process (wastewater, effluents, odors) concerns anticipated	RDF - Moderate risk, proven technology, high O&M, potential shredder explosions; RDF feed to cement plant - limited experience	Is there a limited history of technology and/or limited history of the service provider?
	Siting risks		Siting a WTE facility is complex and will require an acceptable site with adequate buffers and mitigation strategies	Siting a RDF facility is complex and will require an acceptable site with adequate buffers and mitigation strategies	Siting an ATR facility is complex and will require an acceptable site with adequate buffers and mitigation strategies	Siting a thermal gasification facility is complex and will require an acceptable site with adequate buffers and mitigation strategies	Siting a plasma gasification facility is complex and will require an acceptable site with adequate buffers and mitigation strategies	Siting a waste-to-biofuels facility is complex and lengthy multi-dimensional process, and the outcome is not always certain.	Siting a waste-to-biofuels facility is complex and lengthy multi-dimensional process, and the outcome is not always certain.	An existing cement kiln will not require a new siting process, only a permit modification. A successful outcome is more likely.	Siting a WTE facility is complex and lengthy multi-dimensional process, and the outcome is not always certain.
	Procurement issues		Several qualified contractors in the US	Few experienced contractors in US	Proven experience in Europe, not in US	Few experienced contractors in US	Few experienced contractors in US	Few experienced contractors in US	Few experienced contractors in US	Few experienced contractors in US	Is there a lack of qualified competition due to the uniqueness or state of technology development?
	Fatal flaws		No fatal flaws	Minor potential flaws due to equipment performance and potential explosions	No fatal flaws but no demonstration facility with ATR in the US	Uncertain, no commercial experience and data in US, carbon monoxide in syngas	Uncertain, no commercial experience and data in US, carbon monoxide in syngas	Uncertain, no commercial experience and data in US	Uncertain, no commercial experience and data in US	Dependent on the economic viability of the cement plant	Is the project dependent on uncertain factors / conditions, such as the acceptance of a byproduct by an industry that could leave the local community, or income from a byproduct whose price or market is not reliable?
	Contractual risk		Minimal contractual risk	Minimal contractual risk	Minimal contractual risk	Uncertain, no experienced contractors in US	Known vendor filed for bankruptcy protection within the past 5 years	Uncertain, few experienced contractors in US	Uncertain, few experienced contractors in US	Minimal contractual risk	Can the definition of "failure" be clearly described or expressed in a contract?
	Total Score	100	95	85	95	42	37	39	38	72	

With the exception of massburn and RDF WTE technologies, the majority of the waste ranking score candidate conversion technologies do not meet the criteria for commercial-scale operation that have successfully processed waste materials for a minimum of 3 years and supported by publicly available production data.

An alternative related to RDF production and co-combusting the RDF (also known as engineered fuel) in a cement kiln was also evaluated. This form of WTE is based on successful projects in Europe with recent experience on the east coast of the US. Since there are several cement kilns located in the Pacific Northwest, this option for energy recovery may be worth further investigation. An option such as this may be an alternative that could help King County reduce the amount of wastes that require treatment in a WTE facility or landfill. The production of RDF can also be a way to curb the need for additional WTE capacity until enough volume is reached for an additional line or facility. This option, if found to be viable, would require a long-term commitment from the cement kiln owner to accept a minimum amount of engineered fuel on an agreed upon schedule.

One of the thermochemical waste-to-biofuels projects is also an option and should be monitored in the future. Enerkem’s waste-to-biochemicals/biofuels project in Edmonton, Canada, was constructed in 2015 and continues to be operated in a startup production mode. The project is designed to ultimately process 100,000 tpy of RDF for production of 10 million gallons per year (mgy) of fuel ethanol. The RDF for the process is manufactured by the City of Edmonton at their adjacent Mixed Waste Processing Facility (MWPF). Currently, the project is producing only methanol, which has a marketable value as a biochemical used in the manufacture of many consumer and industrial products and is an alternative energy fuel source (may be blended with gasoline). The current low cost of petroleum based liquid and gaseous fuels, along with an established corn ethanol market in the US, may impact Enerkem’s future decision to produce ethanol as originally intended. In addition, the Enerkem’s gasification process requires a relatively large amount of preprocessing to obtain dry (less than 20% moisture) and homogeneous waste specification.

Recommendation for Best Fit WTE Option

Of the qualified and proven WTE technologies, thermal processing via grate combustion with a waterwall boiler (massburn), which includes numerous innovations and design features of ATR, is considered to be the most appropriate and Best Fit WTE option to process King County’s waste.

Other than RDF WTE Facilities, there are no WTE plants in the US that are combined with an advanced material recovery (AMR) process. However, there is a WTE facility in Lee County, Florida, where a C&D recycling facility has been constructed adjacent to the WTE facility and combustible materials from the C&D recycling are delivered to the WTE facility. China may raise the quality requirements for recyclables exported to their country, which could significantly impact the ability to market materials recovered by AMR/ARC type facilities. Recyclable materials recovered from these types of facilities may be limited to domestic markets as a fuel additive if the material cannot meet the future quality standards in China. This type of analysis is not currently in our scope of work, but will be added to our future recommendations for further consideration.

The scores of the eight evaluated WTE technologies summarized in Table 2–2 clearly supports the recommendation for further evaluation of massburn WTE.

2.2.6 Best Fit WTE Option

Analysis of King County's Waste Projection and Non-Processable Waste

King County Waste Projections

King County provided the projections for the quantity of waste requiring disposal from the beginning of the planning horizon in 2028 to 2078. The waste projection is highly dependent on the recycling rate. The County model assumes that the countywide recycling rate will increase from 52% in 2028 to 57% in 2033. Thereafter, the recycling rate is assumed to remain stable at 57% to 2078. However, if a WTE were built and landfilling were phased out, this could result in an increase in the recycling rates (Section 2.2.12 below). The recycling rate is dependent on the participation of the 37 cities within King County. Therefore, the model does not account for the County's goal of meeting the 70% recycling rate. If the County's waste projections are modified, the proposed facility configuration, energy generation, and other key performance parameters are subject to change.

King County's annual quantity of waste requiring disposal is projected to increase from approximately 922,000 tons in 2016 to 1.1 million tons in 2028, which is the first year of the planning horizon. The King County projection of the annual quantity of waste requiring disposal for the 50-year planning horizon (2028 through 2078) is shown in **Figure 2–1**.

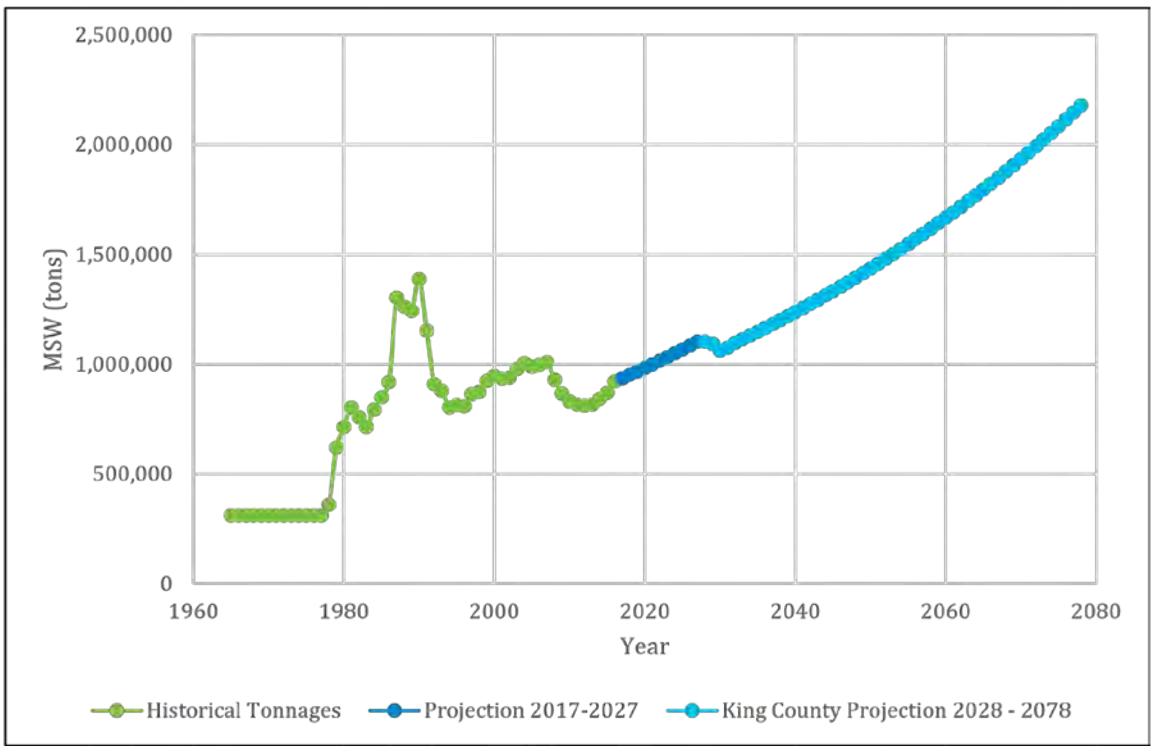

Figure 2–1. King County Historical Waste Tonnages and Projections

For the 20-year planning horizon (Scenario 1) from 2028 to 2048, the annual quantity of waste requiring disposal is projected to increase by an average of 1.2% per year. By 2048, it is projected that there will be approximately 1.39 million tpy requiring disposal.

For the 30-year planning horizon (Scenario 2) from 2028 to 2058, the annual quantity of waste requiring disposal is projected to increase by an average of 1.3% per year. By 2058, it is projected that there will be approximately 1.62 million tpy requiring disposal.

For the 50-year planning horizon (Scenario 3) from 2028 to 2058, the annual quantity of waste requiring disposal is projected to increase by an average of 1.4% per year. By 2058, it is projected that there will be approximately 2.18 million tpy requiring disposal.

King County Waste Composition Analysis

The following waste composition analysis is based on the 2015 King County Waste Characterization and Customer Survey Report prepared by Cascadia Consulting Group. The composition of the waste is shown in **Figure 2–2**. The primary components being Food Waste (21%), Paper (17%), Wood and Yard Waste (17%), Other Organics (15%), and Plastic (12%). These primary components account for 82% of the waste composition.

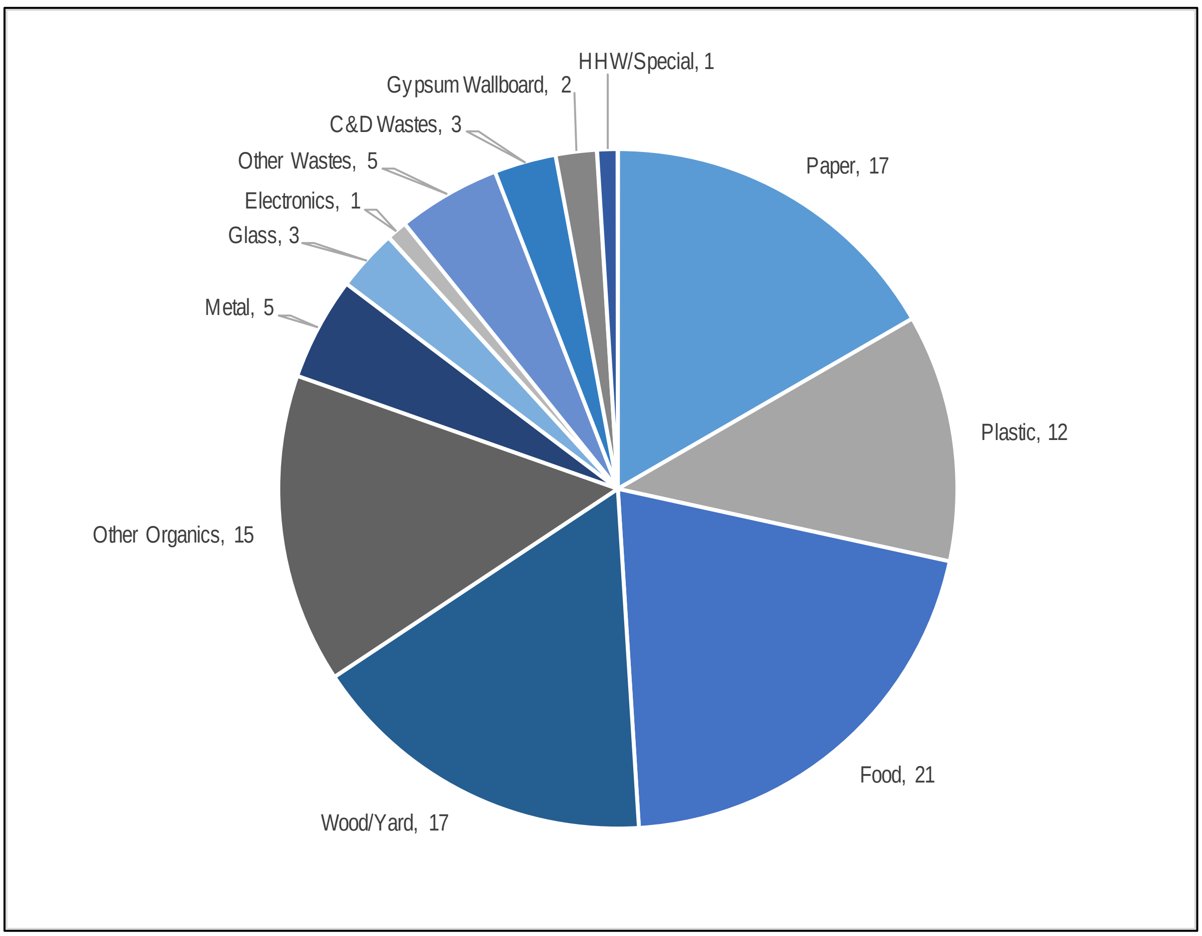

Figure 2–2. King County Waste Composition

The waste composition report indicates that approximately 4.9% (this value will be further evaluated during future discussion and the potential Feasibility Study) of the waste requiring disposal will be non-processable waste, which includes C&D Waste, Gypsum Wallboard, and Electronics. These waste categories were selected as non-processable materials because they are commonly received segregated, are materials that contribute little to no heating value, or may be best and commonly managed in alternative manners. The County may consider implementing policies to segregate non-processable waste at the Citizen Drop-Off Facilities and Transfer Stations. These non-processable wastes will require alternate disposal at appropriate C&D landfills or processing at recycling facilities. As shown in **Figure 2–3**, the quantity of bypass non-processable waste is projected to increase from approximately 54,000 tons in 2028 to approximately 107,000 tons in 2078. The total quantity of non-processable bypass waste from 2028 through 2078 is estimated to be approximately 3.85 million tons. However, a fraction of this non-processable waste is combustible and may not be detrimental to the WTE process. Examples of combustible elements and issues associated with the following waste streams are noted below:

- **C&D Waste**: combustible elements include vegetative waste, wood waste, rubber tires, carpeting, insulation on exterior of electrical wiring, tarpaper and shingles, waterproofing barriers, and membrane roofing. Objects in C&D waste that could be problematic for the WTE combustion process are primarily large objects that can cause jams or plugs in the waste feed chutes or ash expellers. These include long pipes and conduits, bulky electrical fixtures, water heaters, appliances, small construction equipment (wheelbarrow, cement mixers, small generators, etc.), long sections of trees, and large diameter branches. If these problematic materials are not removed, additional effort will be required of the WTE facility operators.
- **Gypsum Wall Board**: the primary ingredient in gypsum is calcium sulfate dehydrate, which is not combustible. Combustible elements include paper on the exterior of drywall and small pieces of wood that may be attached to the wall board. When received in bulk quantities that are easy to spot by the tipping floor attendant or refuse crane operators and some of the drywall could be removed from the MSW by the facility operators. Thorough mixing of small amounts of wallboard with the normal MSW will typically not interfere with the WTE combustion process.
- **Electronics**: combustible elements include wood frames, plastics, polymers, and insulation on wiring. The delivery of small amounts of electronic waste will typically not interfere with the WTE combustion process, but could contribute to the release of heavy metals in the bottom ash, and increase use of reagents for removal by the FGT system. It should be noted that electronic waste is typically managed through a separate program. Though processing of electronic waste at the WTE can occur, this is not a typical practice. Although many of the nonferrous metals are recoverable from the combusted e-waste, there may be greater recoverable value of the metals if the e-waste were processed in a dedicated recycling program.

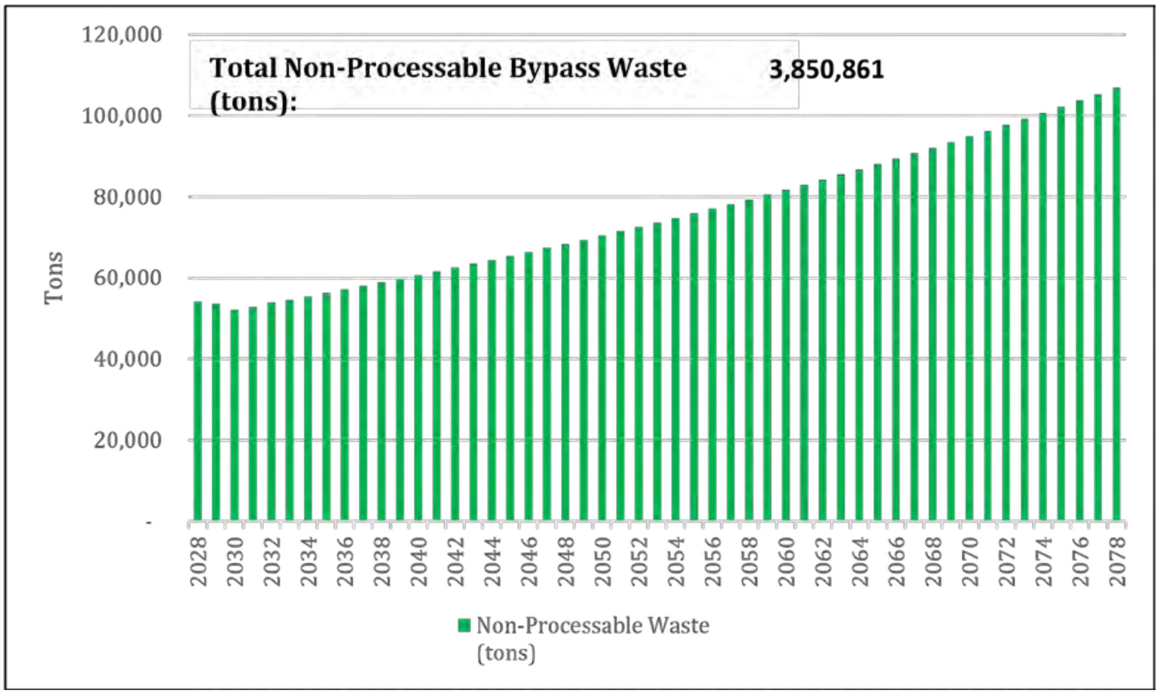

Figure 2–3. Non-Processable Bypass Waste Projection (2028–2078)

King County Waste HHV

Based on the expected waste composition of the processable waste to be delivered to the facility, the HHV of the waste can be estimated. Given the estimated HHV for each waste type and the estimated percent of the waste composition, the estimated composite waste HHV is 5,254 Btu/lb (**Table 2–3**).

Table 2–3. Estimated Waste HHV

Material	Estimated Percentage of Waste Composition	HHV Contribution (Btu/lb)
Paper	16.8	987
Plastic	12.2	1,696
Food	20.5	487
Wood/Yard	16.8	716
Other Organics PM:	15.3	646
Metal	4.7	-
Glass	2.6	-
Other Wastes	9.9	436
HHW/Special	0.7	29
Non-Processable Waste (Removed)	4.9	-
Total		5,254

Most WTE communities continue to see an expansion in their waste generation due to population growth. Achieving future waste diversion and recycling goals and working with manufacturing to reduce the production of waste when making new products as well as being able to integrate high quality recyclables into their processes will help reduce the projected waste growth rate and likely delay the need for expansion of the initial WTE facility. The removal of organic waste (food and vegetation) would drive up the HHV of the remaining waste. If the HHV increases beyond the design HHV value, it would result in lowering the waste processing capability for the WTE facility, which is designed based on a specific HHV and throughput for total heat input. If plastics were also targeted in future waste diversion goals along with organic materials, the two would tend to offset each other. However, if only plastics were targeted, the HHV would likely be reduced. If the reduction in HHV is less than the design HHV value, the WTE facility would be able to process more waste, up to its theoretical design heat input. Complicating this issue, the HHV of a community's waste typically varies on a daily basis (depending on weather) and seasonal basis. In addition, based on many of the newer facilities operating today, other options include the processing of waste from existing landfills (landfill mining, 10%–30% of processed MSW) and/or adding processed sewage sludge (2%–10%). Waste heat from the WTE process could be used to dry sewage sludge and increase its heating value. A certain amount of sewage sludge can be processed raw (15%–20% solids). A future sensitivity analysis on this parameter may be warranted and is one of the recommendations for future consideration.

2.2.7 Final WTE Sizing Strategy

WTE combustion technology has demonstrated the ability to be scaled to meet the needs of the host community (city, county, or several counties) depending on the legal entities that want to build and operate (or have somebody build or operate) such a facility. The current range of overall facility capacities varies from 200 tpd to 5,512 tpd. They are typically constructed with multiple combustion lines to maximize their availability to process waste while allowing scheduled maintenance to be performed without taking the entire plant off line. There are plant configurations ranging from two to six combustion lines around the world. For communities expecting growth, WTE facilities can be designed to accommodate future expansions (additions of one or multiple combustion lines) after first commissioning. Several WTE facilities in the US and Europe have been successfully expanded in the past 15 years.

