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King County

WASTE-TO-ENERGY AND WASTE EXPORT BY RAIL FEASIBILITY STUDY

September 2019

WASTE-TO-ENERGY AND WASTE EXPORT BY RAIL FEASIBILITY STUDY

Prepared for:

King County Office of Performance, Strategy, and Budget

Chinook Building, 8th Floor

401 Fifth Avenue

Seattle, WA 98104

Prepared by:

Arcadis U.S., Inc.

1100 Olive Way

Suite 800

Seattle, Washington 98101

Tel 206 325 5254

Fax 206 325 8218

Our Ref.:

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ACRONYMS AND ABBREVIATIONS

2019 Comp Plan	2019 Comprehensive Solid Waste Management Plan
ACC	Air Cooled Condenser
AD	Anaerobic Digester
APC	Air Pollution Control
AMP	Advanced Metals Processing
Arcadis	Arcadis U.S., Inc.
BACT	Best Available Control Technology
BHC	BHC Consultants, LLC
BNSF	BNSF Railway
B-Town	B-Town Consulting
BTU	British Thermal Units
C&D	Construction & Demolition debris
Cedar Hills	Cedar Hills Regional Landfill
CEM	Continuous Emissions Monitoring
CETA	Clean Energy Transformation Act
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Commercial Operation Date
County	King County, Washington
CPI	Consumer Price Index
CRLF	Columbia Ridge Landfill
CWA	Clean Water Act
CY	Cubic Yard
DAC	Direct Air Capture
DAM	Day Ahead Market
EF	Emissions Factors
eGGRT	Electronic Greenhouse Gas Reporting Tool
EIA	US Energy Information Administration
EIS	Environmental Impact Statement

EPC	Engineering Procurement Construction
FAA	Federal Aviation Administration
FAF	Freight Analysis Framework
FFH	Fabric Filter House
FLEET	Freight Logistics Environmental and Energy Tracking Performance Model
FLM	Federal Land Manager
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCl	Hydrogen Chloride
Hg	Mercury
HHERA	Human Health and Ecological Risk Assessment
HHV	Higher Heating Value
HPA	Hydraulic Project Approval
ILA	Interlocal Agreement
IMF	Intermodal Facility
IPCC	Intergovernmental Panel on Climate Change
KCDLS	King County Department of Local Services
KCDMT	King County Department of Metro Transit
KCSWD	King County Solid Waste Division
kWh	Kilowatt Hour
L&I	Washington State Labor and Industries
LCA	Life Cycle Analysis
LFG	Landfill Gas
LNG	Liquefied Natural Gas
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
MTCO2E/ton	Metric tons of Carbon Dioxide equivalent per short ton
MW	Megawatt
MWh	Megawatt Hour
MWPF	Mixed Waste Processing Facility
N_2O	Nitrous Oxide

NESHAP	National Emission Standards for Hazardous Air Pollutants
NPV	Net Present Value
NIMBY	Not in my backyard
NOC	Notice of Construction
NOx	Nitrous Oxides
NPDES	National Pollution Discharge Elimination System
NSPS	New Source Performance Standards
NSR	New Source Review
O&M	Operations and Maintenance
OECD	Organization for Economic Cooperation and Development
OFM	Office of Financial Management
Pb	Lead
PSB	Office of Performance, Strategy and Budget
PHSKC	Washington Department of Ecology via Public Health Seattle-King County
PM	Particulate Matter
PPA	Power Purchase Agreement
PPM	Parts Per Million
PSCAA	Puget Sound Clean Air Agency
PSC	Public Service Commission
PSD	Prevention of Significant Deterioration
PSRC	Puget Sound Regional Council
R&M	Repair and Maintenance
RCAP	Rail Cost Adjustment Factor (less the fuel component)
RFEI	Request for Expressions of Interest
RFQ	Request for Qualifications
RFP	Request for Proposals
RO	Reverse Osmosis
RP	Republic Services
RPS	Renewable Portfolio Standard
RS	Republic Services
SCR	Selective Catalytic Reduction

SDA	Spray Dryer Absorber
SEPA	State Environmental Policy Act
Services	United States Fish and Wildlife Services and NOAA Fisheries
SOx	Sulfur Oxides
Study	King County Waste-to-Energy and Waste Export By Rail Feasibility Study
T&D	Transport and Disposal
T-G	Turbine-generator
tpd	Tons per Day
tpy	Tons per Year
ULSD	Ultra Low Sulfur Diesel
UPRR	Union Pacific Railroad
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Services
VOCs	Volatile Organic Compounds
WAC	Washington Administrative Code
WARM	Waste Reduction Model
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology
WEBR	Waste Export by Rail
WRG	WIH Resource Group
WSDOT	Washington State Department of Transportation
WM	Waste Management
WTE	Waste-to-Energy

EXECUTIVE SUMMARY

King County's Solid Waste Division ("KCSWD") provides comprehensive municipal solid waste ("MSW") transfer, disposal, recycling, and waste prevention services for approximately 1.3 million residents and 660,000 employees in King County, Washington (the "County"). The solid waste system serves unincorporated King County and 37 of the 39 cities - all of the cities in the County except Seattle and Milton. KCSWD provides waste disposal through landfilling at Cedar Hills Regional Landfill ("Cedar Hills"), which it owns and operates. KCSWD's interlocal agreements ("ILAs") with its partner cities obligate the division to provide waste disposal through 2040. Cedar Hills is estimated to reach capacity before 2040. Prior to reaching capacity, the County will need to identify an alternative waste disposal strategy.

The County Council has directed the Executive to lead a study that evaluates the feasibility of using either Waste-to-Energy ("WTE") or Waste Export by Rail ("WEBR") as the County's next disposal method. The Office of Performance, Strategy and Budget ("PSB") is the lead for the study. Previously, the County had contracted with Normandeau Associates, Inc. to perform an analysis in 2017 related to this topic, which recommended a deeper dive into the potential of WTE and comparison against WEBR. The purpose of this WTE and WEBR Feasibility Study ("Study") is to further enhance the County's understanding of the WTE disposal method, how that compares to WEBR, and evaluate these alternatives over an approximate 20 to 50-year time horizon (2025 to 2075) to assist in the County's decision-making process. This document presents the results of the Study conducted by Arcadis U.S., Inc. ("Arcadis") and partners BHC Consultants, LLC ("BHC"), B-Town Consulting ("B-Town"), and WIH Resource Group ("WRG"), (collectively the "Arcadis Team") on behalf of the County.

Waste Tonnage Forecast

The Arcadis Team developed two distinct waste tonnage forecasting scenarios over 20-year (2025-2045) and 50-year (2025-2075) terms for the purpose of understanding system sizing impacts on potential WTE facility or WEBR systems. The Arcadis Team obtained KCSWD's most recent tonnage forecast (February 2019 forecast) which included three different projections: high bound, baseline, and low bound.

KCSWD developed their forecast through 2028 using variables such as per capita employment, MSW tipping fee and retail sales. For 2028 to 2040, each of the tonnage forecasts in the model was extended using a set growth rate trend based on previous years. As these forecasts were not intended to be extended to 2075, they are stopped at 2040.

The Arcadis Team analyzed two additional tonnage forecast curves based on population projections from the Puget Sound Regional Council ("PSRC"): Land Use Baseline and Land Use Vision[1]. The Arcadis Team also analyzed several model variables that affect the tonnage forecasts. These variables include trends in waste generated and disposed per capita and recycling rate. Based on the tonnage forecasts

[1] PSRC creates two growth projections to model the outcomes of different policy choices in small geographies. Land Use Baseline is one of them; Land Use Vision is the other. Land Use Baseline is a representation of future development based on how the market responds to development capacities established in local jurisdictions' pre-VISION 2040comprehensive plans. Land Use Vision is a growth projection based on local and regional policies, as well as each county's adopted growth targets. PSRC uses Land Use Vision for planning and modeling work.

and model variables, the Arcadis Team proposed two MSW disposal forecast curves for this Study: a low bound tonnage forecast and a high bound tonnage forecast, presented in the following figure.

