King County WTE Study
Task 2 – WTE Existing Conditions Memorandum

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CDM Smith

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Subject:	*Final Task 2 - WTE Existing Conditions Memorandum*

1. Introduction

In accordance with the Scope of Work for the King County (County) Waste-to-Energy (WTE) Study, Normandeau Associates Inc. (Normandeau) and their team members CDM Smith and Neomer have prepared this Task 2 - Waste-to-Energy Existing Conditions Memorandum. This document summarizes the current state of WTE technology from North America and Europe/Asia. A cursory review of WTE developments in Africa and South America was also performed, but there were no recent projects which were found to be of comparable size and applicability to King County. This report develops the basis for analysis and recommendation of the currently available best fit WTE option for King County. A brief summary of the King County Solid Waste Management System is provided in **Appendix A**.

2. Modern WTE Trends and Advancements

Objective of this Section "Modern WTE Trends and Advancements": *This section seeks to provide a broad overview of the origin and evolution of the WTE industry world-wide to provide a common understanding of current WTE facilities and recent trends for North America, Europe, and Asia.*

The WTE industry in the United States 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 United States 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 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.

In North America, there are 85 operating WTE facilities, with 77 facilities in US and 8 in Canada. Three general combustion technologies are utilized in North America for reliable and proven processing of MSW: massburn, RDF (refuse derived-fuel), 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 lastly, modular (7). Two facilities have a combination of massburn and one other combustion technology (Honolulu and Tulsa). Recent expansions and additions in the U.S. 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 half, 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, WA). In the case of the Spokane WTE facility, the City assumed operations from Wheelabrator after the initial 23 years' operating contract expired. The City essentially hired the Wheelabrator staff and has continued to operate the facility.

The capacity of WTE facilities do range widely, from 12 tpd to 3,300 tpd. **Table 2-1** below summarizes the count of WTE facility sizes.

Table 2-1 WTE Capacities by Size

Country	0 to 500 tpd	501 to 1,000 tpd	1001 to 2,000 tpd	2001 to 3,000 tpd	Greater than 3,000 tpd
U.S.	22	19	19	15	2
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 combined heat and power (17), and followed by 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.

Modern WTE facilities continue to advance toward the goals of sustainability, which include significant reductions in emissions (air, water, solids), reduced use of water, chemicals and reagents, improved recovery of energy, metals and minerals from bottom ash, and improved benefits to the local and regional communities which use the facilities. An extensive list of the advantages and benefits associated with WTE facilities is provided in Section 9.

2.1 Recent Trends in the 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, typically bottom ash does not exhibit toxic properties, and future uses such as this would likely involved 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 a 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 which result in reduced combustion air, improved combustion and burnout of waste, and reduced emissions which 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 gasses, nitrogen oxides, dioxins, heavy metals, and particulates. The new WTE facility in Palm Beach County, Florida is the first WTE facility in the U.S. to employ Selective Catalytic Reduction (SCR) technology for reduced emissions of NOx compounds.

4. Improved operation and maintenance techniques (non-destructive 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 higher heating value (HHV) of municipal solid waste 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 BTU fuels present in MSW (used tires, asphalt shingles, and rigid plastics). In Germany, it has been reported that there hasn't 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). The developer of the City of LA waste conversion project (not constructed) indicated that preprocessing of waste for the removal of marketable recyclable materials indicated a decrease of the heating values of about 10 to 15 percent. 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 U.S. and North America include:

    a. One retrofit (1,000 tpd WTE in the City of Tampa 2000);

    b. Three expansions (636 tpd WTE unit in Lee County, FL in 2006; 600 tpd WTE fourth unit in Hillsborough County, FL in 2007; and 200 tpd unit in Olmsted, MN in 2010);

    c. Two new WTE facilities (1,000 tpd unit in Honolulu, HI in 2013, and 3,000 tpd WTE in Palm Beach County, FL in 2015); and

    d. One new WTE facility was added in Canada (436 metric tpd (480 tpd) WTE in Durham York, Ontario in 2015), and one new large WTE facility was recently announced for Mexico City (5,500 tpd in 2020).

8. Evolution of WTE facilities as key components of an integrated solid waste management (ISWM) systems. These include combinations of landfills (ash monofills, construction and demolition (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 have been proposed in number of locations in North America. The new WTE facility in Palm Beach County, FL is located on a 1,320-acre campus which 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 usage 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. The concept of a microgrid, which is being promoted by the U.S. Department of Energy 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 the U.S. Department of Energy (U.S. DOE) is promoting combined heat and power (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 percent 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 percent of their waste as biosolids.

2.2 Recent Trends in the European and Asian WTE Industry

Recent trends in the European and Asian WTE industry are described below.

2.2.1 Recent Trends in the European WTE Industry

1. Dramatic increase in WTE facilities to allow countries to meet very strict landfill reduction requirements (Landfill Directive, more formally Council Directive 1999/31/EC of 26 April 1999);

2. Most of the new WTE facilities utilize massburn technology;

3. Implementation of numerous advanced systems for on-line cleaning and operation and maintenance practices for optimization of annual availability;

4. Extensive innovative technologies for maximizing recovery rates of metals, minerals, glass from bottom ash;

5. Incorporation of extensive air emissions control technology, some far more rigorous than the regulatory requirements;

6. Expansion and additions to WTE facilities have also been completed, similar to the experience in the U.S.;

7. Production of refuse derived fuel (RDF) and combustion of the RDF in fluidized bed combustion units, cement kilns and grate fired boilers to allow for more flexibility in waste composition, with the realization that the requirements for fluidized bed combustion are more stringent with regard to impurities (metals, C&D waste); and

8. Co-generation, or combined heat and power (CHP) generation has been widely deployed. It is a way of increasing the overall thermal efficiency from the 20 percent to more than 85 percent by utilizing waste heat from the production of electricity. In traditional power plants with electricity production only, the efficiency is approximately 20 percent 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 percent energy efficiency (based on the net calorific value).

2.2.2 Recent Trends in the Asian WTE Industry

1. The lack of land and stringent landfill regulations 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 Asia origin (often Japanese), but today more Chinese, as they are building an average of 50 new WTE facilities every year, and now have over 400 with about 40 mass burn under construction; The world's largest WTE facility is currently being designed for the city of Shenzhen and will include six processing lines with a total capacity of 5,000 tonnes per day (5,600 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 mgd of desalinated potable water;

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; and,

5. The Asian WTE facilities follow the more stringent of North American or European air emissions requirements.

2.3 WTE Advancements

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

1. Technical evolution of the entire process continues to advance, from introduction of the MSW fuel to the flue gas treatments. 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 on-line boiler cleaning, and optimized flue gas treatments;

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 which has been 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 inorganic bottom ash;

4. Incorporation of higher heat recovery boiler pressures to increase the amount of energy recovered from the MSW; and

5. 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 percent, compared to 22-25 percent of a conventional WTE facility.

   However, this is only economical in countries with low prices for natural gas, which is currently the case in the U.S. It is also possible to use landfill-gas to operate the gas turbine. This concept may be of interest to local utilities which 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 ways 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.

3. WTE Evaluation Criteria

Objective of this Section "WTE Evaluation Criteria": *This section seeks to summarize a transparent, collaborative, WTE technology comparison that was performed to identify the best fit WTE technology amongst proven, currently available and emerging WTE technologies. A ranking and weighting analysis was performed using a set of nine criteria which King County staff had previously reviewed and commented upon. The intent of this exercise was to provide a snapshot of the current best fit WTE technology for King County as of this writing, which is then used as the basis for subsequent sections; it was <u>not</u> intended to compare WTE against landfilling or other waste conversion technologies.*

A draft WTE criteria matrix for evaluation of waste conversion technologies that are in commercial scale operations was prepared for review and comment by King County. Seven waste conversion technologies were initially identified in the Task 1 - Research Strategy Memorandum and noted across the top row of the proposed matrix along with nine major categories in a column for evaluation and ranking of these technologies. An initial weighting score was proposed for each of the nine categories. This matrix was proposed for evaluation to identify the best fit WTE option for King County, which will be further discussed in Task 3- WTE Option Memorandum.

Many variations of WTE technologies were developed during the 1970s and 80s, including fixed and moving grates, rotary kilns, and fluidized bed combustors. For the purpose of this study, proven WTE conversion technologies are considered to be those which have been successfully implemented on a commercial basis for more than 3 years (and processing U.S. waste materials). Two of the evaluated WTE technologies currently meet this criteria, massburn WTE which is combusted on moving grates (which includes many features of Advanced Thermal Recycling (ATR), and refuse derived fuel (RDF) combusted on moving grates.

3.1 WTE Candidate Technologies

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, engineered fuel). An exhaustive 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.

3.1.1 Proven WTE Processes

1. Massburn WTE - this technology has successfully been implemented for decades in Europe, Asia and North America. The term "mass burn" 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 is most often sent to a turbine to generate electric power for sale. Combustion gases exiting the boiler are cleansed 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 fly ash from the APC are landfilled.

2. Advanced Thermal Recycling (ATR) - advanced thermal recycling WTE is very similar to massburn 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 remainder to maximize materials recycling and the incorporation of advanced systems for recovery of metal and minerals from bottom ash, and 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. Refuse Derived Fuel (RDF) WTE - although not as prevalent as massburn WTE, refuse derived-fuel (RDF) technology has been used worldwide at many facilities. The MSW is first sorted to remove inorganic materials (which are typically landfilled) and wet wastes (organics, including food wastes) which are often 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. Refuse Derived Fuel (RDF) to Cement Kiln - the Refuse Derived Fuel (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 percent) the total energy demand of a cement kiln, which is typically fueled by coal. There are operating facilities where RDF is sent to a cement kiln, one in North America and several in Europe. While creating many benefits (lower greenhouse gas and no fly ash), the facility depends on the cement plant remaining viable over the long-term.

3.1.2 Emerging WTE Processes

1. Thermal Gasification WTE - thermal gasification WTE utilizes a process similar to how charcoal is made – sorted MSW is heated to a high temperature to drive off gases (called syngas) that can be combusted to generate electric power. Thermal gasification is generally viewed as being “cleaner” because the MSW is not directly combusted, but the process is used at only a few facilities worldwide and costs are high. 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 passed through an electric arc to convert the organics into syngas which can be combusted onsite to generate electric power, or purified and sent offsite. This technology is rarely used because of the high cost, and to date, only been commercially applied at relatively small capacities.

3. Biochemical Waste-to-Biofuels - MSW can, after extensive preprocessing to remove impurities, 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 and inorganics) and these materials need 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.

There is a five stage process used in Germany to evaluate the status of development for emerging technologies.

- 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.
- Second stage: Operation of an experimental plant including all process components at different operating modes and loads.
- 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.
- Fourth stage: Stationary operation of a commercial-scale plant over a period of 1 or 2 years (approx. 10,000 operation hours) on the scale required for waste management; expert assessment of operational safety, environmental relevance, usable operational time and cost.
- Fifth stage: Demonstration of commercial-scale application over many years in permanent operation as a waste management plant at least 80 percent of annual usable operational time.

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 world-wide 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.

3.2 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.

3.2.1 Technology Criteria

Note that the numbers 1.0 – 9.0 which follow in this section are the same criteria numbers identified in **Table 3-1**.

1.0 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.

2.0 Technical Performance - This criterion addresses the ability of the proposed waste conversion process to address 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 which are generated by the system users, the need for source separation and/or pre-treatment (removal of items, sorting, and size reduction). The percentage of waste by-passed 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, and its impact on the quantity of materials available for use as a fuel, and possibly a decline in HHV. A future sensitivity analysis on this parameter may be warranted and will be one of the recommendations for future consideration.

3.0 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 aren’t involved in the future.

4.0 Facility Siting and Public Acceptance - This criterion addresses the compatibility of the proposed facilities with the project site. Siting characteristics of significance include the reduction of visual/ other impacts to adjacent properties (odors, noise, dust, debris, number and hours of waste delivery trucks, etc.), grading required to implement the facility and the need for additional utilities; water, power, natural gas, sewage, transportation, and storm water. In our experience, the issues noted above are the minimum criteria for facility siting and public acceptance. There will always be additional local issues that need addressed during a public education campaign. However, since no site has been specifically identified, it is difficult to identify the local issues at this time.

Table 3-1 Waste-To-Energy Evaluation Matrix - King County Waste-to-Energy Study

Criteria Number	Criteria Description (Major / Minor)	Score (points)	WTE	Refuse Derived Fuel (RDF) WTE	Advanced Thermal Recycling (ATR)	Kiln	Comments
1.0	State of Technology Score	15	15	15	14	13	
	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	One cement plant using RDF as a fuel in the US 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 experiences in the EU	One cement plant using RDF as a fuel in the US and several in Europe	How many operational plants and years of successful operation have been recorded?
	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. The technology has basic premise in massburn, with additional processes to improve energy recovery and residual efficiencies.	Fully dependent on the financial viability of the cement plant	Are there identified 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.	One cement plant using RDF as a fuel in the US and several in Europe	What is the capacity and throughput (small, medium, large), and historical system and component annual availability (0-100%)?
2.0	Technical Performance Score	10	9	7	9	7	
	Compatibility with full spectrum of King County waste tonnage (volume and composition)		Yes, except, e-waste, HHW, treated lumber, mercury containing devices, and limited percentage of tires, some co-combust WWTP biosolids	Yes, except numerous non-processible materials removed prior to combustion and disposed of in landfill	Yes, except e-waste, HHW, treated lumber, mercury containing devices,	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 non-ferrous metals, aggregates for use as daily LF cover	Yes, electricity, steam, hot water, ferrous and non-ferrous metal, and aggregates for use as daily LF cover	Yes, electricity, steam, hot water, ferrous and non-ferrous metal, chemicals, minerals, gypsum and aggregates	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 pre-processing		No, other than removal of a small percentage of bulky, and non-processible items (typically < 1% of waste delivered)	Yes, the RDF process extracts metals, glass, and inert materials to create a RDF for combustion, with typical 30% sent to landfill	No, other than removal of bulky and non-processible items.	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	3	3	
	Proven contractor experience in waste processing		Yes, 3 major, 3 minor, domestic private firms, 9 public in US (B&W, Covanta and Wheelabrator)	Yes, 3 major domestic, 3 minor firms, 1 public in US (Covanta, B&W, Xcel Energy, Great River)	Uncertain. Contractor has proven experience with underlying technology though not one contractor and vendor in the US with proven experience in the advanced efficiency technologies	One cement plant using RDF as a fuel in the US 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.	Fair technical support for RDF processing and fair support for using RDF in a cement kiln	Does the proposer have local resources to provide on-going 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	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?
4.0	Facility Siting and Public Acceptance Score	5	5	5	5	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	No ATR in US. Assumes typical industrial area.	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 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 possible sale of steam, internal use of electricity maybe 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)	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 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	Will the local roads be adequate for the project, or will new transfer stations, transfer trucks, or other infrastructure improvements be required?

Table 3-1 Waste-To-Energy Evaluation Matrix - King County Waste-to-Energy Study (Continued)

Criteria Number	Criteria Description (Major / Minor)	Score (points)	WTE	Refuse Derived Fuel (RDF) WTE	Advanced Thermal Recycling (ATR)	Kiln	Comments
	Public acceptance		Yes, many modern WTE with advanced combustion and flue gas controls are located within urban areas close to population centers	Yes, requires greater buffer area due to odors, unless odor treatment system is employed	Uncertain. While the underlying technological premise is similar to mass-burn. There has been no US experience in ATR.	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 mass-burn. There has been no US experience in ATR.	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	14	14	15	
	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's the European experience	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	Credible database, no ash residue (becomes part of the cement)	Is there qualified data to allow permitting agencies to regulate residues and non-processible 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	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	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?
	Reduction in greenhouse gasses		Credible database, on-going debate over biogenic versus anthropogenic emissions	Credible database, on-going debate over biogenic versus anthropogenic emissions	Credible data base, on-going 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?
6.0	Environmental Criteria - Sustainability Score	10	8	8	9	10	
	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	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, WTE facilities are compatible with industrial and institutional locations	With adequate buffer, WTE facilities are compatible with industrial and institutional locations	With adequate buffer, ATR are compatible with industrial locations	With adequate buffer, 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 small sites with well developed mitigation strategies	Minor, well developed mitigation strategies	Minor, well developed mitigation strategies	Minor, well developed mitigation strategies	Are there any significant or potential issues (positive or negative) on the downstream habitat (litter, emissions, noise, 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.	Does the process fully meet all of the local community's environmental goals, such as reduction in pollutants, and greenhouse gasses 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	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 resource and process efficiencies	Yes, there will be no ash stream produced	Does the process afford the opportunity to provides additional benefits to community's public works programs and processes?
7.0	Financial Resources	10	10	10	9	10	
	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 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 upon historical performance	Startup easily achieved based upon historical performance	Uncertain, no commercial experience for the enhanced efficiency processes in the US.	Startup easily achieved based upon 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.	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.	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?

Table 3-1 Waste-To-Energy Evaluation Matrix - King County Waste-to-Energy Study (Continued)

Criteria Number	Criteria Description (Major / Minor)	Score (points)	WTE	Refuse Derived Fuel (RDF) WTE	Advanced Thermal Recycling (ATR)	Kiln	Comments
8.0	Project Economics Score	20	20	19	16	18	
	Requirement for Public capital investment		Typically 100% publically financed with	Typically 100% publically financed with	Uncertain. No commercial experience	Typically 100% publically financed with	What % of commitment is required from local municipality to participate
	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	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)?
	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.	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	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 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	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	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 Score	10	10	9	9	7	
	Economic realities		Competitive with landfill disposal when evaluated over 45 - 50 life cycle, stabilizes disposal rates	Less competitive than WTE, stabilizes disposal rates	Uncertain. No commercial experience in the US	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	Moderate. The underlying thermal technology is proven. The effectiveness of the enhanced efficiency processes is unknown.	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?
	Procurement issues		Several qualified contractors in the US	Few experienced contractors in US	Uncertain. Proven experience in Europe, not 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 demonstration facility with ATR in the 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	Uncertain. The underlying thermal technology is proven. The effectiveness of the enhanced efficiency process is unknown. No contract in US	Minimal contractual risk	Can the definition of "failure" be clearly described or expressed in a contract?
	Contract terms		Yes, demonstrated ability to meet performance guarantees	Yes, demonstrated ability to meet performance guarantees	Uncertain. No contract in US	Limited demonstrated ability to meet performance guarantees	Is the developer willing to include an "escape clause" if the technology fails to achieve benchmark performance goals / guarantees?
	Total Score	100	97	91	88	88	

Most new WTE facilities are sited in urban and suburban settings, in close proximity to population. A public education campaign and series of workshops will be needed to discuss siting issues and options to mitigate concerns. Siting is one of most important criteria, key beneficial mitigation measures will need to be developed and provided to the public which include how the benefits accrue to the local community, system users and rate payers. Also, enhanced architectural designs and other host benefits could be proposed, similar to that done in many other WTE communities.

Options for location of a WTE facility to reduce impacts include: existing or future landfill, industrial areas, adjacent to WWTP facilities and other Public Works projects, retired or active electric power plant sites, brownfield sites, co-located near a steam host (district heating and cooling system, manufacturing facilities, and process industries), marine ports, and even in the heart of downtown districts.

3.2.2 Environmental Criteria

5.0 Environmental Emissions - All waste conversion technologies will generate emissions in solid, liquid, and gaseous phase that represent some impact on 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 greenhouse gases. 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 aren't 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 or energy (electricity, steam, hot water, and chilled water). A WTE plant that at the start only produces electricity doesn't 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 find a definition for 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.

6.0 Environmental Sustainability - This 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.

3.2.3 Financial / Economic Criteria

7.0 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 O&M problems in order 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.

8.0 Project Economics - The economic analysis incorporates the operating expenses associated with a technology (labor, power, chemicals, etc.) and estimate 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 finances the project in order 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 has been done in the past, but essentially, what happens is the public rate payers and users of the system essentially pays off the debt service and there is no guarantee that the contractor will reduce their processing fee after the debt is retired. The low cost, 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). These options are further discussed in Sections 5.1.24 and 5.1.25.

9.0 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.

Additional details of the above are provided in **Appendix B**.

3.2.4 Evaluation and Recommendation for Best Fit WTE

3.2.4.1 Evaluation Results

Each of the above criteria was assigned a specific value (weight) as shown in Table 3-1. King County may change these to reflect their solid waste management goals, community values, area markets, and local solid waste characteristics. Preliminary values have been suggested to arrive at preliminary criteria and technology ranking score in Table 3-1. With the exception of massburn and RDF WTE technologies, the majority of the waste candidate conversion technologies do not meet the criteria for commercial-scale operation that have been 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 in a cement kiln was also evaluated. This form of WTE is based upon successful projects in Europe, with recent experience on the east coast of the U.S. 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 alternate method of WTE that could help King County minimize the amount of wastes that require treatment in a WTE facility or landfill (to be further discussed as part of Task 3).

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 mgy fuel ethanol. The RDF for the process is manufactured by the City of Edmonton at their adjacent Mixed Waste Processing Facility. Enerkem recently announced in late 2016 that after running the plant at approximately 50 percent capacity for the initial startup period (more than a year), they were moving toward their full production goals of 100,000 tpy. 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 U.S. may impact Enerkem's future decision to produce ethanol as originally intended. As an item of note, Enerkem's gasification process requires a relatively dry (less than 20 percent moisture) and homogeneous waste specification.

3.2.4.2 Recommendation for Best Fit WTE Option

Of the qualified and proven WTE technologies, massburn (including 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 massburn WTE plants in the U.S. that are combined with an advanced material recovery (AMR) process. However, there is a WTE facility in Lee County Florida where a construction and demolition (C&D) recycling facility has been constructed adjacent to the WTE facility, in which combustible materials from the C&D recycling are delivered to the WTE facility. Additionally, several years ago, Covanta proposed to the City of Indianapolis that they would be willing to build an Advanced Recycling Center (ARC) adjacent to the existing WTE facility. They predicted that ~19 percent of the materials could be recovered as recyclable materials, with the remaining waste delivered to the WTE facility. A similar arrangement was proposed by Green Conversion Systems for the City of Los Angeles Waste Conversion Project in 2009 in which they projected that a front-end mixed waste processing facility (MWPF) could recover up to 30 percent of the incoming MSW as recyclables. However, like the Indianapolis project, it too was never implemented. As a side note, there is a growing concern that China will again raise the quality requirements for recyclables exported to their country, which could significantly impact the ability to market materials recovered by AMR/ARC facilities. Recyclable materials recovered from these types of facilities may be limited to domestic markets. 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 presented in Table 3-1 and supports this recommendation. Additional details and discussions related to the various technologies which were evaluated are included in **Appendix C**.

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

4.1 Waste Generation Data

Objective of this Section "Preliminary WTE Sizing and Plant Configuration for King County's Waste Projection": *This section seeks to evaluate the composition and projected quantity of waste in King County over the fifty year 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 in nature, and ultimately would require a detailed feasibility analysis to quantify and substantiate various assumptions in order to optimize the number, size and capacity of WTE facilities needed to serve King County.*

4.1.1 Waste Generation Projections and Waste Composition Analysis

4.1.1.1 King County Waste Projections

King County provided the projections for the quantity of waste requiring disposal from the beginning of the planning horizon in year 2028 to year 2078. The waste projection is highly dependent on the recycling rate. The County model assumes that the County-wide recycling rate will increase from 52 percent in Year 2028 to 57 percent in Year 2033. Thereafter, the recycling rate is assumed to remain stable at 57 percent to year 2078. 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 percent 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 year 2016 to 1.1 million tons in year 2028, which is 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 4-1**.