For the purpose of this study, WTE facility combustion lines ranging from 750 to 1,125 tpd capacity were considered for the preliminary sizing of the WTE facility. A large WTE facility in the range of 3,000–6,200 tpd overall capacity would likely require 20 to 40 acres, depending on local conditions (site configuration, presence of wetlands, storm water treatment requirements, access to roadways and transmission corridors, etc.). A smaller WTE facility of 1,000 tpd capacity would typically require 15 to 20 acres.

Strategies for Sizing of Combustion Lines

Two strategies were considered in the sizing of the WTE facility:

- Sizing the WTE facility to maximize the available capacity
- Sizing the WTE facility to minimize bypass waste

Sizing the WTE Facility to Maximize Capacity

Sizing the WTE facility to maximize its available capacity in its initial year of operation will have the benefit of meeting the immediate needs of the County and reducing the initial capital costs of the project. However, given the waste projections, there will be a significant increasing quantity of bypass waste each year that will need to be managed by the County. The County may consider additional recycling initiatives and programs to reduce bypass waste quantity, but given that the current waste projections already consider an increased recycling rate of 57%, the bypass waste will likely need to be sent to an out-of-county landfill for disposal.

Table 2–4 illustrates the required WTE facility sizes and needs for future expansion under this strategy to maximize the available WTE capacity in its first year of operation. (Note: Table 2–4 contains the same information as that in Table 1–1 and is repeated as part of the discussion on the strategy for the final WTE sizing.) Benefits of the Option 1 sizing scenario include:

- Facility is at capacity on day 1, thereby ensuring that it is able to operate optimally at its design condition
- Facility will be smaller and thereby result in lower capital cost associated with larger facilities
- Smaller facility will present opportunity for alternate forms of recycling to be implemented to process additional waste due to growth

Issues/disadvantages of this sizing option include:

- Smaller facility will not be able to process all of waste expected due to future growth, and will require alternate disposal methods
- Reduces the opportunity for the County to provide regional waste disposal services to neighboring communities
- Reduces the opportunity for the County to market additional capacity for regional special wastes which command higher tipping fees

Table 2–4. Combustion Units Sized to Maximize Available Capacity

Planning Scenario: Maximize Available Capacity in its Initial Year of Operation (2028)			
Planning Period	WTE Size in 2028 (tpd)	Additional Capacity (tpd) Needed (Year)	Total Excess Waste (M tons) in Need of Alternate Disposal/Treatment
20-year	3,200	None	3.0
30-year	3,200	800 in 2048	4.4
50-year	3,200	1,600 in 2060	13.5

Sizing the WTE Facility to Minimize Bypass Waste

The second strategy was to initially size the WTE facility to minimize the quantity of bypass waste from the beginning to the end of the planning horizon. This strategy will provide the County the following benefits:

- Reduce the County's reliance on alternate disposal methods
- Reduce the quantity of waste sent to an out-of-county landfill
- Provide the County the option to accept waste from other municipalities to fill unused capacity
- Expand the recycling system and opportunities of County (or public–private partnerships also with manufacturing and industry) owned and operated recycling facilities to produce secondary raw materials made in Washington to reduce dependence on natural resources and obtain desired recycling objectives

The potential issues of this strategy include the following:

- There will be unused capacity at the beginning of the planning horizon.
- Incoming quantity of waste may be unable to meet the efficient operating range of the WTE facility (greater than 75%), unless the excess capacity is marketed to other waste generators.
- Frequent shutdowns or operation of some of the units at reduced load may be required during periods when waste deliveries are unable to meet the capacity requirements. There is a potential cost associated with the frequent operation at reduced load and/or startup and shutdown of a WTE facility related to wear and tear on the plant equipment. Shutdowns due to unavailability of MSW would primarily occur on Sundays or last days of holiday weekends, and could affect one or more boilers. Ideally, it is preferred to operate the WTE facility as close to its design condition as possible.

Table 2–5 illustrates the required WTE facility sizes and needs for future expansion under this strategy to minimize the amount of excess waste that must bypass the WTE facility over the course of the planning period. (Note: Table 2–5 contains the same information as that in Table 1–2 and is repeated as part of the discussion on the strategy for the final WTE sizing.)

Table 2–5. Combustion Units Sized to Minimize Bypass Waste

Planning Scenario: Minimize Excess Waste that Must Bypass the WTE Facility			
Planning Period	WTE Size in 2028 (tpd)	Additional Capacity (tpd) Needed (Year)	Total Excess Capacity (M tons) Available for Regional Markets
20-year	4,000	None	4.2
30-year	4,500	None	8.5
50-year	4,200	2,100 in 2053	16.0

The above two approaches for sizing of the WTE facility were presented to the County for review with a recommendation to size the WTE facility(ies) to minimize the amount of bypass waste to avoid having to manage the excess waste by other means. The three Minimize Bypass Waste Scenarios 1, 2 and 3 that were presented above were also financially analyzed as part of the Task 2 Memorandum.

Minimize Bypass: Scenario 1, 20-Year Planning Horizon

For Scenario 1, the planning horizon is 20 years beginning from facility commencement in 2028 through 2048. The objective for this scenario is for the facility to be sized to minimize the quantity of the bypass throughout the planning horizon. The facility will be sized at 4 units at 1,000 tpd, giving it a total processing capacity of 4,000 tpd. As shown in **Figure 2–4**, the facility will process all the available processable waste from 2028 to 2048.

As shown in **Figure 2–5**, the facility will have an initial excess capacity of approximately 300,000 tons in 2028. As the incoming waste quantity continues to increase over time, the excess capacity will reduce to approximately 24,000 tons by 2048. The total excess capacity throughout the planning horizon from 2028 to 2048 is approximately 4.1 million tons. Given the projections, the WTE facility will initially be operated at 78% of its total capacity utilization in 2028 and will gradually increase over time to 98% by 2048.

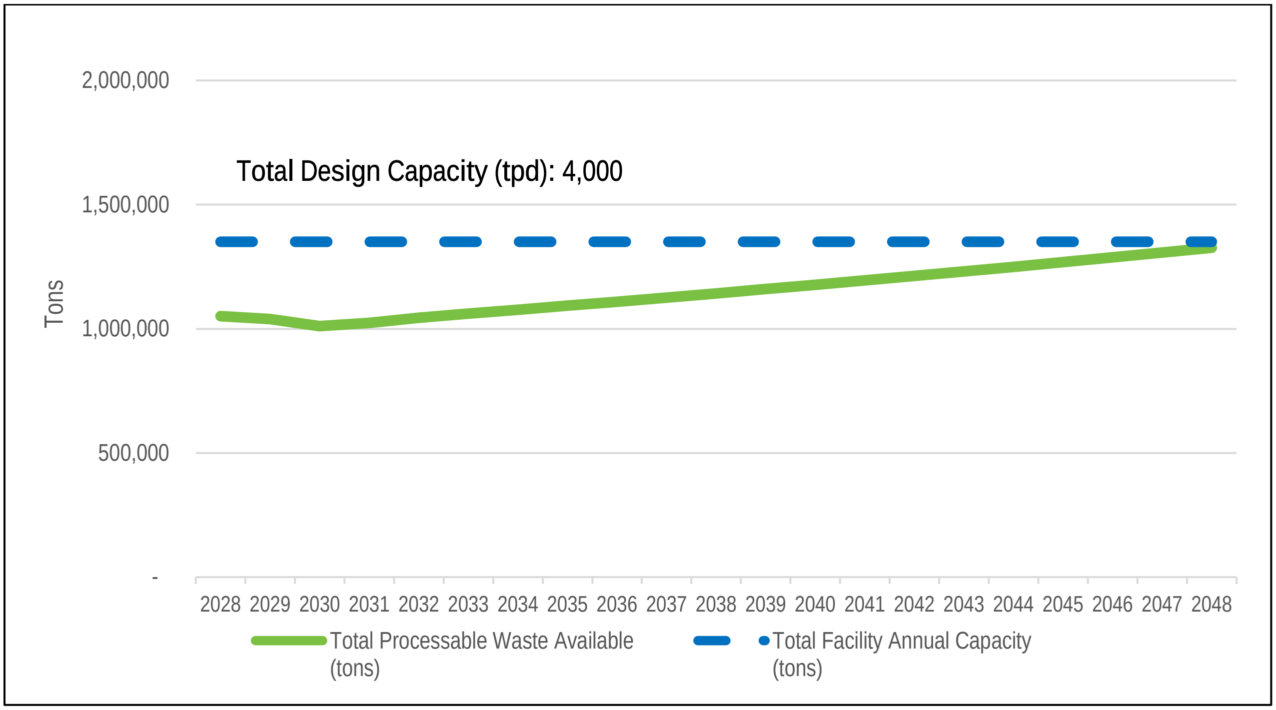

Figure 2–4. Minimize Bypass: Scenario 1, 20-Year Planning Horizon

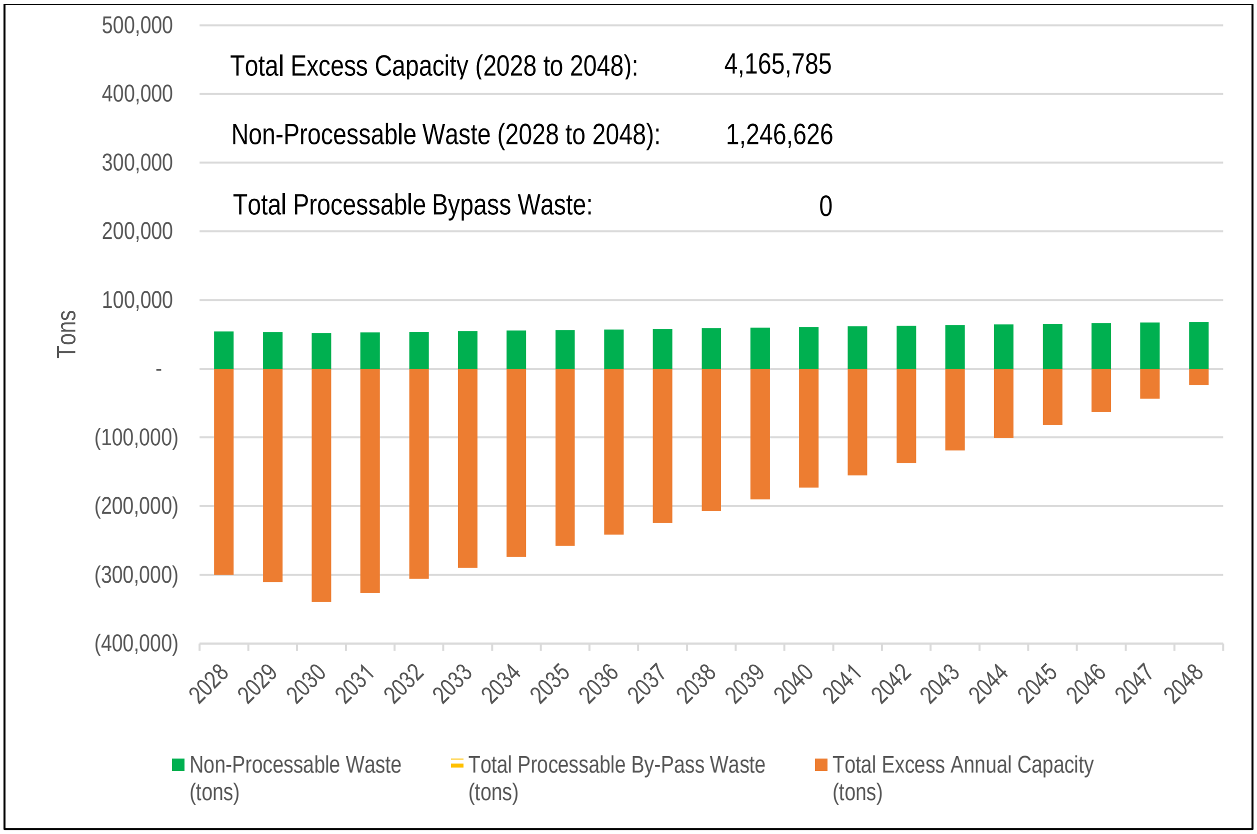

Figure 2–5. Minimize Bypass: Scenario 1, Projected Excess Capacity for 20-Year Planning Horizon

Minimize Bypass: Scenario 2, 30-Year Planning Horizon

For Scenario 2, the planning horizon is 30 years beginning from facility commencement in 2028 through 2058. The objective for this scenario is for the facility to be sized to maximize its processing capacity in its initial year of operation. The facility is sized at 4 units at 800 tpd in 2028, giving it a total processing capacity of 3,200 tpd. As shown in **Figure 2–6**, the facility will process all the available 1.05 million tons of processable waste in 2028. The facility's total processing capacity will continue to meet the demand of the incoming processable waste stream until approximately 2035. At which time, the quantity of the available processable waste will exceed the total capacity of the facility. It is planned that the facility will be expanded in 2048, which will include an additional 800 tpd unit. Beginning in 2048, the WTE facility will have a total processing capacity of 4,000 tpd.

After 2035, the bypass waste quantity will continue to increase until the expansion of the facility in 2048 (**Figure 2–7**). The incoming processable waste will again exceed the total processing capacity of the facility in 2050. By 2058, it is projected that approximately 189,000 tpy of processable waste will need to bypass the facility for disposal. From 2028 through 2058, it is estimated that a total of 2.4 million tons of bypass waste will need alternate processing/disposal.

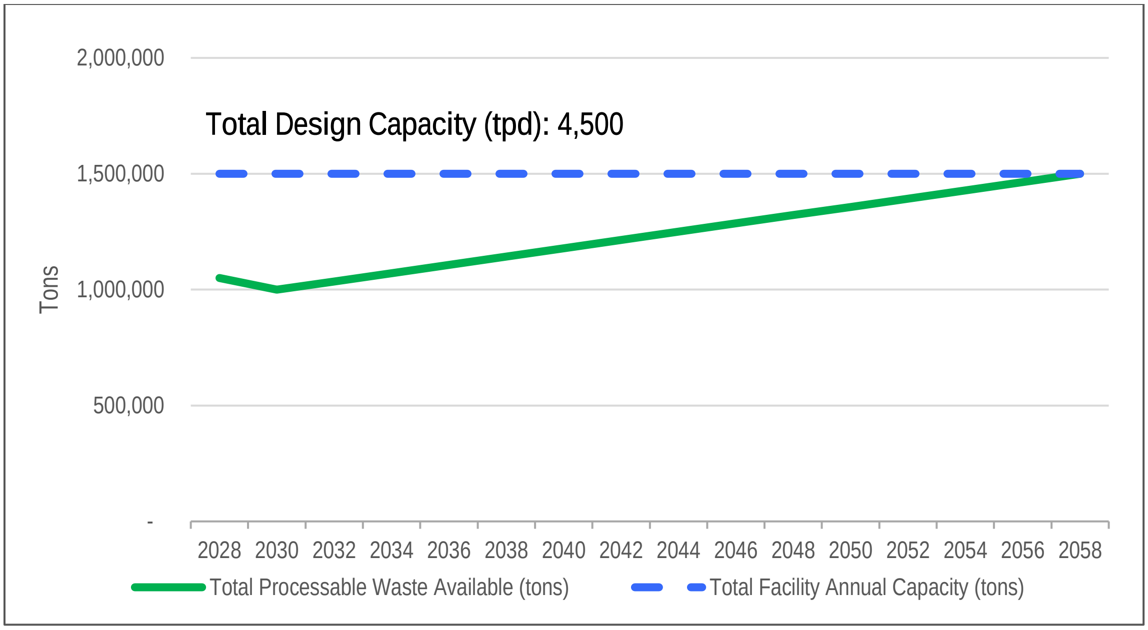

Figure 2–6. Minimize Bypass: Scenario 2, 30-Year Planning Horizon

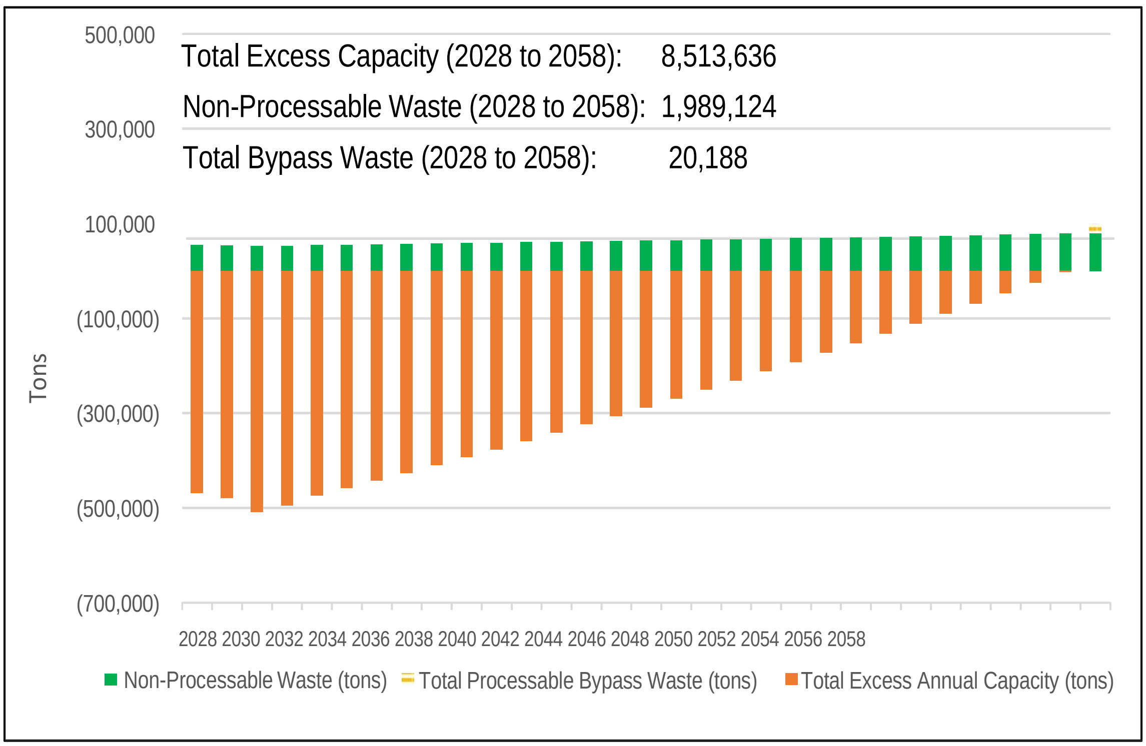

Figure 2–7. Minimize Bypass: Scenario 2, Projected Excess Capacity for 30-Year Planning Horizon

Minimize Bypass: Scenario 3, 50-Year Planning Horizon

For Scenario 3, the planning horizon is 50 years beginning from facility commencement in 2028 through 2078. The objective for this scenario is for the facility to be sized to minimize the quantity of bypass throughout the planning horizon. The facility will be sized at 4 units at 1,050 tpd, giving it a total processing capacity of 4,200 tpd. As shown in **Figure 2–8**, the facility will process all available processable waste from 2028 to 2053. Given the projections, the initial total capacity utilization is estimated to be 74% in 2028 and by 2052 it is projected to be 99%. In 2053, it will be necessary to expand the facility to meet the future demand throughout the remaining planning horizon from 2053 through 2078. To meet this demand, the WTE facility will be expanded by two additional units each with a capacity of 1,050 tpd. The expanded WTE facility will have a total capacity of 6,300 tpd.

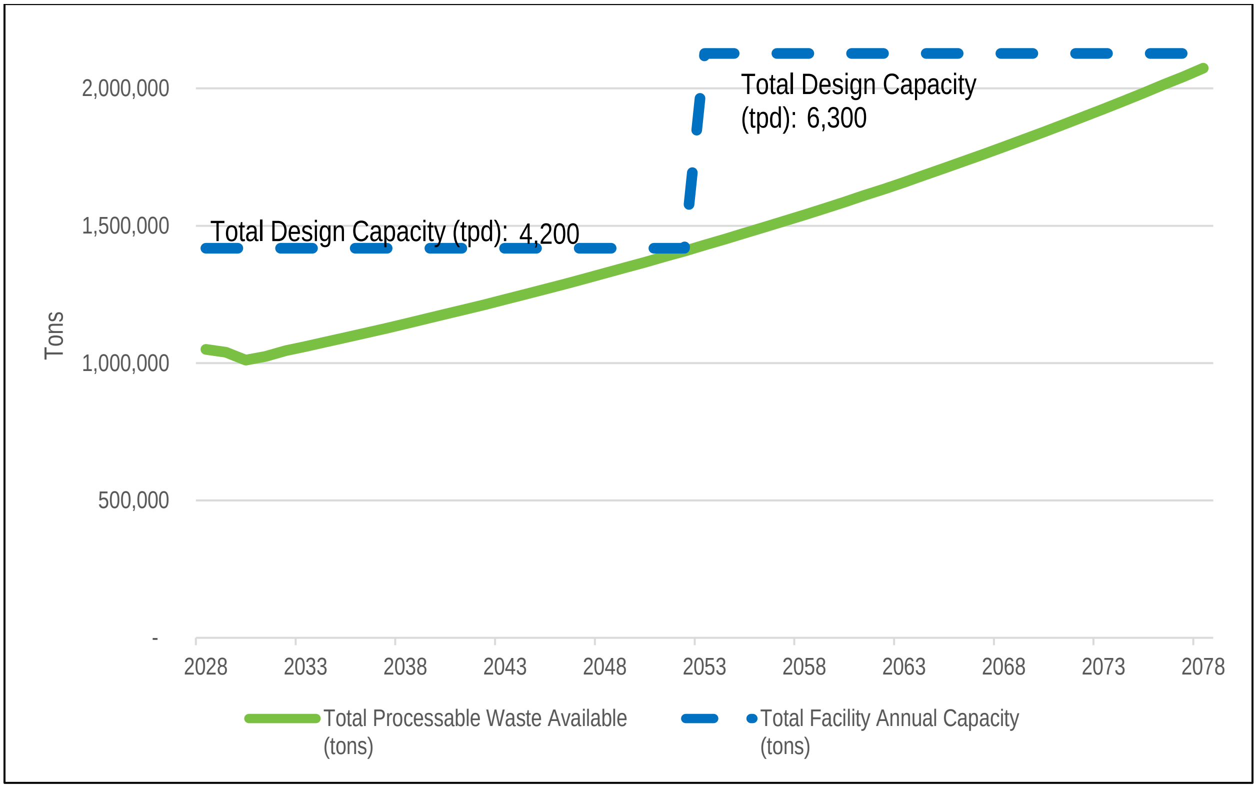

Figure 2–8. Minimize Bypass: Scenario 3, 50-Year Planning Horizon

As shown in **Figure 2–9**, the facility will have an initial excess capacity of approximately 370,000 tons in the year 2028. As the incoming waste quantity continues to increase over time, the excess capacity will be reduced until the incoming waste meets the design capacity in the year 2053 at which time the facility will be expanded. After the expansion in year 2053, the total capacity utilization will reduce to 67% with an excess capacity of approximately 700,000 tons. As the incoming waste stream continues to increase, the total capacity utilization is projected to reach 75% by the year 2060 and 97% by the year 2078. The total excess capacity throughout the planning horizon from year 2028 to year 2078 is approximately 16.0 million tons.