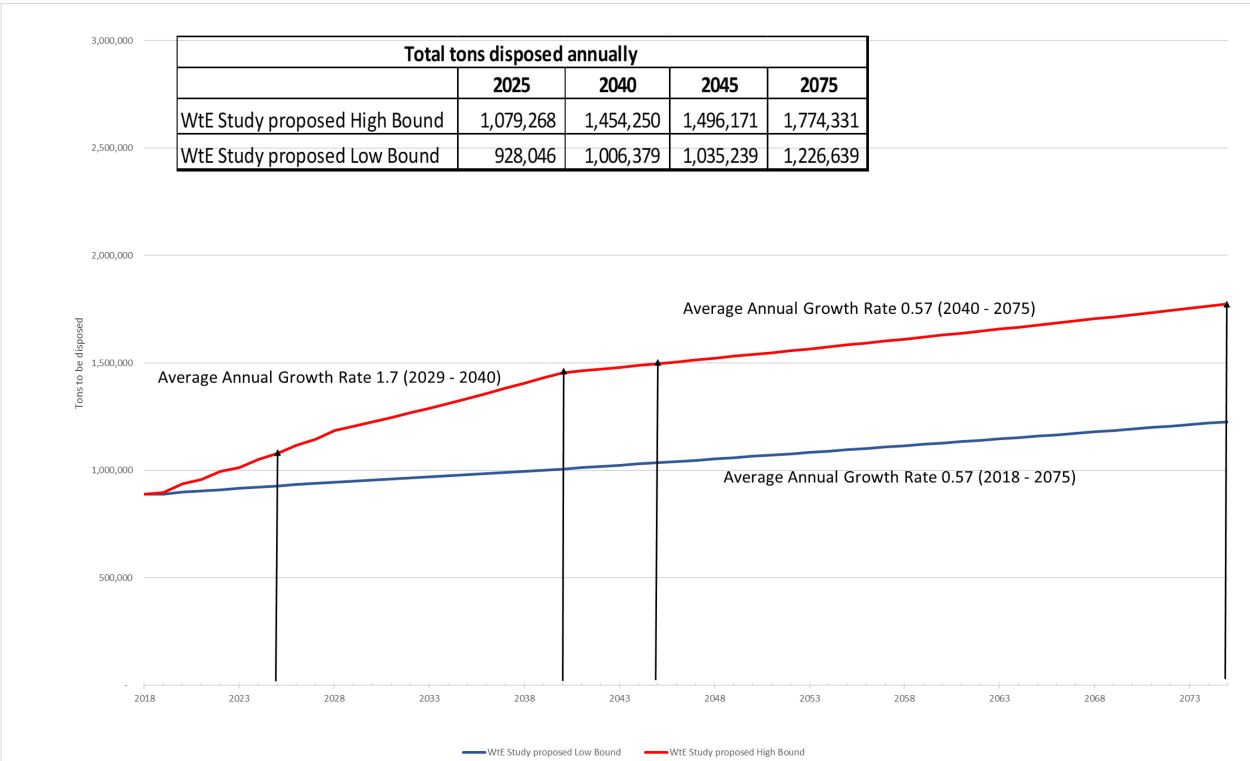


Figure ES-1. WTE Study Proposed High and Low Bound Tonnage Disposal Forecast

Waste-to-Energy Methodology

Based on the forecast curves, the Arcadis Team identified a WTE facility size that would meet the initial 2045 projected tonnages, and a facility size that would meet the 2075 tonnage forecasts under each forecast condition. The facility tonnage forecast, and facility sizes, are presented in Table ES-1 below.

Table ES-1. Waste Tonnage Forecast and Associated WTE Facility Sizes

Option	Tonnage Forecast (tons disposed annually)	WTE Facility Size
Low Bound Forecast	1,006,379 tons (2045) 1,226,639 tons (2075)	3,000 tpd (1,000,000 tpy) Mass Burn Facility with a footprint expansion capacity of 4,000 tpd (1,333,333 tpy)
High Bound Forecast	1,454,250 tons (2045) 1,774,331 tons (2075)	4,000 tpd (1,333,333 tpy) Mass burn Facility with a footprint expansion capacity of 5,000 tpd (1,666,666 tpy)

Note: The tonnage forecasts presented above assume a 52 percent recycling rate.

The Arcadis Team created two Conceptual Layout Options (“Layout Options”) for a proposed mass burn WTE Facility based on the applicable sizes feasible for the low bound and high bound forecasts as summarized in Table ES-1 above. Layout Option 1 incorporates three (3) 1,000 tpd mass burn WTE combustion lines and 90 – 100-Megawatt (“MW”) turbine-generator (“T-G”) into a compact layout, while still providing enough area for expansion capacity. The layout is designed for a fourth 1,000 tpd combustion line to be installed for future expansion between the Boiler Building and the Ash Management Facility. Layout Option 2 incorporates four (4) 1,000 tpd mass burn WTE combustion lines and a 120 – 130 MW T-G into a larger, more traditional layout which provides enough area for operations and maintenance and includes additional expansion capacity. The layout is designed for a fifth 1,000 tpd combustion line to be installed for future expansion between the Boiler Building and the Ash Management Facility. For an expansion of each layout option, additional air pollution control, tipping floor and pit, and T-G capacity would also need to be installed.

Waste Export by Rail Methodology

The Arcadis Team also evaluated WEBR as a potential alternative disposal method for the County’s MSW. WEBR programs are being used to dispose of MSW from similar regional entities such as the City of Seattle, Snohomish County, and Skagit County.

The Arcadis Team interviewed the Union Pacific Railroad (“UPRR”) and the BNSF Railway (“BNSF”), the Class 1 railroads that serve the major privately-owned landfills in Washington and Oregon. UPRR and BNSF provided information about the companies; their ideas and preferences about transporting and disposing of the County’s MSW; and, their perception of the opportunities and constraints that the County faces in preparing for a potential WEBR program. . The Arcadis Team also interviewed Republic Services (“RS”) and Waste Management (“WM”), owners of the two largest private landfills in Washington and Oregon.

Potential candidates to receive the County’s MSW forecast quantity are required to collect and beneficially reuse their landfill gas (methane). The following three privately-owned Northwest regional landfills have adequate capacity for the County’s MSW, are actively served by rail, and meet the gas collection requirement:

- Roosevelt Regional Landfill (owned by RS) – Roosevelt, Washington.
- Columbia Ridge Landfill (owned by WM) - Arlington, Oregon.
- Finley Buttes Landfill (owned by Waste Connections) – Boardman, Oregon. Because this landfill is located farther east along the same UPRR track that serves Columbia Ridge, its transportation costs would be higher than Waste Management’s. Based on available capacity at the Roosevelt and Columbia Ridge Landfills, and the increased transportation costs, it was not researched further for this Study.

Because of each major landfill’s geographic location and the ownership of nearby railroad tracks, these landfills have historically teamed with a particular railroad. Waste Management’s Columbia Ridge Landfill teams with the UPRR and Republic Services’ Roosevelt Regional Landfill teams with the BNSF. These relationships would probably remain intact for a County WEBR program.

A hypothetical model of a WEBR intermodal facility (“IMF”)_ was developed to provide the basis for evaluation and cost estimating, as well as comparison with the conceptual WTE facility. The model was used to project the costs, schedule, design and construction considerations, and impacts to regional transportation and the environment under a WEBR program with a newly constructed IMF, and with an existing IMF.

Comparison of WTE to WEBR

The following section provides a comparison of using WTE versus WEBR as the County’s next MSW disposal method.

Implementation Schedule

The project implementation schedule for a new WTE facility is estimated to take approximately eight to ten years, as compared to an estimated two to six years for an IMF facility. The most significant difference in the project implementation schedules are for the planning / siting / permitting and the design / build to Commercial Operation Date (“COD”). The critical path in the permitting process for a WTE facility contains preparation of the Prevention of Significant Deterioration (“PSD”) permit for air quality control. This is a permit not required for the IMF Facility. As a more complex facility, the design / build to COD phase for a WTE facility is estimated to take approximately four years; whereas the IMF facility may take less than a year if using an existing facility or two years to build a new facility.

Permitting and Regulatory

The construction of either a new WTE facility or IMF facility will require many of the same licenses, permits and / or approvals related to a new construction project. Such permits are listed in Table 3-10 in Section 3.6 and in Appendix B. However, due to the handling and combustion of solid waste, the permitting requirements for a new WTE facility are more robust than for an IMF facility. Permits required for a WTE facility that are not required for an IMF facility include a PSD air construction permit and visibility impact analysis prior to construction, and a Title V operating permit and solid waste handling permit once the facility is operational. Both types of facilities will still be subject to other environmental regulations such as stormwater control and other Federal, State, and local regulations for their respective facility types. As discussed above, the addition of the PSD permit can add time to the siting, planning, and permitting phase of the schedule. Procuring the Title V operating permit and solid waste handling will take place during the construction phase, and should not affect the critical path of the schedule.

Financial Impact Comparison

The financial comparison between WTE facility disposal and WEBR is highly dependent on the different variables and assumptions made in the financial models. The top five risks or assumptions impacting the WTE and WEBR financial models are identified in Section 5, Table 5-10. For comparison purposes, land acquisition and capital cost or fee charged by rail operator for a new IMF facility or existing IMF expansion is included for WEBR since land acquisition and capital cost for WTE facility are included in the WTE financial model. If a new IMF is not required, expansion of existing IMFs would likely be required and therefore require similar capital costs included in the WEBR fee. Hauling costs from the County transfer stations to either the WTE facility or WEBR IMF are also included, assuming similar distances to WTE or IMF as it is to Cedar Hills.

The WTE and WEBR total and costs per ton for the identified term using the low bound tonnage forecast for the 10-year term, 20-year term, and 50-year term are summarized in Table ES-1. The costs include capital and operating costs for each option, but do not include Departmental costs, which are assumed to be the same for both options. In addition, there are revenues associated with the WTE facility, and so all costs used for comparison with WEBR are net costs, which take into account the revenues received to offset the total cost. Note that negative values in the Difference rows indicate savings if WTE is utilized rather than WEBR.

Table ES-1. Cost Comparison between WTE and WEBR – 3,000 Expanded to 4,000 tpd

Total Cost and Average Cost per Ton	10-year Term	20-year Term	50-Year Term
Waste-to-Energy (WTE) – 3,000 expanded to 4,000 tpd			
Total Cost	$1,066,537,361	$2,368,418,483	$6,963,437,423
Cost Per Ton	$106.65	$118.42	$116.06
WEBR Low Bound			
Total Cost	$1,026,526,133	$2,424,490,647	$11,251,567,071
Cost Per Ton	$109.94	$126.35	$215.15
Difference (WTE-WEBR)			
Total Cost	$40,011,228	($56,072,165)	($4,288,129,649)
Cost Per Ton	($3.29)	($7.93)	($99.09)

The WTE and WEBR total and costs per ton for the identified term using the high bound tonnage forecast for the 10-year term, 20-year term, and 50-year term are summarized in the following table. Note that negative values in the Difference row indicate savings if WTE is utilized rather than WEBR.