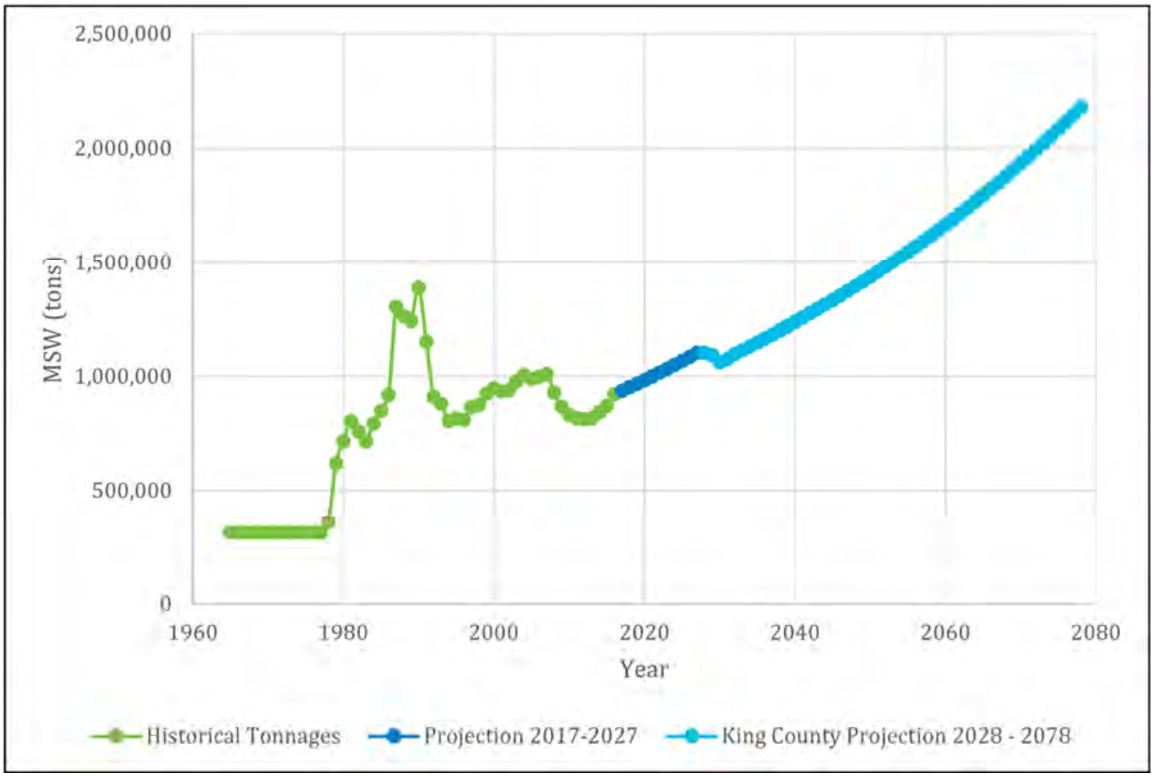

Figure 4-1
King County Historical Waste Tonnages and Projections

For the 20-year planning horizon (Scenario 1 - Section 4.2.2.2) from year 2028 to year 2048, the annual quantity of waste requiring disposal is projected to increase by an average of 1.2 percent per year. By the year 2048, it is projected that there will be approximately 1.39 million tons per year requiring disposal.

For the 30-year planning horizon (Scenario 2 - Section 4.2.2.3), from year 2028 to year 2058, the annual quantity of waste requiring disposal is projected to increase by an average of 1.3 percent per year. By the year 2058, it is projected that there will be approximately 1.62 million tons per year requiring disposal.

For the 50-year planning horizon (Scenario 3 - Section 4.2.2.4), from year 2028 to year 2058, the annual quantity of waste requiring disposal is projected to increase by an average of 1.4 percent per year. By the year 2058, it is projected that there will be approximately 2.18 million tons per year requiring disposal.

4.1.1.2 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 4-2**. The primary components being Food Waste (21 percent), Paper (17 percent), Wood and Yard Waste (17 percent), Other Organics (15 percent), and Plastic (12 percent). These primary components account for 82 percent of the waste composition.

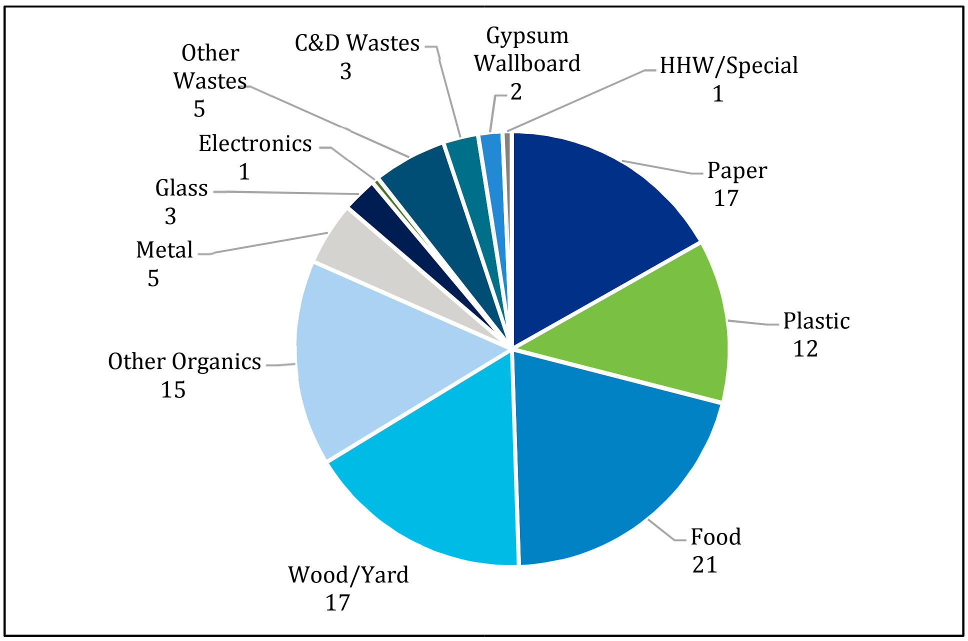

Figure 4-2
King County Waste Composition

The waste composition report indicates that approximately 4.9 percent 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 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. As shown in **Figure 4-3**, the quantity of bypass non-processable waste is projected to increase from approximately 54,000 tons in year 2028 to approximately 107,000 tons in year 2078. The total quantity of non-processable bypass waste from year 2028 through year 2078 is estimated to be approximately 3.85 million tons.

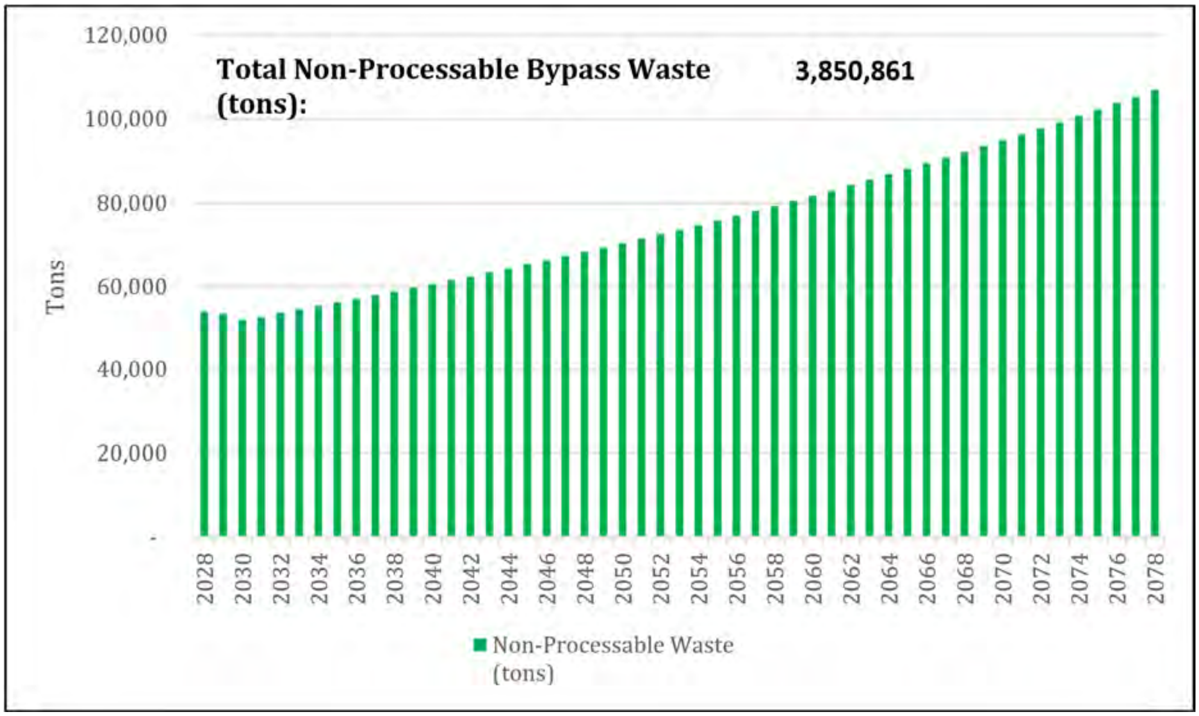

Figure 4-3
Non-Processable Bypass Waste Projection (2028 - 2078)

Based on the expected waste composition of the processable waste to be delivered to the Facility, the Higher Heating Value (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 higher heating value is 5,254 Btu per pound (See **Table 4-1**).

Table 4-1 Waste Estimated Higher Heating Value

Material	Estimated percentage of Waste Composition	HHV Contribution (Btu/lb.)
Paper	16.8 percent	987
Plastic	12.2 percent	1,696
Food	20.5 percent	487
Wood/Yard	16.8 percent	716
Other Organics	15.3 percent	646
Metal	4.7 percent	-
Glass	2.6 percent	-
Other Wastes	9.9 percent	436
HHW/Special	0.7 percent	29
Non-Processable Waste (Removed)	4.9 percent	-
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 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 upon 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 upon weather) and seasonal basis. A future sensitivity analysis on this parameter may be warranted and will be one of the recommendations for future consideration.

4.2. Sizes of Current Generation of WTE Facilities

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 vary 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. However, some facilities with multiple lines do have to be shut down simultaneously for short periods for occasional maintenance, if they have common equipment such as feed water tanks, main steam pipe to a common steam turbine, or require periodical special testing and maintenance, such as that for electrical switchgear and generator protection systems.

There are plant configurations ranging from two to six combustion lines around the world. A facility located in Chester Pennsylvania is rated at a total of 3,510 tpd capacity and is configured with six combustion lines, each rated at 585 tpd. The largest sized combustion lines installed worldwide has been in the range of 1,100 tpd. A WTE facility in Paris, originally constructed in 1969, had two combustion lines, each rated at 1,323 tpd. The largest overall capacity for a single WTE facility is currently under design for Shenzhen, China, which will process 5,500 tpd in five units rated at 1,100 tpd, with the option for a future addition of a sixth combustion line planned in the facility layout.

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 U.S. have been expanded in the past 15 years. One European example includes a WTE facility in Amsterdam, one of the largest complexes with a total capacity of 3,560 tpd. The original Amsterdam WTE facility was constructed in 1969 with four units. An additional two units sized at 887 tpd were added in 2007. Limitations for expansions of an existing facility, or a facility under design, include size of site, number of additional lines, common equipment, such as the capacity of the waste pit, steam turbine, control room, etc. Another important consideration for preliminary sizing is that massburn combustion units can typically be operated in a range of 75 percent to 110 percent of its design capacity, this is referred to as their "turndown ratio".

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 would likely require 20 to 40 acres, depending upon 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 would typically require 15 to 20 acres.

Siting of a future WTE facility is not part of this evaluation and should be included in a future WTE Feasibility Study as a credible next step.

4.3 Preliminary WTE Facility Sizing

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.

Both strategies have benefits and issues for the County. The best fit WTE facility will depend on the County's policies and waste management strategies.

For both strategies, the model estimates that the annual availability of the WTE facility will be 92.5 percent to account for planned and unplanned outages. During these outages, the operator performs maintenance and repairs. Typically, massburn WTE facilities in the U.S. have adopted the following planned outage schedules:

- One planned annual major outage of seven to ten days and one planned annual minor outage of six to eight days for each of the Facility's units. Typically, the major and minor outages are spaced approximately six months apart.
- Two mid-cycle cleaning and inspection outages of approximately two days each for each of the Facility's units.

Without any unplanned (forced) outages, this maintenance schedule results in an annual availability of approximately 94 percent to 95 percent. Any unscheduled forced outages will result in less availability. Many of the current massburn WTE facilities have been able to maintain 92 percent to 96 percent annual availability, even after more than 20 years of operation. This statistic is the result of the industry focus on improved inspections, advanced metallurgy, and a commitment to efficient operation and maintenance.

In Germany, an alternate philosophy has been adopted for their outage schedule. Typically, only one planned outage with a duration of two weeks is performed annually. No additional outages need to be planned with appropriate cleaning and maintenance procedures. This approach to planned maintenance and improved boiler cleaning methods improves the annual availability of the WTE facility to a theoretical 96.2 percent, which is a maximum theoretical value. Most WTE facilities typically incur from a one to two percent reduction in annual availability due to unplanned outages. The predicted overall availability also takes into consideration unplanned outages, which will typically occur a couple of times per year and have a typical duration of two days.

There are several ways to mitigate the need to bypass MSW due to planned outages, primarily by storing the waste in the refuse pit. This would be facilitated by drawing down the refuse pit inventory in advance of the planned outage(s) by running the plant at maximum capacity, to allow waste to continue to be placed in the pit during the outage. Additionally, some amount of waste can be stored on the tipping floor. As a last resort, excess waste may have to bypass the WTE facility for disposal in a landfill. If there is an unexpected long period required for planned or unplanned outage work, the waste could be baled and temporarily stored (in a landfill or other suitable facility) for processing after the shut-down has been resolved (this is not a common practice). However, with three or more combustion lines in operation, this really shouldn't happen often. These practices have been routinely employed by owners/operators of existing WTE facilities.

4.3.1 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 the current projections already consider the projected recycling rate, the bypass waste will likely need to be sent to an Out-of-County Landfill for disposal.

The following scenarios for this strategy consider three different planning horizons:

- Scenario 1 – 20 years from 2028 to 2048
- Scenario 2 – 30 year from 2028 to 2058
- Scenario 3 – 50 year from 2028 to 2078

4.3.1.1 Maximize Capacity: Scenario 1 – 20 Year Planning Horizon

For Scenario 1, the planning horizon is 20 years, beginning from Facility commencement in year 2028 through year 2048. The objective for this scenario is for the Facility to be sized to maximize its processing capacity. The Facility will be sized at 4 units at 800 tons per day (tpd), giving it a total processing capacity of 3,200 tpd. As shown in **Figure 4-4**, the Facility will process all the available 1.05 million tons of processable waste in year 2028. The Facility's total processing capacity will continue to meet the demand of the incoming processable waste stream until approximately year 2035. At which time, the quantity of the available processable waste will exceed the total capacity of the Facility.

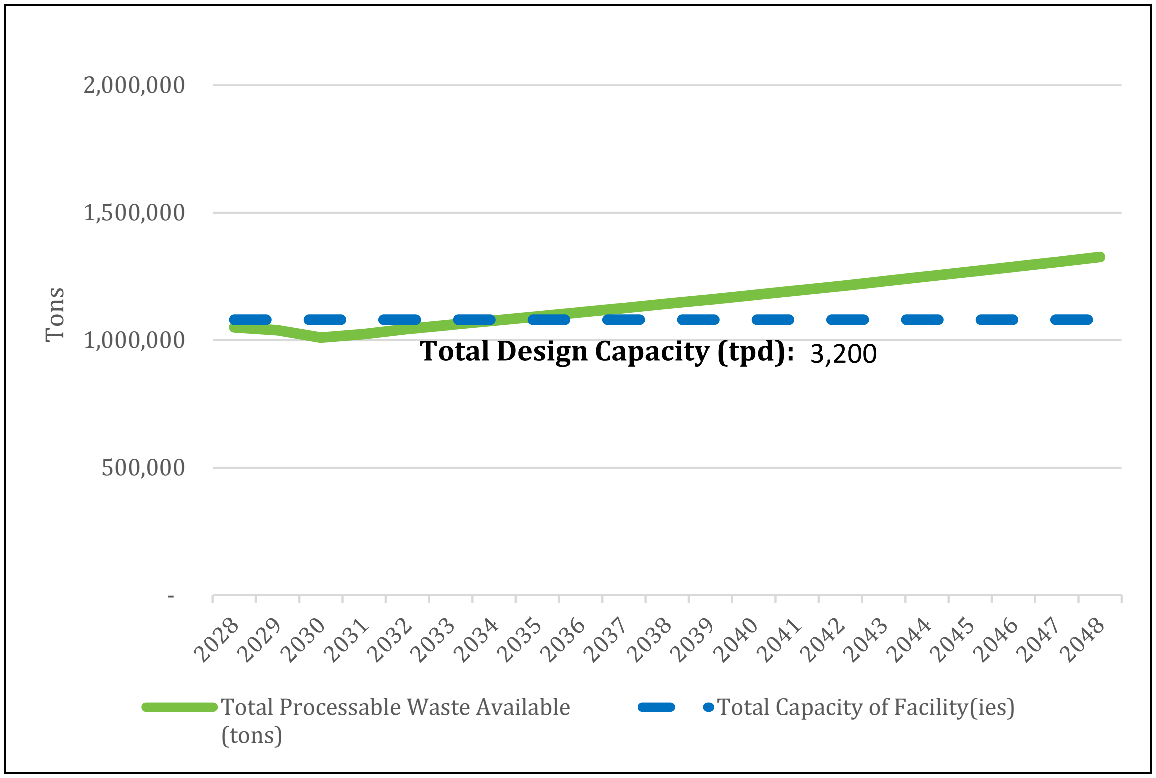

Figure 4-4
Maximize Capacity: Scenario 1 – 20 Year Planning Horizon

After year 2035, the bypass waste quantity will continue to increase as shown in **Figure 4-5**. By the year 2048, it is projected that approximately 246,000 tons per year of processable waste will need to bypass the Facility for disposal. From year 2028 through year 2048, it is estimated that a total of 1.76 million tons of bypass waste will need alternate processing/disposal. This is in addition to the estimated 1.25 million tons of non-processable waste.

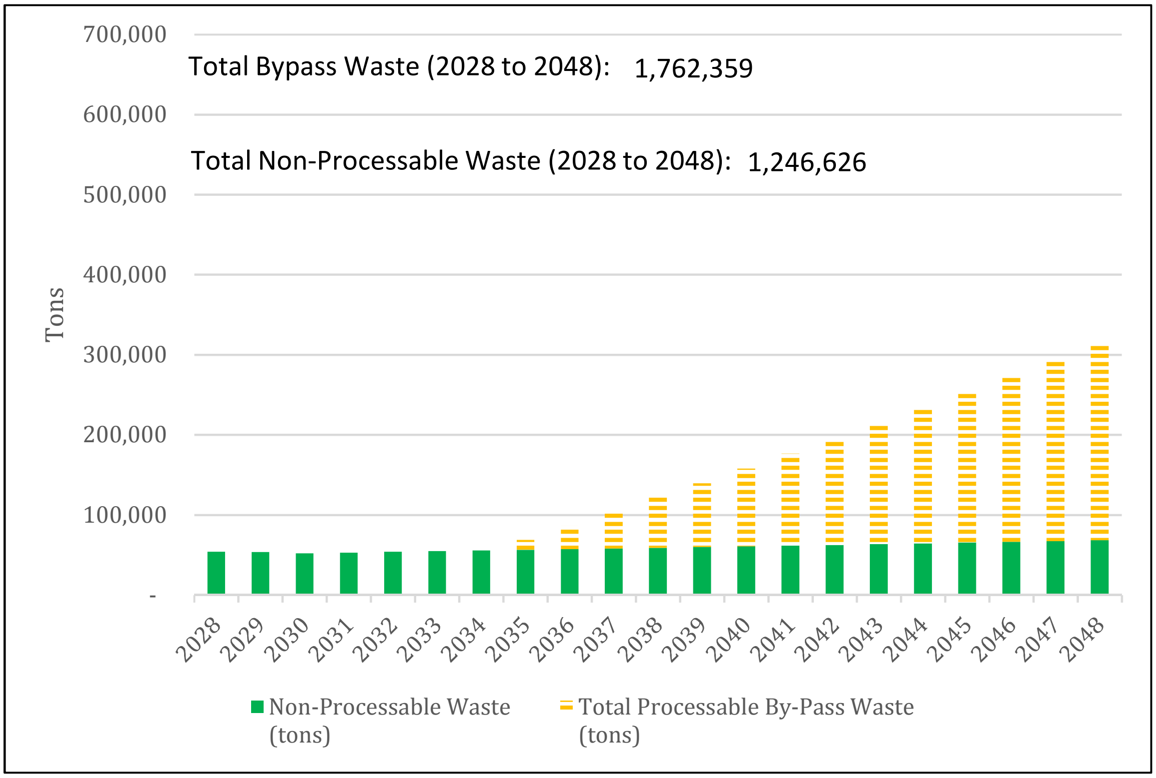

Figure 4-5
Maximize Capacity: Scenario 1 – Projected Bypass Waste for 20 Year Planning Horizon

4.3.1.2 Maximize Capacity: Scenario 2 – 30 Year Planning Horizon

For Scenario 2, the planning horizon is 30 years, beginning from Facility commencement in year 2028 through year 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 tons per day (tpd) in year 2028, giving it a total processing capacity of 3,200 tpd. As shown in **Figure 4-6**, the Facility will process all the available 1.05 million tons of processable waste in year 2028. The Facility's total processing capacity will continue to meet the demand of the incoming processable waste stream until approximately year 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 the year 2048, which will include an additional 800 tpd unit. Beginning in year 2048, the WTE facility will have a total processing capacity of 4,000 tpd.

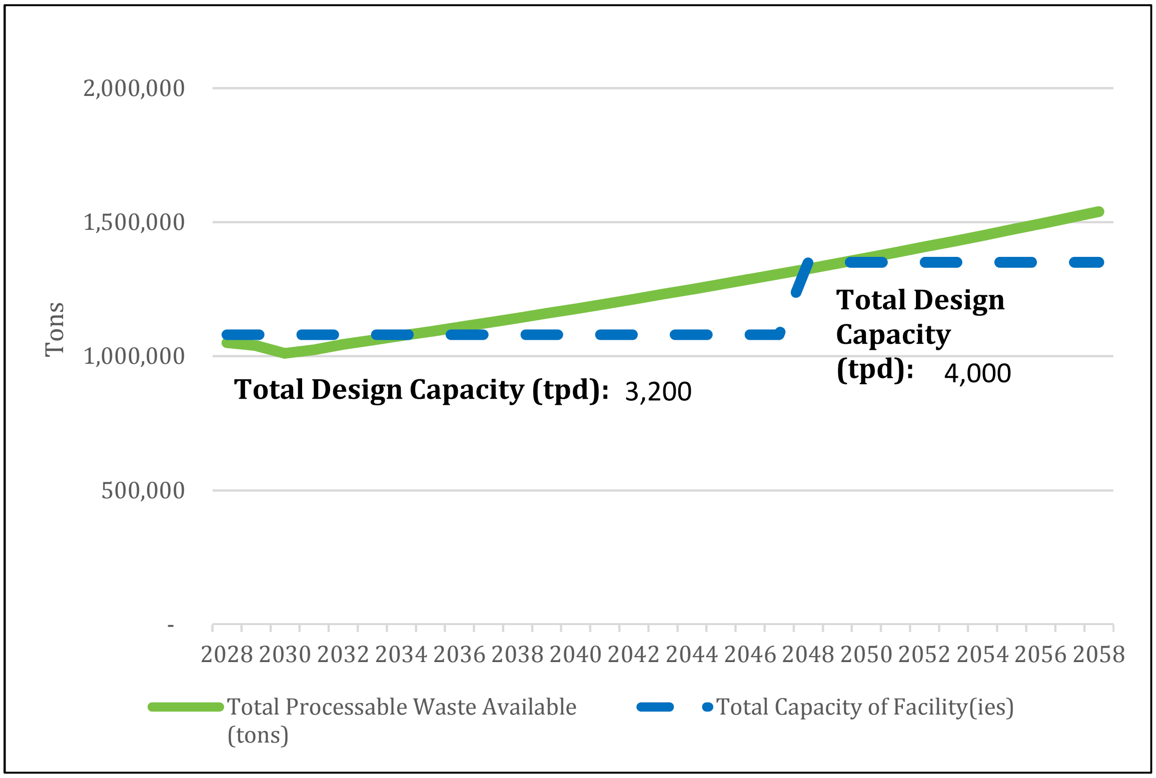

Figure 4-6
Maximize Capacity: Scenario 2 – 30 Year Planning Horizon

After year 2035, the bypass waste quantity will continue to increase until the expansion of the Facility in year 2048, as shown in **Figure 4-7**. The incoming processable waste will again exceed the total processing capacity of the Facility in year 2050. By the year 2058, it is projected that approximately 189,000 tons per year of processable waste will need to bypass the Facility for disposal. From year 2028 through year 2058, it is estimated that a total of 2.4 million tons of bypass waste will need alternate processing/disposal.