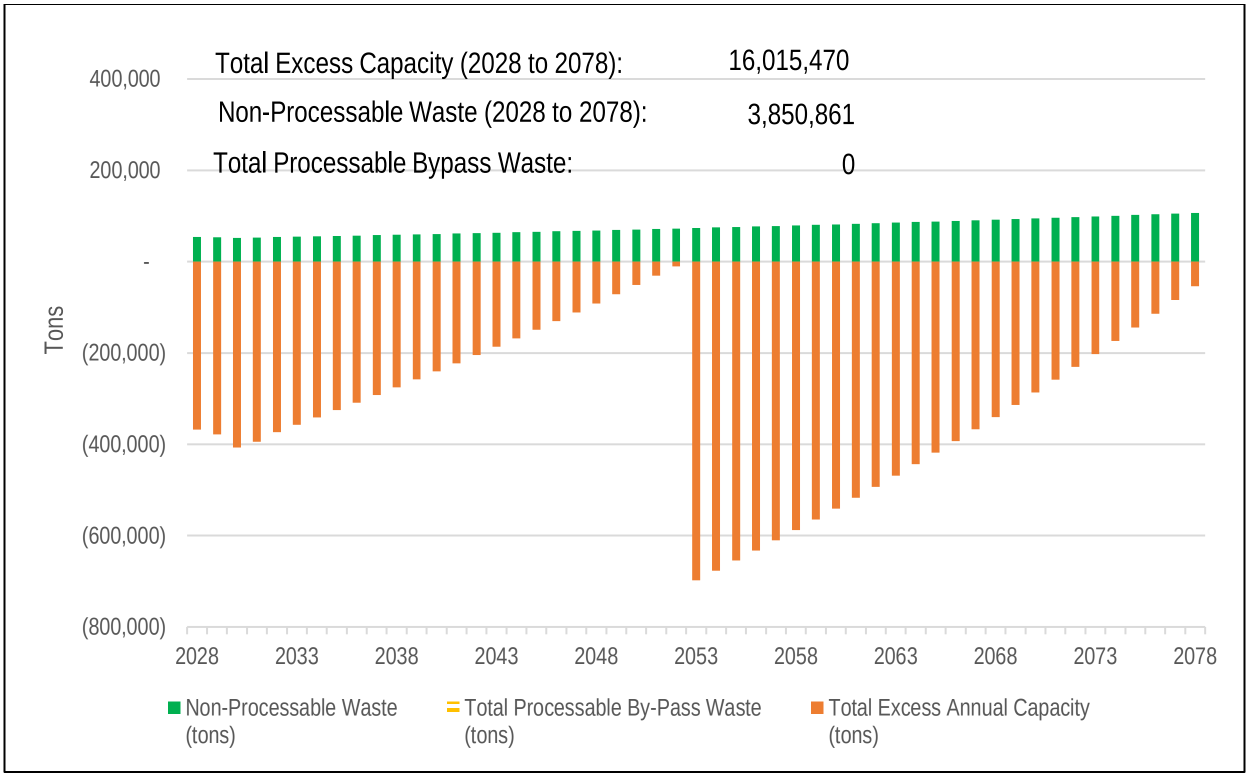

Figure 2–9. Minimize Bypass: Scenario 3, Projected Excess Capacity for 50-Year Planning Horizon

2.2.8 Final Configuration of Best Fit WTE Option

As discussed earlier, the number of innovations and features in the modern WTE industry continues to advance in support of the goals of sustainability with greater attention applied to facility efficiency, recovery of energy and materials, and implementation of local community benefits. The WTE facilities of today offer a wealth of options to achieving desired objectives. The innovations and features are subdivided into the following categories:

Innovations and Features in the Modern WTE Industry that Directly Affect the WTE Facility

- Environmental
- Technical
- Economic
- Aesthetics and Landscaping

Innovations and Features in the Modern WTE Industry that Affect the Overall Waste Management System

- Community Benefits

Each of these broad categories is further discussed in the following subsections with numerous examples of innovations and features that have been successfully implemented in WTE facilities around the world.

Environmental Innovations and Features

- Incorporation of extensive air emissions control technology, some far more rigorous than the regulatory requirements
- Optimized APC systems and FGT equipment for reduced use of reagents and chemicals used in the treatment processes for reduction of acid gases, nitrogen oxides, dioxins/furans, heavy metals, and particulates

  Most US WTE facilities employ Spray Dryer Absorber (SDA) with Fabric Filter Baghouses to meet EPA emission standards. These systems typically will employ ammonia/urea injection into the boiler for control of NO_x compounds, powdered activated carbon injection for control of mercury, slaked pebble lime injection for control of acid gases, and fabric filters for control of particulates.

  The new WTE facility in Palm Beach County, Florida, is the first WTE facility in the US to employ SCR technology for reduced emissions of NO_x compounds. The SCR technology results in very low NO_x emissions (50 ppm on daily basis, 45 ppm on yearly basis).

  Many European WTE facilities have adopted high efficiency FGT systems to minimize air emissions while exceeding EU regulations. Technologies include wet and dry scrubbers, fabric filters, electrostatic precipitators, fabric filters and high efficiency membrane fabric filters. In many facilities, flyash is treated with pozzolans and cement encapsulation to allow disposal in non-hazardous landfill (or beneficially used as daily cover).

  Using Gore Filters in the Flue Gas Cleaning System with active carbon will eliminate aerosols, condensable materials, and particulate matter such as PM and PM 10.

- Use of an air cooled condenser in lieu of wet cooling tower to significantly reduce use of local water supply and eliminate visible plumes from wet cooling towers

Technical Innovations and Features

- Evolution and advancement of the entire combustion process continues to advance from introduction of the MSW fuel to the FGTs

  These improvements include advanced combustion controls, water and air cooling of the high wear zones of the grates and boiler, improved boiler metallurgy (Inconel overlay on boiler tubes and advanced metallurgy for superheater tubes), improved boiler refractories, improved O&M techniques such as online boiler cleaning, and optimized FGTs. Advanced combustion controls result in reduced combustion air, improved combustion and burnout of waste, and reduced emissions that require downstream treatments. Worldwide, WTE facilities have also demonstrated the ability to operate in full compliance with more stringent regulatory emission limits. As a result, WTE is also an important tool in reducing emissions of GHGs. It has been recognized internationally as a source of GHG mitigation, including by the EPA, the EU, CalRecycle, and the Intergovernmental Panel on Climate Change (IPCC).

- Improved O&M techniques (nondestructive testing for predictive and preventive maintenance such as monthly vibration tests, quarterly oil sampling, infrared thermography, ultrasonic testing for metal thickness, acoustic data, to optimize burn out rate, and motor electrical signature tests)

Included in this category is the use of Inconel and other alloy materials for overlay on various boiler and heat transfer surfaces in the boilers. Computerized Maintenance Management Systems (CMMS) are also used by facility operators for intelligent prediction of when parts or equipment may require replacement or maintenance. These are examples of best management practices that result in higher boiler and turbine-generator availability, gross and net electric generation, and lower O&M costs.

- WTE facilities continue to be designed and/or modified for optimized operation and maintenance (clear zones, access platforms, hoists and lifts) to minimize the use of brute force and provide a safer workplace

  A safer workplace translates into improved employee morale and an engaged and attentive staff.

- Use of reclaimed water for cooling systems, when available
- Advanced systems for online cleaning and monitoring of routine O&M practices for optimization of annual boiler availability
- Innovative technologies for maximizing recovery rates of metals, minerals, and glass from bottom ash

  Bottom ash processing (crushing, screening, washing) technologies have been demonstrated for recovery and use of mineral fraction as construction aggregates (road base, aggregates in asphaltic and cement based pavements, and cement based products). Most of the improvements in bottom ash processing have been developed in Europe, where there is a greater focus on material recovery and landfill diversion. Bottom ash utilization has also seen significant growth in recent years in the US.

- Redundant bottom and flyash transfer systems for improved annual facility availability

Economic Innovations and Features

- Co-generation, or CHP generation has been widely deployed, especially in the colder climates of northern Europe

  It is a way of increasing the overall thermal efficiency from 20% to 30% to more than 85% by using waste heat from the production of electricity. In traditional WTE, power plants produce electrical energy only, the efficiency is approximately 20% to 30% and the excess heat is discharged to the atmosphere via the cooling system and flue gas from the stack. CHP can create various forms of energy, including electricity, heat for district heating purposes, steam for process use, cooling for air-conditioning, or energy for water treatment (desalination and other alternate supply sources). By also extracting energy from the flue gas by condensation and heat pumps, it is possible to achieve up to 100% energy efficiency (based on the net calorific value). The world's largest WTE facility is currently being designed for the city of Shenzhen in China and will include six processing lines with a total capacity of 5,000 metric tpd (5,512 tpd). This plant will also provide electricity for the production of 125 mgd of desalinated potable water and is coupled with PV panels that will cover two thirds of the 66,000 square meter roof.

- Advanced metal recovery for course and fine fractions of ferrous and nonferrous metals, and future extraction of precious metals from the fine fraction of nonferrous metals

  High strength magnets and eddy current separators have enabled the optimization of metal recovery from bottom ash. This in turn improves the opportunity for beneficial reuse of bottom ash as aggregates for road base and construction products and the partial inclusion as feedstock in the production of Portland cement. The cement manufacturing industry has shown an interest in using bottom ash as a mineral feedstock for the production of Portland cement. Using bottom ash in this application will be less problematic than using RDF waste as a supplemental fuel in the cement kilns, which is currently being done in a few locations in the US and Europe.

- Increase in energy and cost efficiencies by the synergistic use of energy (both heat and power) of publicly owned WTE facilities for the community's own utilities (water, wastewater) and public works or local institutional facilities

  The concept of a microgrid, which is being promoted by DOE to ensure greater reliability of electric power to critical municipal services (utilities, emergency response, power, etc.), may also prove to be of value in securing improved revenues. Hillsborough County, Florida, is currently operating one of its waste water treatment and water treatment plants with electricity generated by its 1,800 tpd WTE facility. They are also currently evaluating additional "behind the meter" uses for their internal use of power to include an adjacent public works campus. CDM Smith is aware that DOE is promoting CHP projects and trying to help communities in the first step in finding a use for CHP by funding the community's initial feasibility study.

- Incorporation of higher heat recovery boiler pressures (medium and high pressure) to increase the amount of energy recovered from the MSW

- Incorporation of energy saving features to reduce parasitic load

  These loads include LED lighting systems (interior and exterior), high efficiency HVAC systems (including option for steam jet systems based on European experience), variable frequency drives for large motors, translucent siding for natural lighting, and solar PV on rooftops and parking canopies. Reducing the internal parasitic load will maximize the revenues from the sale of electricity to help reduce the cost to the local rate payers and system users.

- Many elements of the local and regional waste stream can be co-combusted in WTE facilities

  The list of special wastes includes wastewater treatment plant (WWTP) biosolids (5–10%), used oils (<5%), used tires (whole or shredded), USDA regulated garbage (also referred to as "International Waste"), auto shredder residue, bulky waste (after size reduction), combustible fraction of C&D waste, expired pharmaceuticals and other special waste in need of assured destruction (confidential paper, uniforms, industrial wastes, illegal drugs and contraband), along with special liquid wastes. Many of the above special wastes can command higher tipping fees to help use available WTE capacity and generate significant revenues.

Aesthetics and Landscaping Innovations and Features

- Greater attention to aesthetics and LEED® standards are commonplace in the modern WTE industry

  This has been demonstrated by the recent construction of LEED Platinum Administration Buildings and Visitor Centers. Most modern WTE facilities employ aesthetically pleasing siding and architectural designs to allow the WTE facility to complement and, in many cases, set the standard for future local development(s). The use of architecturally pleasing siding also serves a dual purpose in that it provides a barrier for transmittal of odors, dust, and noise.

- The use of innovative landscape features

  These features include green roofs, living walls, ground covers, and native plants for xeriscape[3] type landscape typically employed on modern WTE sites

- Modern WTE facilities are sensitive to nighttime lighting trespass concerns

  These facilities have adopted the use of full cutoff luminaires for exterior lighting systems to direct the light downward to the intended areas. In addition, evening deliveries to the WTE are also managed to reduce impact to the community.

Innovations and Features in the Modern WTE Industry that Affect the Overall Waste Management System—Community Benefits

Many WTE facility owners and operators have adopted numerous innovations, features, and special programs to maximize the benefits to the overall waste management system, including:

- Local programs to remove toxic materials from combustible waste

  This includes Mercury Bounty Program to remove mercury bearing items, Fishing for Waste Program to remove and recover energy from marine debris, E-waste Recycling Program to remove from waste stream to allow recycling by bona fide recycling process.

- Many elements of the local and regional waste stream can be co-combusted in WTE facilities

  The list of special wastes, many of which can command higher tipping fees, includes WWTP biosolids (5–10%), used oils (< 5%), used tires (whole or shredded), USDA regulated garbage (also referred to as “International Waste”), auto shredder residue, bulky waste (after size reduction), combustible fraction of C&D waste, expired pharmaceuticals and other special waste in need of assured destruction (confidential paper, uniforms, industrial wastes, illegal drugs and contraband), and special liquid wastes, including landfill leachate when the WTE process is conveniently located near the landfill. Waste from existing landfills can be used as part of the waste stream.

- Widespread use of distributed heating

  This includes use of hot water for community benefits such as heating community centers, pools, greenhouses.

---

[3] Xeriscaping refers to the conservation of water through creative landscaping using low water vegetation. Originally developed for drought-afflicted areas, the principles of xeriscape today have an ever broadening appeal

- Addition of community-specific unique architectural features that offer new economic opportunities

  One example is the ski slope/hiking trail feature that was constructed over much of a new WTE facility in Copenhagen, Denmark.

- Innovative host community programs that may include the co-combustion of biosolids from wastewater treatment plants and used tires

  This is practiced in the new WTE facility in Honolulu. Several other WTE facilities in Florida are also permitted to co-combust up to 5% of their waste as biosolids. WTE facilities in Europe also co-combust biosolids.

- Rail delivery of MSW if adequate real estate and proximity to existing rail lines exist and delivery by barge if water access is available, such as ports

  These two delivery options are for transferring the waste to WTE, not disposal of solid waste.

- Regional WTE project with adjoining county may provide synergies

  Examples include the use of neighboring landfill capacity (existing or future) for disposal of bypassed waste and ash residue that is not recycled.

- Evolution of WTE facilities as key components of an ISWM system

  These include combinations of landfills (ash monofills, C&D, and Subtitle D landfills); organic waste composting systems; material recycling facilities; collection facilities for used tires, oils, and HHW; and C&D recycling. Additionally, the concept for the integration of ISWM with recycling and manufacturing industries in an eco-park has been proposed in a number of locations in North America. The new WTE facility in Palm Beach County, Florida, is located on 24 acres of a 1,320-acre campus that has two WTE facilities (5,000 tpd of total capacity), two landfills (solid waste/ash and inert materials), a biosolids drying/pelletizing facility powered by landfill gas, and a material recovery facility for processing single stream recyclables.

  WTE facilities can be completely closed off and any vents of silos, tanks, etc. are controlled with the appropriate equipment like filters, active carbon filters (for oil tanks or for air vents to reduce odors), siphons, or scrubbers as proposed for the venting of chemical treatment.

Recommendations for King County Best Fit WTE Option

A number of WTE facilities located worldwide were evaluated to identify improvements that have been developed over the past decade as the industry continues to evolve toward higher levels of sustainability.

The preliminary recommendations for a Best Fit WTE option in King County include the following:

Facility Sizing and Siting

- Siting of the WTE facility and US/WA regulations were not included as part of this study. There are numerous options for siting of a modern WTE facility, including:

- Located on existing or closed landfill sites
- Located on a solid waste/recycling campus
- Located on an existing or future wastewater treatment plant site
- Located on an industrial site with adjacent compatible uses
- Located on a Brownfield site with adjacent compatibles uses

- Two approaches for sizing the WTE facility were presented and discussed in the Task 2 Memorandum. The first approach was to size the WTE facility to be at full capacity from the start of commercial operation. The second approach was to size the WTE facility with excess capacity at the start and to reach full capacity at the end of the financing period. Each of the two approaches resulted in slightly different WTE facility capacities, as summarized below:
    - Option 1: Size WTE facility to be at full capacity from start with real estate provided for future expansion. The estimated size of WTE facilities for this approach varied as follows:
        - 3,200 tpd for 20-year planning period
        - 4,000 tpd for 30-year planning period
        - 4,800 tpd for 50-year planning period
    - Option 2: Size WTE facility with excess capacity at start and projected to be at full capacity at the end of the financing period. This option was selected by King County as the desired approach and a financial analysis was performed and presented in the Task 2 Memorandum. The estimated size of WTE facilities for this approach varied as follows:
        - 4,000 tpd for 20-year planning period
        - 4,500 tpd for 30-year planning period
        - 6,300 tpd for 50-year planning period

- Basic configurations that can be considered for the Best Fit WTE option include:
    - Equally sized combustion processing lines (3, 4, 5, or 6) for increased availability and optimization of maintenance cycles
    - Designed for electrical production only
    - Designed for electrical production with provision for future CHP (steam/hot water/chilled water)

      This is considered optional and strongly depends on final site location.
    - Designed for CHP

      This is considered optional and strongly depends on final site location. The ideal location would be in an industrial area with nearby district heating system or large industrial steam user.

Recommended Civil Site Layout and Building Systems

- Fully enclosed system of buildings and structures and native landscaping to provide an aesthetically pleasing appearance and minimize visual impact to neighboring communities
- Fully enclosed tipping building up to the size required to allow waste delivery trucks to enter and maneuver into position for backing up to the refuse pit receiving stations
- Refuse pit sized for 7 days of waste storage based on the ultimate buildout of the facility with a number of truck tipping positions determined based on future waste delivery schedules

  Recent experience in Europe favors the design of a waste pit with separate sections for tipping and storage of the waste. The width of the tipping range will depend on the size of the waste grapples. The storage compartments should have a storage capacity of about a week of nominal waste incineration operation. This concept has some advantages: fire protection and firefighting are enhanced, and there will be enough storage capacity to cover a 2-week overhaul period of one line. The waste cranes can be operated automatically at times when no or small amounts of waste are delivered. Combustion is improved because the waste has started fermenting during the storage and hence has lost humidity. This level of detail is beyond the scope of this study, but is mentioned as a way of demonstrating how innovations in Europe often are transferred to the US after 5–10 years of successful operation.
- Administration, warehouse, and maintenance facilities located integrally with the WTE facility to take advantage of common walls, roofs, and utilities and maintain short travel distances (LEED Certification of the Administration Building is also recommended)
- LEED Platinum Visitor Center not physically connected to WTE but located near the facility
- Parking and contractor staging area appropriately sized and located for outage contractor maintenance staff
- Ash processing and metal recovery system fully enclosed and located adjacent to power block buildings to minimize number and length of transfer conveyors
- Translucent siding used appropriately for natural lighting
- Landscaping elements to include:
  - Native plant species that require less maintenance, fertilizer, and water
  - Living walls and placement of plants to be compatible with goals for noise abatement and shading to reduce heat gain and decreased air-conditioning cost in buildings and decreased heat island effect from paved surfaces
  - Ground cover, shrubs, trees, and mulch to protect slopes from erosion
  - Locally obtained recycled materials for landscape (compost, crushed concrete/rock, and mulch)
  - Irrigation system with Smart Controller that calculates evapotranspiration with a weather sensor or soil probes to provide water to plants only when needed

- Sustainability features to include:
    - Green roofs irrigated with captured rainwater from the roofs
    - Rainwater harvest from rooftops
    - Rainwater (storm water) harvest from pavements
- Provisions for future expansion: many WTE facilities that were constructed in communities destined for growth were designed with future expansion in mind. Typically this involved planning for an additional combustion line of the same size as planned for the initial facility. In the case of fast growing Lee County, Florida, a third combustion line of 636 tpd capacity was added after only 12 years to the initial construction of the first two units of 600 tpd each. In the case of Hillsborough County, Florida, a larger unit of 600 tpd capacity was added 20 years later to their facility originally constructed with three units of 400 tpd each.