Table ES-2. Cost Comparison between WTE and WEBR – 4,000 Expanded to 5,000 tpd

Total Cost and Average Cost per Ton	10-year Term	20-year Term	50-Year Term
Waste-to-Energy (WTE) – 4,000 expanded to 5,000 tpd			
Total Cost	$1,298,013,297	$2,922,300,885	$8,899,802,758
Cost Per Ton	$97.35	$99.62	$112.18
WEBR High Bound			
Total Cost	$1,362,187,218	$3,376,330,508	$16,140,955,031
Cost Per Ton	$110.25	$127.19	$216.90

Total Cost and Average Cost per Ton	10-year Term	20-year Term	50-Year Term
Difference (WTE-WEBR)			
Total Cost	($64,173,921)	($454,029,622)	($7,241,152,273)
Cost Per Ton	($12.90)	($27.57)	($104.72)

Both options cost over $1 billion in the near term (10-years) and over $6 billion in the long term (50-years) but the WTE facility disposal option could cost up to $104.72 per ton less than WEBR over the long term (50-years). For the low bound tonnage estimates and 10-year term, the WEBR total cost is $40 million less than WTE facility disposal, but actually costs $3.29 more per ton because the WTE facility disposal option assumes acceptance of more waste to reach facility design capacity than disposed of by WEBR. In addition, past the first 10-year term, the WEBR cost, capacity, and availability could be drastically different, with even higher prices than projected due to low supply and high demand. For the 20-year term and beyond, WTE facility disposal is lower than projected WEBR costs for both total cost and cost per ton.

Based on the financial models developed, WTE facility disposal costs less per ton of waste and provides the County more financial control of long-term waste disposal costs than WEBR and could result in approximately $4.3 to $7.2 billion in savings over the 50-year term. In addition, the costs for WTE facility disposal are likely lower and more reliable than the potentially volatile WEBR market.

Transportation Needs and Traffic Impacts

Both WTE and WEBR require centralized facilities for reception of waste from the transfer stations (the WTE facility or the IMF). Transportation impacts from trucking to these locations are therefore expected to be comparable to those seen at regional landfills. WTE facility impacts are strongly dependent on the siting of the facility and disposal location for ash, non-processable, and bypass wastes. WEBR impacts will be more regional, resulting in increased rail congestion rather than localized around the IMF, but the degree of congestion and possible mitigation depend on siting and future rail use.

The following tables provides a direct comparison between a WTE facility and WEBR vehicle and rail "ton-miles", or the transport of one ton of MSW for one mile. A WTE facility would have similar or slightly higher vehicle traffic as WEBR, but considerably less rail traffic.

Table ES-3. Transportation Needs of WTE vs. WEBR in 2025

Transportation Metric	WTE Onsite Ash/Bypass Disposal		WTE Out of County Ash/Bypass Disposal		WEBR	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Total Vehicle Ton-Miles	18,560,920	21,585,360	23,757,960	27,629,260	18,560,920	21,585,360
Total Rail Ton-Miles	--	--	83,152,640	96,702,400	296,974,720	345,365,760

Greenhouse Gas Impacts

The amount of net greenhouse gas ("GHG") emissions in metric tons of carbon dioxide equivalents per short ton ("MTCO2E/ton") of waste disposed by landfilling at an out of county landfill using WEBR and by combustion in a WTE facility were evaluated using the latest version (v15) of the U.S. Environmental Protection Agency ("USEPA") Waste Reduction Model ("WARM"). As requested by the County, net GHG emissions were evaluated for WEBR and WTE using the default Microsoft Excel version of the WARM model "Method 1".

Additionally, because the default Microsoft Excel version of the WARM model does not allow the user to make certain refinements to the emission factors and emission credits based on County-specific considerations, the Arcadis Team explicitly identified the emission factors and emission credits in the WARM model documentation. In some cases, the Arcadis Team refined the WARM model emission factors and emission credits based on professional judgement to provide a more specific estimate based on the County's WEBR and WTE disposal strategies ("Method 2"). Adjustments to the WARM model emission factors and emission credits included:

- Decreased the emission factor for rail transportation relative to truck transportation on a per mile basis.
- Increased the WTE offset credit for recycling to account for advanced metals processing ("AMP"), including recycling of non-ferrous metals.
- Added a new emission credit for WTE to account for an assumed ash reuse rate equivalent to 0.075 tons of ash reused for every ton of MSW disposed.
- Increased landfill gas ("LFG") capture efficiency to 80 percent capture to account for efficient landfill gas recovery in dry climate.

Consistent with the Intergovernmental Panel on Climate Change ("IPCC") guidance, carbon sequestration credits for the landfill disposal of biogenic wastes that are not readily anaerobically degraded under landfill conditions (e.g., wood, yard wastes, and paper) are identified and reported separately for informational purposes. The GHG evaluations for WTE and WEBR disposal strategies, including factors that influence the WARM model results, are discussed in Sections 3.12 and 4.6, respectively.

Table ES-5 summarizes net GHG emissions using WARM Method 1.

Table ES-5. Comparison of Net GHG Emissions for WTE and WEBR, WARM Method 1

Description	WTE (MTCO2E/ton)	WEBR (MTCO2E/ton)[1]
Net GHG Emissions, excluding ash recycling [2]	0.13	0.12 to 0.33
Emission Credit for AMP [3]	-0.11	0.00
Emission Credit for Ash Recycling [4]	-0.07	0.00
Total Net Emissions	-0.05	0.12 to 0.33

(1) The WARM model Excel spreadsheet does not explicitly show or allow changes to carbon sequestration credits for landfilling. The lower emission estimate assumes a carbon sequestration credit of 0.21 MTCO2E/ton based on emission credits in the WARM model documentation (see Appendix D).

(2) Net GHG emissions assume short haul trucking of 20 miles to WTE facility. Mileage to landfill was assumed to be 20 miles for trucking to IMF and 320 miles of rail mileage to out of county landfill. The rail mileage was reduced by 80 percent to account for assumed 20-percent lower emission factor for rail versus truck transport. The adjusted WEBR mileage used in this analysis was 84 miles (20 miles + 320/5 miles = 84 miles).

(3) Emission credit assumes additional 0.003 tons of ferrous metals and 0.011 tons of non-ferrous metals can be recovered with AMP compared to WARM model default estimates.

(4) The emission credit for ash recycling was calculated using WARM Method 1. Inputs: 0.075 tons of ash per ton of MSW; composition: fly ash.

Table ES-6 summarizes the WARM model results using the emission factors and emission credits in the WARM model documentation, with refinements to the emission factors to account for lower rail emissions compared to truck transportation on a per mile basis, increased emission credits for Advanced Metals Processing ("AMP") and ash reuse, and increased LFG recovery.

Table ES-6. Comparison of Net GHG Emissions for WTE and WEBR, WARM Method 2

Description	WTE (MTCO2E/ton)	WEBR (MTCO2E/ton)
Facility Sources	0.42	0.34
Transportation Sources	0.01	0.03
Utility Credits	-0.26	-0.08
Other Credits [1]	-0.22	-0.21
Total Net GHG Emissions [2]	-0.05	0.08 to 0.29

(1) Other credits for WTE are associated with increased offsets for AMP and ash reuse. Other credits for WEBR are associated with carbon sequestration of non-anaerobically biodegradable biogenic wastes.

(2) The higher emission value does not include the carbon sequestration credit.

As indicated in Tables ES-5, WARM Method 1 indicates that a net difference of 0.17 MTCO2E/ton of GHGs can be avoided by WTE compared to waste disposal at an out of county landfill using WEBR. If carbon sequestration emission credits are not applied to the landfill, then a net difference of 0.38 MTCO2E/ton of GHG can be avoided by WTE compared to WEBR, assuming a carbon sequestration credit of 0.21 MTCO2E/ton.

As indicated in Tables ES-6, a net difference of 0.13 MTCO2E/ton of GHGs can be avoided by WTE compared to waste disposal at an out of county landfill using WEBR if emission credits for AMP and ash reuse are factored into the analysis. If carbon sequestration emission credits are not applied to the landfill, then a net difference of 0.34 MTCO2E/ton of GHG can be avoided by WTE compared to WEBR, assuming a landfill carbon sequestration credit of 0.21 MTCO2E/ton.

Waste composition can significantly affect the WARM model results. For this analysis, the Arcadis Team used national average MSW waste compositions. Waste compositions with higher amounts of petroleum-based plastics, synthetic rubbers, and synthetic textiles compared to national averages would tend to favor WEBR compared to WTE with respect to comparative net GHG emissions. The potential increased used of biogenic plastics over time would strongly favor WTE compared to WEBR with respect to net GHG emissions.

Waste compositions with higher methane producing wastes such as highly organic food wastes compared to national averages would tend to favor WTE compared to WEBR with respect to net GHG emissions. Waste compositions with higher amounts of biogenic materials that do not biodegrade under anerobic landfill conditions, such as wood waste with high levels of lignin, would increase the carbon sequestration credits in the WARM model for landfilling. The magnitude of impact favoring WEBR would depend on whether the County decides to assign carbon sequestration credits to the landfill.

Summary and Conclusions

The Arcadis Team has performed a review of the relevant information and developed comprehensive financial models and GHG analyses for both WTE and WEBR scenarios. As these evaluations and the limitations of our scope heavily impact the proposed conclusions, the conclusions should be directly reviewed in conjunction with the Arcadis Team’s scope of services, direction received from the County during the Study development, and the complete text of this Study for a clear understanding of the limitations of review and the comprehensive summaries, assumptions, and comparisons for each topic.