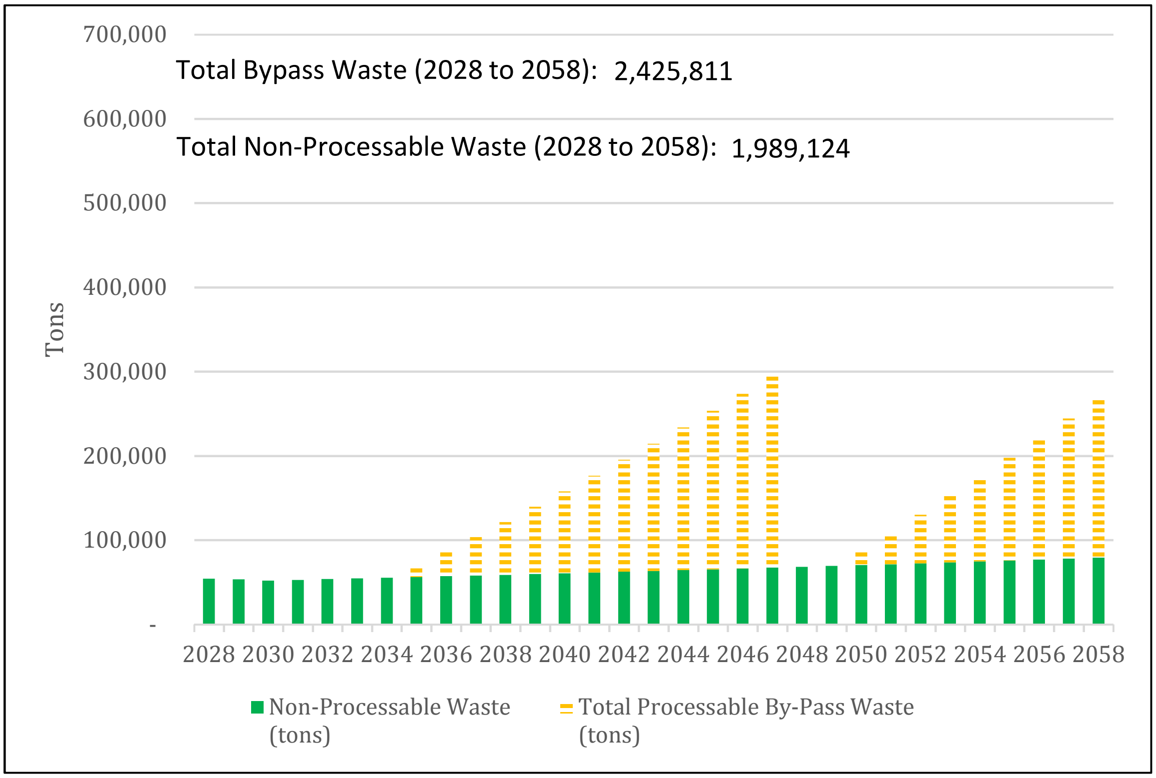

Figure 4-7
Maximize Capacity: Scenario 2 – Projected Bypass Waste for 30 Year Planning Horizon

4.3.1.3 Maximize Capacity: Scenario 3 – 50 Year Planning Horizon

For Scenario 3, the planning horizon is 50 years, beginning from Facility commencement in year 2028 through year 2078. The objective for this scenario is for the Facility to be sized to maximize its processing capacity. The Facility will be sized at 4 units at 800 tons per day (tpd) in year 2028, giving it a total processing capacity of 3,200 tpd. As shown in **Figure 4-8**, the Facility will process all the available 1.05 million tons of processable waste in year 2028. The Facility's total processing capacity will continue to meet the demand of the incoming processable waste stream until approximately year 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 the year 2060 with two additional 800 tpd units, which will provide a total processing capacity of 4,800 tpd.

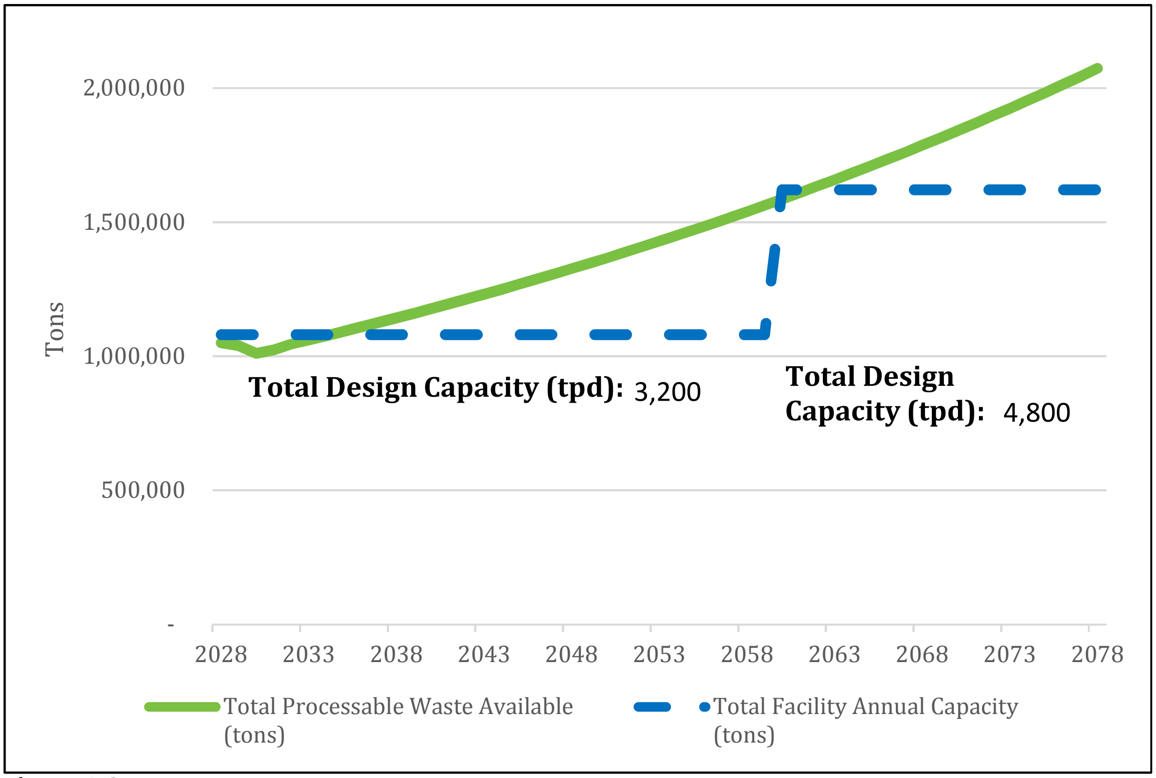

Figure 4-8
Maximize Capacity: Scenario 3 – 50 Year Planning Horizon

After year 2035, the bypass waste quantity will continue to increase until the expansion of the Facility in year 2060, as shown in **Figure 4-9**. The incoming processable waste will again exceed the total processing capacity of the Facility in year 2062. By the year 2078, it is projected that approximately 453,000 tons per year of processable waste will need to bypass the Facility for disposal. From year 2028 through year 2078, it is estimated that a total of 9.68 million tons of bypass waste will need alternate processing/disposal. This amount of bypass waste will require disposal by an alternate means.

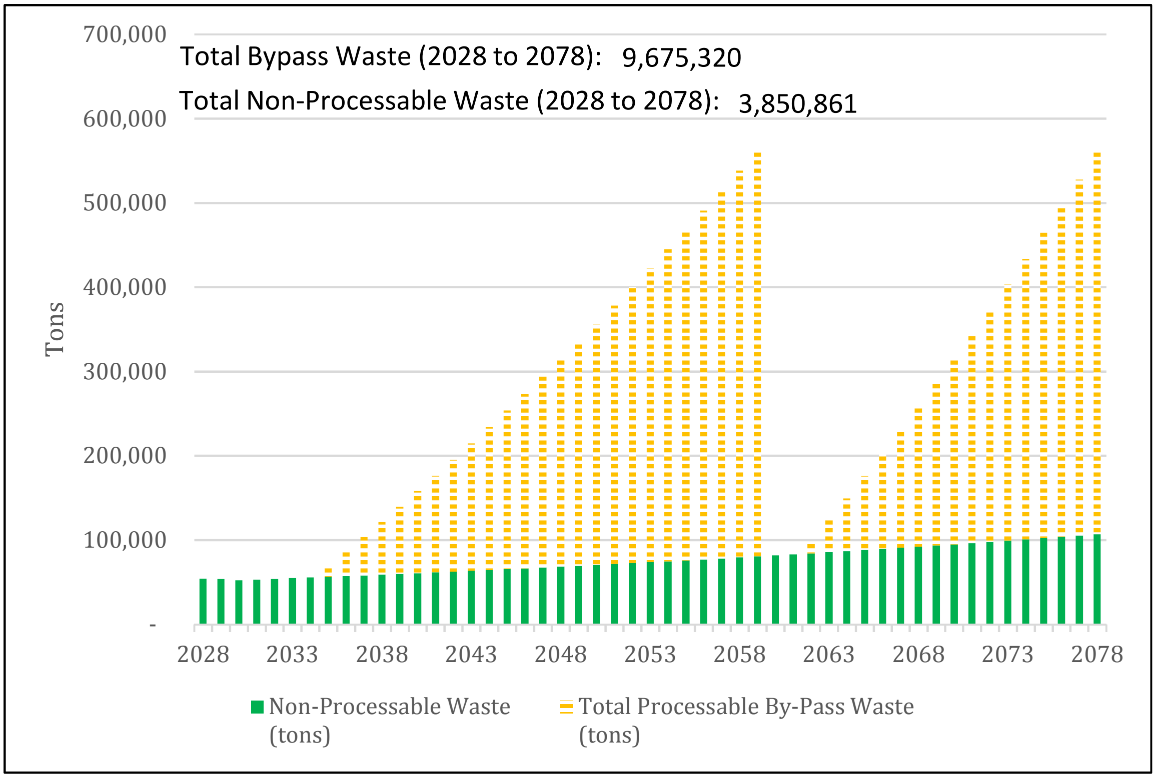

Figure 4-9
Maximize Capacity: Scenario 3 – Projected Bypass Waste for 50 Year Planning Horizon

4.3.2 Sizing the WTE Facility to Minimize Bypass Waste

The second strategy is 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.

The potential issues of this strategy include the following:

- 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 unless the excess capacity is marketed to other waste generators.

- Frequent shutdowns or throttling of some of the units if unable to meet the capacity requirements.

The following scenarios for this strategy consider three different planning horizons:

- Scenario 1 – 20 years from 2028 to 2048
- Scenario 2 – 30 year from 2028 to 2058
- Scenario 3 – 50 year from 2028 to 2078

4.3.2.1 Minimize Bypass: Scenario 1 – 20 Year Planning Horizon

For Scenario 1, the planning horizon is 20 years, beginning from Facility commencement in year 2028 through year 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 tons per day (tpd), giving it a total processing capacity of 4,000 tpd. As shown in **Figure 4-10**, the Facility will process all the available processable waste from year 2028 to year 2048.

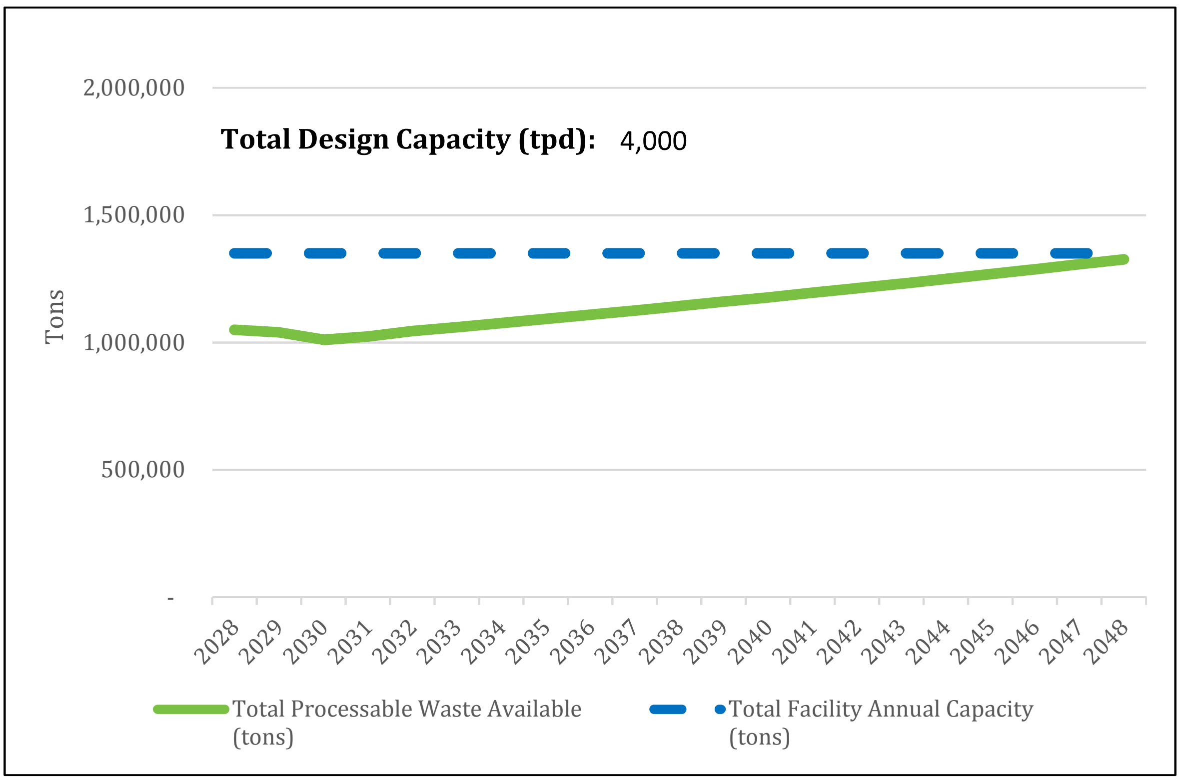

Figure 4-10
Minimize Bypass: Scenario 1 – 20 Year Planning Horizon

As shown in **Figure 4-11**, the Facility will have an initial excess capacity of approximately 300,000 tons in the year 2028. As the incoming waste quantity continues to increase over time, the excess capacity will reduce to approximately 24,000 tons by the year 2048. The total excess capacity throughout the planning horizon from year 2028 to year 2048 is approximately 4.1 million tons. Given the projections, the WTE Facility will initially be operated at 78 percent of its total capacity utilization in year 2028. The total capacity utilization will gradually increase over time to 98 percent by the year 2048.

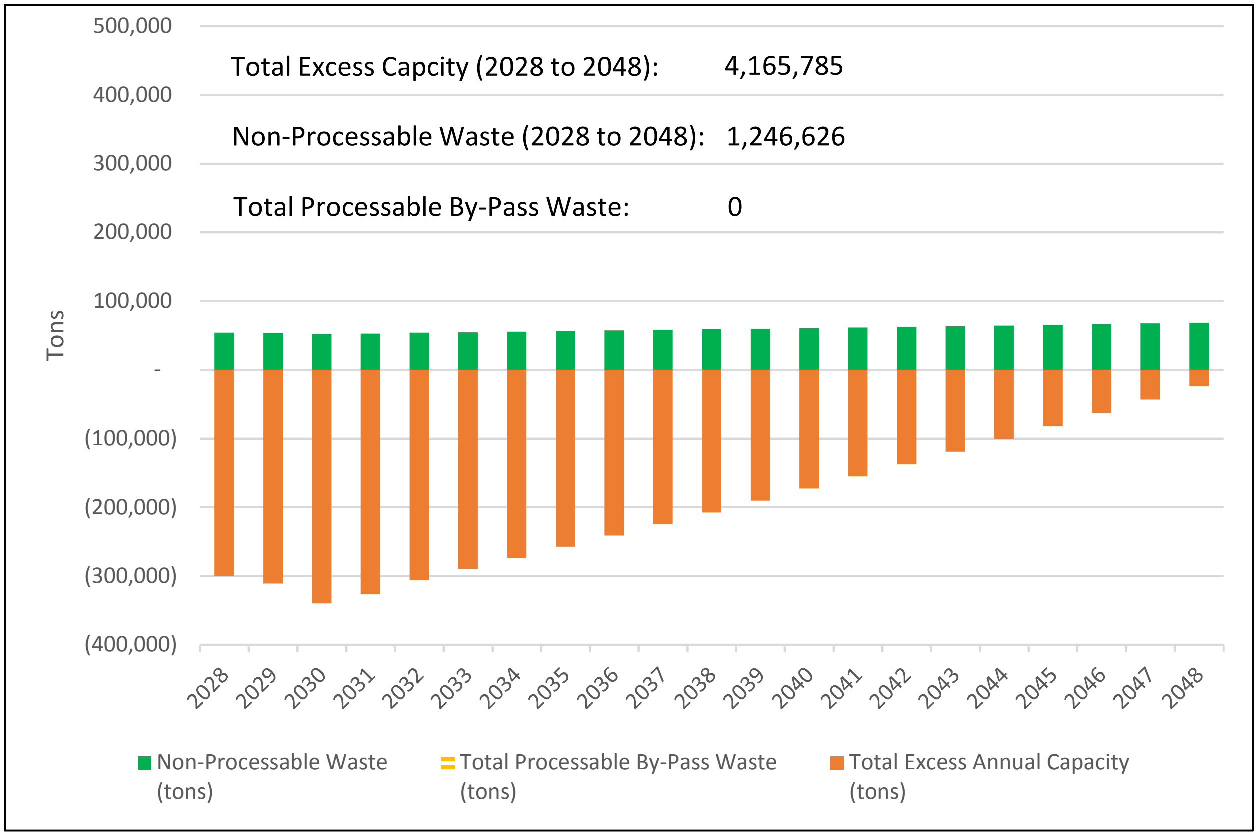

Figure 4-11
Minimize Bypass: Scenario 1 – Projected Excess Capacity for 20 Year Planning Horizon

4.3.2.2 Minimize Bypass: Scenario 2 – 30 Year Planning Horizon

For Scenario 2, the planning horizon is 30 years, beginning from Facility commencement in year 2028 through year 2058. 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 1,125 tons per day (tpd), giving it a total processing capacity of 4,500 tpd. As shown in **Figure 4-12**, the Facility will process the majority of available processable waste from year 2028 to year 2048. Only year 2058, it is projected that there will be approximately 20,000 tons of bypass processable waste that will need be disposed by alternate means. However, the Facility may still be able to process all the waste since it is still within its operating range (turndown ratio).

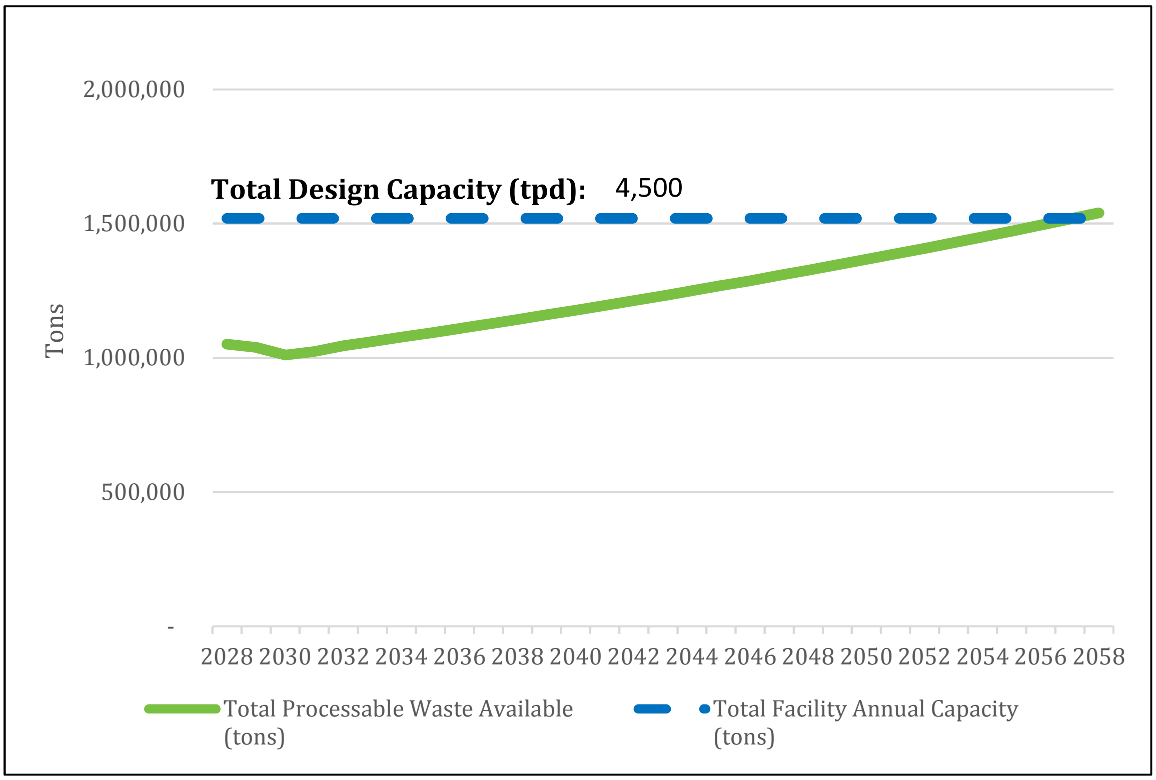

Figure 4-12
Minimize Bypass: Scenario 2 – 30 Year Planning Horizon

As shown in **Figure 4-13**, the Facility will have an initial excess capacity of approximately 470,000 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 2058. The total excess capacity throughout the planning horizon from year 2028 to year 2058 is approximately 8.5 million tons. Given the projections, the WTE Facility will initially be operated at 69 percent of its total capacity utilization in year 2028, which is slightly below the efficient operating range. The total capacity utilization will gradually increase over time. It is projected that the total capacity utilization will reach 75 percent by the year 2038 and 100 percent by the year 2058.

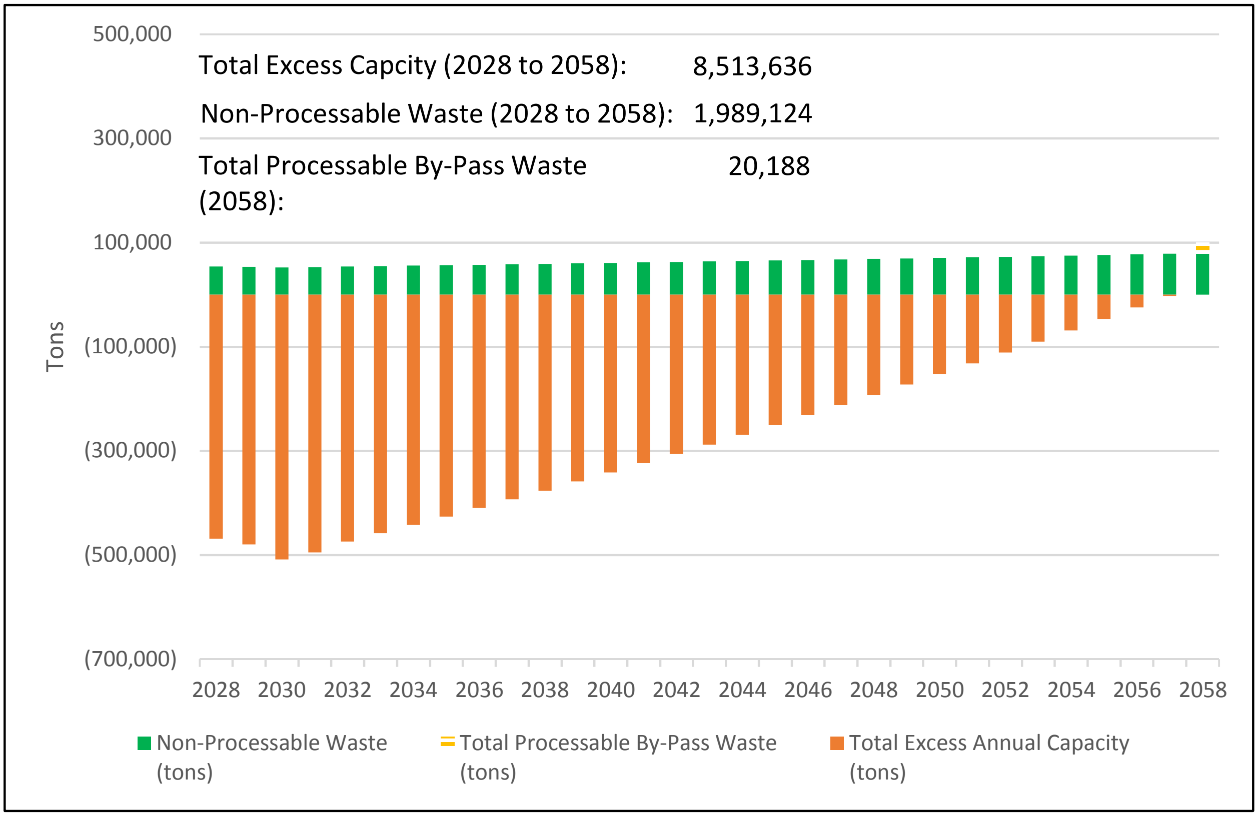

Figure 4-13
Minimize Bypass: Scenario 2 – Projected Excess Capacity for 30 Year Planning Horizon

4.3.2.3 Minimize Bypass: Scenario 3 – 50 Year Planning Horizon

For Scenario 3, the planning horizon is 50 years, beginning from Facility commencement in year 2028 through year 2078. 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 1,050 tons per day (tpd), giving it a total processing capacity of 4,200 tpd. As shown in **Figure 4-14**, the Facility will process all available processable waste from year 2028 to year 2053. Given the projections, the initial total capacity utilization is estimated to be 74 percent in year 2028. By the year 2052, it is projected to be 99 percent. In the year 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.