Planning for a future expansion of the facility requires that sufficient space be dedicated for the additional unit with certain features of the facility designed to accommodate a future unit. Examples include:

- Waste tipping building should be sized of adequate length to accommodate the future unit or allow expansion at a later date
- Refuse storage pit should be sized with storage capacity for the future unit or allow expansion at a later date
- Provisions for extending the refuse building, refuse crane runways, and a new maintenance parking position for an additional crane must be available to receive the future unit
- Space provided for addition of future feed hopper(s), boiler(s), and APC system(s) of approximately the same size as the original units. No facilities of the initial facility should be allowed in this area other than equipment or features that can be easily removed and relocated
- Other ancillary systems that could be designed for the future unit include the addition of a spare flue in the stack, installation of pilings for the additional unit during initial construction, sizing of ash conveyors, and water treatment systems with enough capacity for future units

A conceptual diagram showing the general arrangement of a WTE facility designed to allow future expansion is illustrated in **Figure 2–10**.

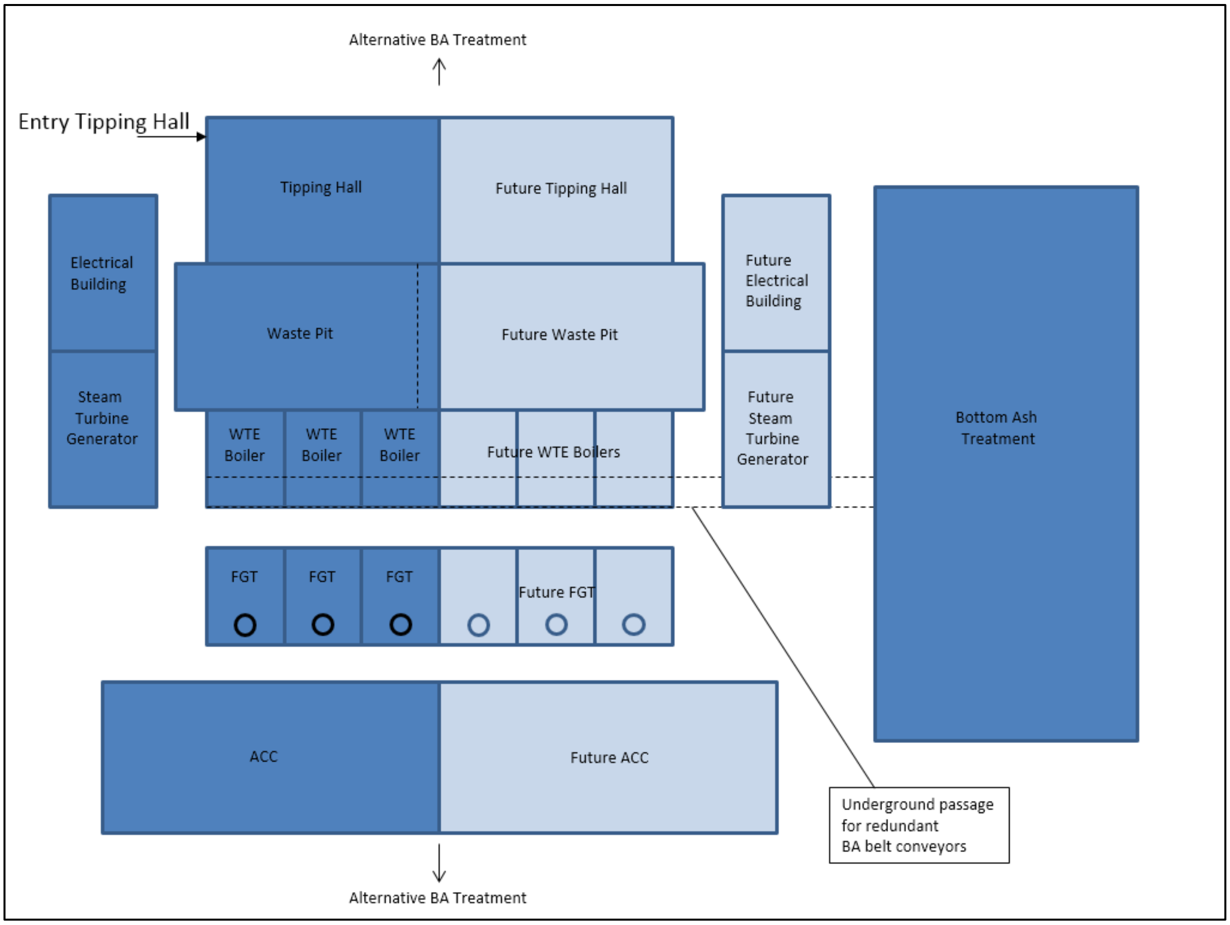

Figure 2–10. Conceptual Layout for WTE Facility with Provisions for Future Expansion and Doubling of Capacity

Recommended Electrical Systems

- High efficiency turbine-generator with capability to operate in "island mode" if disconnected from the local grid
- Pre-manufactured electrical rooms with a high level of insulation to minimize heat gain from exterior and an HVAC system to prevent intrusion of dirt, dust, and humid air
- Overall parasitic plant electrical demand to be minimized

  Numerous sustainability measures are recommended to minimize parasitic electrical load and maximize net electrical exports, including:

  - LED lighting systems (interior and exterior)
  - High efficiency HVAC systems (including option for steam jet systems based on European experience)
  - Variable frequency drives for large motors
  - Solar PV on rooftops and parking canopies

Recommended Mechanical Systems

- Three programmable refuse cranes with ability for semi-automatic and automatic controls and regenerative braking for energy recovery
- Advanced computer based combustion and APCs to optimize combustion process and minimize air emissions
- Medium-pressure multi-pass waterwall boiler for improved gross energy generation in the range of 700 kWh/ton (Inconel overlays of boiler, super heater, and economizer heat transfer components in high wear areas)
- Heat recovery from water cooled grates in hottest combustion zones to result in increased grate bar life and superior combustion (recovered heat from grates to be recycled within WTE process combustion air system)
- Redundant ash conveying systems (bottom ash and flyash) up to the point where the ash is processed for metal and possibly mineral recovery

Recommended APC/FGT System

- Modern WTE facilities continue to improve and optimize combustion technology, APC, and FGT systems for minimizing the release of regulated compounds and elements. Most currently operating US WTE facilities employ the following equipment and air emission controls to meet EPA emission standards:
    - Selective Non-Catalytic Reduction (SNCR): using hydrous ammonia injected into combustion gases above the firing grate reduces the NO_x concentration to a range of less than 50 parts per million by volume (ppmv). (Note: WTE vendors typically have their proprietary and patented technologies for NO_x control systems ranging from standard to low and very low NO_x emissions.)
    - Powdered activated carbon injection upstream of SDA for control of trace (metals, lead, and cadmium)
    - Slaked pebble lime injection inside of an SDA for control of acid gases and SO_2
    - Fabric filters impregnated with catalyst (Gore) for control of particulates

  The above systems act synergistically to result in optimized emission controls as evidenced by the operation of WTE facilities well below their permit limits. The new facility in Palm Beach County, Florida, is the first WTE facility in the US to employ SCR technology for reduced emissions of NO_x compounds. The SCR technology employs hydrous ammonia injection and a catalyst to result in very low NO_x emissions (50 ppm on daily basis). The adoption of the SCR technology will exceed the EPA regulatory standards and may be required to meet future air quality permit conditions in Washington State such as the Puget Sound Clean Air Agency. There are additional FGT configurations in the development stage for recirculating flyash into the boiler and APC systems that include treatment of flyash to recover metal salts suitable for use in metal foundries, internally recycling the mineral fraction, conversion of acid vapors in the flue gas into commercial-grade hydrochloric acid, and conversion of sulfur dioxide into commercial-grade gypsum suitable for manufacturing (e.g., wallboard). **Table 2–6** illustrates the permit limits and recent performance of the Palm Beach County WTE facility for reference. The above APC/flue gas control systems, including SCR (in lieu of SNCR) for control of NO_x compounds, are recommended for the King County Best Fit WTE.

Table 2–6. Summary of Palm Beach County, Florida, WTE Permit Conditions

Pollutant	Maximum Permit Concentration	Test Results*	Control Technology
NO_x	50 ppm	30 – 31 ppm	SCR
SO_2	24 ppm	11 – 21 ppm	SDA
CO	100 ppm	16 – 24 ppm	Optimized combustion design
Opacity	10%	0.4 – 2.4%	Fabric filter
VOCs	7 ppm	0.2 – 2.7 ppm	Optimized combustion design
Particulate Matter (PM)	12 mg/dscm	0.6 – 2.5 mg/dscm	Fabric filter
Pb	125 µg/dscm	0.5 – 8.1 µg/dscm	Fabric filter
H_2SO_4	5 ppm	Non-detectable < 0.01 ppm	SDA
HCl	20 ppm	1.5 – 2.1 ppm	SDA
HF	N/A	Non-detectable < 0.1 ppm	SDA
Dioxins/Furans	10 ng/dscm	0.2 – 0.4 ng/dscm	PAC, SCR
Hg	25 µg/dscm	0.6 µg/dscm	PAC
Cd	10 µg/dscm	0.3 – 2.5 µg/dscm	Fabric filter
NH_3 slip	10 ppm	2.2 – 5.5 ppm	Optimized SCR design

Corrected to 7% O_2 dry basis

PAC = Powdered activated carbon

SCR = Selective Catalytic Reduction

SDA = Spray Dryer Absorber

- Many European WTE facilities have adopted high efficiency FGT systems to minimize air emissions while exceeding EU regulations. Technologies include combinations of SNCR/SCR NO_x controls, wet and dry scrubbers, electrostatic precipitators, fabric filters and high efficiency fabric filters (with special PTFE membrane on a fiberglass fabric designed specifically to control $PM_{2.5}$). In many facilities, flyash is treated with pozzolans and cement encapsulation to allow disposal in non-hazardous landfill (or beneficially used as daily cover on MSW landfills). There are additional FGT configurations in the development stage for recirculating flyash into the boiler and APC systems that include treatment of flyash to recover metal salts suitable for use in metal foundries, internally recycling the mineral fraction, conversion of acid vapors in the flue gas into commercial-grade hydrochloric acid, and conversion of sulfur dioxide into commercial-grade (usually of higher grade than naturally occurring) gypsum suitable for manufacturing (e.g., wallboard). If these types of advanced FGTs are of interest to King County, the only waste to be disposed is a mixture of different salts—less than 1% of the waste input. These high efficiency systems are not initially recommended for the King County Best Fit WTE, but are considered optional features that should be further evaluated by the community if WTE is to be adopted.

- Stack with multiple flues and space for future combustion lines to be built in conformance with Good Engineering Design principles and air emission modeling

  As an option, there may be an alternate approach to the typical taller stacks employed in the US. Some European facilities have been constructed without a prominent single stack by using smaller diameter and shorter stacks for each process line with the bulk of the individual stacks integrated into the FGT building. In this arrangement, the stacks may only need to slightly exceed the height of the tallest building on the campus, which is typically the refuse storage and boiler buildings. A WTE facility was constructed recently on the Seine River on the outskirts of Paris that employs this approach.

- Continuous emission monitoring system for online recording and reporting of all regulated air emissions

Recommended WTE Process Improvements

- Advanced metal recovery system for the recovery of coarse and fine fraction of metals, fully enclosed and located adjacent to the WTE facility

  The metal recovery system should be designed of modular systems with provisions for incorporation of a bottom ash washing or glass separation processes to facilitate future bottom ash recycling programs. The use of high strength magnets and eddy current separators along with a series of screening systems will enable the optimized recovery of metals from the bottom ash. The advanced metal recovery system process includes the following steps:

  - Quenching of bottom ash in water in the bottom ash extractor (typically used in most US based WTE facilities)
  - Screening to remove large particles such as metal parts and unburnt materials
  - Removal of ferrous metals following screening/crushing to separate particles larger than the required maximum particle size of aggregate

    Note: sorting of ferrous metals is important and has priority; separation and crushing of oversized particles is mandatory to optimize recovery of ferrous and maximize the reuse of the mineral fraction.

  - Washing to remove fine particles smaller than 0.1 mm
  - Additional screening for optimal recovery of nonferrous metal

    Note: each eddy current separator employs a high strength magnet at the inlet to the process to remove any remaining ferrous materials that would have a detrimental effect on the downstream nonferrous metal recovery system. Alternate technologies are also being evaluated in Europe for higher automation of the nonferrous metal recovery process.

  - Recovery of glass particles greater than 4 mm and cleaning of recovered glass to obtain required purity of recovered glass for recycling

- The fine particles, which are removed from bottom ash through the washing process, are separated from the wash water and desiccated[4] before being recycled to the WTE furnace for incorporation in newly formed bottom ash. This procedure has successfully been tested by Martin during the development of the Syncom-Plus Process and at Müellverwertung Rugenberger Damm (MVR) in Hamburg, Germany, during a test run on an industrial scale by washing about 4,400 tons of bottom ash.

The above described process is illustrated in a simplified flow diagram in **Figure 2–11**.

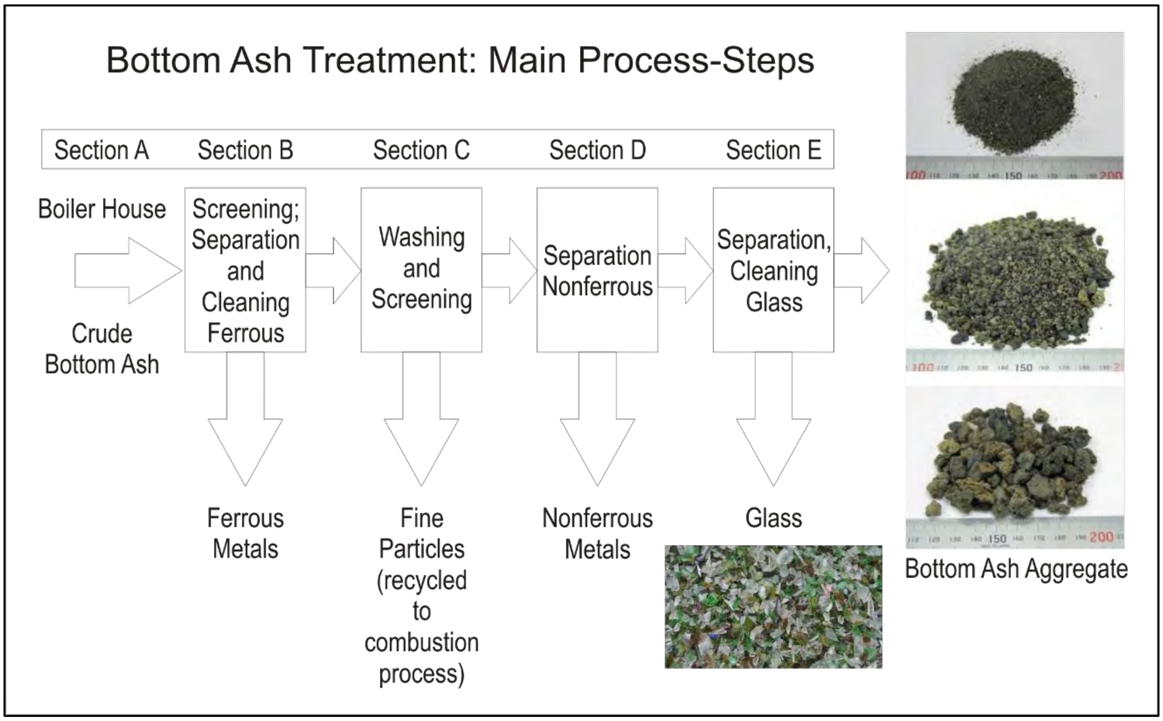

Figure 2–11. Schematic of Proposed Advanced Metal Recovery System

Tests have proven that washed and glass reduced bottom ash aggregate can replace natural gravel by up to 30% in asphalt production. This can be achieved with minor adaptations to the composition of the asphalt (e.g., amount of bitumen required). A number of concrete samples using washed and glass reduced bottom ash samples from MVR were prepared by a minerals firm in California. All of the samples passed both ASTM standards for high-performance concrete and the rigorous Soluble Threshold Limit Concentration extraction tests required by the State of California to demonstrate that a material is not hazardous. Naturally, markets for new products can be developed only after the material becomes available in significant quantities. Therefore, it is anticipated that following commissioning of a new WTE facility a period of two years will be needed to introduce bottom ash aggregate into the applicable recycle and

[4] to preserve the particles by removing the moisture

production processes. Local consultants and aggregate suppliers will be of value to assist with this effort.

- Air cooled condenser in lieu of wet cooling tower to eliminate visible plume of water vapor and reduced water supply and discharge requirements
- Rainwater harvest systems to reduce water consumption and result in zero liquid discharge system
- Use of reclaimed water for WTE process if available for use as makeup water, cooling water, fire protection, and irrigation
- Treatment and recycling of landfill leachate/storm water for WTE process (boiler and cooling tower makeup) if the WTE facility is co-located with or near a landfill
- Zero liquid discharge facility to minimize wastewater other than domestic sanitary sewer discharges

Operation and Maintenance Improvements

- Nondestructive testing for predictive and preventive maintenance (monthly vibration tests, quarterly oil sampling, infrared thermography, ultrasonic and acoustic data, motor electrical signature tests)
- CMMS for intelligent prediction of when parts or equipment may require replacement or maintenance
- Facility designed for optimized operation and maintenance (clear zones, access platforms, hoists and lifts to minimize brute force, etc.)

Local Programs to Support Community Recycling and Waste Diversion Goals

The following processes are recommended for inclusion in the permitting process of a future WTE facility in King County. The following list of processes can result in improved benefits to the system users and rate payers.

- Co-combustion of up to 10% WWTP biosolids
- Co-combustion of used oils (<5%)
- Co-combustion of auto shredder residue
- Co-combustion of used tires (whole or shredded), up to 5%
- Co-combustion of bulky waste

  A bulky waste shredder could be located on tipping floor for processing after normal delivery hours. This will allow size reduction and metal extraction of bulky waste to minimize alternate disposal requirements.

- Co-combustion of combustible C&D waste
- Co-combustion of special waste in need of assured destruction (confidential paper, uniforms, and industrial wastes)

  This type of program could be beneficial to King County by generating additional revenues to help offset costs to the system users and rate payers. Local special wastes include liquid wastes, medical and other regulated waste (such as USDA regulated garbage, which may include waste from international airports, marine ports, and military bases), expired pharmaceuticals, confidential documents, etc.

Programs that Will Result in Improved Community Benefits

- E-waste diversion program to remove electronic waste for recycling by a bona fide recycling process
- Marine debris collection program to provide proper disposal of combustible wastes collected from Washington marine waters

Other Optional Concepts/Features for Future Consideration

- Rail delivery of MSW if adequate real estate and proximity to existing rail lines exists

  This would be an optional feature if there was an interest from other regional communities to participate in the project.

- Regional WTE/Landfill project with adjoining county may provide synergies

  This would include use of their existing or future landfill capacity for disposal of bypassed waste and ash residue that is not recycled.

- High efficiency FGT configurations that are in the development stage in Europe for next generation of WTE facilities

  These advanced systems would result in less than 1% of the waste input requiring landfill disposal.