WTE Conclusions

After review of the appropriate data and models, it is apparent that due to the stability of operational costs and revenue streams, WTE will provide a gross savings of approximately $4.3 to $7.2 billion (low bound to high bound tonnage forecast) when compared to WEBR over the 50-year planning period and WTE has a significant advantage on improving recycling rates and energy recovery when compared to WEBR. While the short-term, 10-year, cost-per-ton differential between WTE and WEBR is nearly even due to the large construction cost for WTE, WTE’s multiple revenue streams significantly lower escalation and inflation impacts and protect against future price increases as the County moves further into the planning period.

Modelling lifecycle GHG emissions for a WTE facility is complex and depends heavily on the assumptions utilized for offsets due to recovered materials and energy generation. However, with or without offsets, WTE has known anthropogenic (fossil fuel-based) GHG emissions for every ton of MSW combusted. Even with offsets for recovered materials, WTE will likely require carbon capture and sequestration technology installed in order to remain viable past deadlines in 2030 and 2045 for carbon neutral and non-emitting utility sources mandated by the Washington State legislature. These GHG capture systems are on the cusp of commercial viability, but would be the first of its kind installed in a commercial fashion on a WTE facility in the US. If complications arise with installation or operation of the system, it could have associated long-term risk of non-compliance with State law, if the law remains unchanged. Those risks are complex and are discussed further in Section 3.9 and 3.11. However, if carbon capture was completely non-functional, the County would be required to purchase off-set credits off the open market (this market does not yet exist in a sophisticated manner), lobby Washington regulators to provide a carve-out similar to the one that exists for the Spokane facility, or show that the facility's offset credits (as shown in the WARM model analysis section) make the facility GHG neutral in order to continue selling electricity in the Washington market after 2030. After 2045, all utility retail electricity is mandated to be from non-emitting and renewable resources. It is possible that this could be ameliorated by lobbying to include MSW as a renewable source and the commercial market perfecting flue gas capture prior to 2045, and as the legislation currently only applies to regulated utilities, it is possible that the County could self-wheel power to its own facilities and/or buildings in the future and save enterprise costs rather than sell on the open market.

WEBR Conclusions

The railroads strongly prefer short-term (e.g. 5-10 year) contracts and fuel escalation adjustment, exposing the County to higher risk of price increases over the planning period. However, the landfills are amenable to longer term contracts and have substantial available capacity, which limits future risk of unavailable disposal. WEBR costs have a high potential for future escalation due to the limitations in existing rail capacity and the potential monopoly effect if an IMF served by both rail lines cannot be found, reducing competition during future re-negotiation of the initial contract. These risks are not built-in to the current pricing comparison and represent a large unknown for future disposal cost and solid waste rate impacts.

GHG estimates of WEBR depend on the waste composition used in the analysis and whether or not carbon sequestration credits for landfilling non-degradable biogenic wastes are included in the analysis. Carbon sequestration credits applied to a landfill is a controversial topic and there is no clear consensus on this issue, which is why the GHG emissions are reported with and without this credit. Based on national average waste composition, WARM modelling using Method 1 and Method 2 suggest that net GHG emissions are 0.13 to 0.17 MTCO2E higher on a per ton basis for WEBR compared to WTE with landfill carbon sequestration credits. Without carbon sequestration credits, net GHG emissions for WEBR are 0.34 to 0.38 MTCO2E per ton higher than WTE. Additionally, WEBR provides no additional ability to recover or re-use certain materials such as metal and aggregate, which will lower the volume of total recyclables collected when compared to WTE.

Summary

Based on these conclusions and the broader discussion throughout this Study, the Arcadis Team recommends that the County consider pursuing additional preliminary evaluation, permitting and siting considerations, and other steps necessary to move forward with WTE facility disposal over WEBR. Due to the long-term cost savings, improved recycling rates, and potential for net negative GHG emissions with the inclusion of carbon capture technology, WTE facility disposal will provide a significant financial and environmental benefit to the County over WEBR. Additionally, even with the potential for hurdles during the permitting and siting process, WTE represents a much more stable long-term financial profile over WEBR to protect the County's solid waste rate structure against future inflation and escalation.

Because of the long timeframe expected to update the County's Comprehensive Plan for Solid Waste Management for any future change to disposal options, the Arcadis Team recommends the County evaluate the opportunity to perform simultaneous siting and planning studies for WTE in parallel with updates to the Comprehensive Plan, recognizing that stakeholder engagement and preliminary agreement from the partner cities would be part of this first siting phase. This would improve the critical path schedule to allow for the WTE facility to enter commercial operation at an earlier date and to maximize available landfill airspace for future risk aversion.

Finally, concurrently with the existing County activities to expand the Cedar Hills landfill, the Arcadis Team recommends that the County evaluate opportunities at Cedar Hills for future ash monofill development and long-term disposal, as well as opportunity to either purchase additional adjacent property or use the buffer space as a potential siting location for the WTE facility. The WTE financial model evaluated within this Study utilized assumptions that were site neutral in an effort to provide the best comparison case, and add conservatism, when comparing against WEBR. If the County utilizes the existing Cedar Hills site for development of the WTE facility and maintains air space for future ash disposal, the County could save an additional $100 million in avoidance of land purchase and $350 million in ash disposal and hauling costs over the 50-year planning period. These combined savings would reduce the total cost per ton for the 50-year period by approximately $6/ton. If the County wishes to maximize future landfill airspace at Cedar Hills or waste forecast tonnages are significantly higher in the short term than expected, the Arcadis Team recommends that the County consider short-term, partial WEBR of a portion of available MSW during the long planning process. Smaller tonnage amounts should be easily implemented with existing IMFs. This would allow for the County to maximize future airspace available or perform long-term expansions or additions of the Cedar Hills landfill for future use as an ash monofill.

1 INTRODUCTION

This document presents the results of a Waste-to-Energy ("WTE") and Waste Export by Rail ("WEBR") Feasibility Study ("Study") conducted by Arcadis U.S., Inc. ("Arcadis") and partners BHC Consultants, LLC ("BHC"), B-Town Consulting ("B-Town"), and WIH Resource Group ("WRG"), collectively the ("Arcadis Team") on behalf of King County, Washington (the "County"). This Study has been prepared in accordance with the terms of Services Contract #6082912 ("Contract") between the County and Arcadis, which should be read in its entirety for its content in connection with this Study.

The County contracted with Normandeau Associates, Inc. (Normandeau Report) to perform previous analysis in 2017 related to this topic. The Normandeau Report recommended a more detailed review into the potential of WTE and comparison against WEBR. This Study provides additional detail and comparison between WTE and WEBR to assist in the County's decision-making process.

1.1 Background

King County's Solid Waste Division ("KCSWD") currently provides municipal solid waste ("MSW") disposal for 37 partner cities, as well as the unincorporated County. KCSWD provides waste disposal through landfilling. The County owns and operates Cedar Hills Regional Landfill ("Cedar Hills").

KCSWD's interlocal agreements ("ILAs") with its partner cities obligate the division to provide waste disposal through 2040. Waste from the unincorporated County is also disposed at Cedar Hills, which is estimated to reach capacity before 2040. Prior to reaching capacity, the County will need to identify an alternative waste disposal strategy.

The County Council has directed the Executive to lead a Study that evaluates the feasibility of using either WTE or WEBR as the County's next disposal method. The Office of Performance, Strategy and Budget ("PSB") is the lead for the Study.

Over the last two years, KCSWD has been working with partner cities and other stakeholders to develop an update to the 2001 Comprehensive Solid Waste Management Plan, known as the 2019 Comprehensive Solid Waste Management Plan ("2019 Comp Plan"), that will set strategic direction for the next six to twenty years. The 2019 Comp Plan does not make a recommendation on long-term disposal strategies beyond recommending maximization of landfill capacity as the next disposal option to serve the regional system through 2040 in accordance with the existing ILAs. However, the plan did include an analysis of two alternative disposal strategies: WEBR and WTE.

1.2 Purpose

The purpose of this feasibility Study is to further enhance the County's understanding of the WTE disposal method, how that compares to WEBR, and evaluate these alternatives over an approximate 20 to 50-year time horizon (2025 to 2075). The general scope of work includes:

- Comparison of the WTE disposal method to the WEBR disposal method.
- Expand on previous studies performed for the County to develop one WTE and one intermodal scenario on which to base a comparison (allowing for variations and options).

- Provide a realistic assessment of the barriers and risks to successfully implementing each scenario (e.g. political acceptance and future regulations are two difficult-to-quantify risks).
- Develop a detailed comparison of the scenarios, which have different risks and barriers to success.
- Show site plans of conceptual layouts for the WTE facility options, showing such features as traffic flow, road configuration, scale house location, and truck queuing.
- Prepare appendices detailing the modeling that accompanies the analysis and provide the models in their native format.

Additional scope items related to individual tasks are also included and will be addressed in each respective section.

2 WASTE TONNAGE FORECAST

2.1 Background

KCSWD currently disposes MSW at Cedar Hills which has limited remaining capacity. The County is considering options for future management of MSW in the County System. As such a Study to review the options of WTE and WEBR has been undertaken by the Arcadis Team. The first step in this Study is waste tonnage forecasting, under the following tasks:

- Review factors that may affect the County's waste tonnage forecast
- Analyze how different assumptions could affect the forecast, with a range of estimates

The main goal of this task is to develop two distinct scenarios over approximately 20-year (2025-2045) and 50-year (2025-2075) terms for the purpose of understanding system sizing impacts on potential WTE facility or WEBR systems.

To achieve this goal the Arcadis Team obtained KCSWD's most recent tonnage forecast ("February 2019 Forecast"), analyzed the factors it used, and assessed whether the methodology should be used through the 2075 planning horizon. The Arcadis Team then developed two tonnage disposal forecasts for this Study.

A comparison of the various tonnage forecasts considered for this Study is presented below followed by a discussion of the Arcadis Team's forecasts.