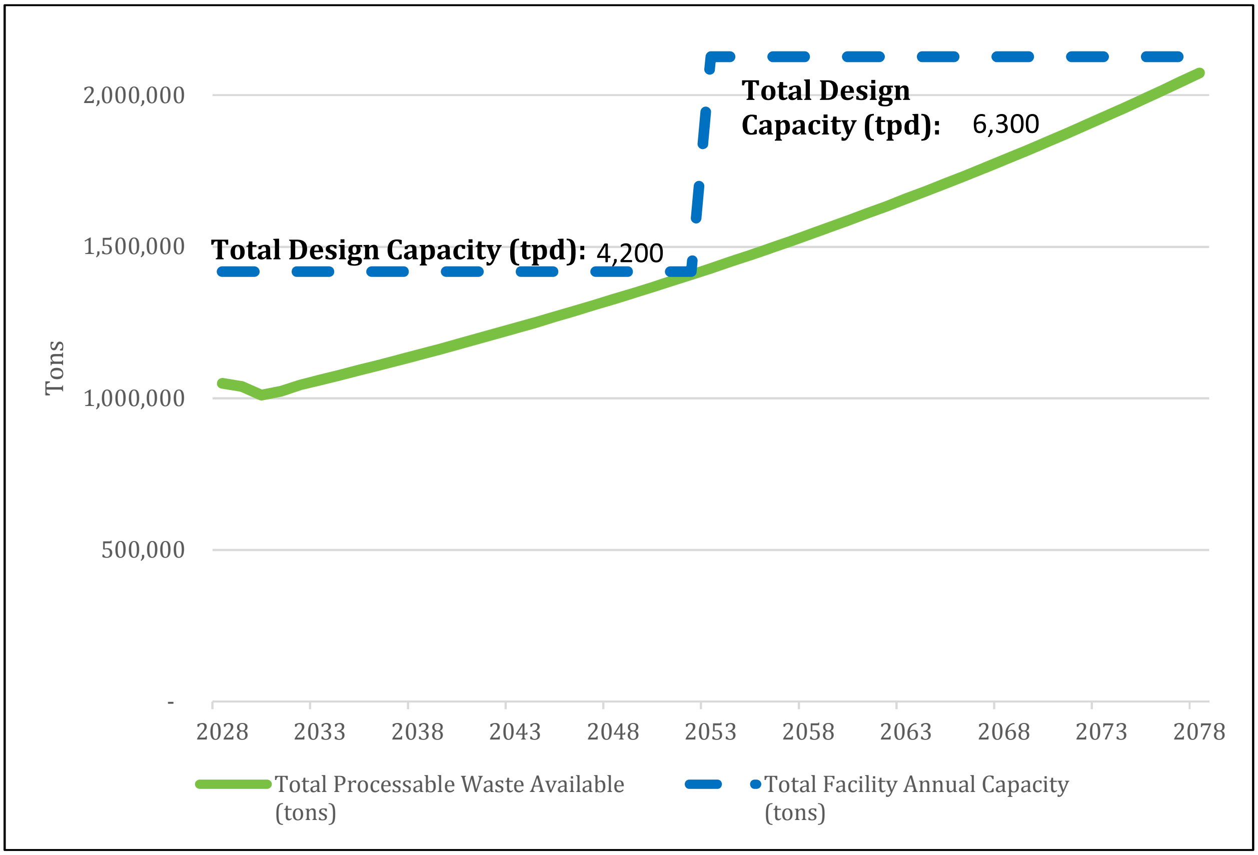

Figure 4-14
Minimize Bypass: Scenario 3 – 50 Year Planning Horizon

As shown in **Figure 4-15**, 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 percent 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 percent by the year 2060 and 97 percent by the year 2078. The total excess capacity throughout the planning horizon from year 2028 to year 2078 is approximately 16.0 million tons.

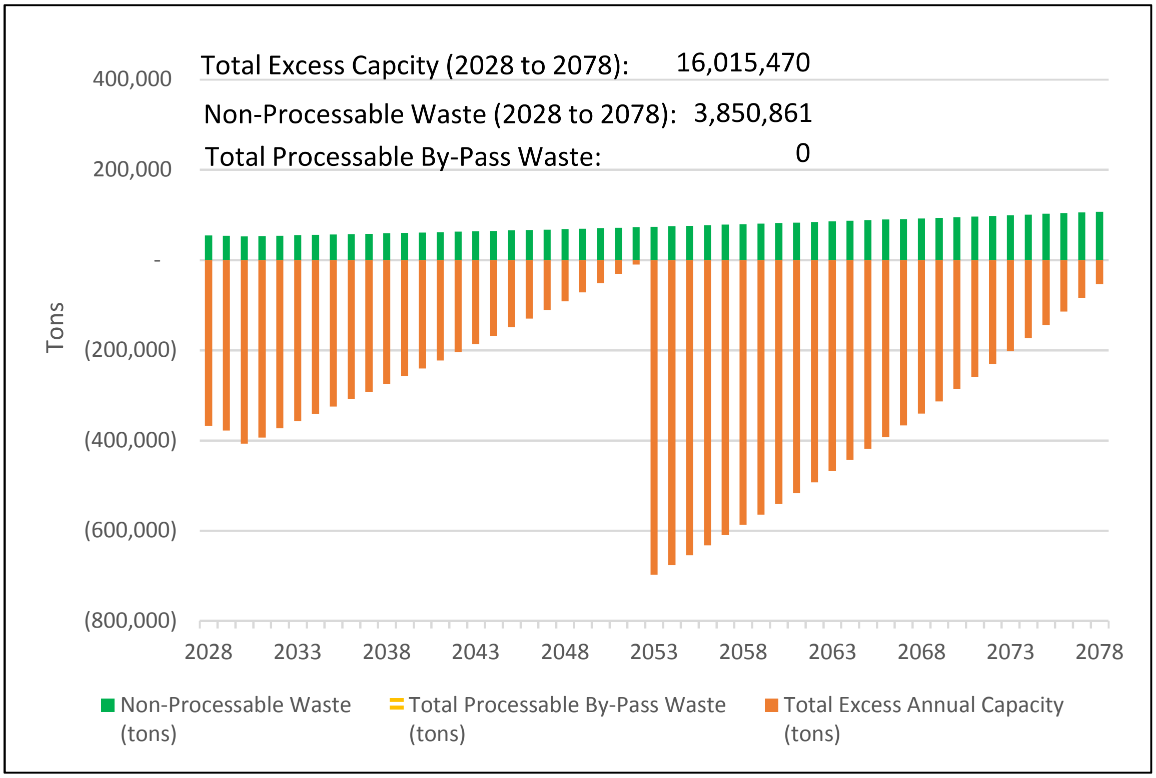

Figure 4-15
Minimize Bypass: Scenario 3 – Projected Excess Capacity for 50 Year Planning Horizon

4.3.3 WTE Facility Sizing Strategy Selection

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 are analyzed further in this technical memorandum.

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 utilized. Additionally, the excess capacity could be marketed under a Special Waste Program for "assured destruction" to regional waste generators. These types of programs have been proven to be successful at other WTE facilities, and can result in additional revenues to help offset costs.

5. Preliminary Assumptions for WTE Financial Model

Objective of this Section "Preliminary Assumptions for WTE Financial Model": *This section establishes preliminary values for key financial variables necessary to estimate costs and revenues of the recommended best fit WTE facility for representative purposes. These variables would need to be confirmed during a future, detailed feasibility analysis, as many of the variables are dependent upon local market conditions and may vary by facility, size, type, location, procurement method, etc.*

5.1 Financial Model Input Data

The following section provides an overview of the key financial parameters used in the financial model. There is no discussion of additional revenues from the sale of steam. Any such discussion would involve a detailed analysis which was not included in this scope and could be performed in a follow-up study.

5.1.1 WTE Facility Annual Availability

WTE facility annual availability has been assumed to be 92.5 percent of design capacity for annual MSW processed. Many of the private operators of first generation WTE facilities were contractually bound to maintain an annual availability guarantee of 85 percent. The percent of time in which a modern WTE facility is available to process solid waste has steadily increased over the past decade due to advancements in the industry. Operational philosophies and consistent and proactive maintenance activities have been implemented to reduce the number of unscheduled shutdowns. The use of high alloy (nickel based Inconel) overlay on boiler tubes and better refractory coverage also reduced the number of unscheduled shutdowns. In addition, more thorough waste inspections via restrictions on incoming wastes and the use of a spotter on the tipping floor for unacceptable waste (such as engine blocks and tree stumps, material that would upset the combustion process or damage the combustion grates) are now practiced. In addition, optimized combustion controls have further reduced unexpected down time. The current annual availability for a mass-burn WTE facility is in the range of 92-96 percent, considerably higher compared to modern fossil power plant industry standards.

5.1.2 WTE Capital Cost Parameters

Capital cost has been estimated at a base cost of $223,333 per tpd of daily waste processing design capacity in 2012$. This base cost was adjusted for the number and size of each unit in calculating a series of unit costs for the following:

- 4 units of 1,000 tpd (Scenario 1)
- 4 units of 1,050 tpd (Scenario 3)

- 4 units of 1,125 tpd (Scenario 2)

The unit cost was also adjusted for inflation between 2012 and 2017.

This cost does not include a site acquisition or project development costs which are included at the end of this section. This unit cost includes project design, and construction management by the selected contractor as a part of a design, build, operate (DBO) contract. This estimate is based upon the most recent WTE project built in the past 20 years in Palm Beach County, Florida constructed during the period 2012 - 2015. This facility is a large 3,000 tpd plant, and the unit capital cost for the successful contractor was $223,333 per ton of daily capacity. This facility had numerous features which could be replicated in King County, including a very large tipping building with 24 truck tipping positions, a large refuse pit with storage capacity for eight to ten days, a Platinum LEED certified Visitor's Center and a large Maintenance/Warehouse Building, both of which were not integral with the WTE facility. The location of the visitor's center required the construction of a 400-foot-long elevated covered walkway to eliminate the opportunity for WTE truck traffic to comingle with visitor foot traffic. The Palm Beach County project cost also included a $12,000,000 allowance for improved aesthetics, and an allowance of $10,000,000 for spare parts.

In addition to the base cost of $223,333 adjusted for the number of units and sizes, there was a 5 percent increase used to allow for seismic design standards, 8.6 percent of material added for sales tax, a 1.5 percent increase for owner costs and 5 percent for contingency. Several cost items initially required are not based on tpd calculations, but are a one-time costs. These include the site acquisition, the electrical interconnection and incremental costs for an advanced ash processing building and equipment.

The details of the capital costs used in total are presented as follows in **Table 5-1**.

Table 5-1 Capital Costs

Capital Cost	Value	Applicable %s	Scenario #1 1,000 tpd $237,812	Scenario #3 1,050 tpd $230,943	Scenario #2 1,125 tpd $221,576
Construction (2017$)					
Labor %	36.50%		$88,845	$86,278	$82,779
Equipment/Material %	36.50%		$84,768	$82,320	$78,981
Other %	27.00%		$64,199	$62,345	$59,816
Seismic Increase	5.00%	61.00%	$7,253	$7,044	$6,758
Subtotal			$245,065	$237,987	$228,334
Sales Tax - Equipment	8.60%	36.50%	$7,290	$7,080	$6,792
Owner Costs*	1.50%		$3,676	$3,570	$3,425
Subtotal			$256,031	$248,636	$238,551
Adjust to (rounded)	2028	2.200%	$325,000	$316,000	$303,000
Contingency (rounded)	5.00%	100.00%	16,000	16,000	15,000
Total Unit Cost			$341,000	$332,000	$318,000
Initial Costs - Additive					
Electrical Interconnection			$1,350,000	$1,350,000	$1,350,000
Site			$5,000,000	$5,000,000	$1,000,000
Incremental Ash - Bldg & Equipment			$15,000,000	$15,000,000	$15,000,000

* Owner Costs include planning, procurement, permitting, finance, design and construction monitoring.

5.1.3 Gross Electrical Generation

The Gross electrical generation rate has been assumed at 700 kWh/ton of MSW processed. The industry wide trend has been toward greater electrical output as boiler operating conditions (pressure / temperatures) have increased over the past years to result in higher gross electrical generation. In addition, the typical waste stream composition has changed over time. Yard waste, metals, and construction and demolition materials in MSW have been reduced by local recycling programs and waste segregation, while plastic containers have become more prevalent, driving up the energy value in MSW. However, it should be noted that the waste composition and hence the HHV are not the decisive criterion for the design of the grate or boiler, it is the corrosive components of the waste, limiting the temperature of the primary steam.

5.1.4 Internal Use of Electricity

The internal use of electricity for WTE plant operations has been conservatively assumed at 13 percent of gross electrical generation. Often referred to as parasitic load, this portion of the electric generation is used to power the motors and electrical systems which are necessary to operate the WTE process equipment and supporting facilities. Typical parasitic loads range from 11 – 15 percent, depending upon the processes employed at the WTE facility.

5.1.5 Net Electrical Energy Generation

The net electrical energy generation rate for a modern WTE facility in King County has been calculated at 609 kWh/ton of MSW processed based upon the above two assumed parameters (700 kWh/ton gross electric generation and 13 percent parasitic load).

5.1.6 Average Electrical Energy Sales Price

A number of sources of electrical prices were reviewed. Each of the most relevant sources are described below, with information provided as to their inclusion or exclusion in their use in the financial model.

- U.S. Energy Information Administration. This agency provides monthly retail electric prices for various sectors of use and geographical region on their website. The electric prices that are most relevant are for the industrial sector for customers in Washington State. The historical prices in kWh for this source are as follows:

Year	2010	2011	2012	2013	2014	2015	2016
$/kWh	0.0408	0.0409	0.0413	0.0423	0.0432	0.0435	0.0453

While these prices are pertinent to the Washington area, they are also retail prices and were not used for that reason.

- Puget Sound Energy (PSE), Electric Tariff G, Schedule 91. This schedule contains the most current power purchase agreement prices, with a selection presented below:
    - 2017 – $44.54 per MWh
    - 2028 - $58.44 per MWh

While these prices would normally be relevant for our use, they are only for the co-generation electricity produced by small power providers, or less than 5 MW. It is for this reason that we are not using these prices.

- Puget Sound Energy (PSE), Electric Tariff G, Schedule 26. This is the current electric price for large demand general service customers - $0.056631/kWh.

This is a retail price and is therefore not used.

- R.W. Beck 2007 WTE Export and Conservation Report. This report was prepared in the 2007/2008 time frame, with the range of prices from $46.29/MWh in 2012 (2007$) to $60.30 in 2036 (2007$).

These prices were projected prior to the introduction of natural gas as a major component of the fuel supply for producing electricity. The costs for the production of electricity have dramatically decreased since this time period and the electricity prices projected are therefore not current.

- Northwest Power and Conservation Council (Council), Northwest Conservation and Energy 7th Power Plan, Chapter 3. This council is an independent agency that produces a least-cost power plan every five years. The 7th Power Plan prepared by this Council provided a number of projected electrical prices based on various parameters, including the ability to meet various state renewable portfolio standards (RPS) and meet electrical demands in a cost-effective manner.

  Extensive cost models were prepared in Chapter 3 for a range of retail scenarios. The scenarios included the current mix of supply and demands, reductions in carbon, the retirement of coal as a source and meeting regional RPS of 35 percent as well as many other scenarios. Prices for electricity for the period of 2016 through 2035 were in 2016$ and ranged from $22.04 ($/MWh) in 2016 to $78.35 ($/MWh) in 2035.

  However, these were retail prices and were therefore not used.

- Northwest Power and Conservation Council (Council), Northwest Conservation and Energy 7th Power Plan (7th Power Plan), Chapter 8. Wholesale prices were found in Chapter 8, with prices ranging from $19.00/MWh in 2017 (2012$) to $69.00/MWh in 2036 (2012$). There were five scenarios prepared, forecasting electric prices.

  - High Price Fuel
  - Low Price Fuel
  - High Demand
  - Low Demand
  - Medium Range of Price and Demand

Figure 5-1 presents a comparison of these scenarios. For purposes of the financial model, the annual wholesale electricity price forecast in the 7th Power Plan was used (Mid-C Medium (Base Case)), primarily because these prices (2012$) were not overly optimistic nor pessimistic, and also reflected prices for the wholesale industry. The rates estimated in the 7th Power Plan were only provided for the years 2028 through 2036 (Appendix). These values were escalated for inflation at 2 percent and used in the financial analysis as noted in the below summary **Table 5-2**. The last published value in the 7th Power Plan for 2036 was then adjusted at 2 percent inflation for the years 2037 through 2078.The prices used for the 20-year, 30-year and 50-year alternatives are as follows, with the dollars expressed in both 2012$ and inflated by an annual 2% to the year of analysis.

Table 5-2 Estimated Sales Price of Electricity ($/kWh)

Year	2028	2036	2048	2053	2058	2078
2012$	$0.03760	$0.0450	Increased by 2% Per Year			
Inflated $	$0.04909	$0.0724	$0.09180	$0.1013	$0.1119	$0.1663

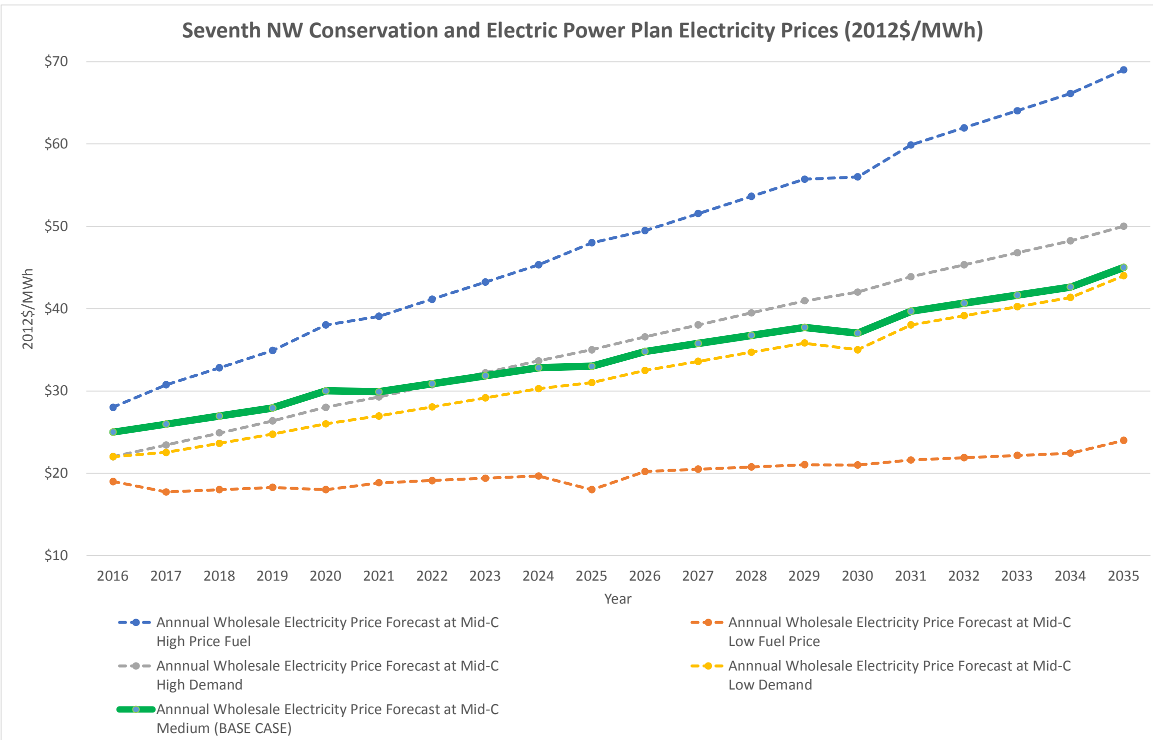

Figure 5-1
Comparison of Scenarios from the Seventh NW Conservation and Electric Power Plan Electricity Prices

5.1.7 Renewable Energy Credits (RECs) Sales Price

According to the current state of Washington legislation, WTE from MSW is not considered a renewable energy source and any RECs that may be generated there would not be acceptable for purposes of meeting compliance requirements of the state's Renewable Portfolio Standard (RPS) - which requires that 15 percent of energy generated by 2020 must be from renewable sources. There was also found to be an extremely small market, if any at all, for the sale of WTE RECs in the regional voluntary market ($1/MWh for a REC, if any value at all). Most voluntary RECs originate from wind and solar, and there are also geographic restrictions. Through extensive research and interviews with experts in the renewable energy markets in Washington and across the country, revenue from the sale of RECs does not appear to be feasible for this project at this time, due to

little or no demand for them and rare acceptability for them for RPS compliance purposes. It may also be possible to sell electricity into grids in nearby states. There is a small possibility of the future value of RECs for the purposes of meeting the state's Clean Air Rule requirement. In summary, our financial models assume no revenue from RECs. If state regulations change or there is an increased demand for WTE-RECs in the future, these concepts should be revisited to determine if some revenue value could be assigned to RECs, but for the purposes of this project, that is not expected to occur by the date this plant might to come online in 2028. A thorough discussion of the value and cost to monetize RECs is provided in **Appendix D.**

5.1.8 Verified Carbon Unit (VCU) Sales Price

Through extensive research and interviews with experts in the renewable energy and carbon offset markets in Washington and across the country, revenue from the sale of VCUs do not appear to be feasible for this project at this time, due to little or no demand for them and rare acceptability for them for RPS compliance purposes. There is a small possibility of value of the VCUs for the purposes of meeting the state's Clean Air Rule requirement. In summary, our financial models assume no revenue from VCUs. A thorough discussion of the value and cost to monetize VCUs is provided in Appendix D.

5.1.9 Ferrous Metal Recovery Rate

The ferrous metal recovery rate has been assumed at 4.0 percent of processed MSW based upon the use of an advanced European style metal recovery system which recovers both the course and fine fraction of ferrous metals. In order to maximize the recovery of non-ferrous metals, a through removal of ferrous metals is required. The presence of ferrous metals affects the efficiency of the non-ferrous metal recovery system. As a result, there are typically multiple magnets employed in the advanced metal recovery systems, thereby maximizing the recovery of ferrous metals. An additional cost of $4,000,000 has been added to the capital cost estimate to account for the additional magnets and associated equipment (conveyors, screens, structures), plus additional building requirements.