Table 2–7 summarizes the recommended base-case design parameters for the Best Fit WTE option along with optional features for consideration by King County. The base-case features listed are the basis for the financial analysis summarized in Table 1–3 and fully discussed in Sections 5 and 6 of the WTE Memorandum

Table 2–7. Facility Design Parameters for Base-Case Best Fit WTE Option

Facility Design Parameters for Base-Case		Optional Facility Improvements		
System Feature	Description	Optional	Estimated Cost	Net Benefit
Daily design capacity (tpd)	Varies (4,000 for 20-year, 4,500 for 30-years, 6,300 for 50 years)			
Annual availability (percent)	92			
Number of solid waste processing trains	Varies (3 to 6)			
Capacity of each processing train, tpd	Varies (1,000 to 1,125)			

Facility Design Parameters for Base-Case		Optional Facility Improvements		
System Feature	Description	Optional	Estimated Cost	Net Benefit
Energy production	Electricity	Combined heat and power (CHP) depending on location of site	Varies with steam parameters; additional costs at WTE facility negligible; cost of steam pipe and condensate return pipe dependent on distance between facility and customer	Enhanced revenues
Overall Site Layout and Aesthetics				
Site size (acres)	Varies (15 acres minimum, 40 acres maximum)			
Future WTE expansion	Site and WTE structures located to allow future expansion of WTE facility	Additional flue in stack for future expansion line	No additional cost if each line has its own stack (structural steel pipe, glass fiber compound liner, reference MVB, MVR) avoids massive concrete structure, which could be rated as source of optical pollution	Avoids future work in difficult area
Parking areas	Separate areas for WTE and County employees, visitors, and maintenance contractors			
Architectural enhancement of stack	Integration into natural landscape or to highlight a specific theme (Ex: Story Pole connection to heritage via tribes)	Custom theme	Varies $0 - 0.5M	Community acceptance
Architectural treatment of buildings	Fully enclosed with sheet metal and fiber reinforced polymer (FRP) siding, translucent panels and skylights for natural lighting	Enhanced features / treatments (LEED)	Varies $5-10M	Community acceptance
Location of warehouse and maintenance buildings	Integrally located within WTE power block buildings for close proximity and easy access by O&M staff			
Location of administration and visitor education buildings	Located within walking distance of WTE power block buildings			
Location of ash processing building	Located in close proximity or adjacent to WTE boiler building	Located below Air Cooled Condenser	No additional cost	Potential cost savings
Landscaping treatment	Living walls and placement of plants for noise abatement and shading, native plants, ground covers and vegetation to reduce mowing, xeriscaping for reduced water demand, rainwater harvesting for irrigation	Enhanced landscape features / treatments	Varies $1-2M	Community acceptance

Facility Design Parameters for Base-Case		Optional Facility Improvements		
System Feature	Description	Optional	Estimated Cost	Net Benefit
Water recycling	WTE process designed for zero liquid discharge, rainwater harvest from rooftops and pavements for reuse in WTE process (makeup water, plant wash-downs, ash quenching) and irrigation systems. Locate large cisterns of storage of rain water underground ex in the waste pit structure below that waste crane parking areas at minimal cost			
Waste Receiving and Storage				
Radiation detection system	Radiation detection system to be located at weigh scales or at entrance door to tipping building to avoid contamination of the facility and bottom ash, along with protection of WTE staff			
Waste reception hall (tipping building)	Fully enclosed for control of odors, dust, and noise			
Refuse storage pit (days of waste supply)	5 day minimum, 7 day maximum, internal divider walls for enhanced fire protection, improved waste management in waste pit. Automatic waste crane operation possible during night shifts, and on weekends and holidays			
Bulky waste size reduction and metal recovery	Can be accomplished inside tipping building to a limited degree using front-end loaders during non-delivery hours	Separate receiving and shredding area with discharge to refuse pit	$1-2M	Community benefit, less disposal
Refuse feeding	3 overhead monorail cranes (operation in manual, semi-automatic, and automatic controls)			
Combustion Technology and Controls				
Combustion technology	Massburn combustion on movable grates			
Advanced combustion controls	Computer based			
Ultrasound or infrared based controls		Recommended for optimal NOx reduction	$0.5 million	Lower emissions, higher energy recovery, lower operational cost
Energy Recovery				
Boiler	Waterwall with superheaters and economizer			

Facility Design Parameters for Base-Case		Optional Facility Improvements		
System Feature	Description	Optional	Estimated Cost	Net Benefit
Steam pressure & temperature	Medium-pressure (~900 psi/950F)			
Gross electrical generation (kWh/ton)	700 kWh per ton of processed MSW			
Electrical power - Turbine Generator (T-G)	High efficiency with ability to operate in island mode	Second T-G - only with the construction of additional lines (if extension possible on site)	$10-15M	Improved plant flexibility
Cooling system	Air cooled condenser (ACC)			
Internal power consumption	Approximately 13-15% of gross power			
Ash System				
Bottom ash collection	Wet-type discharger			
Number of bottom ash conveyors	Two (primary and secondary) for system reliability			
Type of bottom ash conveyors	Rubber belt			
Bottom ash storage	Storage bunkers – 5 days storage time			
Advanced bottom ash processing	No Storage bunker required. Ability to utilize bottom ash as an aggregate. Optimized metal recovery and (optional) glass recovery.	Recommended		95% - 96% diversion from landfill, replacing natural resources
Bottom ash loading system	Front-end loaders to remove ash from bunkers into trucks			
Metals recovery from bottom ash	Advanced recovery system employing multiple screens, magnets and eddy-current separators four maximum recovery of metals			
Flyash collection	Collection by screw and drag chain conveyance systems, flyash to be stabilized prior to landfilling, pneumatic conveying system			
Flyash storage	Storage silos – minimum 5 days storage, greater than 10 days preferred			
Utilities and Wastewater Treatment				
Wastewater Discharge	Zero wastewater discharge, all process effluents treated and recycled for internal use, avoids treatment at WWTPs			
Water Supply	Potable water if available, otherwise groundwater for domestic uses only	Treatment of landfill leachate for recycling in WTE process	$1-2M	Treatment costs could be assigned to landfill operations

Facility Design Parameters for Base-Case		Optional Facility Improvements		
System Feature	Description	Optional	Estimated Cost	Net Benefit
Air Pollution Control				
NOx compounds	Automated combustion controls with Selective Non-catalytic Reduction	Selective Catalytic Reduction (SCR) for lower NOx emissions	$25-50M	Reduced NOx emissions
Carbon Monoxide (CO)	Advanced combustion controls			
Particulate	Fabric filters	Optional use of catalytically coated filter bags if SNCR is used	No net cost due to longer life	Reduced Nox, particulate and ammonia emissions
Particulate	Use of advanced Gore Filters	Standard	Higher cost offset by longer life	Reduced Emissions
Acid gases (e.g. SOx, HCl, HF)	Slaked pebble lime injection via a Spray Dryer Absorber (SDA) upstream of fabric filter			
Trace organic control	Automated combustion controls and filter bags	Use of catalytically coated filter bags	No net cost due to longer life	Reduced emissions
Mercury	Powdered activated carbon (PAC) addition upstream of spray dryer absorber and fabric filter	Mercury waste amnesty program	$0.5M per year	Better control of Hg-emissions, enables continuous Hg-monitoring (mandatory in Europe), activated carbon injections controlled according to Hg-emissions
Emissions Monitoring	Continuous Emissions Monitoring System (CEMS)			
Advanced flyash treatment system	Only possible with wet scrubbers, minimizes flyash (recirculation of flyash into furnace results in higher metal recovery and reduction of flyash)	Recycles particulates internally, and recovers metal salts for up to 99% landfill diversion	Approximately $5M per line	Minimizes emissions, may result in lower stack height
Electrical Systems				
Sustainability measures	High efficiency motors with variable frequency drives, high efficiency HVAC systems, LED lighting systems, solar PV if applicable	Solar PV if applicable	$0.5 - 1M	May help qualify for LEED certification
Electrical rooms	Pre-manufactured with insulation and cooling	Steam jet cooling	Approximately $1.5 per Line	Considerable reduction of parasitic electrical consumption

Facility Design Parameters for Base-Case		Optional Facility Improvements		
System Feature	Description	Optional	Estimated Cost	Net Benefit
Mechanical Systems				
Heat recovery from grates (water cooled)		Only sensible for high HHV waste, best if facility is connected to a local district heating system	$0.5M per combustion line	Improved longevity and reduced maintenance
Operation and Maintenance Improvements				
Predictive and preventive maintenance	Nondestructive testing programs			
Computer Maintenance and Management	Intelligence based system for optimizing equipment replacements and repairs			
Equipment layout	Designed for optimized operation and maintenance			
WTE Permitting Considerations				
Co-combustion of WWTP biosolids	Ability to include WWTP sewage/biosolids 5%-10% (common with WTE) - no additional cost of sewage dewatered (dried) to 40% moisture content, 'waste' heat from WTE facility can be used in drying process	Option for consideration	Additional cost could be carried by Waste Water Treatment Plant	Reduced cost and CO_2, minimize environmental impact
Co-combustion of landfilled waste	Ability to process mined landfilled waste (approximately 10-30 percent of total processed MSW)	Option for consideration	Depends on ownership of facility. If owned by King County, no additional cost other than mining of waste	Reduced future cost of landfill maintenance and environmental impact; Remediate prime real estate

2.2.9 Benefits/Advantages of the Best Fit WTE Option (Thermal Processing on Movable Grates with Waterwall Boilers)

WTE is a sustainable option for management of solid waste resources and can be a key component of King County's drive to zero waste. Modern WTE has been integrated into many solid waste management systems and tailored to meet the needs of communities throughout North America and worldwide over the past 20–25 years. The recovery of energy and materials from waste via modern WTE is ranked above disposal in waste management hierarchies recommended by both the US EPA and European Waste Framework Directives. WTE can provide communities a cost-effective process to maximize the recovery of energy and materials from municipal resources remaining after local recycling programs. A 2011 paper titled "The Economic Development Benefits of Waste-to-Energy Facilities" by SWANA Advanced Research Foundation concluded that "Over the life of the WTE facility—which is now confidently projected to be in the range of forty to fifty years—a community can expect to pay significantly less for MSW disposal at a WTE facility than at a regional MSW landfill."

The following are advantages of the thermal WTE process recommended for the Best Fit WTE option:

Reduction of Landfill Volume

WTE provides a proven, safe and effective means of thermally treating and reducing the amount of waste that has typically been disposed of in landfills. It is a proven means of eliminating disease causing agents in (and associated with) raw solid waste. The ash residue remaining after combustion is approximately 10% of the volume of the processed solid waste of 25% of the weight, which can be further reduced by the recovery of recyclable material such as metals and glass and utilization of bottom ash as an aggregate.

Environmental and Land Usage

WTE is a stringently regulated waste treatment and disposal alternative by both US federal and state/local governments. WTE is a robust waste processing technology (proven in over 1,200 installations worldwide) that significantly reduces the consumption of land resources for disposal sites. It provides assured destruction and sterilization of infectious materials and other compounds that pose health and safety concerns along with recovery of energy and material resources that would otherwise be wasted. WTE also preserves valuable open spaces and aesthetics. The amount of acreage required for WTE facilities varies depending on the overall capacity of the facility. Existing WTE facilities in the US have been developed very flexibly to accommodate specific land features. Existing WTE facilities in the US have been constructed on sites as small as 4 acres or as large as 40–70 acres.

Air Quality

Worldwide, WTE has demonstrated the ability to meet continually restrictive environmental air emission limits with proven, state-of-the-art APC equipment that allows the plant to operate well below its environmental permit conditions. WTE emissions are continuously monitored and recorded during operations. Dioxins and Furans are often below detection limits and NO_x levels can be reduced to below 5 ppm. The web site for the EPA notes that over one ton of CO_2 equivalent emissions (CO_{2e}) are avoided for every ton of MSW combusted due to avoided methane emissions from disposal of MSW in landfills, avoided CO_2 emissions from generating an equal amount of electricity using fossil fuels, and avoided CO_2 emissions from mining of virgin materials for manufacturing of new ferrous and nonferrous metals.[5] Using the most recent IPCC numbers from the 5th assessment, up to 4 tons of CO_{2e} can be avoided for each ton of waste processed by WTE when compared to landfill disposal. Finally, WTE avoids the need to transport waste out of the community over long distances to remote landfills (in and out of state), resulting in reduced air emissions, fuel usage, traffic accident risks, and rail/road attrition.

Surface and Groundwater

WTE is more protective of valuable groundwater resources because volatile organic compounds are destroyed in the combustion process and leachate from ash is more environmentally benign. Many recent WTE facilities have been designed to be zero liquid discharge facilities, further avoiding direct water pollution impacts. Reclaimed water, harvested rainwater, storm water, or treated landfill leachate (when co-located near a landfill) can be used for process and makeup water in the WTE process, thereby conserving potable water resources.

[5] US EPA Website: Wastes-Non Hazardous Wastes-Municipal Solid Waste-Air Emissions from MSW Combustion Facilities-Greenhouse Gases

Economic Performance

Municipally owned WTE facilities currently provide long-term rate stabilization/control over pricing, since most WTE facilities are implemented through the execution of facility construction and operation contracts that clearly specify both the construction and operating costs of the facility. As a result, tipping fees have been shown to be both predictable and under the control of the local or regional governments that own the facility.

WTE allows recovery of additional ferrous and nonferrous metals, which increase local recycling rates and provide sources of additional project revenues. Hundreds of high quality jobs and well-paying jobs are created during the (typically 30–36-month) construction period, while at least 60–70 high quality, full-time employment positions remain throughout the 45–50-year life of a typical WTE facility. WTE also generates an economic ripple effect for the local business community (local contractors, equipment and supply firms, etc.). Examples of local purchase of goods and services include:

- Plant supplies, such as fuels (gasoline, diesel, and propane), janitorial supplies, safety and first aid supplies, fire protection and repairs, mobile equipment, lubricants, welding supplies, electrical and mechanical equipment inspections and repairs, mechanical pipefitting, carpentry, tools, calibration gases, and water treatment chemicals
- Environmental testing (annual flue gas tests, ash residue, and wastewater)
- Subcontracted services, such as temporary labor, mechanical and electrical outage service contractors, employee travel and entertainment, printing, office supplies, building services, mobile equipment maintenance, landscaping services, and residue hauling
- General and Administration services, including plant equipment rental, utilities (electric, water, gas), printing and office equipment, maintenance, charitable contributions, community support programs, seminars and training, medical testing, uniforms, safety equipment, and catering services

WTE can also provide opportunities for shared savings between the King County solid waste and wastewater departments. If WTE is co-located at other municipal utility facilities, such as a municipally operated, publicly owned treatment works (POTW), the WTE electricity could be synergistically used to power the POTW. Greater revenues can be generated by the WTE facility with lower costs to the POTW rather than buying electricity at a higher cost from the local electric utility. Although not currently qualified in the State of Washington, there would be additional revenue to the WTE project if legislation were enacted to qualify WTE for RECs. There may be opportunities for the sale of RECs in other regional markets. Also, WTE does qualify for Voluntary Carbon Unit offsets in numerous voluntary markets, and this market may provide additional revenues for a WTE project in King County.

WTE-Derived Energy

WTE can provide significant benefits to the local electric grid and especially to the utility that purchases the power. WTE is a proven and reliable base load (24/7) source of electrical energy with an average annual capacity factor of +92%. By comparison, many of the traditional renewable energy systems currently being implemented (solar PV and wind) are intermittent and less predictable sources of power that need to be coupled with energy storage solutions and smart grids. In cases where WTE can be co-located with other municipal facilities that have significant electrical demand, WTE-derived electricity can be synergistically used to power the other municipal facility. This has occurred in Shenzhen, China, whose WTE project will be the world's largest WTE facility and will process over 5,000 metric tpd (5,512 tpd) while providing electricity to an adjacent 125 mgd desalinated water treatment plant. This plant also will have solar PV panels on its roof for generation of additional renewable energy (**Figure 2–12).**

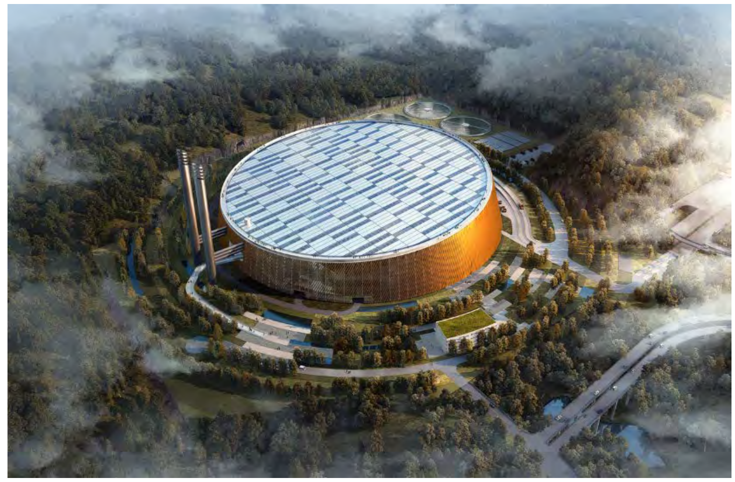

Figure 2–12. Shenzhen, China: World's Largest WTE to be Co-Located with 125 mgd Desalinated Water Treatment Plant

(Architectural design by Schmidt Hammer Lassen Architects and Gottlieb Paludan Architects)

Typically located within the urban/suburban area, WTE is a distributed source of generation that helps harden and strengthen the resiliency of the local grid with reduced line losses (voltage drop, normally 6–7% and more under peak operating conditions). WTE can help control voltage, regulate frequency, and provide reactive power response for the local electrical grid and alleviate strain on challenged transmission and distribution infrastructure. WTE could also help reduce reliability risks associated with increased system load and potentially delay the need to permit new base load units and long distance transmission upgrades. WTE avoids the need to use higher cost fossil powered peak power plants. WTE also provides power during storm events due to adequate supply of MSW "fuel" from storm debris.

WTE provides diversity to local fuel supply for electrical generation and reduces dependence on fossil fuels such as natural gas and coal supplies while improving local fuel diversity for the local electrical grid. This provides improved reliability during interruptions in fossil fuel and hydro supply during an array of events (e.g., extreme weather events, sabotage, and terrorism). A detailed study would be necessary to determine if a future WTE facility in King County would mitigate the need for additional power due to the closing of their fossil coal fired power plants while potentially minimizing impacts of a proposed new transmission system that would transect through numerous cities in eastern King County.

Societal Impacts

Many WTE facilities in the US and Europe are located in urban areas, close to where the wastes are produced. Residential, commercial, and institutional developments are in close proximity to many WTE facilities, often developed after the WTE facility was placed into commercial service. When properly designed, WTE facilities encourage, rather than discourage, investments in community development projects in their vicinities. For example, the Hennepin County, Minnesota (Minneapolis), facility is essentially located 'downtown,' and a $1.2 billion urban redevelopment project has been constructed immediately adjacent to the WTE facility. The primary anchor tenant in this redevelopment is Target Field **(Figure 2–13)**, home to the Minnesota Twins baseball team.

Worldwide, there are many other WTE projects that have been tailored to serve the needs and interests of their host communities, including Copenhagen, Denmark, where a WTE project has been built with a multipurpose ski slope/hiking trail feature over the WTE facility to provide year-round recreational activities **(Figure 2–14).** This plant is also a CHP project that provides heat for the City's district heating district, which also reduces local emissions.

Figure 2–13. Hennepin County, Minnesota: WTE Plant Located in Downtown Area (Background) Adjacent to Target Field Baseball Stadium

Figure 2–14. Copenhill WTE: Located in Downtown Copenhagen with Recreational Ski Slope and Hiking Trail over the Facility

<u>Special Programs/Opportunities for Enhanced Community Benefits</u>

WTE can provide communities with many potential opportunities to advance recycling and deliver vital municipal services by integrating WTE with other municipal utilities, such as electricity, water or wastewater treatment plants, existing landfills, and recycling programs. Over time, the owners and users of these facilities have worked collaboratively to maximize local and regional benefits. Examples of dedicated, beneficial programs and best management practices adopted by the owners and operators of WTE facilities throughout the world to maximize local and regional benefits include:

- Processing of special wastes in need of assured destruction

  Items include confidential documents, contraband, expired pharmaceuticals, regulated medical waste, USDA regulated garbage (International Waste from international airports, marine ports, and military bases), and marine/fishing wastes.

- Processing of whole passenger tires and/or chipped tires

  This increases the heating value of the fuel, which may be beneficial during wet weather periods.

- Installing shredder systems on the tipping floor to process bulky wastes during the non-delivery hours

  Some WTE facilities in the US have installed these, reducing the amount of non-processable wastes that bypass the WTE facility and must be handled separately.

- Processing WWTP residues and biosolids in the range of 5–10% of the total waste processed

- Implementing mercury bounty collection programs

  WTE operators in many communities have begun culling mercury bearing items from the waste stream at community drop-off centers (i.e., thermostats, thermometers, switches, elemental mercury, dental supplies, fluorescent light bulbs, CFC bulbs, etc.) and sponsored E-waste diversion programs.

- Extracting ferrous and nonferrous metals

  Advanced metal recovery systems as well as optical sorting systems for the separation of glass from bottom ash have created opportunities for beneficial reuse of recyclable minerals from bottom ash for maximized landfill diversion. When bottom ash is recycled, an estimated 15% could be included in a community's recycling rate.

- Becoming the anchor tenant in a community's ISWM system and development of a future eco-campus

  WTE can be located in close proximity to landfills and wastewater treatment plants.

- Implementing special after hours waste delivery programs

  Numerous WTE facilities have implemented these hours to help haulers avoid rush hour traffic and issues with waste collection at the end of day.

2.2.10 Issues/Disadvantages of the Best Fit WTE Option (Thermal Processing on Movable Grates with Waterwall Boilers)

The following are issues associated with thermal WTE that will need to be mitigated:

Relatively High Capital Cost

WTE facilities represent a higher order of waste treatment and require a significant investment of capital cost. It is important to evaluate full lifecycle costs over the long-term (estimated 45- to 50-year life of a WTE facility) when comparing to other waste management alternatives to fully and equitably capture annual operating expenses, which may include long-haul transportation of waste to landfills. It should be pointed out that the capital and operating costs can be calculated fairly accurately for the first 20–25 years (that is the normal write off period). Afterwards there are, in principle, no capital costs only O&M costs, so the tipping fee should go down considerably.

Need for Backup/Supplemental Landfill Capacity

Although WTE can process the vast majority of a community's municipal waste and significantly reduce the volume of wastes requiring ultimate disposal, it will not eliminate the need for backup landfill capacity completely for the disposal of non-processable wastes, excess/bypass waste, and, depending on the combustion technology and the design of the facility, any residues remaining after beneficial reuse of bottom and flyash.

Limitations on Steam and Electricity Markets

There has been an unprecedented reduction in demand for electricity in the US over the past ten years for a number of reasons, including the prolonged protracted economy in the US, a growing awareness of the benefits of energy conservation, implementation of distributed energy generation with rooftop solar PV generation on residential and commercial facilities, energy efficiency appliances (washers, dryers, water heaters, heating and air-conditioning systems, refrigerators), LED lighting fixtures, and programmable and smart appliance control systems. The Energy Information Agency notes that while fuel and power purchase costs have decreased over the decade with the decrease in natural gas costs, the nonfuel costs have risen. Nonfuel costs are considered to be those associated with building, upgrading, operating, and maintaining the generation, transmission, and distribution system.

Compared to the remainder of the US, the Pacific Northwest still remains a growth market for electricity. According to the 7th Northwest Generation and Electric Power Plan (adopted February 10, 2016), regional demand for electricity is estimated to grow at an annual rate of 0.5% to 1.0% per year. However, the need for additional generation will be small compared to historical experiences as cost-effective efficiency measures will meet much of the anticipated growth.

As a result of the above, along with the comparatively low cost of domestically produced natural gas, long-term power purchase agreements (PPAs) for WTE projects are no longer as lucrative as they were in the late 1980s and 1990s. In the past, PPAs would include payments for both "capacity" and "energy" production. As a result, many current owners of WTE facilities are negotiating PPAs of a shorter duration (e.g., 5–10 years), and only offering payments for the delivered energy due to the low or declining need for additional capacity.

As a mitigating strategy, some WTE owners are using portions of their produced power internally for public works operations (water treatment facilities, recycling, and solid waste support facilities, etc.) and have also implemented steam sale agreements with local industries and heating districts. In many cases, steam sales can add significant revenues compared to electrical sales. In many states, WTE is qualified as a renewable energy resource to meet local clean or low carbon energy goals.