2.2 Comparison of Tonnage Forecast Models

Figure 2-1 presents a comparison of the various MSW tonnage disposal forecasts discussed in this section through 2075. The KCSWD February 2019 Forecast included three different projections: high bound, baseline, and low bound. KCSWD developed their forecast through 2028 using variables such as per capita employment, MSW tipping fee and retail sales. For 2028 to 2040, each of the tonnage forecasts in the model was extended using a set growth rate trend based on previous years. Those growth rates in percent per year are 2.91 (high bound), 1.70 (baseline), and 0.57 (low bound). All three of these scenarios are shown on Figure 2-1 as KCSWD High Bound, KCSWD Baseline, and KCSWD Low Bound. As these forecasts were not intended to be extended to 2075, they are stopped at 2040.

Table 2-1 presents the summary of forecasted annual waste disposal for the different forecasts at specific milestone years and notes to accompany Figure 2-1.

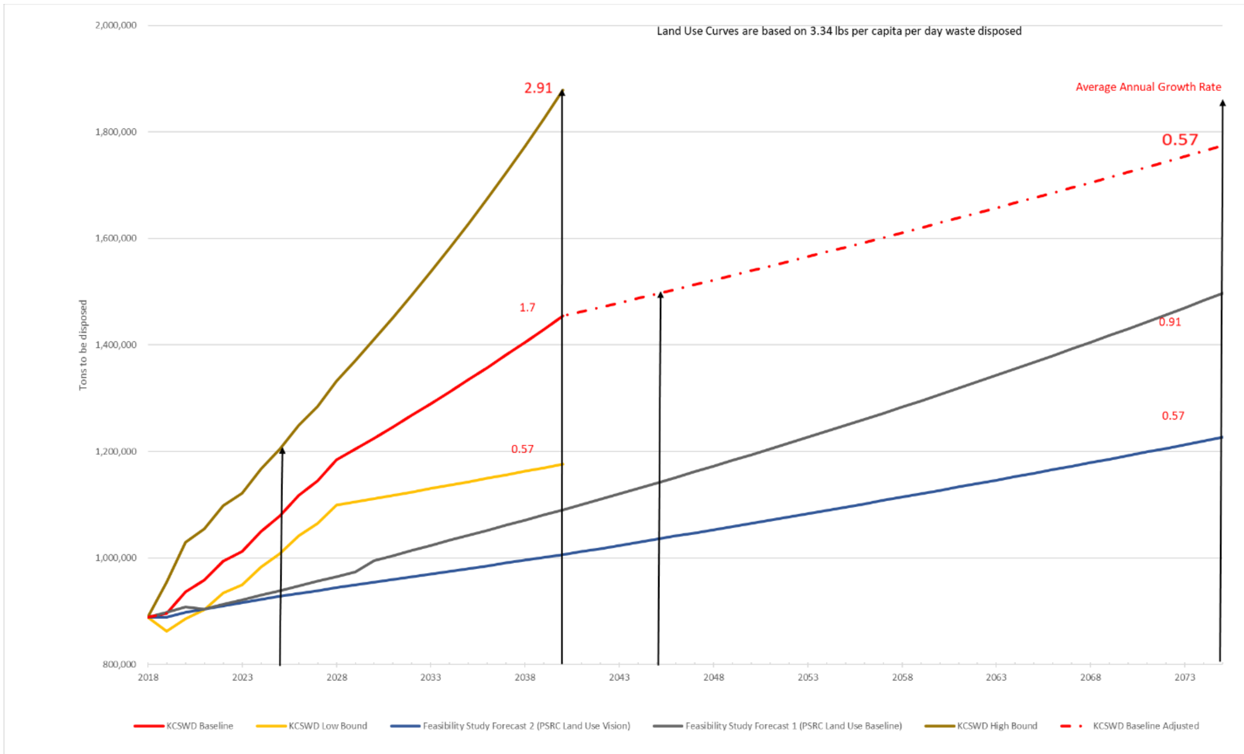


Figure 2-1. Comparison of Tonnage Forecast Models1

Table 2-1. Annual Waste Disposal Forecast and Notes to Figure 2-1 (Total tons disposed annually)

	2025	2040	2045	2075
KCSWD High Bound[1]	1,204,685	1,878,554	NA	NA
KCSWD Baseline[1]	1,079,268	1,454,250	NA	NA
KCSWD Baseline adj. 2040		1,454,250	1,496,171	1,774,331
KCSWD Low Bound[1]	1,008,710	1,175,875	NA	NA
Feasibility Study Forecast 2 (PSRC Land Use Vision)	928,046	1,006,379	1,035,239	1,226,639
Feasibility Study Forecast 1 (PSRC Land Use Baseline)	938,796	1,090,361	1,140,879	1,497,114

[1]KCSWD Baseline, High Bound and Low Bound are based on the KCSWD February 2019 Solid Waste Forecast. These are not intended for long term tonnage projections. These curves were not extended to 2075.

Two additional tonnage forecast curves are shown on Figure 2-1 based on population projections from the Puget Sound Regional Council ("PSRC"): Land Use Baseline and Land Use Vision. PSRC creates two growth projections to model the outcomes of different policy choices in small geographies: Land Use Baseline and Land Use Vision. Land Use Vision is a growth projection based on local and regional policies, as well as each county's adopted growth targets. PSRC uses Land Use Vision for planning and modeling work. The difference between the two population model approaches is as follows:

- Land Use Baseline is a market-based growth projection of current growth patterns, i.e., the future growth pattern if the region made no further efforts to implement VISION 2040 beyond the plans, policies and development regulations currently in place.
- Land Use Vision is a policy-based growth projection developed to align with the VISION 2040 Regional Growth Strategy, local growth targets and the regional macroeconomic forecast, i.e., the future growth pattern the region is planning for.

It should be noted that Land Use Vision is currently being updated along with VISION 2050 to provide population projections to 2050; however, the updated Land Use Vision projection will not be available until Spring of 2020.

For the purposes of this Study, each of the population projections were extended through 2075 using the average projected growth rate from 2020 through 2040. Those population growth rates in percent per year are 0.91 for the Land Use Baseline and 0.57 for the Land Use Vision. The difference between Land Use Baseline and Land Use Vision is that the Land Use Baseline is directly from the PSRC economic model; whereas, the Land Use Vision projection is adjusted to account for County land use policies. Therefore, the PSRC indicated that the Land Use Vision projection is more consistent with the Vision 2040 Plan and is the most appropriate projection for planning purposes.

Disposal tonnage for the Land Use Baseline and Land Use Vision were based on 3.34 pounds of MSW disposed per capita per day. This disposal tonnage is the disposal rate in 2018, which is considered most likely to be representative of future disposal rates because 2018 was the first full year that the County banned construction and demolition ("C&D") debris from disposal at its transfer stations. A discussion of historical per capita MSW generation, recycling, and disposal rates is presented in a later section.

One other curve is shown on Figure 2-1, KCSWD Baseline Adjusted. This is a modification of the KCSWD Baseline that changes the disposal growth rate to 0.57 percent per year after 2040, which is based on the Land Use Vision population forecasted population growth rate from 2020 to 2040.

Table 2-2 presents a summary of the tonnage forecasts characteristics as discussed in this section as well as references the Proposed Low and High Bound forecasts used for this Study.

Table 2-2. Summary of Individual Model Characteristics

Model Line	Population Data	Waste Disposed Data	Waste Disposed Per Capita	Recycling Rate	Average Annual Growth Rate (2040-2075)	Comments
KCSWD High Bound	County Model	County Model	County Model	Set at 52%	N/A	Model not intended to be extended past 2040.
KCSWD Baseline	County Model	County Model	County Model	Set at 52%	N/A	Model not intended to be extended past 2040.
KCSWD Baseline Adjusted	County Model	County Model	County Model Adjusted	Set at 52%	0.57	This line shows the KCSWD project baseline but is adjusted at 2040 to show a slowed growth rate. WTE Study Proposed High Bound.
KCSWD Low Bound	County Model	County Model	County Model	Set at 52%	N/A	Model not intended to be extended past 2040.
Feasibility Study Forecast 1 (PSRC Land Use Baseline	PSRC	Starting from actual tons disposed at Cedar Hills in 2018	3.34 lbs. (2018 actual figure)	Set at 52%	0.91	
Feasibility Study Forecast 2 (PSRC Land Use Vision)	PSRC	Starting from actual tons disposed at Cedar Hills in 2018	3.34 lbs. (2018 actual figure)	Set at 52%	0.57	WTE Study Proposed Low Bound

2.3 Model Variables

Several model variables affect the tonnage forecasts. A discussion of how changes in these variables could impact the forecasts is presented below.

2.3.1 Waste Disposed per Capita

The waste disposed per capita depends on several factors including economic factors (e.g., the amount of waste generated per capita typically decreases during recessions); technological factors (e.g. packaging, recycling infrastructure); social factors (e.g. a person's attitude toward waste minimization and recycling); and administrative/governmental factors (government policy's on recycling and how easy or difficult it is to recycle).

Figure 2-2 shows historical waste disposed per capita and population in the County over a 22-year period. These values are based on recorded tonnage disposed at Cedar Hills and the population for the County (less Seattle, less Milton) from the Office of Financial Management ("OFM").

This figure shows a relatively stable period from 1997 through 2007 of between 4.3 and 4.5 pounds disposed per capita per day. The per capita disposal began a steady decrease in 2008 that reached a low of about 3.3 pounds disposed per capita per day in both 2012 and 2013. This decrease is attributed to the recession (2007 through 2014). Per capita disposal increased from 2013 through 2017 to over 3.5 pounds disposed per capita per day. In 2018, the per capita disposal rate decreased to 3.34 pounds per capita per day. This 2018 decrease is attributed to: the implementation of a C&D waste ban; the recycling rate holding steady (2014 onwards); and, changes in packaging (i.e. less plastic, glass etc.).