5.1.10 Non-Ferrous Metal Recovery Rate

The non-ferrous metal recovery rate has been assumed at 0.80 percent of processed MSW based upon an advanced European style metal recovery system. Non-ferrous metal recovery systems have been adopted by more and more WTE facilities in response to reliable eddy-current separation technology which has evolved over the past decade, primarily in the scrap automobile metal recovery industry. Nonferrous metals in the MSW stream originate from a wide variety of sources, many of which are not collected as a part of curbside recycling programs. These sources include: home appliances, automobile parts, patio furniture, and household items. Assuming 1 percent of the processed MSW is nonferrous metals (equal to 20 percent of all metals, which is typical of European composition of residual wastes) and assuming 80 percent efficiency of modern non-ferrous separators, the non-ferrous metal recovery rate is estimated at 0.8 percent. The advanced non-ferrous metal recovery systems typically employ multiple eddy current separators for each of the range of material sizes which are screened to optimize the recovery of the valuable non-ferrous metals. An additional cost of $11,000,000 has been added to the capital cost estimate to account for the additional eddy current separators and associated equipment (conveyors, screens, structures) plus additional building requirements.

5.1.11 Potable Water Cost

Potable water supply is assumed for domestic potable use only. There is no makeup supply for boiler water treatment systems assumed, with air cooling recommended, in lieu of a wet cooling tower. The potable water consumption rate of 80 gallons/capita/day has been assumed, with 60 personnel using potable water.

Potable water cost of $5.58/1,000 gallons has been estimated for this analysis. The trend within the WTE industry has been to reduce potable water by using lower quality waters for plant cooling needs. In many cases, where locally available, reclaimed water is used as makeup water for cooling towers, fire water storage tanks, and plant irrigation. The most recent WTE project in Palm Beach County used an air -cooled condenser in lieu of an evaporative cooling tower to minimize the use of local water supplies. This can be further reduced by using rain water using underground cisterns at a capacity of several thousand cubic meters for storage, which has been built for relatively low cost in Germany in the area of the waste pit (below the parking areas of the waste cranes). Due to the rainfall amounts in King County, these options are viable.

5.1.12 Wastewater Disposal/Treatment Cost

Wastewater disposal / treatment rate has been conservatively estimated at 80.0 gallons capita (60 staff)/day at a cost of $7.89/1,000 gallons for treatment by a local publicly-owned wastewater treatment facility. The process wastewater system is assumed to be designed for zero liquid discharge, which has been done at a number of facilities world-wide. The wastewater treatment system would be designed with a cascading system with internal wastewater flows treated so that they can be used as process water with lower quality requirements in several stages, with the last stage being used for quenching of the bottom ash, and/or evaporation of the wastewater in the flue gas treatment system, if required. In Europe, it has been a common practice or all residues of the wastewater treatment system to be returned to the waste pit to be thermally treated. The actually treated amounts of this waste stream are negligible. No additional cost is assumed for a zero liquid discharge system as this was the configuration used at Palm Beach County's new WTE facility which is used as the basis for the capital cost estimate.

5.1.13 Ash Disposal Cost

The cost for transportation and disposal of WTE combined ash at a regional Subtitle D landfill (or ash monofill) is estimated to be $54.44 per ton for an out of county ash monofill. An alternative would be the separate disposal of stabilized fly ash and beneficial reuse of the mineral fraction of bottom ash, as road base or use in asphaltic and concrete pavements, as demonstrated in Europe over the long-term, and more recently approved for reuse in Florida. This reuse option should also be further evaluated as a potential source of reduced costs or additional revenues.

5.1.14 Bypassed Waste Disposal Cost

The cost for transportation and disposal of non-processable and bypassed waste is included in the analysis of the WTE However, it would be important for King County to have an operating Subtitle D landfill, or have access to a regional landfill for numerous reasons, including:

1. Disposal of some components of ash residue from the WTE process will be required, until viable ash recycling programs are approved. However, it should be noted that there may be no approval necessary for using the higher quality treated ash residue for daily cover on a lined Subtitle D landfill;

2. Bypass waste during periods when the quantity and quality of the waste exceeds the processing and storage capacity of the WTE (most common reason for bypass waste is that there is more waste than the WTE can process due to waste quantity growth, seasonal periods of high HHV of the waste, combustion unit downtime (scheduled and unscheduled; etc.);

3. Disposal of non-processable waste estimated at 4.9 percent of the total projected MSW; and

4. Retain landfill market competition. Communities without a landfill may find that they are charged by regional landfill owners/operators based on their market prices.

5.1.15 Bottom Ash Recycling Rate

Bottom ash recycling rate will be assumed to be zero for the base analysis. A sensitivity analysis will be performed to evaluate the effect of an ash recycling process after five years of ash data has accumulated and the necessary approval has been received. There are viable options for recycling ash residue as an alternate daily cover on existing lined landfills, along with other technologies for beneficial use of ash residue as construction aggregates, and/or feedstock for production of Portland cement. The four primary ingredients used to manufacture Portland cement (Alumina (Al_2O_3), Ferric Oxide (Fe_2O_3), Lime (CaO), and Silica (SiO_2) have been found to be ideally matched in some WTE bottom ash sources. The opportunity to recycle a certain size fraction of bottom ash in local cement kilns will be explored with a local Seattle based recycling firm. The quality of bottom ash is improved by the removal of ferrous and non-ferrous metals, and can be used in the manufacturing of Portland cement with the proper environmental approvals. A test burn will soon take place in a cement kiln using bottom ash from the Miami-Dade County, Florida WTE facility. What is being proposed there is to use a certain portion of bottom ash (minus ½" in size) as a mineral supplement for the production (manufacturing) of Portland cement, which is the cementitious materials used for making concrete. The manufacturing plant for Portland cement is typically a high temperature cement kiln, equipped with modern air pollution controls. A recycling consultant in Seattle is very familiar with the process, (e.g., once worked with the City of Tampa to explore a similar reuse project in Florida) and interested in helping to develop this for the King County Region.

5.1.16 WTE Operation and Management Cost (Year 1)

The O&M fee for massburn WTE facilities depends upon many variables, ranging from size of plant, risks shared between owner and operator, pass-through costs for utilities, chemical and reagents, sharing of revenues associated with the sale of electricity, steam, and recovered metals. The year 1 O&M contractor service fee has been estimated at $23.00/ton of MSW processed for the 4,000 TPD Scenario 1 reference plant; $22.50/ton of MWS processed for the 4,200 TPD Scenario 3 reference plant; and $22.00/ton for the 4,500 TPD Scenario 2 reference plant. Annual escalation of O&M service contract is typically based upon agreed upon industrial indices, which have been applied to this analysis.

5.1.17 Electrical Interconnection Costs

Typically, purchasing electric utilities charge up to $100,000 to perform a feasibility and reliability study to determine how the non-utility's distributed generation may affect their electric system. If the study reveals that there will not be any significant adverse impacts to the grid, a second investigation will be necessary to determine the specific design, hardware and electrical protection systems for the associated interconnect.

The cost of the second study along with purchasing and installing the associated hardware can be approximately $250,000. Ownership, operation and maintenance responsibilities for the newly installed interconnect equipment will reside with the incoming electric generating entity. Additionally, any future modifications necessary to the interconnection facility, and costs associated with construction or upgrading the transmission line from the WTE facility to the nearest substation will be borne by the owner of the new generating plant. Since this project does not include a specific site, it will not be possible to accurately estimate these costs. However, as a place marker, a value of $1,000,000 has been assumed.

5.1.18 Site Acquisition Cost

Although a specific site has not been proposed for this study, an estimated cost of $5,000,000 is assumed for a site up to 40 acres as a place marker.

5.1.19 County Project Management Cost

Annual costs (salary plus benefits) assumed for 1.0 full time employee (FTE) for Project Manager and 0.5 FTE Assistant Project Manager is $210,000 in 2017$.

5.1.20 Project Contingency

A contingency value of 5 percent, applied to the capital cost only, is assumed. This value is in line with the amount of detail which has been applied to this financial analysis.

5.1.21 Washington State Sales Tax

A state sales tax of 8.6 percent has been applied to the material cost only, with the assumption that the WTE project would be located in unincorporated King County.

5.1.22 Local Business and Occupations Tax

1.5 percent of all gross receipts generated by the WTE plant will not be collected as a local Business and Occupations tax. An attorney familiar with the Business and Occupations Tax should review the application of this tax. Department of Revenue section RCW 82.04.310 indicates that electricity that is sold either within or outside the state and then resold, is not subject to this tax.

5.1.23 County's Administration Cost

The estimated cost for the County to develop this project, including public education, project siting and sizing, permitting, procurement, bid evaluation and contractor selection, and project management over the duration of the construction period and WTE facility acceptance testing is 1.5 percent of the construction cost. This value would cover a six-year period and includes the hiring of a Consulting Engineer to assist with some of the technical duties.

5.1.24 Alternate Financing Mechanisms

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 (assured destruction) to local industries and businesses, which have been proven to be significant sources of additional revenues in many WTE communities with excess capacity. The sale of steam has not been incorporated into the financial model as it is dependent of the WTE site, and would require a subsequent report.

Other incentives could be via grants from federal government (USDA, DOE, DOI, or possibly future Infrastructure Reinvestment programs). Local and state incentives may also be available for development of regional WTE projects in which larger community helps smaller neighboring rural communities manage wastes for energy and material recovery.

As noted earlier, CDM Smith is aware of a program that the U.S. Department of Energy is promoting to help communities in the first step in finding a use for combined heat and power (CHP) by funding the community's initial feasibility study.

5.1.25 Combined Heat and Power Opportunities

WTE projects have been demonstrated worldwide in combined heat and power (CHP) applications (often referred to as co-generation) to produce both heat and electricity simultaneously. CHP projects are significantly more efficient and cost effective than conventional power generation, where electricity and thermal energy are produced separately using two different processes and fuel sources. In conventional WTE power generation, solid waste fuels are used to generate the electricity, with significant amounts of heat produced as a byproduct lost to the atmosphere via cooling tower plumes and flue gas up a stack.

Cogeneration projects capture waste heat that is created as a result of the WTE process and recycle it in the form of steam, hot water or other uses. Although counter-intuitive, steam can be used as a prime mover for compressors that power industrial chillers and refrigeration systems. One of the difficulties of CHP applications for WTE projects are related to the variability of the energy demand of the host energy users. Energy demands of heating and cooling districts vary seasonally with ambient temperature swings, while industrial and institutional processes can vary for many reasons based upon the plant's production needs, and operation and maintenance practices. However, in countries such as Denmark, with a large number of district heating loops in most major cities and towns, there is a mandate that WTE projects must be CHP. In many cases, the revenues from the sale of electricity is significantly less than the revenues from the sale of steam and heat.

The applications of the forms of energy from CHP can include: district heating and cooling of buildings, public utilities (wastewater, potable water, solid waste, and recycling), industrial cleaning (laundries), colleges/schools, hotels, recreational sites, governmental and military facilities, commercial office buildings, and industrial processes that include manufacturing, wood, pulp/paper industries, refineries and chemical production facilities, food production, commercial scale laundries, hospitals/health care facilities, and opportunities for production of biofuels and biochemical (e.g., liquefaction of natural gas, and production of biofuels, such as ethanol and other alcohol fuels, synthetic aviation, gasoline, and diesel).

In addition to eliminating solid waste and increasing energy production efficiency, CHP solutions have many other advantages, including:

- Improved revenues for the WTE owner by the sale of steam, hot water, or chilled water;
- Improved predictability and more accurate financial forecasting by mitigating some of the volatility from the traditional sale of electricity to the local grid at low power purchase prices, or spot market prices;

- Improved revenues from the sale of RECs, green certificates, carbon offsets and other environmental attributes resulting from cogeneration; and
- Reduce emissions due to improved thermal efficiencies, which have been demonstrated for many projects with efficiencies in the range of 85-100 percent. CHP projects can reduce the project carbon footprint by reduction of greenhouse gas emissions by up to 30 percent.

Benefits to the Local Electric Grid include:

- Unlike intermittent and low capacity factor renewables, CHP projects are reliable sources of electric power and promote sustainability initiatives;
- CHP projects are readily available to enhance a grid's resiliency (reliability and stability), their intrinsic ability to operate in an "island" mode as part of a microgrid may allow them to serve in a "black start" function in recovery of event of a bulk power system (BPS) failure; and
- The reliability of the BPS requires a close balance between generation and load, with precise regulation. There is monetary value associated with these ancillary services and should be included in any future negotiations of a power purchase agreement (PPA).

The value of electricity from a WTE facility in King County may be far in excess of the value currently offered by electric utilities which serve the PNW. Key meetings with the Utilities and other Agencies should occur to discuss these values and this should be part of a follow-on study to maximize the revenues associated with the sale of WTE electricity.

This preliminary financial analysis does not account for additional revenues from the sale of steam or hot and chilled water. This type of analysis is best to be completed in a follow-on study.

A summary of all of the key financial data assumptions, including escalation factors is provided in **Table 5-3**. These preliminary assumptions will be discussed with King County to obtain input and verification regarding local costs, bonding information, etc.

Table 5-3 Basis for King County Financial Analysis Model Assumptions

Financial Model Assumptions	King County Analysis (Best Fit)	
Population and Waste Generation Data	Value	Reference Plant / Source of Data
Population served	1,588,103 (2028); 3,151,636 (2078)	State Growth Projections (net of Seattle)
Per capita MSW generation rate requiring disposal	3.79 pound/person/day	Tonnage Projections divided by Population Projections
Waste projections for 2028-2078 period	Data provided by King County for the 50-year period accounts for increased recycling goals	1,104,594 tons (2028) 2,180,320 tons (2078)
Estimated percent of non-processable waste	4.90%	Estimated by CDM Smith based upon analysis of data in 2015 Waste Composition Report
Annual average Higher Heating Value of waste processed	5,000-5,254 Btu/lb.	Estimated by CDM Smith based upon analysis of data in 2015 Waste Composition Report
WTE Facility Sizing		
Size of WTE facility (tpd) 20-year service life (Scenario 1)	4,000 tpd (4 units @ 1,000 tpd) for 20-year period	Estimated by CDM Smith based upon analysis of waste projection (minus 4.9% non-processible)
Size of WTE facility (tpd) Scenario 2 30-year service life	4,500 tpd (4 units @ 1,125 tpd) for 30-year period	Estimated by CDM Smith based upon analysis of waste projection (minus 4.9% non-processible)
Size of WTE facility (tpd) Scenario 3 50-year service life	4,200 tpd (4 units @ 1,050 tpd) in 2028 2,100 tpd (2 units @ 1,050 tpd) in 2053	Estimated by CDM Smith based upon analysis of waste projection (minus 4.9% non-processible)
WTE facility annual availability	92.5%	Palm Beach County, FL 3,000 tpd WTE (2015)
WTE Facility Capital Costs		
WTE facility capital unit cost ($ per ton of daily capacity - 2017)	$256,031 - 1,000 tpd, $248,636 - 1,050 tpd, $238,551 - 1,125 tpd in 2017$	The PBC capital cost of $223,333 in tpd was adjusted for number and size of unit (rule of six-tenths) in calculating a series of unit costs; 1,000 x 4, 1,050 x 4, 1,125 x 4.
WTE spare parts allowance (included in capital cost)	$10,000,000	Palm Beach County, FL 3,000 tpd WTE (2015) @ $10,000,000
Capital Cost escalation factor for seismic area	5% of Building portion of Capital Cost	National Institute of Standards and Technology - Cost Analyses and Benefit Studies for Earthquake- Resistant Construction in Memphis, TN, December 2013 = 1.4%, increased to 5% for pre-1999 seismic standard.
Financial Data – Debt Service		
Debt service period	20, 25 or 30 years - based on capacity usage	Typically 20-30 years for municipal bond financing
Debt service interest rate	5.0%	Hillsborough County, Florida 7.6 % original facility (1985 bonds) 4.75% expansion (2008 bonds)
Debt Service Coverage	10.0%	With a revenue bond with a user fee revenue pledge there will be a coverage requirement, typically the percent that the net revenue must exceed the annual debt service payment by. No add on was used in the calculation, as the annual CIP amount should exceed the 10% coverage factor.
Cost to issue bonds	1.0%	
Construction Financing		
Length, months	42 months	
Interest Rate	2.0%	
Financial Data – Electrical Generation and Sales		
Gross electrical generation rate	700 kWh/ton	Palm Beach County, FL 3,000 tpd WTE (2015)
Internal use of electricity	13.0%	Palm Beach County, FL 3,000 tpd WTE (2015)
Net electrical generation rate	609 kWh/ton MSW	Palm Beach County, FL 3,000 tpd WTE (2015)
Average electric energy sales price	$49.09/MWh in 2028$ $27.60/MWh in 2017$	Northwest Power and Conservation Council, Northwest Conservation and Energy 7th Power Plan, Chapter 8 - Wholesale electric prices, medium range price of $25 increased by 2% inflation from 2012 to 2017.
Electrical revenue sharing ratio up to net electrical guarantee	90 percent owner's portion up to net generation guarantee	Typical for WTE Service Agreements
Operator energy revenue share above Net kWh/Ton	N/A, not using net guarantee for this analysis	Typically 50/50 split
Sale of environmental attributes - Renewable Energy Credits (RECs)	Assume zero for base case.	Does not currently qualify in Washington State.
Sale of environmental attributes -Voluntary Carbon Units (VCUs)	Assume zero for base case.	Does not currently qualify in Washington State.
Financial Data – Recovered Metal Revenues		
Ferrous metal recovery rate	4.00% of MSW processed	Pasco County, FL (1,050 tpd WTE) Spokane, WA (800 tpd WTE) Assumes advanced metal recovery system
Ferrous metal recovery sales price	$50/ton 2017$	Pasco County, FL (1,050 tpd WTE) Spokane, WA (800 tpd WTE) Assumes fly ash separated from bottom ash until after metal recovery

Table 5-3 Basis for King County Financial Analysis Model Assumptions (Continued)

Financial Model Assumptions	King County Analysis (Best Fit)	
Non-ferrous metal recovery rate	0.80%	Pasco County, FL (1,050 tpd WTE) Spokane, WA (800 tpd WTE) Assumes advanced metal recovery system
Non-ferrous metal sales price	$750/ton 2017$	Hillsborough County, FL (1,800 tpd WTE) $728/ton actual (February 2017)
Recovered metal revenue sharing	50 percent owner / 50 percent operator	Typical sharing ration at many U.S.WTE facilities
WTE Facility Operation & Maintenance Cost - Reagents		
Pebble lime consumption rate	15 pounds/ton MSW processed	Palm Beach County, FL 3,000 tpd WTE (2015) guarantees <15.3 lb./ton
Pebble lime cost	$160/ton 2017$	Local Tampa Bay WTE facilities
Powered activated carbon consumption rate	0.75 pounds/ton MSW processed	Palm Beach County, FL 3,000 tpd WTE (2015) guarantees <0.75 lb./ton
Powered activated carbon cost	$1,100/ton 2017$	Pinellas County, FL 3,000 tpd WTE
Ammonia consumption rate	1.5 pounds/ton MSW processed	Palm Beach County, FL 3,000 tpd WTE (2015) guarantees <1.52 lb./ton
Ammonia cost	$300/ton 2017$	
WTE Facility Operation & Maintenance Costs - Utilities		
Potable water consumption rate	80 gallons/capita/day - 60 personnel	Palm Beach County - air cooled process, with potable water for personnel use
Potable water cost	$5.58 / 1,000 gallons (2017$)	City of Seattle 2017 General Service/Outside City rate adjusted from CCF to kgal.
Wastewater disposal rate	80 gallons/capita/day - 60 personnel	Palm Beach County - air cooled process, with potable water for personnel use
Wastewater cost	$7.89 / 1,000 gallons	King County 2017 rate adjusted from CCF to kgal.
Natural gas consumption	50,000 MMBtu	Operator pays for all natural gas use in excess of limit
Natural gas cost	$4.00/MMBtu	EIA index for Henry Hub natural gas pricing
WTE Facility Operation & Maintenance Costs – Ash Disposal		
Combined Ash Generation (%)	20%	Assumes advanced metal recovery (recovery of +4% metals) and separation of fly ash from bottom ash for metal recovery
Landfill ash tipping fee and transport	$54.44/ton 2017$	Assumes transportation and disposal at Roosevelt Regional ash monofill
Ash Recycling percentage	N/A	To be considered in future
Ash Recycling costs / benefits	N/A	To be considered in future
WTE Facility Operation & Maintenance Costs – Labor and Markups		
Base O&M contractor service fee (Year 1)	$23.00/ton 1,000 tpd; $22.50/ton 1,050 tpd; $22.00/ton 1,125 tpd in 2017$	The PBC operating cost of $21.00/ton was adjusted for number and size of unit in calculated series of unit costs; 1,000 x 4, 1,050 x 4, 1,125 x 4.
King County Annual Management Costs		
King County (or other managing entity) project management staff	$210,000/year	Assumes 2 new staff (full-time PM with junior staff assistance)
Environmental Consulting Fees	$350,000/year	Typical for numerous Florida based municipally owned WTE facilities for operations monitoring, permitting, and annual reporting.
Cost for registration, verification, and sale of RECs	Assume zero for base case.	Does not currently qualify in Washington State.
Cost for registration, verification, and sale of VCUs	Assume zero for base case.	Does not currently qualify in Washington State.
WTE Cost Escalation Factors		
Other Revenue - Inflation	1.50%	Based on 2015 to 2017 actual percent increase for non-ferrous revenue - Pinellas
Electric Revenue - Inflation	2.00%	Bureau of Labor Statistics - PPI - Electric Power - average increase 2007 - 2017
O&M Costs - Labor	24.00%	Percent used for previous WTE study
O&M Costs - Materials and Consumables	18.00%	Percent used for previous WTE study
O&M Costs - External Services	23.00%	Percent used for previous WTE study
O&M Costs - Other Costs	35.00%	Percent used for previous WTE study
Operating Costs - Labor Inflation	3.20%	County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years, blended labor
Operating Costs - Equipment Inflation	2.80%	County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years general inflation
Operating Costs - Other Inflation	2.80%	County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years general inflation
Operating Costs - Reagent Inflation	3.00%	BLS Chemical Indexes WPU061 - Average of increases 2010 - 2017
Contract Operating Costs - Combined Inflation	2.90%	Equals the average of above.
WTE Capital Cost - Labor Inflation	2.68%	Engineering News Record, Skilled Labor Index - average of 2012 - 2016
WTE Capital Cost - Equipment Inflation	1.72%	Engineering News Record, Skilled Materials Index - average of 2012 - 2016
WTE Capital Cost - Other Inflation	2.20%	Bureau of Labor Statistics -Machinery & Equipment (WPU114) - average increase 2010 - 2016

6. Preliminary Results of WTE Financial Model

Objective of this Section "Preliminary Results of WTE Financial Model": *This section summarizes 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-year). Sensitivity analyses were also completed to help identify key variables, which would improve financial performance of such a WTE project.*

6.1 WTE Scenario Discussions – 20 Year Plan, 30 Year Plan, 50 Year Plan

There were several key parameters; capital costs, debt service terms and interest rate, electricity sales price, and operation and management costs that were summarized on Table 5-2 and discussed in Section 5. This section presents these items in terms of the three alternatives which were examined in the 20-Year, 30-Year and 50-Year plans. There was only one scenario which resulted in a small amount of bypass waste (30-Year plan). The bypass waste equals the processable waste that exceeds the WTE facility capacity, for which there was only a minor quantity projected in year 30 of the 30-Year Plan. The cost of landfilling both non-processable waste and bypass waste is also provided. It is also assumed that the ash residue that is generated by the WTE facility is not being recycled as part of the base case analysis. It is also important to point out that there was no recognition given to the discontinuation of use at the Cedar Hills Regional Landfill in terms of reduced costs (labor, equipment, etc.). However, both of these can be included in a future analysis.

6.1.1 Scenario 1 - 20-Year

The 20-year plan indicates a large decrease in the cost per ton in 2048, which is due to the debt service having been repaid. There was only one bond issued, which was for a 20-year period. The details that make up the summary of revenue, operating costs and debt service payments are presented on **Tables 6-1, 6-2, and 6-3**. The summary of these items and the related cost per ton is presented on **Table 6-4**. There has been a deduction of 1.5 percent for the Business and Occupations Tax for the Ferrous/Non-Ferrous revenue. It is not clear whether this tax is applicable to the Power Revenue, as Department of Revenue Section RCW 82.04.310 indicates that electricity that is sold for resale whether within or outside the state is not subject to this tax. It was however assumed that this tax would be applicable to the tipping fee revenue, with this item shown as an addition to the fee calculated on Table 6-4.