Public Education and Outreach on the WTE Industry

Extensive public education and outreach needed to provide the public with information regarding the current state of the WTE industry and their sustainability programs, for example:

- WTE emissions have low impact to the local air quality.
- WTE air emissions are continuously monitored to demonstrate that emissions are generally well below permitted limits.

- WTE bottom ash residue is inert, and it can be safely be used in local construction projects.

There is a wide range of public information on WTE published by numerous trade associations, including Solid Waste Association of North America, Energy Recovery Council, Columbia University's Waste-to-Energy Research and Technology Council (WTERT), USEPA, International Solid Waste Association, Confederation of European Waste-to-Energy Plant and various other European environmental agencies.

Variability in Methods for Accounting of GHG Emissions

GHGs are emitted from WTE facilities though at a relatively low rate when compared to other facilities within the solid waste management industry.[6] Approximately 53% of GHG emissions are from biogenic sources (biomass derived), while the remaining 47% are from anthropogenic sources (petroleum based materials). The EPA notes that for every ton of waste combusted, a ton of CO_{2e} is eliminated when the waste is not disposed of in a landfill. However, for both WTE and landfills, the science associated with the calculation and comparison of GHG emissions in the US is currently in a state of uncertainty with many analytical models producing conflicting results based on assumptions made for numerous input variables. Two EPA-sponsored models have been developed to examine lifecycle emissions from different management methods of MSW: WARM and the MSW Decision Support Tool.[7] These models both show that MSW combustors actually reduce the amount of GHGs in the atmosphere compared to landfilling. Conversely, in Europe the science and methodology for calculating GHG emissions has been clearly identified.

Need for Consistent, Long-Term Flow as Input to WTE Facilities

WTE, as do other proven waste conversion technologies, requires a continuous flow of waste and a long-term commitment by the participating communities to use the facility. The commitment of waste is only required for the financing period, after which the capital costs are reduced to almost zero and the tipping fee can be adjusted to a much lower rate, depending on the required capacity.

Impact on Community Recycling Goals/Performance

Opponents to WTE claim that it removes some of the opportunities to recycle materials in a future circular economy (with increased numbers of end products designed with more raw materials recovered from recycling). However, the WTE process actually allows the disassembly of materials typically composed of many materials (composites and assemblies) that would require complex disassembly processes to recover the various recyclable materials. WTE combustion is an efficient process for the disassembly of common municipal waste materials, thereby allowing the recovery of ferrous, nonferrous, precious and rare-earth metals, minerals, and aggregate that have been processed to provide the highest quality materials. Many communities in the US and Europe that have implemented WTE on a significant scale also have the highest recycling rates (Section 2.2.12 below).

---

6 Energy Recovery Council, 2016 Directory of Waste-to-Energy Facilities, Ted Michaels and Ida Shiang

7 US EPA Website: Wastes-Non Hazardous Wastes-Municipal Solid Waste-Air Emissions from MSW Combustion Facilities-Greenhouse Gasses

2.2.11 Reference WTE Projects in US and Europe

There are eight facilities that our team selected exemplifying the technologies that are examples of proven technologies and/or components that we suggest for the county to consider in moving forward. The facility locations are:

- Palm Beach County, Florida (ISWM campus, six transfer stations, two adjacent WTE facilities [2,000 tpd and 3,000 tpd], SCR technology for low NO_x control, aesthetically pleasing, and the most recent new WTE facility in the US)
- Lee County, Florida (ISWM campus with C&D recycling and Material Recovery Facility (MRF) for processing single stream recyclables, 636 tpd WTE facility expansion, and aesthetically pleasing WTE facility)
- MVR, Hamburg, Germany (ATR facility with advanced FGT system and demonstrated advanced bottom ash process, which includes mineral recovery and washing of glass, urban setting, and enhanced architecture)
- Rothensee, Germany (two identical plants adjacent to each other and CHP with 350,000 megawatt hours [MWh] of district heat)
- Copenhagen, Denmark (state-of-art new facility with enhanced architecture that includes public ski slope and hiking trail around plant and CHP for local district heating)
- Brescia, Italy (ISWM campus, aesthetically pleasing, thermal capacity of 100 megawatts [MWs] with largest combustion line for biomass in the world)
- Giubiasco, Switzerland (located in the valley of a mountainous region surrounded by agricultural fields and vineyards and one of most sophisticated FGT systems)
- Amsterdam, Netherlands (largest WTE facility operating in Europe treating up to 1,370,000 tons of household and similar waste a year, CHP for district heating and one of highest energy efficiency productions of any WTE facility in operations worldwide at over 30% efficiency)

Palm Beach County, Florida

The Solid Waste Authority of Palm Beach County (Authority) has managed solid waste in Palm Beach County for over 40 years. The Authority has become an international leader in the field and has developed one of the most comprehensive ISWM systems in the world. The Authority's 1,320-acre solid waste campus includes a class 1 (solid waste) and class 3 (inert material) landfill, recovered materials processing facility, biosolids processing facility, two WTE facilities totaling 5,000 tpd capacity, a network of six (6) transfer stations, scales, fleet maintenance, and other administration and support buildings.

Palm Beach Renewable Energy facility #2 (PBREF #2) is the most recent addition to the Authority's ISWM system. The facility is located on approximately 24 acres and is capable of processing 3,000 tpd of post-recycled MSW and generating 100 MW of electricity. The technology selected by the Authority for PBREF #2 uses proven massburn technology, incorporating the latest in APC and water conservation technologies. A portion of the electricity produced is used to power the WTE facility along with other processes in the Authority's ISWM campus, while the bulk of the energy is sold to Florida Power and Light.

In 2004, as part of a master planning effort to ensure the long-term ability of its ISWM system to meet their future disposal needs and maximize landfill life, the Authority conducted an extensive evaluation of process capacity and review of existing and emerging technologies that might be employed to meet the growing population's needs. Ultimately, the Authority decided to expand their commitment to WTE and began the permitting, design, and construction of PBREF #2, which is located adjacent to the existing PBREF #1 WTE facility (2,000 tpd RDF), as shown in **Figure 2–15**. This is the first Greenfield WTE facility built in the US since 1995.

Figure 2–15. View of PBREF #1 and PBREF #2 from the Authority's Landfill

The 3,000 tpd WTE facility incorporates numerous features that may be applicable for King County and, as such, is an appropriate reference facility for many reasons, including:

1. The use of SCR rather than SNCR for NO_x control. This is the first use of SCR technology on a WTE facility in the US.
2. Innovative wastewater recycling system, which includes a rainwater capture system from over 12 acres of roof and 2 million gallons of recycled water storage, allows the facility to operate using almost entirely recycled water.
3. LEED Platinum rated Education Center provides a first class venue for the Authority to provide education and outreach to the community and the industry on the virtues of WTE and sustainability. The new Education Center represents the center piece of the campus. The center was designed and constructed to LEED Platinum standards, demonstrating the Authority's commitment to the cutting edge in sustainability and conservation. The Education Center (**Figure 2–16**) is connected to the main WTE facility by an elevated walkway (**Figure 2–17**) that was constructed to eliminate the potential co-mingling of pedestrian traffic with vehicular traffic.

Figure 2–16. PBREF #2 LEED Platinum Education Center

Figure 2–17. Elevated Walkway from Education Center to WTE Facility

4. A tipping floor (**Figure 2–18**) large enough to handle 24 tractor trailers delivering waste to the facility allows the facility to maximize the amount of accepted waste while minimizing truck idle and wait times.

Figure 2–18. Tipping Floor can accommodate up to 24 Delivery Trucks

5. One of the largest waste storage pits in the industry (enough to handle over seven full days of storage, or approximately 23,000 tons of waste) provides operational flexibility in handling short-term interruptions to the operation. The refuse pit allows disposal of all types of MSW, including vegetative waste and some bulky items.

6. Three boilers designed by B&W each capable of processing over 1,000 tpd of MSW. The B&W Volund Dyna-grate system installed on each of the boilers provides state-of-the-art technology providing for precise combustion control. This precise control allows better combustion techniques to deal with wet waste and organic wastes.

7. The air cooled condenser system (rather than a wet cooling tower) condenses the steam without large quantities of available cooling water.

Lee County, Florida

Lee County's WTE project is another example of an ISWM system. This system is a regional project between two neighboring counties. Lee County, situated on the southwest coast of Florida centered on Ft. Myers and with a population of 620,000, is the host WTE community. Hendry County to the east, a smaller and typically rural community, hosts the regional landfill (ash monofill, solid waste landfill, and a yard waste/biosolids composting facility). Lee County provides collection services for all unincorporated areas and two cities using a franchise collection system for residential and commercial sources (5 franchise areas). Lee County also provides disposal and recycling processing for all areas and cities with one trash, one recycling, and one yard waste collection per week. The initial 1,200 tpd WTE facility was constructed in 1995 and is the keystone of the system. Due to growth, the initial facility was subsequently expanded with an additional 636 tpd combustion unit in 2007. The recycling facility located on the ISWM campus was upgraded and expanded to a single stream system in 2010. A C&D debris recycling facility was placed into service on the WTE campus in 2011. Lee County also has a yard waste mulch program with community distribution along with a yard waste/biosolids compost processing facility (located at the Hendry County landfill site), household chemical waste collection center, and a curbside electronic waste collection and recycling process. Tires from commercial sources are received at the WTE facility for processing at a rate of $105 per ton. Approximately 300 to 350 tons are received per month and utilized as fuel at the WTE facility. Electricity from the WTE facility is used to power the WTE process and other ancillary facilities on the ISWM campus with the remaining bulk of power sold to the local electric grid.

The Lee County ISWM system, anchored by the WTE project (**Figure 2–19**), is an appropriate reference facility for King County for the following reasons:

1. The WTE facility is the keystone of an ISWM system campus that allows management of solid waste within the County's jurisdiction.
2. It is a regional project with neighboring rural Hendry County, which hosts the landfill and biosolids compositing processes.
3. Facility was designed for future expansion and was successfully upgraded without interruption of the initial WTE facility's ability to process MSW.

Figure 2–19. Lee County ISWM System and WTE Facility

MVR Project Hamburg, Germany

The MVR project in Hamburg, Germany (**Figure 2–20**), started operations in 1999. Of special interest is that massburn and gasification were the final two concepts considered by the City-State of Hamburg. In the end, the decision was based on the guarantees that were made. The massburn development group gave the City-State of Hamburg the guarantee that for each ton of waste it could not process according to the contract, it would pay the City 100 German Marks (roughly $234 US) to cover the cost of disposal at another facility. As the other technology provider was not willing to make such a commitment, the technology for the facility (now known as MVR) was selected and constructed. Now in operations for 17 years, MVR has its own proven track record. It has not needed to make any payments, for disposal at another facility. The reason why our team chose MVR is that it has one of the most advanced bottom ash processes among WTE technologies. MVR was the basis for the award of the City of Los Angeles WTE project, which was not built.

The Altenwerder Container Terminal (**Figure 2–21**), one of the world's most modern fully automated container terminals, was built entirely on bottom ash (500,000 tons) as a carrying layer. Using bottom ash from MVR saved 40% in the construction cost and has been a preferred aggregate in new Port of Hamburg construction projects.

MVR also has a proven 17-year emissions (1999–2016) track record. **Figure 2–22** and **Figure 2–23** show the MVR 2014–2016 emissions data from the 2016 Environmental Statement.


Figure 2–20. MVR in Hamburg, Germany


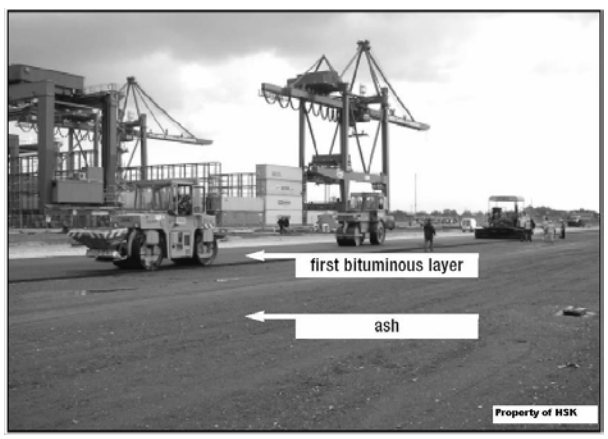

Figure 2–21. Altenwerder Container Terminal

MVR Emissions 1999 - 2007

	year	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average	Permit limit
NOx	mg/m³	80	82	83	78	79	79	66	78	76	78	100
CO	mg/m³	8.4	8.0	6.9	6.7	6.5	6.8	12	15	13	9.3	50
Particulates	mg/m³	0.14	0.4	0.4	0.6	0.79	0.4	0.8	0.9	0.01	0.49	3
C_{tot}	mg/m³	0.52	0.5	0.4	0.35	0.31	0.4	0.7	0.8	0.2	0.46	8
HCL	mg/m³	0.35	0.1	0.1	0.24	0.1	0.2	0.5	0.9	0.3	0.31	3
SO_2	mg/m³	3,5	2.44	4.6	6.1	2.23	2.0	3.3	5.4	2.6	3.57	15
HF	mg/m³	0.05	0.03	0.02	0.02	0.02	0.02	0.03	0.06	0.03	0.028	0.1
Cd,Tl	mg/m³	0.0003	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0006	0.0006	0.00056	0.002
Hg	mg/m³	0.00035	0.0005	0.0004	0.00025	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.02
Sb,As,Pb,Cr,Co, Cu,Mn,Ni,Va,Sn	mg/m³	0.017	0.008	0.0079	0.008	0.0087	0.009	0.008	0.021	0.008	0.011	0.05
As,BaP,Cd,Co,Cr	µg/m³					1.5	1.7	1.6	2.4	1.6	1.76	50
PCDD/F	ng/m³	0.0002	0.0023	0.0017	0.004	0.0027	0.001	0.0004	0.0025	0.0024	0.0019	0.05

m³: equal dscm: reference oxygen content: CO 11%, all others approx. 7-8% (actual oxygen-content of emitted flue gas), in accordance with 17th Ordinance

PCDD/F (dioxins, furans) measured as International Toxic Equivalent according to WHO

Conversion factor from mg/m³ to ppmdv: NOx 0.52; CO 0.86; SO2 0.376; HCL 0.66; HF 1.20

Detection limit, mg/m³: HF 0.04
Detection limit, µg/m³: Cd 0.05; Tl 1.0; Hg 0.5; Sb, As, Pb, Cr, Co, Mn, Sn 1.0; Cu, Ni 2.0; Va 4.0; BaP 0.5 (assumed)
Detection limit, ng/m³: PCDD/F 0.005 ng/m³ (any values measured below 0.005 ng/m³ are neglected)

Figure 2–22. 1999–2007 MVR WTE Emission

Rothensee, Germany

The fourth reference facility selected is the Müllheizkraftwerk (MHKW) Rothensee (**Figure 2–24**), which started operations in 2006. What makes Rothensee interesting to our team is that besides being state-of-the-art, there are two identical plants running side by side. The first facility was so successful regarding environmental and economic performance and coupled with the continuous growth and amount of non-recyclable waste in the region that it was decided to build a second, identical facility right next to the first one. Annually, 650,000 tons of household and similar commercial waste are processed at the two facilities, producing 370,000 MWh of electricity that is fed into the grid of Städtische Werke Magdeburg (SWM Magdeburg), the municipal utilities company. This keeps more than 40,000 households and businesses in the state's capital supplied with power. In addition, 350,000 MWh of district heat are made available for more than 44,000 households. This is equivalent to saving 18,000 tons of fuel oil or 20 million cubic meters of natural gas every year.

Figure 2–23. WTE Facility in Rothensee, Germany

Copenhagen, Denmark

One of the newest WTE facilities worldwide just came online in Copenhagen, Denmark. It is also called the Copenhill facility (see Figure 2–14) as, in addition to the state-of-the-art technology used, the facility is an architectural masterpiece incorporating the disposal of non-recyclable waste with features that will allow the public to ski down its slopes. Processing about 400,000 tpy of waste, the facility provides about 60,000 homes with clean energy. The facility will be an integral part of the city's plan to make Copenhagen the first zero-carbon city by 2025.

Brescia, Italy

Another awarded[8] facility for economic and ecologic performance is located in Brescia, Italy (**Figure 2–25**). Original startup of the WTE facility was in 1998. An additional line was added and started operations in 2004. Termed Line 3 has a thermal capacity of 100 MWs and is the largest combustion line for biomass in the world. The WTE facility supplies heat to about 65% of Brescia's inhabitants. ASM Brescia operates the WTE facility, an adjunct power plant, a composting plant for source separated household and garden waste, and a sanitary landfill.

Figure 2–24. WTE Facility in Brescia, Italy

[8] WTERT Industry Award 2006, http://www.seas.columbia.edu/earth/wtert/wmeeting_awards.html

Giubiasco, Switzerland

The Giubiasco, Switzerland, WTE facility (**Figure 2–26**) is located in the valley of the mountainous region of Ticino and offers some of the most sophisticated FGT systems. It serves the southern part of Switzerland. The facility started operations in July 2009. Besides its exceptional environmental performance, one of its characteristics is its architectural design. The facility is surrounded by agricultural fields and vineyards.

Figure 2–25. WTE Facility in Giubiasco, Switzerland

Amsterdam, Netherlands

The largest WTE facility operating in Europe is in Amsterdam (**Figure 2–27**), treating up to 1,370,000 tpy of household and similar waste. The facility produces 1 million MWh of electricity annually, enough to power 320,000 households. In addition, the facility produces up to 600,000 gigajoules of heat per year, which is used for district heating. The Amsterdam WTE facility has one of the highest energy efficiency productions of any WTE facility in operation worldwide at over 30% electric only.

Figure 2–26. WTE Facility in Amsterdam, Netherlands

2.2.12 Integrated Reuse Recycling Recovery Program

In 2017, King County will be generating approximately 930,000 metric tpy of MSW (approximately 2,600 metric tpd). According to a customer survey report by Cascadia Consulting Group (2016), recycled materials are broken down to the following categories: 12% plastics, 17% paper, 5% metal, and 36% food or other organics. It is expected that this amount will double in the next 50 years.

A key element of dealing with the waste we produce today is a system that adequately addresses the materials and chemicals used to make the products that are essentially the basis of our economy, standard of living, and our comfort and well-being. There are many discussions about integrated systems, zero waste, waste management hierarchies, sustainability, etc., that can occur. To find a solution that best suits the needs and wants of King County and its citizens, it is critical to understand waste, the technologies, and other components that are our tools to not only safely but economically deal with the ‘waste’ that we cannot avoid.

Waste Avoidance

There is a general consensus that the potential gains from waste avoidance/prevention are significant. These economic-ecologic gains can facilitate a move toward zero waste and a circular economy, where nothing is wasted. Moving up the waste hierarchy requires a joint effort by all parties involved: consumers, producers, policy makers, public sector agencies, waste treatment facilities, etc. Consumers willing to sort their household waste can only recycle if an adequate recycling infrastructure for collecting their sorted waste (paper and cardboard, glass [in three fractions: white, green, brown], lightweight packaging, biowaste from kitchen and yard, etc.) is in place. The opposite also applies; for municipalities to recycle an increasing share of their waste and households need to sort their waste.

Recycling

In recent months, the discussion regarding recyclables has increased significantly. China has voiced concern over the quality of materials being sent as recyclables to China and is now considering to refuse up to 60%. This is likely to have a major effect on recycling practices in the US and other countries around the world.

Compatibility with Recycling

WTE does not interfere with recycling. In fact, experience and data collected in both the European Union (EU) and the US have shown that WTE and recycling work very well together. In the EU, WTE and recycling have proven that they are complimentary (**Figure 2–28**). To understand more about the directives that govern the EU for the management of waste, it is important to understand that the primary reason for phasing out landfilling is not the lack of available space (Germany has over 500 years of capacity left, Denmark over 200, etc.), but is due to the scientific understanding that putting waste into landfills is not a good solution when considering environmental impacts over time.

To gain a more detailed insight into the advancements in WTE and the driving factors for the increasing success of European countries in regards to how waste is managed, it is important to understand how waste is viewed by the EU.

In Europe, as in many other countries around the world, waste is seen as a resource. As all resources on earth are limited, extracting fewer materials and using existing resources would help avert some of the impact created along the chain of material management. In this context, unused waste also represents a potential loss.

Dr. Helmut Schnurer, Former Deputy Director General for Waste Management, German Federal Ministry of the Environment and Continuing Advisor to the EU on Waste Management, explained the direction and position of the European Commission on September 3, 2017 as follows: The 1999 EU Landfill Directive (99/31/EC) formulated for the first-time strict uniform requirements for site selection, construction, operation, after care and closure including the requirement for financial reserves for continued maintenance. Furthermore, the objective was to reduce the landfill of biodegradable MSW rapidly and drastically, namely to 75% of the quantities accrued in 1995 until 2006, to 50% by 2009 and to 35% by 2016. Germany and some other EU countries already achieved these targets before these set dates. For Germany, the 1993 Technical Requirement Waste (TASi) states that starting June 1, 2005, the disposal of non-pretreated municipal waste, with limits for the organic fraction (ignition loss (Gluehverlust) or Total Organic Content) and a number of eluate criteria, specifically for heavy metals, is prohibited. Other EU countries, especially in Eastern and Southern Europe, still lag behind such regulations.

These targets can be achieved by means of thermal pretreatment. Strict regulation for the limitation of emissions from waste incineration facilities where adopted in Germany (17th BlmSchV of 1974, updated several times, with a most recent revision in 2013). The regulation is specifically designed to protect humans, animals, plants, soil, water, atmosphere and cultural heritage from immissions and emissions (see inset).

Difference between Emissions and Immissions

A corresponding European regulation on the limitation of emissions from waste incineration did not take place until 2000, by Directive 2000/76/EC.