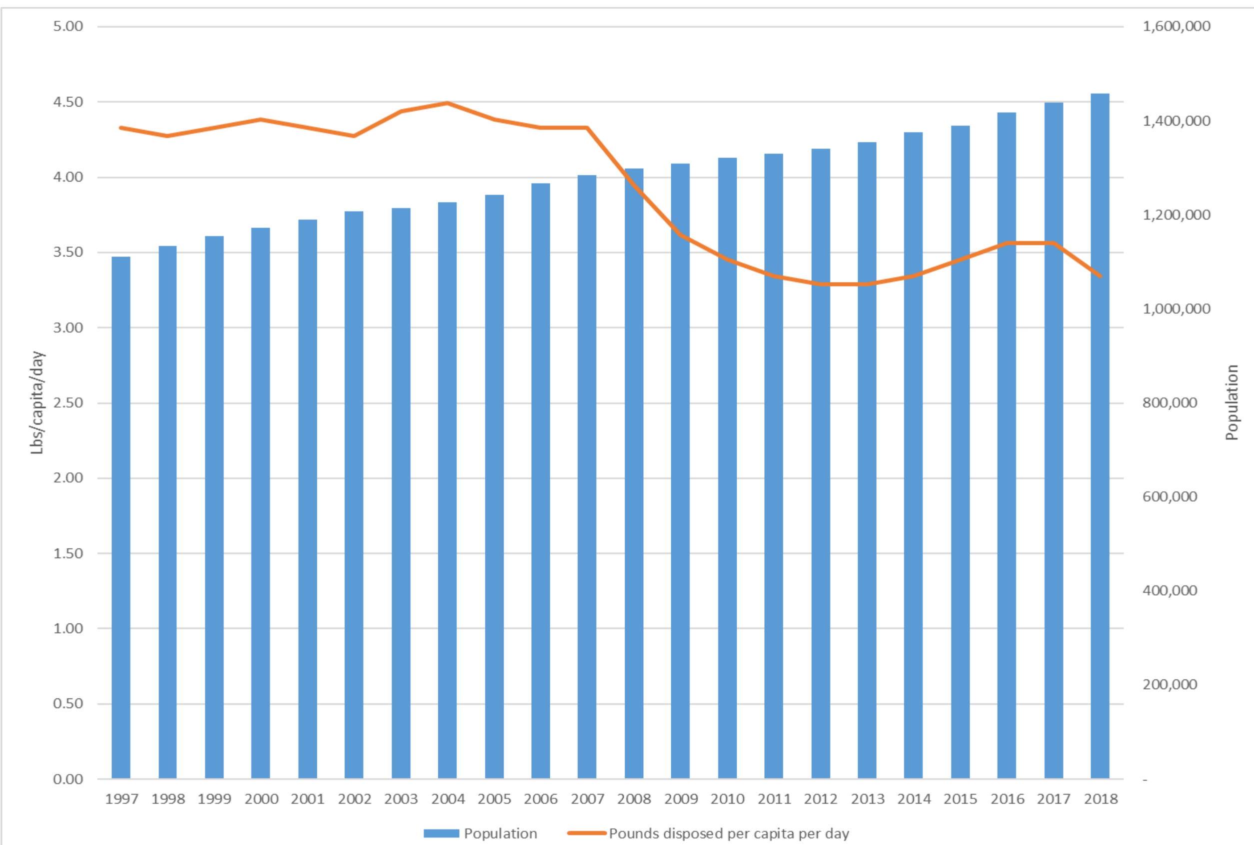


Figure 2-2. County Waste Disposed per Capita per Day Versus Population Growth 1997-2018

Based on this waste disposal trend in Figure 2-2, the 2018 figure of 3.34 pounds per capita per day is used in the Arcadis Team's tonnage forecast model with no variance through 2075.

2.3.2 **Recycling Rate**

Figure 2-3 shows MSW per capita disposal and recycling rates in the County for 2000, 2007, 2010, and 2015. Recycling rates have steadily increased through this period with a 58 percent rate in 2015. It should be noted that the County has limited control of recycling practices because MSW collection for most of the system is managed by the 37 partner cities.

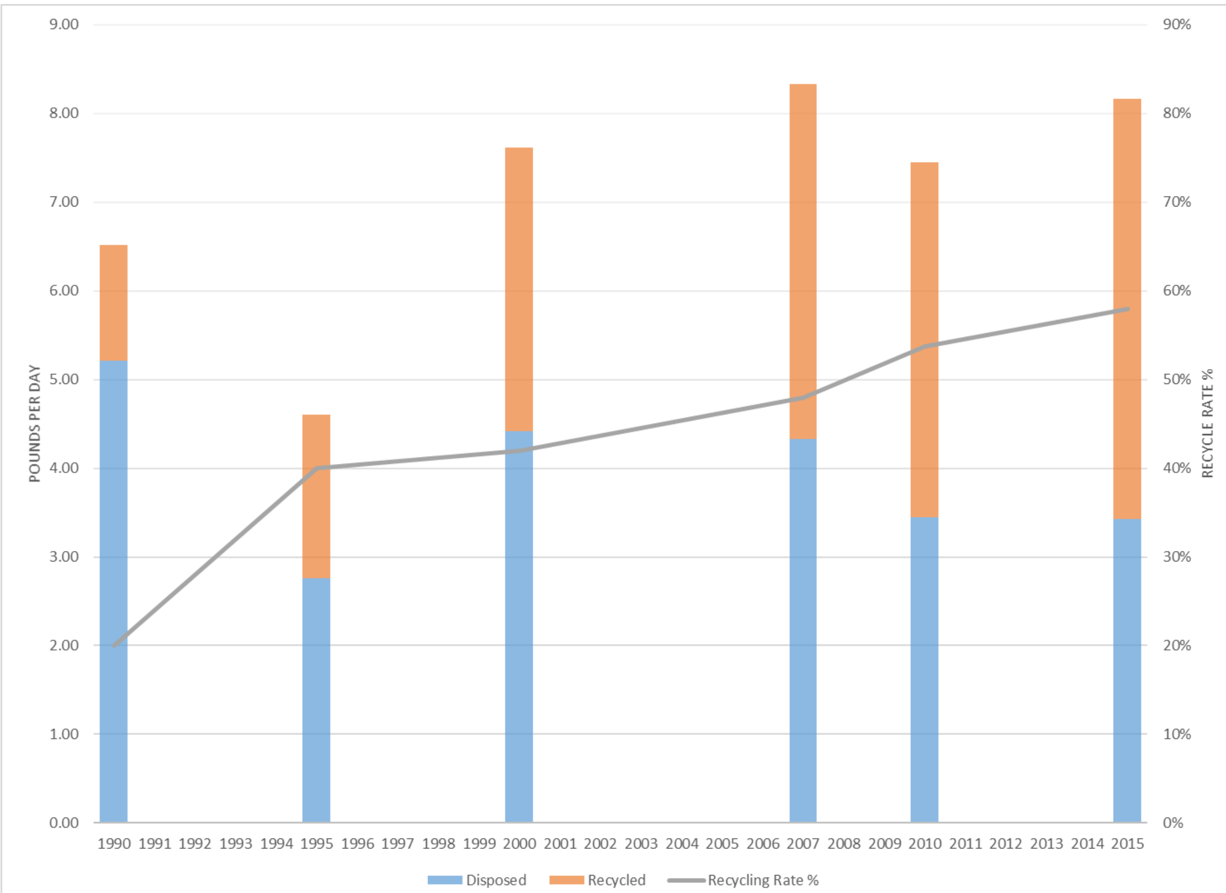


Figure 2-3. County Waste Generation and Recycling Rates

Figure 2-4 shows waste generation and recycling data compiled by the USEPA for 1990, 1995, 2000, 2007, 2010, and 2015. The figure also shows an increasing trend for the period; although, the rate of increase was very low between 2010 and 2015 with a recycling rate of 35% in 2015. Figure 2-4 also shows a steadily decreasing per capita disposal rate.

For the purpose of this Study, the recycling rate was kept at 52 percent for both high bound and low bound forecasts. The basis for this includes the levelling off in the recycling rate in recent years and the observation that the County does not have any regulatory means to enforce recycling rate improvements in the partner municipalities.