Table 6-1 Revenue Details for 20-Year Plan

WTE - 20 Year Plan		2028	2048
Facility Capacity (Design Basis)		4,000	4,000
Availability Percentage/Capacity	92.5%	1,350,500	1,350,500
Capacity - Tons Used		1,050,469	1,326,538
Revenue Details			
Assumptions			
Power Revenue			
Net Generation kWh/ton (700 gross less 13% parasitic)	609	639,735,556	807,861,360
Electrical Sales Price - $/kWh		$0.04909	$ 0.09180
Total Electrical Power Revenue		$31,405,000	$74,162,000
County Share of Power Revenue	90%	**$28,265,000**	**$66,746,000**
Ferrous/Non-Ferrous Metal Revenue			
Ferrous Metal - % Recovery from MSW	4.00%	42,018.76	53,061.50
Ferrous Metal Sales Price - $/ton		$58.90	$79.33
Total Ferrous Metal Revenue		$2,475,000	$4,209,000
Non-Ferrous Metal - % Recovery from MSW	0.80%	8,403.75	10,612.30
Non-Ferrous Metal Sales Price - $/ton		$883.46	$1,189.89
Total Non-Ferrous Metal Revenue		$7,424,000	$12,627,000
County Share of FE/Non-FE Metal Revenue	**50%**	**$4,949,500**	**$8,418,000**
Business & Occupations Tax on FE/Non-FE Revenue	**1.5%**	**($74,000)**	**($126,000)**

Table 6-2 Operating Cost Details for 20-Year Plan

WTE - 20 Year Plan		2028	2048
Facility Capacity (Design Basis)		4,000	4,000
Availability Percentage/Capacity	92.5%	1,350,500	1,350,500
Capacity - Tons Used		1,050,469	1,326,538
Annual O&M Details			
Assumptions			
Potable Water Consumption - Gallons/cpd	80	1,752,000	1,752,000
Potable Water Consumption - Personnel Using Shower	60		
Potable Water Cost - $/1,000 Gallons		$7.76	$14.12
Potable Water Cost		**$14,000**	**$25,000**
Wastewater - Gallons/cpd	80	1,752,000	1,752,000
Wastewater - Personnel Using Shower	60		
Wastewater - $/1,000 Gallons		$10.97	$19.97
Wastewater Disposal Cost		**$19,000**	**$35,000**
Management Cost - King County and Consultant		**$759,000**	**$1,319,000**
Operation and Management Fee - Contractor $/ton		$31.50	$55.80
Reagent Cost - $/ton		$2.54	$4.59
Operation & Management and Reagent Cost		**$35,758,000**	**$80,110,000**
Non-Processable Waste Disposal - tons	4.9%	54,125	68,349
Non-Processable Waste Disposal & Transportation - $/ton		$69.51	$126.52
Non-Processable Waste Disposal Cost		**$3,762,000**	**$8,648,000**
Ash percent and tons	20%	210,094	265,308
Ash Transportation and Disposal Cost - $/ton		$77.02	$140.19
Ash Transportation and Disposal Cost		**$16,181,000**	**$37,193,000**
Total Operation and Management (O&M) Cost		**$56,493,000**	**$127,330,000**

Table 6-3 Capital and Debt Service Cost Details for 20-Year Plan

WTE - 20 Year Plan		2028	2048
Facility Capacity (Design Basis)		**4,000**	**4,000**
Capital Costs			
Assumptions			
Capital Cost - $/ton		$341,000	
Capital Cost		$1,364,000,000	
Construction - Additive (Ash Equipment, Electric Interconnect, Site)		$21,350,000	
Financing			
Terms - Years		20	
Interest Rate - Percent		5.00%	
Issuance Cost - Percent		1.00%	
Construction Interest - Months		42	
Construction Interest - Interest Percent		2.00%	
Construction Interest		$48,487,250	
Annual Debt Service		**$116,205,000**	**$0**

Table 6-4 Summary for 20-Year Plan

WTE - 20 Year Plan		2028	2048
Facility Capacity (Design Basis)		**4,000**	**4,000**
Availability Percentage/Capacity	**92.5%**	**1,350,500**	**1,350,500**
Capacity - Tons Provided		**1,104,594**	**1,394,887**
Revenue			
Electrical Power Revenue		$28,265,000	$66,746,000
Ferrous/Non-Ferrous Metal Revenue		4,875,500	8,292,000
Subtotal - Revenue		**$33,140,500**	**$75,038,000**
Operation/Maintenance Expenses		**$56,493,000**	**$127,330,000**
Debt Service		**$116,205,000**	**$0**
Net Income		**($139,557,500)**	**($52,292,000)**
Tipping Fee Annual		**$139,557,500**	**$52,292,000**
Tipping Fee - $/ton		**$126.34**	**$37.49**
Business & Occupations Tax on Tipping Fee - $/ton	**1.5%**	**$1.90**	**$0.56**

6.1.2 Scenario 2 - 30-Year

The 30-year plan provides an analysis of the costs solely for the 30-year period, with one 30-year bond. The details that make up the summary of revenue, operating costs and debt service payments are presented on **Tables 6-5, 6-6 and 6-7**. The summary of these items and the related cost per ton is presented on **Table 6-8**. There has been a deduction of 1.5 percent for the Business and Occupations Tax for the Ferrous/Non-Ferrous revenue. It is not clear whether this tax is applicable to the Power Generation Revenue, as Department of Revenue Section RCW 82.04.310 indicates that electricity that is sold for resale whether within or outside the state is not subject to this tax. It was however assumed that this tax would be applicable to the tipping fee revenue, with this item shown as an addition to the charge on Table 6-8.

Table 6-5 Revenue Details for 30-Year Plan

WTE - 30 Year Plan		2028	2048	2058
Facility Capacity (Design Basis)		4,500	4,500	4,500
Availability Percentage/Capacity	92.5%	1,519,313	1,519,313	1,519,313
Capacity - Tons Used		1,050,469	1,326,538	1,519,313
Revenue Details				
Assumptions				
Power Revenue				
Net Generation kWh/ton (700 gross less 13% parasitic)	609	639,735,556	807,861,360	925,261,313
Electrical Sales Price - $/kWh		$0.04909	$0.09180	$0.1119
Total Electrical Power Revenue		$31,405,000	$74,162,000	$103,537,000
County Share of Power Revenue	90%	**$28,265,000**	**$66,746,000**	**$93,183,000**
Ferrous/Non-Ferrous Metal Revenue				
Ferrous Metal - % Recovery from MSW	4.00%	42,018.76	53,061.50	60,772.50
Ferrous Metal Sales Price - $/ton		$58.90	$79.33	$92.07
Total Ferrous Metal Revenue		$2,475,000	$4,209,000	$5,595,000
Non-Ferrous Metal - % Recovery from MSW	0.80%	8,403.75	10,612.30	12,154.50
Non-Ferrous Metal Sales Price - $/ton		$883.46	$1,189.89	$1,380.92
Total Non-Ferrous Metal Revenue		$7,424,000	$12,627,000	$16,784,000
County Share of FE/Non-FE Metal Revenue	**50%**	**$4,949,500**	**$8,418,000**	**$11,190,000**
Business & Occupations Tax on FE/Non-FE Revenue	**1.5%**	**($74,000)**	**($126,000)**	**($168,000)**

Table 6-6 Operating Cost Details for 30-Year Plan

WTE - 30 Year Plan		2028	2048	2058
Facility Capacity (Design Basis)		4,500	4,500	4,500
Availability Percentage/Capacity	92.5%	1,519,313	1,519,313	1,519,313
Capacity - Tons Used		1,050,469	1,326,538	1,519,313
Annual O&M Details				
Assumptions				
Potable Water Consumption - Gallons/cpd	80	1,752,000	1,752,000	1,752,000
Potable Water Consumption - Personnel Using Shower	60			
Potable Water Cost - $/1,000 Gallons		$7.76	$14.12	$19.05
Potable Water Cost		**$14,000**	**$25,000**	**$33,000**
Wastewater - Gallons/cpd	80	1,752,000	1,752,000	1,752,000
Wastewater - Personnel Using Shower	60			
Wastewater - $/1,000 Gallons		$10.97	$19.97	$26.95
Wastewater Disposal Cost		**$19,000**	**$35,000**	**$47,000**
Management Cost - King County and Consultant		**$759,000**	**$1,319,000**	**$1,739,000**
Operation & Management Fee - Contractor $/ton		$30.13	$53.37	$71.03
Reagent Cost - $/ton		$2.54	$4.59	$6.17
Operation & Management and Reagent Cost		**$34,319,000**	**$76,886,000**	**$117,291,000**
Non-Processable Waste Disposal - tons		54,125	68,349	74,446
Bypass Waste Disposal - tons				25,064
Non-Processable Waste Disposal & Transportation - $/ton		$69.51	$126.52	$170.69
Non-Processable & Bypass Waste Cost		**$3,762,000**	**$8,648,000**	**$16,985,000**
Ash percent and tons	20%	210,094	265,308	303,863
Ash Transportation and Disposal Cost - $/ton		$77.02	$140.19	$189.14
Ash Transportation and Disposal Cost		**$16,181,000**	**$37,193,000**	**$57,473,000**
Total Operation and Management (O&M) Cost		**$55,054,000**	**$124,106,000**	**$193,568,000**

Table 6-7 Capital and Debt Service Cost Details for 30-Year Plan

WTE - 30 Year Plan	2028	2048	2058
Facility Capacity (Design Basis)	4,500	4,500	4,500
Capital Costs			
Assumptions			
Capital Cost - $/ton	$318,000	$0	
Capital Cost	$1,431,000,000	$0	
Construction - Additive (Ash Equipment, Electric Interconnect, Site)	$21,350,000		
Financing			
Terms - Years	30	30	
Interest Rate - Percent	5.00%	5.00%	
Issuance Cost - Percent	1.00%	1.00%	
Construction Interest - Months	42	42	
Construction Interest - Interest Percent	2.00%	2.00%	
Construction Interest	$50,832,250	$0	
Annual Debt Service	**$98,762,000**	**$98,762,000**	**$0**

Table 6-8 Summary for 30-Year Plan

WTE - 30 Year Plan		2028	2048	2058
Facility Capacity (Design Basis)		4,500	4,500	4,500
Availability Percentage/Capacity	92.5%	1,519,313	1,519,313	1,519,313
Capacity - Tons Provided		1,104,594	1,394,887	1,618,823
Revenue				
Electrical Power Revenue		$28,265,000	$66,746,000	$93,183,000
Ferrous/Non-Ferrous Metal Revenue		4,875,500	8,292,000	11,022,000
Subtotal - Revenue		**$33,140,500**	**$75,038,000**	**$104,205,000**
Operation/Maintenance Expenses		**$55,054,000**	**$124,106,000**	**$193,568,000**
Debt Service		**$98,762,000**	**$98,762,000**	**$0**
Net Income		**($120,675,500)**	**($147,830,000)**	**($89,363,000)**
Tipping Fee Annual		**$120,675,500**	**$147,830,000**	**$89,363,000**
Tipping Fee - $/ton		**$109.25**	**$105.98**	**$55.20**
Business & Occupations Tax on Tipping Fee - $/ton	**1.5%**	**$1.64**	**$1.59**	**$0.83**

6.1.3 Scenario 3 - 50-Year

The 50-year plan indicates that the costs per ton will remain stable over this study period. There were two bond issues, with the 2028 bond issue for 25 years and the 2053 bond issue for a 25-year period. The details that make up the summary of revenue, operating costs and debt service payments are presented on **Tables 6-9, 6-10, and 6-11**. The summary of these items and the related cost per ton is presented on **Table 6-12**. There has been a deduction of 1.5 percent for the Business and Occupations Tax for the Ferrous/Non-Ferrous revenue. It is not clear whether this tax is applicable to the Power Revenue, as Department of Revenue Section RCW 82.04.310 indicates that electricity that is sold for resale whether within or outside the state is not subject to this tax. It was however assumed that this tax would be applicable to the tipping fee revenue, with this item shown as an addition to the charge on Table 6-12.

Table 6-9 Revenue Details - 50-Year Plan

WTE - 50 Year Plan		2028	2048	2053	2058	2078
Facility Capacity (Design Basis)		4,200	4,200	6,300	6,300	6,300
Availability Percentage/Capacity	92.5%	1,418,025	1,418,025	2,127,038	2,127,038	2,127,038
Capacity - Tons Used		1,050,469	1,326,538	1,429,057	1,539,501	2,073,484
Revenue Details						
Assumptions						
Power Revenue						
Net Generation kWh/ton (700 gross less 13% parasitic)	609	639,735,556	807,861,360.03	870,295,859	937,555,910	1,262,751,951
Electrical Sales Price - $/kWh		$0.04909	$0.09180	$0.10130	$0.1119	$0.1663
Total Electrical Power Revenue		$31,405,000	$74,162,000	$88,161,000	$104,913,000	$209,996,000
County Share of Power Revenue	90%	**$28,265,000**	**$66,746,000**	**$79,345,000**	**$94,422,000**	**$188,996,000**
Ferrous/Non-Ferrous Metal Revenue						
Ferrous Metal - % Recovery from MSW	4.00%	42,018.76	53,061.50	57,162.29	61,580.03	82,939.37
Ferrous Metal Sales Price - $/ton		$58.90	$79.33	$85.46	$92.07	$124.00
Total Ferrous Metal Revenue		$2,475,000	$4,209,000	$4,885,000	$5,670,000	$10,284,000
Non-Ferrous Metal - % Recovery from MSW	0.80%	8,403.75	10,612.30	11,432.46	12,316.01	16,587.87
Non-Ferrous Metal Sales Price - $/ton		$883.46	$1,189.89	$1,281.85	$1,380.92	$1,859.90
Total Non-Ferrous Metal Revenue		$7,424,000	$12,627,000	$14,655,000	$17,007,000	$30,852,000
County Share of FE/Non-FE Metal Revenue	**50%**	**$4,949,500**	**$8,418,000**	**$9,770,000**	**$11,339,000**	**$20,568,000**
Business & Occupations Tax on FE/Non-FE Revenue	**1.5%**	**($74,000)**	**($126,000)**	**($147,000)**	**($170,000)**	**($309,000)**

Table 6-10 Operating Cost Details - 50-Year Plan

WTE - 50 Year Plan		2028	2048	2053	2058	2078
Facility Capacity (Design Basis)		4,200	4,200	6,300	6,300	6,300
Availability Percentage/Capacity	92.5%	1,350,500	1,418,025	2,127,038	2,127,038	2,127,038
Capacity - Tons Used		1,050,469	1,326,538	1,429,057	1,539,501	2,073,484
Annual O&M Details						
Assumptions						
Potable Water Consumption - Gallons/cpd	80	1,752,000	1,752,000	1,752,000	1,752,000	1,752,000
Potable Water Consumption - Personnel Using Shower	60					
Potable Water Cost - $/1,000 Gallons		$7.76	$14.12	$16.41	$19.05	$34.70
Potable Water Cost		**$14,000**	**$25,000**	**$29,000**	**$33,000**	**$61,000**
Wastewater - Gallons/cpd	80	1,752,000	1,752,000	1,752,000	1,752,000	1,752,000
Wastewater - Personnel Using Shower	60					
Wastewater - $/1,000 Gallons		$10.97	$19.97	$23.19	$26.94	$49.06
Wastewater Disposal Cost		**$19,000**	**$35,000**	**$41,000**	**$47,000**	**$86,000**
Management Cost - King County and Consultant		**$759,000**	**$1,319,000**	**$1,514,000**	**$1,739,000**	**$3,021,000**
Operation and Management Fee - Contractor $/ton		$30.81	$54.58	$62.97	$72.65	$128.69
Reagent Cost - $/ton		$2.54	$4.59	$5.33	$6.17	$11.15
Operation & Management and Reagent Cost		**$35,033,000**	**$78,491,000**	**$97,605,000**	**$121,343,000**	**$289,956,000**
Non-Processable Waste Disposal - tons		54,125	68,349	73,632	79,322	106,836
Non-Processable Waste Disposal & Transportation - $/ton		$69.51	$126.52	$146.95	$170.69	$310.69
Non-Processable Waste Disposal Cost		**$3,762,000**	**$8,648,000**	**$10,821,000**	**$13,540,000**	**$33,192,000**
Ash percent and tons	0.2	210,094	265,308	285,811	307,900	414,697
Ash Transportation and Disposal Cost - $/ton		$77.02	$140.19	$162.84	$189.14	$344.27
Ash Transportation and Disposal Cost		**$16,181,000**	**$37,193,000**	**$46,542,000**	**$58,236,000**	**$142,768,000**
Total Operation and Management (O&M) Cost		**$55,768,000**	**$125,711,000**	**$156,552,000**	**$194,938,000**	**$469,084,000**

Table 6-11 Capital and Debt Service Cost Details - 50 Year Plan

WTE - 50 Year Plan	2028	2048	2053	2058	2078
Facility Capacity (Design Basis)	4,200	4,200	6,300	6,300	6,300
Capital Costs					
Assumptions					
Capital Cost - $/ton	$332,000		$572,019		
Capital Cost	$1,394,400,000		$1,201,239,967		
Construction - Additive (Ash Equipment, Electric Interconnect, Site)	$21,350,000				
Financing					
Terms - Years	25		25		
Interest Rate - Percent	5.00%		5.00%		
Issuance Cost - Percent	1.00%		1.00%		
Construction Interest - Months	42		42		
Construction Interest - Interest Percent	2.00%		2.00%		
Construction Interest	$49,551,250		$42,043,400		
Annual Debt Service	**$105,006,000**	**$105,006,000**	**$89,096,000**	**$89,096,000**	**$0**

Table 6-12 Summary - 50-Year Plan

WTE - 50 Year Plan		2028	2048	2053	2058	2078
Facility Capacity (Design Basis)		4,200	4,200	6,300	6,300	6,300
Availability Percentage/Capacity	92.5%	1,418,025	1,418,025	2,127,038	2,127,038	2,127,038
Capacity - Tons Provided		1,104,594	1,394,887	1,502,689	1,618,823	2,180,320
Revenue						
Electrical Power Revenue		$28,265,000	$66,746,000	$79,345,000	$94,422,000	$188,996,000
Ferrous/Non-Ferrous Metal Revenue		4,875,500	8,292,000	9,623,000	11,169,000	20,259,000
Subtotal - Revenue		**$33,140,500**	**$75,038,000**	**$88,968,000**	**$105,591,000**	**$209,255,000**
Operation/Maintenance Expenses		**$55,768,000**	**$125,711,000**	**$156,552,000**	**$194,938,000**	**$469,084,000**
Debt Service		**$105,006,000**	**$105,006,000**	**$89,096,000**	**$89,096,000**	**$0**
Net Income		**($127,633,500)**	**($155,679,000)**	**($156,680,000)**	**($178,443,000)**	**($259,829,000)**
Tipping Fee Annual		**$127,633,500**	**$155,679,000**	**$156,680,000**	**$178,443,000**	**$259,829,000**
Tipping Fee - $/ton		**$115.55**	**$111.61**	**$104.27**	**$110.23**	**$119.17**
Business & Occupations Tax on Tipping Fee - $/ton	**1.5%**	**$1.73**	**$1.67**	**$1.56**	**$1.65**	**$1.79**

6.2 Net Present Value

Alternatively, another means of analysis for the purposes of comparing the economic feasibility of the 20, 30, and 50-year lifespan options is a net present value analysis. **Figure 6-1** provides a comparison of the three alternative scenarios.

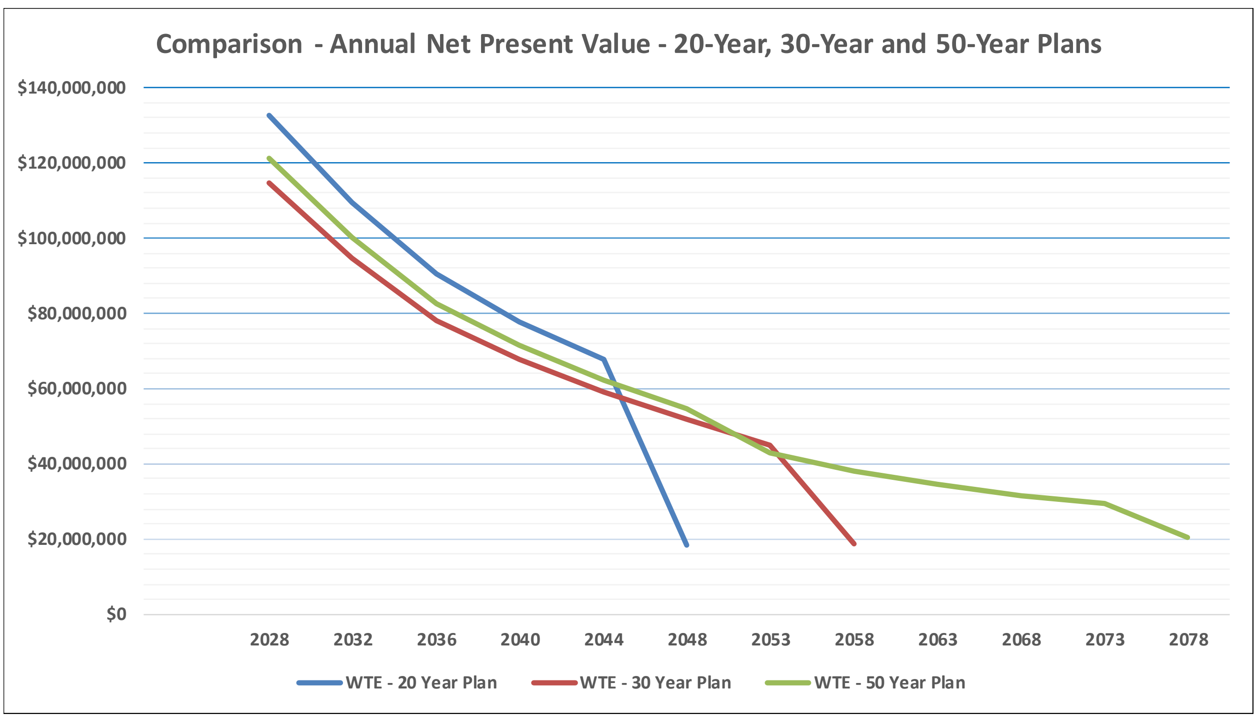

Figure 6-1
Comparison of Net Present Values – 20-Year, 30-Year and 50-Year Plans

Figure 6-1 presents the 30-Year Plan as being slightly less expensive than the other 2 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 30-year debt service payments rather than either 20 or 25-year debt service payments.

The total of O&M costs are consistent for all three scenarios, with the increases between scenarios due largely to the increase in MSW processed. The revenue amounts are consistent for all scenarios. A nominal discount rate of 4.76 was used, which is a combination of an inflation rate of 2.71 percent and a discount value of 2 percent. Net present value analysis, while valuable for comparing options, does not correlate to rate impact. SWD must set rates to have sufficient cash on hand in any given rate period to pay operating costs, debt service, and other obligations.

6.3 WTE Financial Sensitivity

The above scenarios presented are based upon the key operating parameters, revenues and expenses. There are various elements that may significantly improve the resulting costs. The following items have been evaluated in the sensitivity analysis, which includes:

- Addition of supplemental waste program offering assured destruction services (higher tipping fees),
- Change in power sales revenue,
- Recycling of bottom ash,
- Disposal of ash in local ash monofill,
- Addition of revenues from the sale of environmental attributes (RECs and VCUs),
- Change of inflation factors, and
- Change in interest rate.

The following sensitivity items were not evaluated for the reasons stated below:

- Revised capital cost analysis to compare three units versus four units – due to the maximum unit size required to meet the needs of King County's waste projections, and four large units were used in the base scenarios. There are several factors at play with respect to the overall capacity of the WTE facility (larger facilities enjoy an economy of scale and typically cost less on a per unit cost basis), while facilities with more units of smaller capacity may result in higher operation and maintenance costs.

- Addition of enhanced bottom ash processing, washing and glass recovery system – the ash process assumed for the best fit WTE facility includes the most currently available advanced metal recovery system that is most cost beneficial.
- Cost/benefit analysis of non-ferrous metal recovery rate based upon proven experience in Europe and more recently in the U.S.
- Cost/benefit analysis of development of zero liquid waste facility to minimize demand for wastewater service to domestic uses only – this item was included in the base scenarios.