Another milestone was the **Waste Framework Directive of 2008** (Waste Framework Directive 2008/98/EC). Regarding landfills the regulation contains a new hierarchy (order of priority):

1. Avoidance of Waste
2. Preparation for Reuse
3. Recycling (material utilization)
4. Other utilization (use for the production of energy and recovery of materials)
5. Landfill

Within the German hierarchy, landfilling is thus the last option and should only be considered for waste that cannot be treated at any of the priority hierarchical levels. As a result of the numerous ecological and economically viable alternatives, most of the MSW is no longer landfilled. The Framework Directive does not provide a quantitative objective for the lower ranking and still permissible landfill practice but makes it clear that Member States should discontinue to landfill. The Commission checks via means of obligatory reporting by the Member States, if they are in compliance with the Waste Framework Directive. The declared goal in Europe is the exit from landfilling. The reasons are obvious: Landfilling of municipal waste leads inevitably to dangers to **human health** (leachate into groundwater, emissions into the air), the release of **climate damaging** gases (CO_2, NH_3, etc.) and the **destruction of resources** that otherwise could replace primary raw materials or fossil fuels (energy raw materials). The improvement of resource efficiency has become a priority in Europe (that now also applies to waste disposal).

For the first time, **the proposal by the European Commission to amend the Landfill Directive** (1999/31/EC) of 2015 (pending final adoption) also contains quantitative goals starting in 2030. By the year 2030, 65% of MSW has to be recycled; 75% of packaging materials have to be recycled, and a maximum of 10% of municipal waste can be landfilled. In addition to numerous other measures, economic instruments shall be used to limit landfilling (…discourage landfilling).

The European objective/goal will take time in some of the member states, as well as it will require investments in new facilities for the collection, sorting, material and energy recovery of the waste generated. The politics and policies of the EU fully confirm the path taken decades ago by Germany and other environmentally proactive countries – the move away from landfills.

"In the European Union (EU), waste management is almost totally regulated by EU directives, which supply a framework for national regulations. The main target in view of sustainability is the prevention of direct disposal of reactive waste in landfills. The tools to comply with these principles are recycling and material recovery as well as waste incineration with energy recovery for final inertization. The adaptation of the principles laid down in EU directives is an ongoing process."[9]

Conclusively, the European Environment Agency states that "There is no evidence to support [the argument that] incineration of waste with energy recovery hinders the development of recycling." The five EU countries with the highest recycling rates all use WTE extensively to process waste left over from recycling (Eurostat 2014, Figure 10).

In the European system where landfilling is being phased out the evidence shows a well working symbiosis between recycling and WTE (**Figure 2–29**). In Germany, for example, the system has now reached over 68% recycling (inclusive composting), less than 32% WTE, and less than 1% landfill. Since 2008 the rates have dropped considerably. First research shows that waste disposal rates in countries like Denmark, The Netherlands, Austria and Germany etc. have leveled out and are lower than what the average King County resident pays. It is recommended to further investigate the logistics. With the closure of more landfills and the potential need to export waste long distance to landfills, the costs are expected to increase. The German and other European systems show that an integrated waste management system with an emphasis on zero landfill is economically advantageous.

[9] Title: 'European Union waste management strategy and the importance of biogenic waste' Authors: Juergen Vehlow, Britta Bergfeldt, Rian Visser, Carl Wilén - Forschungszentrum Karlsruhe GmbH, Institute for Technical Chemistry – Thermal Waste Treatment Division, POB 3640, 76021 Karlsruhe, Germany

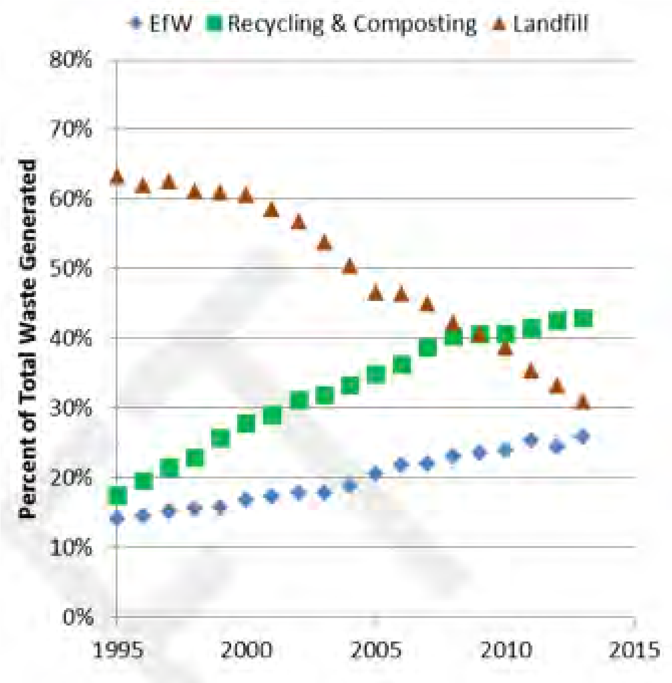

Figure 2–27. EU27 Waste Management Trend

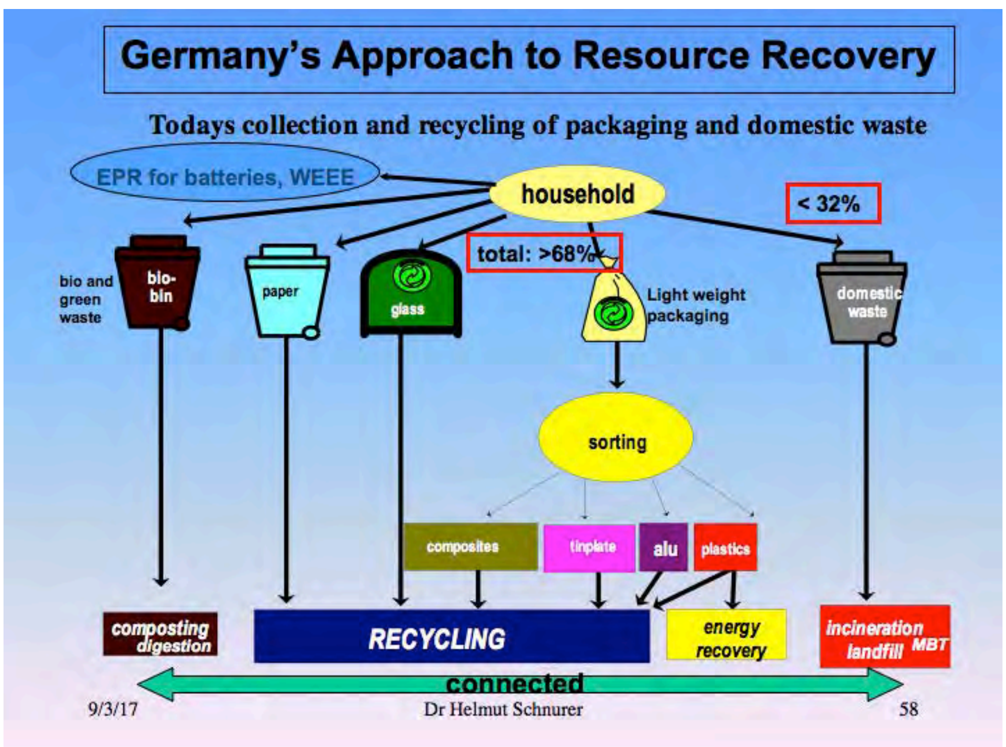

Figure 2–28. System Developed in Germany

Impact on Community Recycling Goals/Performance

WTE removes some of the opportunity to recycle materials as biological and technical inputs in the circular economy. However, the same process allows disassembly of materials that are typically composed of many materials (composites and assemblies) that would require taking them apart to recover the various recyclable materials. WTE combustion is an efficient process for the disassembly of common municipal waste materials, thereby allowing the recovery of metals and minerals for beneficial reuse.

Since WTE facilities are often built at large scales, they can remove the incentive for communities to improve their recycling efforts in other ways. However, the economy of scale often works favorably for the community's rate payers with reduced disposal costs over the long-term, especially after the end of the financing period. Retirement of principal payments represent a significant reduction of the annual O&M fee.

Compilation of Sources Discussing WTE and Recycling

- As the Florida Department of Environmental Regulation (FDEP) pushes toward a statewide recycling goal of 75% by 2020, counties with WTE facilities in the Tampa Bay area are leading the charge. Hillsborough and Pinellas have already surpassed the state's goal, tying in first place for countywide recycling at 82%, state records show.[10] "Recycling is one of the easiest ways that Tampa Bay residents can help the environment and the local economy," Hillsborough County officials wrote in announcing the local accomplishments. "Recycling helps conserve resources, reduces the amount of pollution associated with manufacturing, leads to the development of new products, and creates jobs. FDEP tracks progress made by counties across the state on an annual basis. The agency includes a number of factors as credits when establishing a county's overall recycling rate. Credits, for example, come from 'waste-to-energy' facilities that burn garbage to produce renewable energy," Hillsborough officials explained. Both Pinellas and Hillsborough counties own and use their own WTE facilities that help cut down on the amount of trash that ends up in their landfills. Other counties (per the FDEP website) across the region have also made great strides toward meeting the goal. Pasco and Sarasota are both tied with recycling rates of 66%. Other counties in the region, however, are lagging behind and a county-by-county breakdown of credits can be viewed on the state's website. Pinellas and Hillsborough county officials credit residents, businesses, and city partners for helping them lead the state, but state that more work needs to be done.
- From the Report of EU Environmental Agency on Europe's Environment: *Recycling and WTE are Complementary* (October 10, 2007), when comparing waste disposal options, it is sometimes argued that incineration of waste with energy recovery hinders the development of recycling. However, there is no evidence to support this. The report shows that those countries with the lowest level of landfilling of municipal waste (less than 25%) also have the highest levels of both recycling and incineration with energy recovery. In contrast, countries with a medium level of landfill (25%–50%) have a medium rate of recycling and limited incineration with energy recovery. Countries with

[10] https://patch.com/florida/brandon/hillsborough-pinellas-lead-florida-recycling 8/7/17

a high share of landfill (greater than 50%) have limited recycling and limited incineration with energy recovery.

- Taking into account the fact that not all municipal waste is suitable for recycling, waste that can be separated easily at source should be recycled. The remaining residual waste should be transformed into energy in clean and safe WTE plants instead of being buried in landfills. Countries that have most successfully reduced dependence on landfill (1% and below) have the highest recycling rates in Europe and have achieved this in combination with WTE (e.g., Germany, Netherlands, Austria, and Sweden), proving that recycling and energy from waste is the solution.

Composting

Composting and WTE are not at odds. Because compostables such as food and yard waste have a certain moisture content, it is beneficial to keep the food and yard waste (biowaste/mass) separate from the black bin waste (going to WTE) as a higher moisture content reduces the heating value of the WTE process. In addition, collecting compostables separately can also yield soil amendments as well as fertilizers. It is not uncommon for biowaste to be used in anaerobic digesters to create energy in the form of heat or electricity. Keeping compostables out of landfills is also important as it creates methane, a climate damaging gas.

Recovery

Recovery usually pertains to the recovery of energy and materials from the waste that cannot be avoided or recycled/composted. During the thermal treatment of waste, energy is released from the waste and recovered. This energy is then either used as steam for heating and cooling or for the creation of electricity. Other materials recovered through the thermal treatment process are nonferrous and ferrous metals for recycling and bottom ash that can be used in lieu of gravel or concrete. The EU Waste Framework Directive of 2010 promotes the production of energy from waste that cannot be recycled. Recycling of waste by reprocessing it into new products can make the most efficient use of the resources contained in waste. Where waste recycling is not the environmentally preferable option, technically not feasible, or economically not viable, waste should be used to generate energy and materials should be recovered from the process. The Waste Framework Directive promotes the recovery of energy and materials. With the R1 Formula, the framework introduced an incentive for the thermal treatment of municipal waste to contribute to the energy supply for industry and households. Municipal thermal treatment facilities meeting or exceeding the energy and material efficiency threshold of this R1 Formula can be classified for the efficient recovery of energy from waste according to the waste hierarchy.

3 Solid Waste Export Considerations

3.1 Introduction

King County’s only active landfill, Cedar Hills Regional Landfill (CHRL), is expected to close when the landfill reaches capacity, and the County is evaluating options to handle solid waste disposal once CHRL reaches capacity. In 2001, the County adopted a *Comprehensive Solid Waste Management Plan* (2001 Plan) that concluded that waste export transported by rail was the preferred alternative to the construction of a new landfill or the construction of an incinerator. The analysis determined that solid waste export was the lowest cost alternative, compatible with the County’s waste reduction and recycling programs, and consistent with the adopted policy that the “county shall contract for long-term disposal capacity at an out-of-county landfill or landfills. It is anticipated that export of the region’s mixed MSW will begin when the CHRL has reached its permitted capacity. However, the County will remain open to considering and implementing private sector proposals for early waste export. An orderly transition to waste export should occur before Cedar Hills is closed” (see 2001 Plan, p. 7-2).

In 2007, the King County Council approved the *Solid Waste Transfer and Waste Management Plan* (Transfer Plan), which presented a blueprint for implementing the 2001 Plan and included recommendations for modernizing the solid waste transfer system to support the transition to solid waste export. The Transfer Plan recommended that the County seek to maximize the capacity of CHRL and modernize the transfer system by constructing four new transfer stations, retaining five existing transfer stations, and closing three existing transfer stations. The Transfer Plan concluded that rail transport was likely to be the most feasible option for long-haul transport and that an intermodal facility would be integral to the solid waste transfer system. Transfer Plan also recommended that the County issue a Request for Proposals for partial early export of 20% of the waste stream prior to CHRL closing to determine if the option would be more effective than disposal at the landfill and allow the County to test the market.

The 2001 Plan is the most current comprehensive plan adopted by the County. It has been reviewed every 3 to 5 years and was updated by the King County SWD in the *2013 Comprehensive Solid Waste Management Plan.* The plan, however, was not adopted by the King County Council, and the SWD is currently in the process of working with its advisory committees and the SWD on the *2019 Comprehensive Solid Waste Management Plan.* The SWD anticipates incorporating a number of policy and program changes, including the consideration of WTE and other conversion technologies in addition to waste export and partial early export.

This section builds on the 2007 Transport Plan by providing an assessment of potential regional landfills and evaluating the railway capacity available for long-haul transport of solid waste.

3.2 Regional Solid Waste Landfills

The Transport Plan identified seven landfill sites potentially available by rail and, due to their location, anticipated to provide competitive costs for solid waste disposal:

1. Roosevelt Regional Landfill, Klickitat County, Washington
2. Columbia Ridge Landfill and Recycling Center, Gilliam County, Oregon

3. Finley Buttes Regional Landfill, Morrow County, Oregon
4. Simco Road Regional Landfill, Elmore County, Idaho
5. Northeastern New Mexico Regional Landfill, Mora County, New Mexico
6. Eagle Mountain Landfill, Riverside County, California
7. Mesquite Regional Landfill, Imperial County, California

Of these seven potential sites, only four remain as viable options and are discussed and analyzed below. Significant issues with three of the potential sites prevent them from being viable alternatives, as described below.

Northeastern New Mexico Regional Landfill (NENMRLF): NENMRLF is located in Mora County, New Mexico, is operated by GGH Wagon Mound, LLC, and spans 439 acres, including 57 acres of currently permitted waste cell area. The facility is served by rail and provides service to customers across northeast New Mexico and portions of Colorado and Texas (see www.gghcorp.com). NENMRLF can receive up to an average of approximately 100 tpd of solid waste and may receive more or less solid waste depending on market conditions (see www.env.nm.gov/swb/documents/PNhearingEnglish2NENMRLF11-6-14.pdf). The site is permitted by the State of New Mexico to accept MSW through 2017. Given the distance (1,616 miles from King County) and site capacity, this site is not recommended for further consideration.

Eagle Mountain Landfill: Plans for the development of the Eagle Mountain Landfill Project in Riverside County were withdrawn in 2013. This occurred when the Board of Directors Sanitation Districts of Los Angeles County ceased negotiations with Mine Reclamation Corporation, a subsidiary of Kaiser Ventures, the developer of the project (see www.lacsd.org). Therefore, it is not available for consideration (2,125 miles from King County).

Mesquite Regional Landfill: The Mesquite Regional Landfill is owned by the Sanitation Districts of Los Angeles County, is located in Imperial County, California, and consists of a landfill and an intermodal waste-by-rail facility. The landfill has a capacity of 600 million tons with a life span of about 100 years. The infrastructure was completed in 2011 and it is permitted to receive 20,000 tpd of MSW, including 1,000 tons from Imperial County. In addition, the site appears to be limited to receive non-hazardous MSW from southern California counties (see www.mrlf.org). It is 2,110 miles from King County. Due to conditions in the solid waste disposal market, it is not yet operational and therefore is not an option for King County.

The four remaining landfills in Washington, Oregon, and Idaho that are recommended for consideration are Roosevelt Regional Landfill in Washington, Columbia Ridge Recycling and Landfill and Finley Buttes Regional Landfill in Oregon, and the Simco Road Regional Landfill in Idaho.

3.2.1 Washington Landfill

Roosevelt Regional Landfill, Klickitat County, Washington

Roosevelt Landfill has been owned and operated by Republic Services since 1990. It is located in Klickitat County near Roosevelt, Washington, which is in an arid region of south central Washington east of the Cascade Mountains. A site expansion was authorized in 2002, which expanded the total capacity from 180 million cubic yards to 245 million cubic yards and the annual limit from 3 million tpy to 5 million tpy. The property covers 2,545 acres with 915 acres permitted and a remaining capacity of approximately 162 million tons (see *2013 Klickitat County Solid Waste Management Plan Update* p 1-15). The remaining capacity available at the facility at the current fill rate is estimated to be approximately 70–100 years (see 2017 *Metro Transportation and Disposal Evaluation – Phase 1 Final Results*).

Roosevelt provides waste disposal services to 12 counties in Washington State, Alaska, Idaho, Oregon, and Hawaii and to Canada (British Columbia and Alberta). At the site, there is one small local aquifer that is 100 feet below the surface and is confined to the site. The balance of the site has 1,500 feet of separation from the bottom of the landfill to the closest regional aquifer. The geology separating the landfill and this regional aquifer includes 340 feet of low permeability natural clay (see www.local.republicservices.com/site/roosevelt). The site is located in a sparsely populated region with less potential for adverse social impacts from the facility. The landfill is located approximately 330 miles from Seattle (approximately 11 hours via rail and truck haul).

Roosevelt is permitted (CFR40 Subtitle D landfill) to accept residential and commercial waste including MSW, C&D debris, wood wastes, and petroleum-contaminated soils (see *2013 Klickitat County SWMP Update—Waste Quantities by Region*). Roosevelt is not a Subtitle C Landfill and therefore it does not accept hazardous waste. Ninety-seven percent of the waste arrives in containers that are hauled to the landfill via truck from the rail unloading area. The containers are loaded onto trucks for the uphill haul to the landfill and then emptied by tilting lifts that upend the container/trailer assembly. Waste also arrives from a network of nine intermodal yards that connect the landfill to sources from Idaho, California, and Canada. Waste from Alaska is barged near the site then transferred to truck. Empty trash trains take fruits, agricultural products, and other goods back to Seattle via different containers.

The landfill also accepts municipal incinerator ash in a double-lined ash monofill. The landfill does produce landfill gas (methane) and it supports the generation of 20 MW of electrical power. This “gas-to-electricity” system is located at the H.W. Hill Landfill Gas Power Plant with the potential to generate 37 MWs and will provide power to 30,000 homes annually. Local municipalities/counties have the right to purchase energy from the landfill gas system. There are 300 landfill gas wells that have been installed and 200 miles of plastic pipes connecting the subterranean well.

The MSW rate for Roosevelt is estimated to be approximately $24 per ton (*2013 Solid Waste Transfer/Disposal Alternatives, Spokane County, WA*).

3.2.2 Oregon Landfills

Columbia Ridge Recycling and Landfill, Gilliam County, Oregon

The Columbia Ridge Landfill, which opened in 1990, is owned and operated by Waste Management Disposal Services of Oregon, a division of Waste Management, Inc. It is located in Gilliam County, which is in an arid region of Oregon east of the Cascade Mountains. The landfill is located approximately 320 miles from Seattle. The rural location allows a 10,000-acre buffer that is managed for agriculture and wildlife.

The facility consists of 12,000 acres with a permitted footprint of 760 acres. The Columbia Ridge Landfill is a modern Subtitle D landfill, which accepts primarily MSW and household waste as well as industrial and special wastes (e.g., incinerator ash, C&D debris, petroleum-contaminated soils, asbestos, and sewage sludge). It is permitted and regulated by the Oregon Department of Environmental Quality.

The facility processes 8,000 tpd and over 2 million tpy of waste. There is approximately 329 million tons of remaining permitted capacity and a projected remaining life of 120–143 years. In addition to solid waste from the City of Seattle, the site serves Portland Metro, King County (C&D waste), and Kitsap County and communities in Alaska, Idaho, Oregon, Washington, and Canada (see *wmnorthwest.com/landfill/pdf/columbiaridge.pdf).*

The MSW rate for Columbia Ridge is estimated to be approximately $35 per ton (*2013 Solid Waste Transfer/Disposal Alternatives, Spokane County, WA*).

Finley Buttes Regional Landfill, Morrow County, Oregon

Finley Buttes Landfill is located in Morrow County, Oregon. The facility is privately owned and operated by Waste Connections, Inc., and began operation in 1991. It is the primary/designated disposal site for MSW from Clark County. The site has a permitted footprint of 510 acres with a projected life of 300 years and an estimated available fill capacity of 131,859,000 tons (see *2015 Clark County Solid Waste Management Plan* p. 10-4). The site receives 500,000–700,000 tpy of solid waste, which includes MSW, C&D wastes, and special wastes (including liquids). This solid waste disposal facility is permitted by Oregon Department of Environmental Quality (DEQ) and is in full compliance with Oregon DEQ rules and regulations.