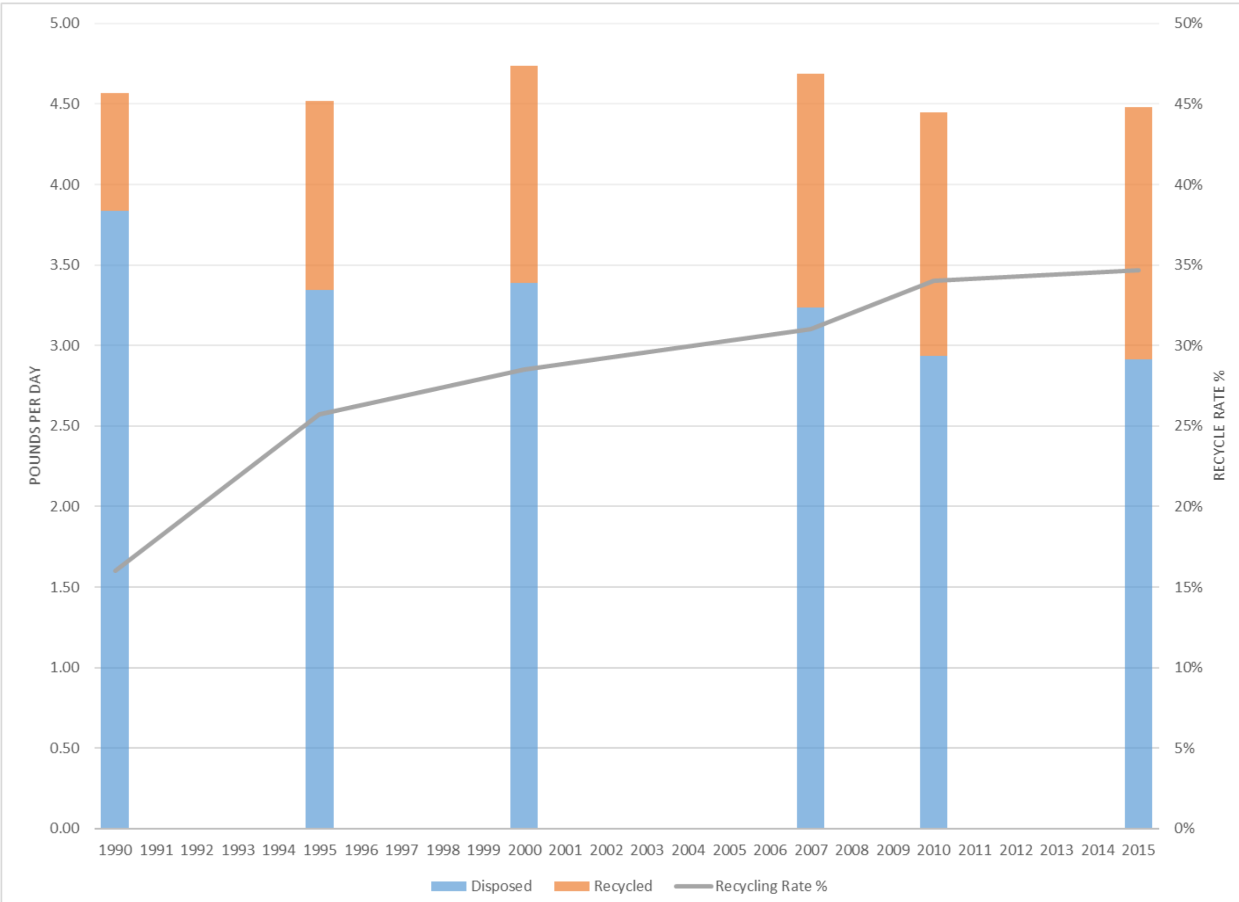


Figure 2-4. USEPA National Average Waste Generation and Recycling Rates

2.3.3 **Waste Generation**

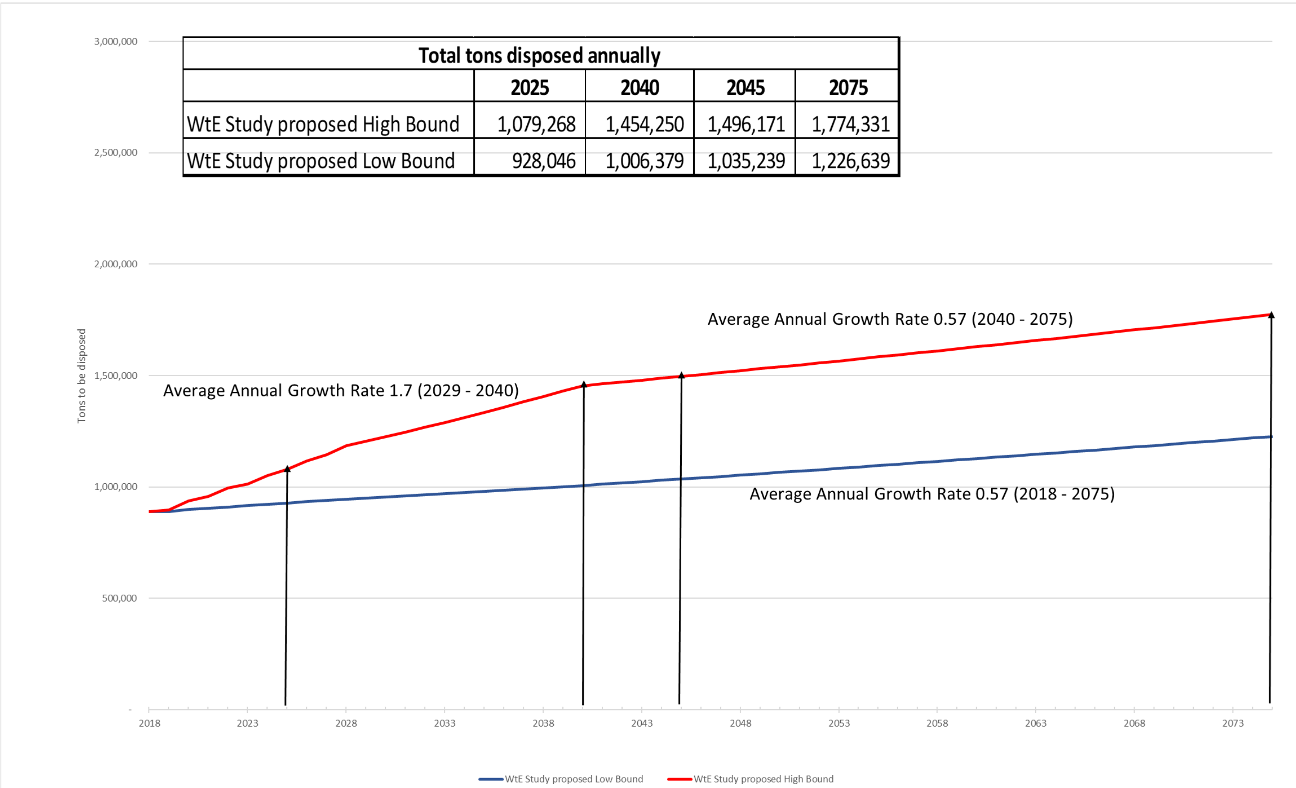
Figure 2-3 shows a total waste generation for the County at just over 8 pounds per person per day in 2015. As a comparison, the US Annual MSW Generation data reported by the USEPA shows per capita MSW generation increased by 22 percent from 1980 through to 2015, from 3.7 pounds to 4.5 pounds per person each day, although per capita generation has decreased slightly since 1990[2]. In Europe, MSW generation rates (in lbs./person/day) are 2.8 in Sweden, 3.7 in Germany, and 2.9 in the United Kingdom[3].

This comparison shows the County levels of waste generated and therefore disposed are higher than the national average which is expected because the County is a largely urban and affluent area.

[2] U.S. Environmental Protection Agency (EPA) (2018) Advancing Sustainable Materials Management: 2015 Fact Sheet.
[3] Organization for Economic Cooperation and Development (OECD) (2015) Environment at a Glance 2015.

2.4 Proposed Tonnage Forecasts

Two MSW disposal forecast curves are developed for this Study which are shown in Figure 2-5. For the purposes of identifying WTE facility sizing, the 2045 projected tonnages will be used initially with the ability to expand to meet the 2075 tonnage forecasts.



Total tons disposed annually				
	2025	2040	2045	2075
WtE Study proposed High Bound	1,079,268	1,454,250	1,496,171	1,774,331
WtE Study proposed Low Bound	928,046	1,006,379	1,035,239	1,226,639

Figure 2-5. WTE Study Proposed High and Low Bound Tonnage Disposal Forecast

The WTE Study proposed High Bound forecast is based on the KCSWD baseline model to 2040 (with an average annual growth rate of 1.7) and then adjusted from 2040 to 2075 (with a lower average annual growth rate of 0.57). The WTE Study proposed Low Bound forecast is based on Feasibility Study Forecast 2 (PSRC Land Use Vision) with an average annual growth rate of 0.57 for the entire study period.

Using the high and low bound forecasts proposed there are a number of benefits, such as, two differing model approaches are incorporated, one more conservative than the other in terms of growth due to a consistent waste disposal value use throughout. Using a range of figures for MSW disposal such as these, allows for flexibility, as modelling so far into the future is difficult with so many variables and unknowns.

3 WASTE-TO-ENERGY

This section summarizes the key assumptions related to the development of a mass burn WTE Facility for the County's planning and management of its MSW. The Arcadis Team reviewed various scenarios; however, the primary focus of the evaluation was to accommodate the following WTE facility scenarios based on the tonnage projections.

Table 3-1. Summary of Waste-to-Energy Facility Scenarios

Forecast	MSW Capacity in 2045 (tons)	MSW Capacity in 2075 (tons)	Initial Facility Size (tpy)	Initial Facility Size (tpd)	Expansion Year	Expansion Size (tpy)	Expansion tpd
Low Bound	1,034,239	1,226,639	1,000,000	3,000	2048	333,333	1,000
High Bound	1,496,171	1,774,331	1,333,333	4,000	2040	333,333	1,000

Facility processing estimates on a ton per day ("tpd") basis are based on an estimated rated design with waste averaging 5,000 British Thermal Units ("BTU") per pound on a Higher Heating Value ("HHV") basis. Typically, a facility is expected to be able to process up to 10% more than the tpy size. A more detailed and comprehensive conceptual design will be provided during the permitting phase if the County decides to move forward with development of the WTE option.

3.1 Facility General Description

A mass burn WTE facility requires minimal front-end processing other than to separate and remove large objects that may impair the feed system or the ash handling system. Examples of large objects that are removed from the front end include large appliances, bed springs, and automobile parts. MSW is delivered to the facility in transfer trailers or standard collection vehicles. These vehicles then discharge their loads into the refuse storage pit. An overhead bridge crane located above the refuse storage pit is used to mix, stack, and convey the MSW to charging hoppers used to feed the boiler stokers. Combustion occurs in a controlled furnace combustion system that automatically adjusts the refuse feed rate and the combustion air to provide the optimum conditions for achieving desired steam flows from the boilers. Heat from combustion is recovered in a heat recovery boiler designed to protect boiler tubes and heating surfaces from the corrosive gasses produced when combusting the MSW.