6.3.1 Supplemental Waste Program

Supplemental waste was evaluated in two ways:

1. Assuming that the volume processed equals the difference between the facility capacity and the County volume being processed (essentially filling up the WTE plant), and
2. Special waste was marketed at the rate of 400 tpd to partially fillup the available capacity of the WTE facility during the early years.

For both scenarios noted above, it was assumed that the price/ton was 150 percent of the cost/ton that was calculated in 2028, with a resulting fee of $189/ton. This is a modest increase in tipping fees, with many WTE facilities currently marketing these types of services at significantly higher prices. The value of assured destruction has been demonstrated to be well worth the price to many waste generators, ranging from confidential documents to products which are out of specification and/or expired sales dates, to USDA regulated garbage (international waste). The additional revenues provided by a Special Waste Program ranges from an optimistic value of $56,705,879 (40.6 percent reduction of base cost, or $57.33/ton savings on the tipping fee) to a modest $27,594,000 (19.8 percent reduction of base cost, or $24.98/ton savings on the tipping fee). This type of program was found to result in the highest potential benefits to the King County solid waste rate payers, in comparison to the other parameters studied in this sensitivity analysis. It may be worth consideration as part of a future study beyond the scope of this project.

6.3.2 Power Sales

The change in power sales revenue was evaluated in two ways:

1. Assuming that all of the electrical power was used internally and the 2017 value was $0.06/kWh, and
2. Assuming that the value of the sales price for electricity ($/kWh) increased by $0.01/kWh above the base value.

The option for using all of the electrical power internally provides the highest value to King County, with $19,178,162 of additional revenues in the first year of operation (2028). In order for this to occur, legislation would be required to allow municipal WTE facility owners to transmit ("wheel") power to their infrastructure, while paying a fair and reasonable tariff for the use of the local transmission system. The probability of this occurring is considered low without a strong push from the King County Council and/or State legislature. A more likely scenario could result if a WTE facility were to be co-located adjacent to one of the King County wastewater treatment facilities, in which case the electrical power could be used for its operation. A similar situation where this is currently being done is in Hillsborough County, Florida. Over the past ten years, the 1,800 tpd WTE facility has provided approximately 2 MW of electricity to an adjacent 12-mgd WWTP.

A second sensitivity analysis was run to show the impact of increase in electrical sales price by 1 cent per kilowatt-hour ($0.01). In this scenario, the resulting benefit was found to be worth $7,903,978 in the first year of operation (2028). This equates to a reduction in the estimated tipping fee of approximately 5.7 percent or $7.16/ton. Each additional penny above the estimated power sales price for the base case would result in an additional savings as noted above. There may be opportunities to negotiate with local and regional electricity providers on a long-term power purchase agreement (PPA), given the current dynamic nature of the electric power industry. A modern WTE facility is capable of providing numerous benefits to the local electric utility and bulk power system. Section 9.7 discusses these benefit, many of which could be discussed and negotiated with a willing buyer.

6.3.3 Bottom Ash Recycling

For the recycling of bottom ash, it was assumed that nearly all of the bottom ash would be recycled (75 percent of total ash). Based upon the proven success of recycling bottom ash in Europe, this assumption is reasonable. Diverting bottom ash from disposal to beneficial reuse not only improves the local recycling rate, but also helps the bottom line with modest $11,211,129 (8.0 percent reduction of base cost, or $10.15/ton savings on the tipping fee). The above estimated benefit does not assume any revenues derived from the sale of the minerals and glass that is recoverable from WTE bottom ash. Once the requirements of the marketplaces are known and achieved, it is conceivable that additional revenues could be derived from the sale of construction grade aggregates and feedstocks for manufacturing of Portland cement.

6.3.4 Local Ash Monofill

For the disposal of ash on site, it was assumed that the cost/ton would be approximately half of the amount of the out-of-county rate used, or $25/ton versus $54.44/ton in 2017$. Diverting ash disposal from out of county landfills to local ash monofills provides $8,204,162 in avoided costs (5.9 percent reduction of base cost, or $7.43/ton savings on the tipping fee).

6.3.5 Environmental Attributes

For the sale of RECs or VCUs, a rate of $10/MWh was used and multiplied by the quantity of power produced. Although RECs and VCUs are not currently part of the State of Washington's renewable energy program, they could be included in the future, pending legislative approval. The sale of REC's at $10/REC results in a modest $6,397,356 in avoided costs (4.6 percent reduction of base cost, or $5.79/ton savings on the tipping fee).

6.3.6 Inflation Factors

For the reduction in inflation rates, it was assumed that the inflation rates for operation and maintenance were decreased by 0.5 percent for each category of cost. Reducing the inflation rates provides $3,226,754 in avoided costs (2.3 percent reduction of base cost, or $2.92/ton savings on the tipping fee).

6.3.7 Construction Loan Interest Rates

The interest rate for the bond issue was decreased from 5 percent to 4.5 percent. This results in a net benefit of $1,981,800 in the first year of operation (2028). This equates to a reduction in the estimated tipping fee of approximately 1.4 percent or $1.79 / ton. Large municipally backed projects of this nature may be of interest to financial firms in the future, and it is well within the realm of possibility that the interest rate for a WTE project could be competitively bid.

Figure 6-2 presents the result of the sensitivity evaluation, using the 20-Year Plan with data from 2028.

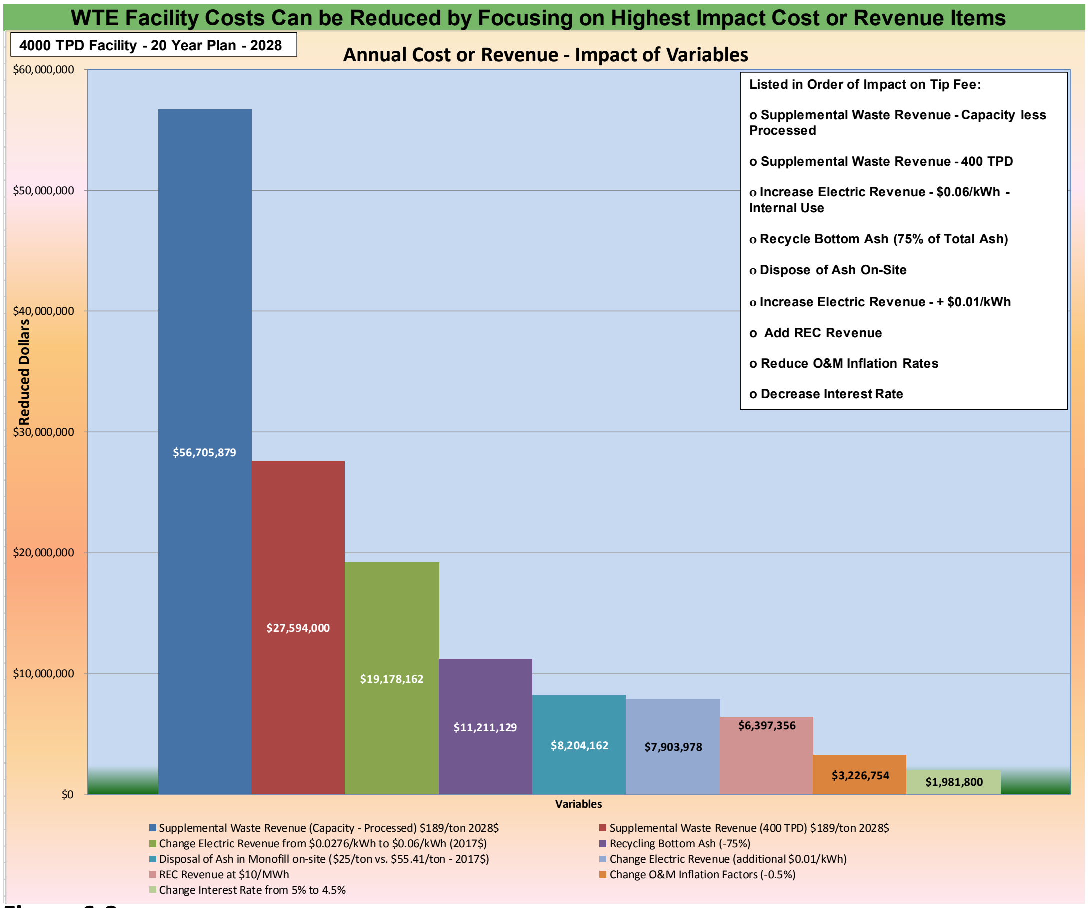

Figure 6-2
Sensitivity Analysis for 20-Year Plan in Year 2028 in Annual Impact Dollars

The above sensitivity items are not all mutually exclusive. In other words, a combination of these items may be implemented. For example, the addition of supplemental waste can be implemented by the creation of 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 a monofill on-site for ash disposal could result in a reduction in the tipping fee of up to $7.43/ton. These options are all possible within the authority of the County and could cumulatively lower the tipping fee in 2028 to $100/ton or less. A summary of the various sensitivity runs is shown in **Table 6-13**, 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 are three combinations which illustrate the potential benefits to King County solid waste system rate payers, which show a wide range in the potential reduction of Tipping Fees from a maximum of 70.8 percent to 25.7 percent.

Table 6-13 Summary of Sensitivity Analysis

Options for Improved Revenues and Reduced Cost of WTE to King County Rate Payers													
			Standalone Benefit			Option 1 (Best Combination)			Option 2 (Optimistic Combination)			Option 3 (Items Controlled by KC)		
Option	Improved Revenues	Reduced Cost	Net Gain ($/year)	Reduction in Base Case Cost (%)	Reduction in Tipping Fee ($/ton)	Net Gain ($/year)	Reduction in Base Case Cost (%)	Reduction in Tipping Fee ($/ton)	Net Gain ($/year)	Reduction in Base Case Cost (%)	Reduction in Tipping Fee ($/ton)	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	$56,705,879	40.7%	$51.34						
Supplemental Waste Revenue (400 tpd - 10% of capacity)	Yes		$27,594,000	19.8%	$24.98				$27,594,000	19.8%	$24.98	$27,594,000	19.8%	$24.98
Internal use of all electricity (valued at 6 cents/kWh in 2017$)	yes		$19,178,162	13.7%	$17.36	$19,178,162	13.7%	$17.36						
Recycle 75% of bottom ash		Yes	$11,211,129	8.0%	$10.15	$11,211,129	8.0%	$10.15	$11,211,129	8.0%	$10.15			
Disposal of all ash into local ash monofill		Yes	$8,204,162	5.9%	$7.43							$8,204,162	5.9%	$7.43
Additional 1 cent/kWh on electric power sales	Yes		$7,903,978	5.7%	$7.16				$7,903,978	5.7%	$7.16			
Sale of RECs at $10/Rec	Yes		$6,397,356	4.6%	$5.79	$6,397,356	4.6%	$5.79	$6,397,356	4.6%	$5.79			
Reduced O&M Inflation Factors by -0.5%		Yes	$3,226,754	2.3%	$2.92	$3,226,754	2.3%	$2.92	$3,226,754	2.3%	$2.92			
Reduced Construction Financing Interest Rate by -0.5%		Yes	$1,981,800	1.4%	$1.79	$1,981,800	1.4%	$1.79	$1,981,800	1.4%	$1.79			
					Total Combined Benefits	$98,701,080	70.8%	$89.37	$58,315,017	41.8%	$52.80	$35,798,162	25.7%	$32.41

Section 7 - Elements of a Feasible WTE Project

Objective of this Section "Elements of a Feasible WTE Project": *Sections 3-6 identified a best fit WTE facility based on a number of key assumptions, inputs and performance metrics. This section discusses 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 in this section are those that should be thoroughly addressed in a detailed feasibility analysis, if a King County WTE Facility is considered a viable option for the County and the Region.*

There are a number of key project attributes and elements for a WTE facility to be considered feasible. In the U.S, a WTE facility may never be the lowest cost option when evaluated over the short term, however, it may be considered cost-effective when evaluated over the long-term and special conditions. In Europe and other parts of the world, WTE has been shown to be cost effective when compared to other solid waste management and treatment options.

7.1 WTE Feasibility

There are numerous elements that are necessary to define a feasible WTE project, each is described in the following subsections.

7.1.1 Economics

The cost of a WTE facility can be reduced with the following actions:

1. Locating the facility near or close to the centroid of waste generation will reduce the cost to collect and haul MSW to the facility (Note that transportation cost to the WTE plant is

not part of the WTE tipping fee and can only be compared with the cost for transportation to an alternative disposal site;

2. Selection of certain WTE technologies (massburn, and to some degree, RDF WTE) will result in many design/build/operate (DBO) vendors bidding for the project, resulting in competitive pricing;

3. Recovering materials from the raw or combusted waste and selling them;

4. Energy sales can significantly offset operating costs; and most WTE facilities generate and sell electric power to the local electric utility. Further, depending on local conditions, some WTE facilities sell steam or hot water to local industries or district heating systems. Steam can be exported via insulated pipeline up to 5-10 miles, whereas hot and chilled water may be transported up to 20 miles. Hence there may be opportunities for a remotely located WTE facility to serve a distant CHP project. Ideally, the WTE and energy host would be optimized if they were adjacent, or within close proximity to each other; and,

5. The cost of a WTE facility can be reduced by having the local governmental entity guarantee whatever borrowing mechanism is used to fund the capital cost (municipal bonds typically have reduced interest rates).

7.1.2 Reliability

A WTE facility is a significant investment and must provide reliable service for decades. The key reliability factors include:

1. The number of similar facilities currently in operation world-wide – the more the better.

2. There should be multiple DBO vendors with lengthy experience to ensure an experienced vendor is selected.

7.1.3 Impact on Solid Waste Collection

Solid waste is currently collected from residential, commercial, Institutional and governmental buildings and the WTE solution selected should create the least negative impact on the waste haulers and current rate paying entities.

7.1.4 Public Acceptability

The WTE facility needs support from the public and there are multiple attributes that can improve public acceptability including:

1. Location – a location that is supported by the public and local community will reduce the risks of siting a facility and meeting any schedule for the facility to be online;

2. Recycling – recycling programs are viewed by the public as "good", so the WTE solution must be consistent with current recycling programs, and possibly future programs, and contribute toward the community's goals for additional recycling credits and landfill diversion;

3. Technology – the public may not have good knowledge of certain WTE technologies and a plan must be implemented to ensure the public that the proposed technology addresses their concerns, as well as providing a long-term solid waste solution;

4. Architecture – the aesthetics and appearance of the facility can be designed for minimal cost to make it more acceptable to the public (public advisory committees can assist with this aspect);

5. Environmental – the public and contracting agency will want reassurance that the proposed WTE facility meets or exceeds all environmental requirements;

6. Job Opportunities – the WTE facility will create many stable job opportunities, both during construction and over the long-term operational period of 50 years, along with significant purchases of local goods and services from local businesses; and,

7. Community Benefits – often the WTE facility incorporates facilities that can benefit the local community and/or the operator can provide services that benefit the community, such as the processing of local or regional special wastes (international wastes regulated by USDA, out of specification or out of date pharmaceutics, confidential documents, and numerous other wastes which can command a higher tipping fee) in need of assured destruction;

Public support can be achieved through the following:

1. Showing the WTE facility furthers regional sustainability goals;

2. Showing the WTE facility will not interfere, but actually is complimentary with recycling goals;

3. Engaging community stakeholders in early siting/permitting/environmental/regulatory processes; and,

4. Gaining support from the private sector indicating minimal impacts to local businesses that generate MSW and rely on reliable and cost-effective transport and disposal of municipal solid waste.

7.1.5 Environmental impact

The environmental impact of the WTE facility must be minimized and quantification can be ascertained via Health Risk Analyses that prove the facility can protect the public and the environment; especially in comparison with other alternatives. Environmental/Regulatory compliance is a broad category that should cover many areas including:

1. Minimal risks associated with stack emissions;
2. Quantifying and comparison of greenhouse gases (GHGs) with other treatment options;
3. Maximizing recycling opportunities while increasing landfill diversion rate; and,
4. Incorporating the best technology to protect people and the environment.

7.1.6 Governmental Commitments

For a WTE facility to be successful and provide reliable and cost-effective MSW processing over the long term, the governmental entity will be expected to provide support in multiple areas.

1. A reliable source and quantity of MSW delivered to the WTE facility;
2. MSW that has characteristics within reasonable ranges for energy content (compared to other fuels used for power generation);
3. A reliable outlet for the sale (or internal use) of electric power and/or other form of energy; and
4. A reliable location for the receipt of stabilized fly ash bottom ash generated by the WTE (ash is the inorganic fraction within MSW) and bypassed and/or un-processed MSW to a landfill (when the WTE facility is offline for maintenance or when tonnage exceeds facility capacity).

7.1.7 Contractual Arrangements

To contractually link the governmental entity and DBO vendor into a long-term agreement, the following need to be agreeable to both sides.

1. Creation of ownership and operation arrangements (public versus private) and financing options;
2. Agreement on the approach to procurement;
3. Conduct of evaluation, contract negotiations, and final construction and operation / management agreements; and,

4. Appropriate allocation of project risks between the governmental entity and DBO vendor:
    a. Typical risks assigned to public agencies
        i. Waste stream availability
        ii. Flow of funds to project
        iii. Facility siting and permitting
    b. Typical risks borne by private entities
        i. Technology and system integration
        ii. Construction cost control and schedule
        iii. Long-term operation and maintenance at fixed price

7.2 Example of Successful US WTE Project

Following is a description of the active WTE project in the state of Washington.

7.2.1 Spokane, Washington WTE Facility

More than twenty-five years ago, the Spokane Regional Solid Waste System (SRSWS) had the progressive foresight to build a waste-to-energy facility into their integrated solid waste management plan. The primary driver for this project was a decline in nearby landfill disposal capacity. Spokane's waste-to-energy facility was the recipient of SWANA's 2013 WTE Excellence Award. The facility processes 800 tons per day, and was designed, constructed, and operated by Wheelabrator from 1991 until 2015, at which time the City assumed responsibility for the operation and management of the facility. Under Wheelabrator's care, the facility continually achieved high 90 percentage annual availability every year. Wheelabrator and the Spokane Regional Solid Waste Systems (SRSWS) upgraded the air quality control system at the beginning of operations in 1991 by choosing to install polytetrafluoroethylene (PTFE) coated fabric filter baghouse bags as opposed to non PTFE fiberglass bags. This resulted in improved performance of the fabric filter baghouse and reduced emissions. The WTE facility is one component of the integrated solid waste system that serves 475,000 residents in Spokane County, and has provided dependable, environmentally safe disposal of municipal solid waste since its commercial operation in 1991, while generating clean electricity for sale to the local utility. The facility was financed with both a Department of Energy grant and tax-exempt bonds totaling $105 MM issued in 1989. The components of the SRSWS integrated waste management system consist of the Northside Landfill, the waste-to-energy facility, two solid waste transfer stations, three recycling centers and a refuse collection system. In 2011, the WTE facility completed 20 years of operation and became "debt free" with the last bond payment on December 1, 2011.

7.3 Examples of Recent WTE Retrofit and Expansion Projects

Examples of recent WTE projects that were either retrofitted or expanded include:

1. City of Tampa, Florida (1,000 tpd massburn retrofit) in 2000
2. Lee County, Florida (636 tpd massburn expansion) in 2006
3. Hillsborough County, Florida (600 tpd massburn expansion) in 2007

One primary reason attributed to these successful projects relates to the fact that these facilities have become the cornerstones of their community's integrated solid waste management system. The benefits and advantages of WTE are numerous, and over time have become accepted as a viable waste reduction and stabilization technology (refer to Appendix A for a list of benefits).

Many WTE communities have demonstrated a desire to continually improve their existing WTE facilities by rebuilding and/or expanding them. They also have a commitment to maximize the recovery of energy, metals and other by-products. This in turn has increased local recycling rates and system revenues. In a display of environmental awareness, many WTE owners have voluntarily made improvements to their facility’s combustion and air pollution control systems to minimize air emissions. And finally, one of the key points of the modern WTE industry is that many of the facilities are well on their way to reliably operating over a period of 50 years. As a result, once the facility construction loan has been paid, a significant reduction (30-40 percent) in annual costs can be avoided for the benefit of the system rate payers.

7.4 Examples of Recent Successful New WTE Projects in North America

Examples of WTE facilities recently implemented in North America include:

1. Honolulu, Hawaii (1,000 tpd massburn addition to existing RDF WTE facility) in 2013
2. Palm Beach County, Florida (3,000 tpd new massburn addition to existing RDF WTE facility) in 2015
3. Durham-York, Canada (488 tpd new massburn WTE) in 2015

7.4.1 Honolulu, Hawaii and Palm Beach County, Florida

In the case of the first two – Honolulu, HI and Palm Beach, FL WTE facilities – the primary drivers for these projects was that additional waste processing capacity was needed due to continued population growth, and the communities decided against permitting new landfill capacity. The additional capacity was provided with massburn combustion units to existing RDF WTE projects. It is interesting to note that both of these communities did not continue with the RDF technology. Instead, they chose massburn technology, primarily for reasons of lower cost, and the ability to process more of the local waste streams without diversion of a significant amount (~25-30 percent) of the waste stream which is not processible by RDF combustion technology. One of the additional benefits for the massburn WTE additions is that it can also accept the normally bypassed residuals from the RDF process, thereby helping to minimize the amount of bypassed wastes which require disposal by other means.

7.4.2 Durham-York, Ontario

The Durham York WTE facility serves as an integral component of the comprehensive solid waste management program of the Regions of Durham and York in the Province of Ontario in Canada. The facility processes municipally collected household waste left over after the Regions' aggressive diversion efforts, which include curbside and drop-off recycling and composting programs. The facility is capable of producing 17.5 megawatts of clean renewable energy at full operating conditions. In the future, steam generated at the facility may be utilized for district heating in an industrial park adjacent to the facility. Currently, the facility produces enough energy to power 10,000 homes. The facility also recovers ferrous and nonferrous metals for recycling. The procurement process for bidders began with a Request for Qualifications (RFQ) which resulted in 5 companies being qualified. Four of the companies completed the Request for Proposal (RFP). In April 2009, following an extensive competitive procurement process and evaluation review, the Durham Regional Council selected Covanta as the vendor to design, build, operate and maintain the WTE facility. The facility's continuous emissions control technology establishes it as one of the cleanest WTE facilities in the world. It was estimated that construction of the facility created approximately 400 jobs over a three-year period, and the project currently employs approximately 40 skilled workers on a full-time basis.

7.5 Examples of Recent Un-successful WTE Projects That Did Not Get Constructed

Examples of recent WTE projects that were not successfully constructed include: Vancouver, BC; Big Island, Hawaii; Energy Answers Renewable Energy Park; and Plasco Energy Group, Ottawa, Canada

7.5.1 Vancouver, BC (new WTE Procurement)

Metro Vancouver, an entity that provides potable water, wastewater treatment and solid waste services to southwest British Columbia, implemented a massburn WTE facility in 1988 with a capacity of 285,000 tonnes per year. However, rapid growth in the area has caused a dramatic increase in the amount of solid waste and a feasibility study determined a second massburn WTE facility best fit the need to process the net waste stream after extensive recycling programs. This recent project (2013-2015) involved the planning of potential waste conversion facilities for additional capacity for Metro Vancouver. The project resulted in an open invitation to prospective developers to propose a suitable waste conversion technology. A total of ten responses from DBO vendors were received, multiple sites were identified and a Business Case was developed. However, the project was not implemented due to a lack of legal flow control to allow them to direct MSW to a dedicated WTE facility. As a result, private haulers resisted the project in favor of transporting collected waste to the lowest cost option (a landfill).

7.5.2 Big Island, Hawaii (new WTE Procurement)

This proposed 250 tpd massburn WTE facility did not proceed primarily for economic reasons. A Hawaii County's effort to build a WTE facility as an alternative to landfills was halted in January 2015, because of changes in the project's economics. It would have been the county's most expensive public works project, with an estimated cost of more than $100 million. A decrease in oil prices from $100 per barrel to less than $50 drove down what Hawaii Electric Light Co. would have paid the county for electricity. When the county initially released its request for qualifications last year, the cost the utility would have paid for power from an outside source was estimated to be about 20 cents per kilowatt hour. It was previously estimated that a WTE facility could be cost-effective selling power for 17 cents a kilowatt hour. However, the "avoided cost" to be paid by the utility for power from the WTE facility dropped significantly based upon the current low price of oil.