Co-located on the same site is the Finley Bioenergy Landfill Gas to Energy Facility. It is made up of vertical extraction wells and a high-density polyethylene piping network. It has a CHP system that collects and uses methane, which generates 4.8 MWs of energy (enough to power 3,500 homes). In addition, much of the waste heat from the electrical generating plant is used by Cascade Specialties (a nearby onion and garlic dehydration plant), which reduces their need to purchase natural gas.

The MSW rate for Finley Buttes is estimated to be approximately $33 per ton (*2013 Solid Waste Transfer/Disposal Alternatives, Spokane County, WA*).

3.2.3 Idaho Landfills

Simco Road Regional Landfill, Elmore County, Idaho

Simco Road Regional Landfill (SRRL) is located on 1,080 acres near Mountain Home in Elmore County, Idaho, which is 25 miles east of Boise and a few miles off Interstate 84. It is located in a very rural area with less than 6 inches of annual rainfall. It was developed in 1999 by Idaho Waste Systems Inc. (IWS). The permitted footprint for the site is 810 acres with a capacity of 210 million tons. Daily volumes at the SRRL range from 500 – 1,000 tons (see City of Boise Solid Waste Strategic Plan, 2007). The remaining capacity of the facility is well over 150 years (EPA Landfill Methane Outreach Program, 2017).

SRRL has been exploring how to expand its client base with more competitive pricing, but its distant location remains an issue for Pacific Northwest cities/counties. It receives approximately 10% of Boise's MSW for disposal and also services clients in Idaho (primarily in the southwest portion of Idaho), California, Oregon, Nevada, Utah, and Washington. The waste is delivered by transfer trailers via Republic's Boise Transfer Station. SRRL does not have rail access to the site, but the Union Pacific (UP) main line runs nearby with 10,000 feet of rail spur. SRRL has an onsite container handler and all equipment required to offload railcars and dispose of material that is delivered by rail via trucks. UP also has an agreement with IWS to remove and dispose of site cleanup waste materials from their gondola cars. The station processes the waste, which is truck hauled 30 miles to SRRL. The landfill accepts MSW from commercial and residential generators, C&D debris, and special waste "indirect industrial byproducts."

The tipping fees for SRRL are estimated to be approximately $16.50/ton (*2013 Solid Waste Transfer/Disposal Alternatives, Spokane County, WA*).

While the tipping fees cited above have been obtained from publicly available sources, it is possible that direct negotiations, for long-term contracts, with the landfills could result in lower rates.

3.2.4 Solid Waste Landfill Capacity Summary

Table 3–1 summarizes the remaining permitted landfill capacities at each of the landfills at the current rates and projects the years remaining with the addition of King County's MSW. This is a very conservative estimate as most of these landfills have undeveloped land and other options available to expand their capacity as it becomes necessary.

3.3 City of Seattle's Solid Waste Export Program

The following is an overview of the City of Seattle Public Utilities Department's (SPU) Solid Waste Export Program.

Until the 1960s, Seattle disposed of its solid waste in landfills within city limits. The City then owned and operated the Midway Landfill from 1966 to 1986 and the Kent Highlands Landfill from 1983 to 1986. Once those landfills reached capacity, Seattle contracted with King County to use the CHRL for the disposal of the City's solid waste. To address the increasing costs of solid waste disposal, the City considered various options including incineration and long-haul export. Strong opposition to incineration led the City to focus its efforts on programs which would reduce solid waste and contract to export solid waste and non-recyclables (see Seattle Solid Waste Plan 2011 Revision).

Table 3–1. Summary of the Remaining Permitted Landfill Capacities

Landfill	Permitted Acres[1]	Remaining Capacity (tons)[2]	Currently Receiving (tons/year)[3]	Remaining Capacity at current fill rate (years)[4]	CHRLF Tons[5]	Projected Tons/year w/CHRLF redirected (new fill rate)	Years remaining at new fill rate
Columbia Ridge	760	329,000,000	2.6 to 2.7 mill	120-140	1.1-2.2 mill	3.7-4.9 mill	67-88
Roosevelt	915	162,000,000	2.2 to 2.4 mill	70-100	1.1-2.2 mill	2.3-4.7 mill	35-70
Finley Buttes	510	131,859,000	500,000–700,000	200+	1.1-2.2 mill	1.6-2.9 mill	45-82
Simco Road	810	208,000,000	365,000 ±	150-200+	1.1-2.2 mill	1.4-2.5 mill	83-148

Sources:

1. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco–City of Boise Solid Waste Strategic Plan (2007)
2. Columbia Ridge (www.wmnorthwest.com/landfill/columbiaridge.htm); Roosevelt–2013 Kickitat County SWMP Update; Finley Buttes–2015 Clark County Solid Waste Management Plan; Simco (www.epa.gov/lmop/project-and-landfill-data-state)
3. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco (estimated)
4. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco (www.epa.gov/lmop/project-and-landfill-data-state)
5. Cedar Hills Regional Landfill (CHRLF) 2028-2078 Solid Waste Tonnage Forecast (2016), KCSWD

In 1991, the City contracted with Waste Management (WM) of Washington for both rail haul and disposal of all non-recyclable waste to Columbia Ridge Recycling and Landfill in Arlington, Oregon. The City's solid waste planning efforts since that time have focused on reducing the volumes of solid waste generated and diverting as much waste as possible from landfill disposal. In 2007, the City adopted a policy of "Zero Waste" in an effort to increase recycling and reduce the amount of solid waste that is disposed through its long-haul contract. The City set a goal of recycling 60% of the waste produced within the city by 2012, and 70% of the waste produced within the city by 2025 (see City of Seattle Zero Waste Resolution 30990). Seattle's solid waste programs have made progress toward these goals. In 2016, Seattle generated 747,964 tons of MSW, of which 308,292 tons were disposed and 439,672 tons (58.8%) were recycled (see SPU 2016 Recycling Rate Report). The City states that the cost of collecting, processing and transporting recyclables is approximately 50% less per ton than the cost of shipping the material to the landfill in Arlington, Oregon.[11]

The City's solid waste is compacted into double stacked shipping containers (owned by WM) at its two recycling and transfer facilities: North and South Transfer Stations. The containers are then transported to the Argo Rail Yard and loaded onto a dedicated "unit train" that goes directly to the landfill approximately six times per week (SPU 2017). The Argo Yard is owned and operated by UP, and is located in the Duwamish Manufacturing/Industrial Center. Empty containers are returned to the transfer stations via truck. The cost for transport of this waste is $41.55/ton, and the current contract for these services will expire in 2028 (SPU 2017).

[11] www.seattle.gov/util/myservices/garbage/houseresidentsgarbage/garbageratesfaqs/

3.4 Overview of Rail Capacity

Washington State Department of Transportation's (WSDOT) Freight Rail Plan (2010–2030) was adopted in 2009. The Plan is in the process of being updated, and an August 2017 draft is available for public review (see www.wsdot.wa.gov/Freight/systemplan.htm).

The 2014 WSDOT Washington State Rail Plan 2013–2035 (Rail Plan) is a unified planning document that includes information, policies and recommendations for both passenger and freight rail. The Rail Plan highlights the importance of freight rail to Washington's transportation system and economy. The Washington State Segment of the Pacific Northwest Rail Corridor links the cities in Washington with Portland, Oregon, and Vancouver, British Columbia. In 2007, approximately 83 million tons and 41% of all interstate freight (where Washington was the origin or destination) were carried via rail through this corridor. Rail is one of the most cost-effective modes of shipping bulk and heavy commodities over land in Washington and is critical to the competitiveness of a number of industries. The current capacity of the system has been meeting the demand for rail transportation. However, by 2035, the system is forecasted to handle 260 million tons of cargo (more than double the amount carried on the system in 2010), which will exceed 100% of the track capacity on a most of the rail network. Additional operational or infrastructure improvements will be required to accommodate the anticipated volumes (WSDOT 2014 State Rail Plan).

The freight rail system in Washington State is operated by Burlington Northern/Santa Fe (BNSF) and UP, which are both privately owned enterprises and own the majority of the rail infrastructure. These entities work closely with WSDOT's Rail Department which provides planning, helps to manage the system, owns short line, switching or terminal railroads and provides funding along with other Federal, State, and local agencies. The following briefly describes these entities.

3.4.1 Burlington Northern/Santa Fe (BNSF)

BNSF is the largest rail operator in Washington, handling a total of 1.367 million carloads (2011) over a 1,633-mile network in the state. Its primary network consists of three east-west lines and one north-south line from British Columbia to Oregon and more than 44% of the rail system in the state. The east-west line passing through the Cascade Tunnel under Stevens Pass is its primary route for intermodal traffic. This line provides service to the Wenatchee landfills used by King County for C&D debris. The second route crosses the Cascade Range through Stampede Pass, and the third route follows the north bank of the Columbia River from Vancouver, Washington, to Pasco. BNSF's rail network is key for Washington State, linking the transcontinental routes and the large economic centers along the Pacific Coast. BNSF has three commercial intermodal container yards in Seattle (Interbay), Tacoma, and Spokane. It also has yards that are located in Auburn, Centralia, Seattle, Tacoma, Vancouver, and seven other locations in northern/eastern Washington (WASDOT State Rail Plan 2014).

3.4.2 Union Pacific (UP)

UP is the second largest rail operator in Washington by both mileage and volume. It operates 532 miles of track and an additional 260 miles are through trackage rights on other railroads, which equates to more than 16% of the state's rail system. The total number of rail carloads handled on their Washington routes in 2010 was 550,000. UP has operating rights on BNSF tracks between

Portland and Tacoma and between Tukwila and the Port of Seattle. It operates on its own right-of-way between Tacoma and Tukwila. UP also has two commercial intermodal container yards in Seattle and Tacoma (Argo is the facility that the City of Seattle SPU uses to load the solid waste to UP's containers).

3.5 Rail Capacity for Solid Waste Export

The critical rail corridors and other available access to the Regional Landfills under consideration are summarized in **Table 3–2** below.

Table 3–2. Available Intermodal Access to Regional Landfills[12]

Landfill Name/Location	Rail Access	Truck Access	Barge Access
Roosevelt Regional Landfill Klickitat County, Washington	BNSF	WA SR 14	No
Columbia Ridge Recycling and Landfill Gilliam County, Oregon	Union Pacific	I-84	No
Finely Buttes Regional Landfill Morrow County, Oregon	Union Pacific	I-84	Yes
Simco Road Regional Landfill Elmore County, Idaho	Union Pacific	I-84	No

The critical rail segment for all of the options described above is BNSF's 177-mile Seattle Subdivision, connecting Seattle with Portland, Oregon. It is the most heavily trafficked rail line in Washington State, conveying BNSF and UP trains (the latter via trackage rights) to and from the major Pacific Coast ports.[13]

According to the Washington State Freight Rail Plan, as early as 2008 the segment, from Tacoma to Kalama/Longview (both with and without the Point Defiance Bypass) has been operating at 103% of capacity, and it is anticipated that by 2028 demand will continue to exceed capacity with the segment without the bypass surging to 137% of capacity. It is also expected that by 2028, the Kalama/Longview to Vancouver, Washington, segment, without future Passenger Improvements, will reach 143% of capacity. Likewise both the UP and BNSF segments from Vancouver, Washington, to Pasco will be at 100% of capacity in 2028 and the UP segments from Pasco to Spokane and Spokane to Sandpoint, Idaho, will reach 100% of capacity by 2028.[14] The lack of available capacity is likely to cause an increase in unit shipping costs that will need to be accurately modeled in the future, but is beyond the scope of this report. In addition, a current study is ongoing to evaluate the addition of High Speed Light Rail on this BNSF corridor between Seattle and Portland, Oregon.

For planning purposes, in 2006 King County assumed the average rail transport distance would be 350 miles and that rail would be the most cost-effective transportation option.[15] Since the

[12] Proposed Recommendations, Solid Waste Transfer and Waste Export System Plan, September 2006, p33

[13] WA State Freight Rail Plan Appendix 3-B, p 66

[14] Washington State 2010-2030 Freight Rail Plan, Chapter 3: Rail System and Freight Rail Services in Washington State, 2009, page 3-28

[15] *Proposed Recommendations, Solid Waste Transfer and Waste Export System Plan*, September 2006, P 34

potential landfills under consideration remain unchanged, this factor remains the same. Given the anticipated challenges rail capacity, the County will need to monitor improvements to the rail system and will need to model cost effectiveness of rail transport.

3.6 Summary

This evaluation demonstrates that the number of operating landfills within Washington and the Region with the capacity to accommodate King County's current solid waste export needs are limited to a few large regional landfills. Based on the distance and increased rail costs to SRRL it appears that the potential landfills options could be Roosevelt, Columbia Ridge Regional, and/or Finely Buttes landfills. Furthermore, it appears King County should support efforts to increase rail capacity for both freight and passenger rail along BNSF's corridor from Seattle to Vancouver, Washington.

4 Conclusions and Next Steps

4.1 Preferred WTE Option(s) Recommendations for Future Work

1. Visit the Palm Beach County, Florida, integrated solid waste management campus. It has the newest WTE facility in North America. Consider looking at other facilities in Florida as well (Hillsborough County, 28-year-old WTE facility providing electric power to adjoining WWTP; Pasco County, 26-year-old facility located on ISWM campus and currently pursuing bottom ash recycling).
2. Finalize WTE sizing based on review of waste projections for 50-year planning horizon with respect to desired 70% recycling and future zero waste goal. Identify potential recycling programs that may be implemented and their impact on both waste composition and waste quantity.
3. Evaluate cost effectiveness of high efficiency FGT configurations that have been proven for the past 16 years at the MVR WTE facility in Hamburg, Germany. These include internally recycling the mineral fraction, conversion of acid vapors in commercial-grade hydrochloric acid, and conversion of sulfur dioxide in commercial-grade gypsum suitable for manufacturing (e.g., wallboard). Additionally, they are in the development stage at MVR and in Europe for treatment of flyash to recover metal salts. The application of these types of advanced FGTs would result in less than 1% of the waste input requiring landfill disposal.
4. Evaluate the potential for the State of Washington to initiate the Renewable Energy Credit (REC) program for in-state WTE facilities.
5. Evaluate potential for incorporating a MWPF/Dirty MRF or AMR facility with WTE to increase recycling rate and reduce size of WTE facility.
6. Evaluate potential for incorporating a standalone Anaerobic Digestion (AD) facility with adjacent WTE to increase recycling rate and reduce size of WTE facility. Evaluate options for use of bio-methane from AD for sale as pipeline quality compressed natural gas or as supplemental fuel for adjacent WTE.
7. Conduct comparative analysis for determining cost effectiveness of WTE v. landfill disposal (in-county v. out-of-county). Evaluate cost effectiveness of various waste conversion technologies.
8. Evaluate recycling technologies/recycling processes to determine cost per percentage of waste diversion.
9. Meet with local cement kilns to determine interest in use of engineered fuel (RDF) or sized bottom ash in their Portland cement production plants.
10. Meet with local Investor Owned Utilities and municipal utilities to determine their interest in long-term PPAs and/or interest in financial participation in WTE project.
11. Research local options for internal use of electricity and/or steam, hot water, and chilled water in CHP applications. Opportunities may include existing or future WWTPs, marine ports, district heating/cooling system operators, industrial and production facilities, military bases, etc.

12. Explore opportunities with DOE for promoting CHP projects and trying to help communities in the first step in finding a use for CHP by funding the community's initial feasibility study.
13. Evaluate options for preliminary sites for WTE facility, or multiple facilities. Candidate sites could include existing or closed landfills, existing or future WWTPs, industrial and/or Brownfield sites, existing power generation sites, cement kilns, public work facilities, or greenfields.
14. Evaluate options for extending capacity of Cedar Hills Landfill for use as ash disposal and bypass waste disposal.
15. Evaluate options for mining unlined portions of Cedar Hills Landfill for reclamation with processing of combustible fraction of waste in WTE facility.
16. Evaluate options for mining other closed local landfills for reclamation with processing of combustible fresh waste in WTE facility.
17. Form an architectural committee and begin evaluation of architectural design features such as partnering with the tribes on a Smoke Stack Story/Dream (Totem) Pole, Amazon Helipad and Executive Suites, Whale with blow hole, etc.
18. Evaluate the addition of a radiation detection system to the landfill operations to protect workers and eliminate potential for contamination of leachate.
19. Meet with neighboring cities/counties to discuss interest in participating in regional WTE projects.
20. Conduct full WTE feasibility study (waste quantity, control of waste, site options, waste conversion technology, energy production/sales, facility ownership/operation, environmental modeling).
21. Use other GHG modeling such as the Decision Support Tool, IPPC Model, and Afvalzorg and evaluate and compare to WARM model.
22. Evaluate WTE in an integrated waste management approach (v. standalone) and compare to landfill.
23. Evaluate the economic-ecologic opportunities through increased local recycling infrastructure—More Local-Less Export.
24. Evaluate recycling in context of what can and cannot be recycled, what happens to the non-recyclables, and what opportunities there are for use.
25. Bottom ash utilization should be thoroughly investigated in regards to best use and potential use applications.
26. Evaluate recyclables with a focus on Secondary Raw Material (SRM) Made in Washington production. Recycling often has single-use/application; investigate multi-use application.
27. Investigate the option for an integrated waste management system that includes WTE with the goals of Zero Waste, Landfilling, Recycling, and Research & Development of new technology.

4.2 Summary of the Conclusions and Next Steps

Based on the WTE Options and Solid Waste Export Considerations of this Report and previous Memoranda, it is recommended that the County consider WTE in their future plans as an appropriate option to address the County's long-term solid waste management needs. The most appropriate and "Best Fit Technology" to process King County's solid waste is a thermal treatment system, which uses combustion on a movable grate with a waterwall boiler to recover heat for production of steam and electricity. This System, also referred to as massburn, which is the process of MSW being received and fed unsorted into combustion units, will also include numerous innovations and design features of advanced thermal recycling (generally practiced in Europe).

The proposed "Next Steps" are recommended to begin the development process for a public education program and a detailed Feasibility Study. The Feasibility Study will provide an overview of the "Best Fit WTE Option" and key ancillary recycling and disposal components of an Integrated Solid Waste Management (ISWM) system, including a review of existing SWD Infrastructure Systems (e.g., transportation, collection, reuse, avoidance, recycling, landfill), Design/Permitting/Construction Requirements, a Public Outreach Program Architectural Options, Environmental Opportunities and an Economic/Cost Assessment for the various Project components. In addition, an Implementation Plan which will be developed to identify the Key Tasks and Schedule for the siting/design/build of the proposed WTE and key infrastructure systems should be considered as the next step.

4.2.1 Approach for Public Education Program

- Develop a plan or strategy for public education (identify committees and representation)
- Develop a plan/outline for identifying and maintaining a library of technical information, environmental data, architectural preferences, and public policies
- Identify type and schedule of public workshops
- Identify approach for maintaining historical project information (meeting agendas and minutes) and establishing methods for ensuring transparency

4.2.2 Approach for Feasibility Study

- Conduct analysis of existing conditions of SWD to determine compatibility with WTE anchored system (evaluate existing waste collection system and determine needs for improvements, evaluate existing recycling programs and analyze to determine costs and percentage of waste that is truly recycled, the life cycle of recycled waste, and diverted from disposal, research other WTE anchored ISWM systems and identify alternate recycling programs, which are compatible with WTE and suitable for King County to help achieve recycling and future waste reduction goals).
- Conduct analysis of environmental regulation and permitting process (identify environmental regulatory agencies and regulations, which are necessary for WTE and other proposed components of the ISWM system, develop list of criteria and permit limits, which must be met by WTE facility(ies), identify anticipated length of time necessary for permitting process).

- Conduct analysis of solid waste quantities and composition and demonstrate that King County has control of an assured quantity of waste for appropriate sizing of WTE facility and ancillary treatment, recovery and recycling facilities and potential for disposal needs.
- Conduct investigation for determining availability of a fairly priced energy, metals and materials markets (explore viable options for combined heat and power projects, state or local funding sources to conduct CHP feasibility studies, interest of local electric utilities (Investor Owned Utilities and Public Utilities) to explore interest in project participation or purchase of electricity from WTE, opportunities for co-location of WTE with other municipal utilities for shared savings by using electricity internally, identify local metal markets and material specifications to maximize the value of recovered ferrous and nonferrous metals, identify local aggregate and construction material suppliers that may be interested in using bottom ash and metals and minerals recovered from flyash).
- Depending on growth, conduct investigation for determining appropriate site for WTE, ash monofill for transition period, and bypass/backup disposal facilities (develop siting criteria, identify candidate sites, explore interest in private entities willing to host sites, explore interest in regional project and division of waste management system components, evaluate and rank preliminary sites, and prepare report on site recommendation).
- Conduct evaluation of integration of proven and emerging technologies for small amounts of bypass waste with commercially demonstrated solid waste technology(ies) (for example, this could include a mixed waste processing facility to manufacture Engineered Fuel for sale to local cement kilns and industrial boiler [RDF], such a process and concept may help reduce the amount of waste, which requires thermal treatment and disposal, identify final equipment and process specifications based on other evaluations).
- Perform analysis of financial alternatives (ownership, financing, and procurement) for control of an assured flow of funds to the project (evaluate options for ownership and operation of WTE and other components of the ISWM system, evaluate allocation of appropriate risks among private/public partners, prepare final cost estimate of WTE facility based on final equipment selection).
- Develop conclusions and recommendations report (preliminary and final implementation plan developed to identify the Key Tasks and Schedule for the siting/design/build of the proposed WTE and key infrastructure systems).