7.5.3 Energy Answers Renewable Energy Park, MD (new WTE development)

A proposed 4,000 tpd RDF WTE facility did not proceed primarily due to significant delay in procurement which resulted in the permit expiration prior to construction. The permit was procured with the understanding that RDF is not technically a waste, but rather an Engineered Fuel. However, the permit expired prior to actual construction work. The environmental permit for the project was issued in 2010, but after many years of no activity (due to issues related to financing of the project), the permit had expired because no work had taken place there for more than 18 months, which was a requirement of the permit. Additionally, there were two local protest groups which objected to the location of the facility. Energy Answers planned to sell electricity for 10 years from the Fairfield Renewable Energy Power Plant, a 160 MW WTE facility to be built in Baltimore.

The participating entities included the governments of Baltimore City and Baltimore, Carroll, Harford and Howard counties; the cities of Annapolis, Aberdeen and Bowie; public schools in Baltimore City and Anne Arundel, Baltimore, Harford and Howard counties; community colleges in Anne Arundel, Baltimore, Harford and Howard counties; the Baltimore City Housing Authority;

Baltimore County Libraries and Revenue Authority; Baltimore Museum of Art; and Walters Art Gallery. The plant would have processed approximately 4,000 tons/day of refuse derived fuel from processed solid waste to generate steam and electricity. The large plant would have required more than 180 permanent "green collar" jobs, with the potential for hundreds more in the energy intensive industries that could have co- located in the Fairfield Eco-Industrial Park. Compatible industries which were suggested included manufacture of concrete products, recycled paper milling, bio-fuels production, climate-controlled warehousing, and research laboratories.

7.5.4 Plasco Energy Group, Ottawa, Canada

This project evolved over a period of approximately 10 years and did not proceed primarily due to technical scale up and economic reasons. This project started in 2006 as a private developer initiative for a small pilot plant using a novel plasma gasification process to be operated on a batch basis. In this process, waste would be treated by high temperature plasma to produce a synthesis gas for power generation, along with an inert slag of metals and minerals for recycling. Plasco had its first full demonstration in February 2008, converting a load of municipal garbage into electricity that was sold to Hydro Ottawa. Eventually the project grew into a 400 tons per day plant with an expected startup date in early 2010, at an estimated cost of $125 million. After numerous pilot plant starts and stops, environmental issues, employee layoffs and contract renegotiations, in December of 2014, Plasco missed its third deadline set by the city to prove it has secured the financing it needs to build a WTE plant in Ottawa by 2016. In February 2015, Mayor Jim Watson terminated the contract with Plasco as the company filed for creditor protection.

7.6 Examples of Recent Un-successful WTE Projects That Were Constructed

Examples of recent WTE projects that were constructed, and subsequently shut down or did not pass their acceptance test include: North Broward County, FL WTE project, Alter NRG Plasma Gasification Project, Tees Valley, England, and INEOS New Planet BioEnergy Facility, Indian River County, Florida.

7.6.1 Broward County, Florida (existing WTE facility that closed)

The 2,250 tpd North Broward Facility was closed primarily for loss of waste supply contracts due to economic reasons – In May of 2015, Wheelabrator Technologies Inc, announced that they would close one of their two privately owned WTE facilities in Broward County, Florida. Although paid for by taxpayers, the WTE facility was owned by Waste Management and is currently not being considered for sale. Waste Management sold Wheelabrator Technologies Inc. in December 2014 to

Energy Capital Partners. The disbanding of a regional alliance of cities and the county in 2012 ultimately led to the demise of the north WTE facility. The facility temporarily lost customers to a remote landfill, but the waste is currently processed in nearby Palm Beach County's new WTE facility. Meanwhile, Broward County and local cities will continue to send about 540,000 tons of waste to the South Broward County WTE facility, which continues to be operated by Wheelabrator.

7.6.2 Alter NRG Plasma Gasification Project, Tees Valley, England

This $1B project involved two 1,000 tpd WTE projects which were to use plasma gasification technology for production of syngas from municipal waste. The syngas was to be combusted in a gas turbine, with the hot turbine exhaust routed through a heat recovery steam generator in a process known as Gas Turbine Combined Cycle (GTCC) for the production of 50 MW of electricity. The first of the two units was completed in late 2014 (TV1), and had been undergoing testing and analysis during the second quarter. The results indicated that additional design and operational challenges would require significant time and cost to rectify. Consequently, construction of the second twin unit was halted in late 2015 to allow time to incorporate lesson's learned on unit #1. However, in December of 2016, the project developer abandoned the project and it is currently for sale. Air Products, the project owner and developer, said that the decision was due to technical difficulties in making the technology work as expected. The project is currently for sale.

7.6.3 INEOS New Planet BioEnergy Facility, Indian River County, Florida (waste-to biofuel project)

This $150M waste-to-biofuels projects was a demonstration scale project designed to produce 8 million gallons of advanced cellulosic bioethanol and six megawatts (gross) of renewable power using renewable biomass including yard, vegetative, and agricultural waste. The project was partially funded with a $50 million grant from the U.S. Department of Energy and a $75 million loan guarantee from the U.S. Department of Agriculture, and construction commenced in 2012. During the long startup and commissioning period, lasting almost four years, there were several reoccurring problems that ultimately led to the closing of the facility at the end of 2016. The major problems of this technology primarily were due to technical issues, primarily incompatibility between feedstock and the gasifier design. The project is currently being offered for sale by the owner.

8. Greenhouse Gas Analysis of Best Fit Waste to Energy Option

Objective of this Section "Greenhouse Gas Analysis of Best Fit WTE Option": *This section shows two methods for estimating impacts of GHG emissions and applies them in a preliminary fashion to the best fit WTE facility described in previous sections. This analysis is representative only and would need to be refined as part of future evaluation of WTE by King County.*

Two approaches were used in the GHG estimate: the Waste Reduction Model (WARM) and the Greenhouse Gas Mandatory Reporting Rule (GHGMRR).

WARM is a material life-cycle-based comparative model that estimates the carbon dioxide, total carbon and energy equivalent of different waste management practices. WARM offers a direct comparison of different waste management methods. It should be noted that the WARM has a number of modeling assumptions that should be discussed to more fully understand the comparative GHG conclusions. WARM is designed for solid waste planning to compare GHG reductions across disposal types from a baseline. It provides a planning-level and life-cycle analysis that includes the up and downstream impacts of the waste (such as the GHG emitted from the production of a waste). It is not intended to be used as an accounting tool and therefore, is unable to give solid waste managers an idea of future compliance obligations or voluntary annual emissions.

The GHGMRR is a regulation based GHG estimate where the estimate is based on site specific testing. The GHGMRR was recommended as the magnitude of GHG release has regulatory implications and offers a more accurate picture of the actual GHG release at a point in time. Unlike WARM, the results of the GHG estimate from the GHGMRR should not be compared directly with landfill disposal unless multiple year GHG release from the landfill is accounted for. In addition, landfill GHG emissions varies by the landfill operation, capping and energy recovery techniques. The MRR method provides solid waste managers with an idea of future compliance obligations or voluntary annual emissions reporting requirements, and therefore gives King County an understanding of how GHG emissions from waste fit into the County's full GHG emissions profile.

Both approaches were performed without accounting for waste transport and only for the WTE GHG potential, where applicable.

In accordance with the Scope of Work for the King County (County) Waste-to-Energy (WTE) Study, CDM Smith, as part of the Normandeau Associates Inc. (Normandeau) team was tasked to estimate the greenhouse gas (GHG) emissions potential of the WTE Facility for King County. The following preliminary analysis was performed by CDM Smith via two methods from the U.S. Environmental Protection Agency (EPA): Waste Reduction Model (WARM) and Greenhouse Gas Mandatory Reporting Rule (MRR). This memo compares the GHG potential results of these two methods for the WTE Facility for the 20-, 30- and 50-year planning scenarios. Results are summarized in **Table 8-1**.

This memo compares the GHG potential results of these two methods for the WTE Facility for the 20-, 30- and 50-year planning scenarios. Results are summarized in Table 8-1.

Table 8-1 GHG Analysis Summary

Scenario	WTE Facility Design Capacity (tons per day)	Tonnage Processed (tons per year)	WARM Mixed MSW (metric ton CO2e per year)	WARM Material Categorization (metric ton CO2e per year)	MRR (metric ton CO2e 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 the WARM model, depending on the categorization of the waste materials and the scenario selected, the WTE Facility may have a lifecycle GHG emissions potential from 12,073 to 125,357 metric tons of carbon dioxide equivalent.
- According to GHG MRR, total 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 CO2e 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.

8.1 Recommendations

Further analysis of the potential CO2e 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 of the 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 recovery systems are considered.
- GHG emissions accounting between biogenic and anthropogenic sources from the WTE process via reporting from current WTE facilities.
- Potential GHG emissions decrease if a combined heat and power (CHP) project is developed. The focus of the work to-date has been on the potential greenhouse gas (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).

The methodology for conducting these future analyses may be determined based on the need. It may be informed by the most relevant GHG emissions calculations available, including scientific findings from the Intergovernmental Panel on Climate Change.

Detailed background, assumptions and methodology to calculate the GHG emissions potential for the two methodologies are provided in Section 8.2.

8.2 Exhibit 1 – Model Assumptions

8.2.1 Waste Reduction Model

The WARM is a lifecycle analysis, where the energy requirements for creating the source material that is to be disposed of and the possible energy off-set via combustion of fossil fuels is considered. It is an Excel-based spreadsheet model that calculates the total GHG emissions in CO2e, total carbon equivalent and energy equivalent of different waste management practices, based on material type.

The WARM is a comparative model, with baseline waste management practices and six alternative waste management practices – source reduction, recycling, combustion, composting, anaerobic digestion and landfilling.

The primary focus of WARM is that it offers user inputs of 54 material types to determine GHG emissions. King County's waste stream was provided by Cascadia's waste composition study and found to have 97 different materials. This was tailored to match the 54 material WARM input options and is attached. Waste composition is assumed to remain steady for the foreseeable future and therefore, future GHG emissions can be prorated as a percentage of the current comparative emissions.

This WARM analysis was performed only for the GHG potential if the waste was combusted, for the 20, 30 and 50-year scenarios, with two given assumptions.

One assumption categorizes all the waste is as "Mixed MSW."

The second assumption categorizes the given 97 materials into the 54 material types available in WARM. This assumption, along with the definitions between the materials, is included as **Appendix E**.

8.2.2 Greenhouse Gas Mandatory Reporting Rule

CDM Smith had recommended using the Greenhouse Gas Mandatory Reporting Rule (MRR) to estimate the GHG impact. MRR calculates GHG direct emissions from a facility and represents future compliance or voluntary GHG emissions reporting. MRR is established by 40 CFR Part 98 and Subpart C is the applicable to a WTE Facility which has the potential to emit GHG over 25,000 MTCO2e annually.

The GHGMRR also accounts for biogenic GHG, whereas WARM model does not. The accounting for biogenic GHG in the MRR assumes that GHG that would have been generated via natural decomposition of biogenic wastes (woody yard waste, grass clippings, food waste) is part of the natural waste cycle that would had been generated regardless of the method of disposal. The accounting for biogenic GHG is the central to the debate of whether WTE has a GHG benefit over the traditional and innovative waste management techniques at landfills.

The GHG analysis uses the default equations and emission factors for of 40 CFR 98, Subpart C to estimate GHG.

It should be noted that WTE facilities of the sizes in the three proposed scenarios will be required to install continuous emissions monitors (CEMs) that measures carbon dioxide as a part of its air emissions monitoring program. MRR Subpart C would require the CEMs data to be used for reporting purposes for facilities the size King County is proposing. Using CEMs data is expected to provide a more accurate measurement of GHG emissions from a WTE Facility and may show lower emissions than the standard approach used for this exercise. In addition, segregation between anthropogenic and biogenic GHG emissions via the sample gas testing is required, which would further refine the level of GHG emissions from a WTE Facility.

9. Advantages and Disadvantages of WTE

Objective of this Section "Advantages and Disadvantages of WTE": *This section seeks to objectively identify primary attributes of a modern WTE facility that must be balanced across two categories: (1) those that benefit municipalities and their residents (i.e. General Advantages of WTE); and (2) those that would need to outperform other solid waste management options, if WTE is to be considered further/implemented (i.e. General Disadvantages of WTE). Each of these items is influenced greatly by facility and site-specific factors and those would require detailed investigation as part of a future feasibility analysis.*

WTE is a sustainable option for management of solid waste resources, and can be a key component of a community's drive to Zero Waste. The following pages present a brief summary of the key benefits associated with using WTE for the management of municipal solid waste resources and key disadvantages that must be considered.

9.1 General Advantages of WTE

The following general advantages of WTE are discussed in the following sub-sections:

- Section 9.1.1 Reduction of Landfill Volume
- Section 9.1.2 Environmental & Land Usage
- Section 9.1.3 Air Quality
- Section 9.1.4 Surface & Groundwater
- Section 9.1.5 Economic Performance
- Section 9.1.6 WTE-Derived Energy
- Section 9.1.7 Societal Impacts
- Section 9.1.8 Special Programs/Opportunities for Enhanced Community Benefits

9.1.1 Reduction of Landfill Volume

WTE provides a proven, safe and effective means of 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 percent of the volume of the processed solid waste of 25 percent of the weight, which can be further reduced by the recovery of recyclable material such as metals and glass.

9.1.2 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 world-wide) 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 vary depending upon the overall capacity of the facility. Existing WTE facilities in the U.S. have been developed very flexibly to accommodate specific land features. Existing WTE facilities in the U.S. have been constructed on sites as small as 4 acres, or as large as 40-70 acres.

9.1.3 Air Quality

Worldwide, WTE has demonstrated the ability to meet continually restrictive environmental air emission limits with proven, state-of-the-art air pollution control equipment. Dioxins and Furans are often below detection limits and NOx levels can be reduced to below 5PPM. WTE emissions are continuously monitored and recorded during operations. The web site for the U.S. 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 CO2 emissions from generating an equal amount of electricity using fossil fuels and avoided CO2 emissions from mining of virgin materials for manufacturing of new ferrous and non-ferrous metals[1]. Using the most recent IPCC (International Panel of Climate Change) numbers from the 5^{th} assessment, up to 4 tons of CO_{2e} can be avoided for each ton of waste processed by WTE, when compared to landfill disposal.

9.1.4 Surface and Groundwater

WTE is protective of valuable groundwater resources. Many recent WTE facilities have been designed to be zero liquid discharge facilities. 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.

9.1.5 Economic Performance

The life of a WTE facility is conservatively projected to be in the range of 45 to 50 years. WTE provides 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. Tipping fees are both predictable and under the control of the local or regional governments that owns the facility. WTE allows recovery of additional ferrous and non-ferrous 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 approximately 60 - 70 high quality, full-time employment positions remain throughout the 45- 50 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.).

9.1.6 WTE-Derived Energy

WTE can provide significant benefits to the local electric grid, and especially to the utility which purchase the power. WTE is a proven and reliable base load (24/7) source of electrical energy with an average annual capacity factor of 92+ percent. By comparison, many of the traditional renewable energy systems currently being implemented (solar PV and wind) are intermittent and less predictable sources of power which need to be coupled with energy storage solutions and smart grids. In instances 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 is the case in Shenzhen, China, whose WTE project which will be the world's largest WTE facility processing over 5,000 Mtpd (5,500 US 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 9-1).**

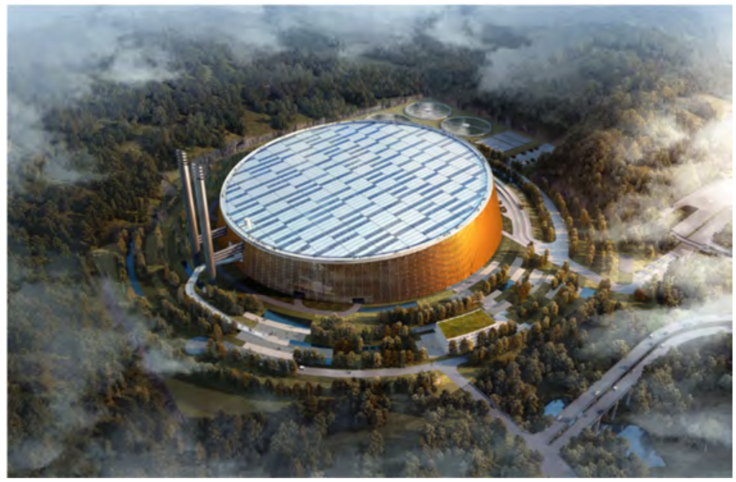

Figure 9- 1
Shenzhen, China - World's largest WTE to be co-located with 125 mgd desalinated water treatment plant **(Architectural design by Schmidt Hammer Lassen Architects and Gottlieb Paludan Architects)**

9.1.7 Societal Impacts

Many WTE facilities in the U.S. and Europe are located in urban areas, close to where the wastes are produced. Residential, commercial and institutional developments have been developed in close proximity to many WTE facilities, often 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, MN (Minneapolis) facility is essentially located 'downtown' - a $1.2 B urban redevelopment project has been constructed immediately adjacent to the WTE facility. The primary anchor tenant in this redevelopment is Target Field, home to the Minnesota Twins baseball team **(Figure 9-2)**.

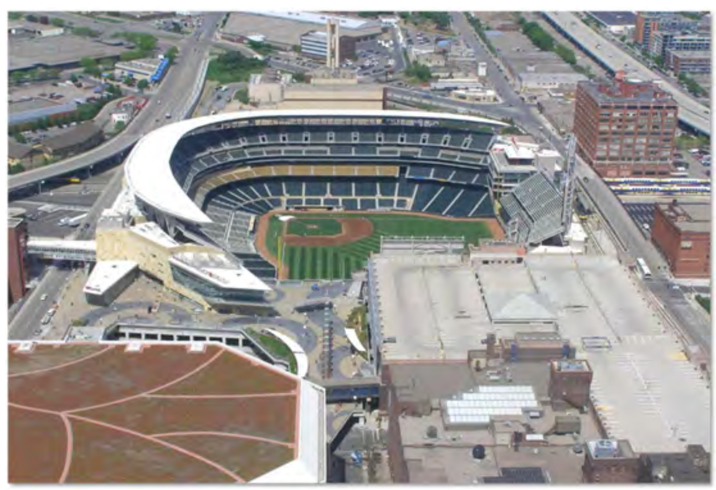

Figure 9- 2
Hennepin County, MN - WTE plant located in downtown area (background), adjacent to Target Field baseball stadium

World-wide, there are many other WTE projects which have been tailored to serve the needs and interests of their host communities, including Copenhagen, Denmark – this WTE project has been built with a multipurpose ski slope/hiking trail feature over the WTE facility to provide year-round recreational activities **(Figure 9-3).** This plant is also a combined heat and power (CHP) project which provides heat for the City's district heating district, which also reduces local emissions.

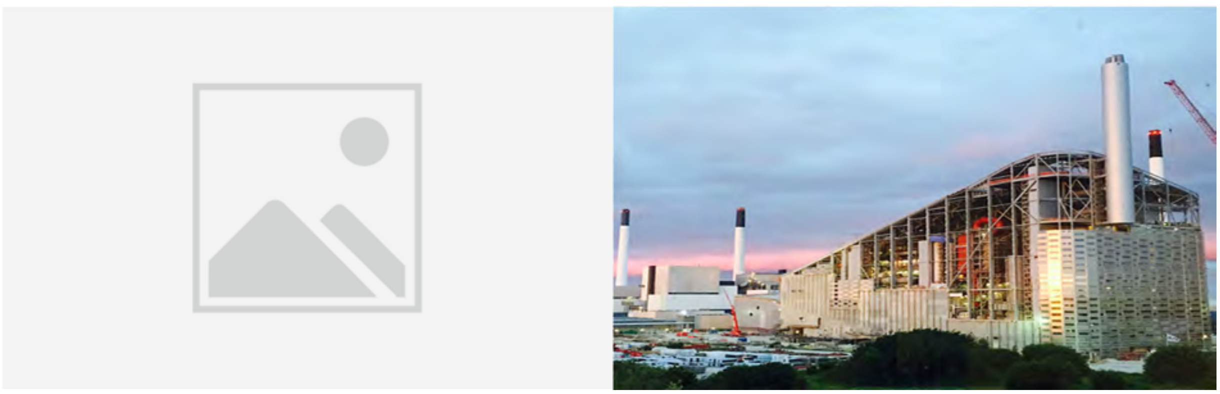

Figure 9- 3
Copenhill WTE - Located in Downtown Copenhagen with Recreational Ski Slope and Hiking Trail over the Facility

9.1.8 Special Programs/Opportunities for Enhanced Community Benefits

WTE can provide communities 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. Additionally, there are numerous examples of dedicated, beneficial programs and best management practices adopted by the owners and operators of WTE facilities throughout world to maximize local and regional benefits including:

- Processing of special wastes in need of assured destruction, such as confidential documents, contraband, expired pharmaceuticals, regulated medical waste, USDA regulated garbage (International Waste), used tires, marine/fishing wastes, and bulky wastes (after size reduction). WTE can also process biosolids, along with whole passenger tires (and/or chipped tires).

  - WTE operators in many communities have implemented mercury bounty collection programs - 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.

- Advanced metal recovery systems which extract ferrous and non-ferrous metals, 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.

9.2 General Disadvantages of WTE

The following general disadvantages of WTE are discussed in the following sub-sections:

- Section 9.2.1 Relatively High Capital Cost
- Section 9.2.2 Need for Back-Up/Supplemental Landfill Capacity
- Section 9.2.3 Limitations on Steam and Electricity Markets
- Section 9.2.4 Publicly Available Information on Modern WTE Capabilities
- Section 9.2.5 Variability in Methods for Accounting of GHG Emissions
- Section 9.2.6 Need for Consistent, Long-Term Flow as Input to WTE Facilities
- Section 9.2.7 Impact on Community Recycling Goals/Performance

9.2.1 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 maintenance and operational costs, so the tipping fee should go down considerably.

9.2.2 Need for Back-Up/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 <u>not</u> eliminate the need for backup landfill capacity completely for the disposal of non-processable wastes, excess/bypass waste and depending upon the combustion technology and the design of the facility, any residues remaining after beneficial reuse of bottom and fly ash.

9.2.3 Limitations on Steam and Electricity Markets

Due to the unprecedented reduction in demand for electricity in the U.S. over the past five years, along with 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. As a result, many current owners of WTE facilities are negotiating power purchase agreements of a shorter duration (for example 5 – 10 years). 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.

9.2.4 Publicly Available Information on Modern WTE Capabilities

Extensive public education and outreach is required to widely disseminate substantiated data regarding the current state of the WTE industry and its evolution toward sustainability. Specifically, continuing education is required to demonstrate that:

- WTE emissions have low impact to the local air quality.
- WTE air emissions are continuously monitored with actual data to demonstrate that emissions are typically well below permitted limits.
- WTE bottom ash residue is inert, and many of its constituents can be safely recycled for use in local construction projects.

9.2.5 Variability in Methods for Accounting of GHG Emissions

Greenhouse gasses (GHG) are emitted from WTE facilities, though at a relatively low rate when compared to other facilities within the solid waste management industry[1]. Approximately 53 percent of GHG emissions are from biogenic sources (biomass derived), while the remaining 47 percent are from anthropogenic sources (petroleum based materials). The U.S. EPA notes that for every ton of waste combusted, a ton of CO2e 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 U.S. is currently in a state of uncertainty, with many analytical models producing conflicting results based upon assumptions made for numerous input variables. Two EPA-sponsored models have been developed to examine life-cycle emissions from different management methods of MSW, the Waste Reduction Model (WARM) and the MSW Decision Support Tool (DST)[2]. These models both show that MSW combustors actually reduce the amount of

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

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

GHGs in the atmosphere compared to landfilling. Conversely, in Europe the science and methodology for calculating GHG emissions has been clearly identified.

9.2.6 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 upon the required capacity.

9.2.7 Impact on Community Recycling Goals/Performance

Opponents to WTE claim that it removes some of the opportunities to recycle materials as biological and technical inputs in a future circular economy. In the future perfect world where the principles of the circular economy are fully integrated, technical resources will be easily recovered and recycled into higher value products. However, WTE process actually allows the disassembly of materials which are 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, non-ferrous, precious and rare-earth metals and minerals which have been liberated by combustion. The European countries which have implemented WTE on a significant scale also have the highest recycling rates.