The steam generated from the boilers is typically used to drive a steam turbine connected to a generator to provide both the internal electricity required to operate the facility as well as produce excess electricity that is sold to local utilities. Steam generated is also used within the facility for other processes such as soot blowing or sold to users of steam external to the facility where such steam heating grids or steam customers are available.

Flue gas exiting the boiler is scrubbed of acid gasses, heavy metals, and particulate matter in the air pollution control system. The ashes remaining from combustion are categorized as bottom ash and fly-ash. Both ferrous and non-ferrous metals are removed from the bottom ash and sold to local recycling companies. After metals removal, the two (2) ash streams are typically combined and in Washington State are transported to an ash monofill; however, there may be opportunities to further separate ash components and / or reuse the ash for beneficial purposes such as alternative daily landfill cover or as construction materials as done in other states.

A mass burn fired system will typically reduce the incoming volume of waste by 85 to 90 percent and 75 percent or more by weight. A sample profile equipment configuration of a mass burn WTE facility is provided in Figure 3-1.

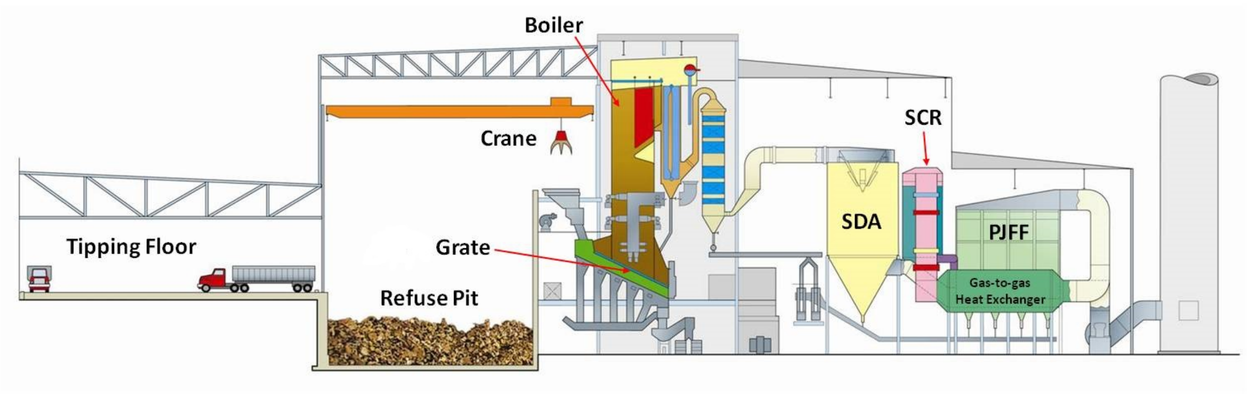


Figure 3-1. Profile Configuration of a Mass Burn WTE Facility

Note: Image used with permission from the Solid Waste Authority of Palm Beach County

3.2 Methodology

The Arcadis Team developed two WTE Conceptual Layout Options ("Layout Options") for a proposed mass burn WTE Facility based on the applicable sizes feasible for the Low Bound Forecast and High Bound Forecast as summarized in Table 3-2 below:

Table 3-2. Layout Option Descriptions

Option	Task
Layout Option 1	3,000 tpd Mass Burn Facility with a footprint capacity of 4,000 tpd
Layout Option 2	4,000 tpd Mass burn Facility with a footprint capacity of 5,000 tpd

The location of the equipment in each proposed facility layout was strategically located to achieve enough room for waste receiving and storage, maintenance access, delivery of materials, ash removal, and employee access. Each Layout Option was designed with adequate spacing to enable proper operation and maintenance activities throughout the life of the proposed WTE Facility. The Layout Options also include a roadway structure that allows truck traffic to access the tipping floor and other structures. All Layout Options also were designed to include an expansion capability for one unit of 1,000 tpd nominal capacity. The potential expansion areas are labeled "future expansion" in the Layout Options provided as Figure 3-2 and Figure 3-3.

The Layout Options presented are intended to be preliminary and subject to refinement during conceptual design. They are presented to illustrate the potential alternative footprint impacts and layouts which may be achieved during the actual design process. Actual site layouts will be dependent on many factors including site constraints, access to major roadways, utilities, etc.

3.2.1 **Mass Burn Layout Option 1: Low Bound Forecast**

Layout Option 1 incorporates three (3) 1,000 tpd mass burn WTE combustion lines and a 90 to 100-Megawatt ("MW") turbine-generator ("T-G") into a compact layout, while still providing enough area for expansion capacity. The layout is designed for a fourth 1,000 tpd combustion line to be installed for future expansion between the Boiler Building and the Ash Management Facility. Additional air pollution control, tipping floor and pit, and T-G capacity would also need to be installed.

3.2.2 **Mass Burn Layout Option 2: High Bound Forecast**

Layout Option 2 incorporates four (4) 1,000 tpd mass burn WTE combustion lines and a 120 to 130 MW T-G into a larger, more traditional layout which provides enough area for operations and maintenance and includes additional expansion capacity. The layout is designed for a fifth 1,000 tpd combustion line to be installed for future expansion between the Boiler Building and the Ash Management Facility. Additional air pollution control, tipping floor and pit, and T-G capacity would also need to be installed.

3.3 Facility Site Plan

The Arcadis Team created a potential site plan for each of the two Layout Options to show prospective layout of the buildings and determine the total site acreage. The following section provides the assumptions, buildings and structures, and area requirements associated with each Layout Option.

3.3.1 **Assumptions**

The following assumptions were considered when developing the Layout Options for the prospective WTE Facility:

- Existing MSW transport travel patterns would be maintained.
- The total site acreage would require a range of between approximately 43 to 55 acres based on the layouts shown, depending on the design and future processing capacity of the facility (1.5 M tpy to 2.0 M tpy). However, the footprint could potentially be reduced during further detailed design.
- The facility would at a minimum consist of the following buildings and structures:
  - Scale House
  - Tipping Floor Building
  - Refuse Storage Pit
  - Boiler Building
  - Air Pollution Control ("APC") Building with equipment achieving best available control technology ("BACT"), including spray dryer absorber ("SDA") or equivalent dry system, fabric filter house ("FFH"), selective catalytic reduction ("SCR"), and carbon injection.

  - Ash Management Building with advance metals recycling and aggregate processing
  - Turbine-Generator Building, Switchyard and Switch Gear Room
  - Air cooled condenser (“ACC”) rather than a cooling tower to minimize water usage
  - Water Treatment Building
  - Maintenance and Administrative Buildings
- The Layout Options provide room for future expansion of one additional boiler unit, necessary auxiliary equipment, and stack.
- Ash would either be disposed of at Cedar Hills in a separately-lined area for ash disposal only or using WEBR in the future. Ash disposal has been financially modelled using WEBR for the purpose of this Study.
- The Facility will utilize the following utilities: potable water, sanitary sewer, reclaimed and/or industrial water, natural and/or treated landfill gas, and electric power.
- Rainwater harvesting will also be incorporated into the layout.

Carbon capture and sequestration has been anticipated to be included in the cost due to current Washington State regulatory environment, but is not specifically shown in the Layout Options. Additional potential alternative technologies could be incorporated by the County to help increase diversion and recycling rates in addition to WTE in the future, but have not been included in the evaluation at this time. Such technologies include, but are not limited to, mixed waste processing and anaerobic digestion.

3.3.1.1 WTE Facility Prototype Site Requirements

A hypothetical WTE Facility model was considered to provide the basis for evaluation and cost estimating, as well as comparison with the conceptual WEBR option. Some of these assumptions are made to allow construction or other costs to be estimated. It should be noted that a fully designed facility sited in an actual location would probably differ from the model in several material aspects. For this Study, the WTE Facility is assumed to conform to the following requirements:

- The WTE facility is located in proximity to an IMF for out of County disposal of process residuals using WEBR.
- Land use zoning is consistent with medium or heavy industry.
- The WTE facility is located away from sensitive receptors to minimize noise impact and to protect against other nuisances.
- The WTE facility should be located in close proximity to existing or planned major thorough fares that will be in place prior to construction of the facility to provide sufficient access to the site.
- The WTE facility should be located in close proximity to the waste generation centroid to minimize idle time on the road to the extent possible.

- Sufficient capacity for public utilities (i.e., water, power, and sewer) should be available to operate and maintain the facility to meet the performance guarantees and within close proximity to the site to avoid high construction and operating costs.
- The WTE facility should be in close proximity to the connection point for a surplus energy distribution network to avoid high construction and operating costs.
- The site access / perimeter road should be a permanent roadway meeting appropriate truck loading standards and allow for a sufficient number of collection and transfer vehicles to be queued on-site without detriment to the surrounding communities' traffic flow.
- The WTE Facility should be sited within the borders of the County.
- Parcel shape roughly rectangular and suitable for required facility components.
- Reasonable topography: ground slopes are compatible with vehicle traffic, and buildings and structures.
- Sufficient space for equipment laydown and storage during construction.

Additional information regarding the building layouts and discussions are noted in the following sections.

3.3.2 Buildings and Structures

The Arcadis Team established the appropriate sizing of all associated buildings and structures for each Layout Option based upon review of existing facilities of similar size, specifications provided by individual vendors, and industry standards. The Layout Options are illustrated in Figure 3-2 and Figure 3-3, respectively.

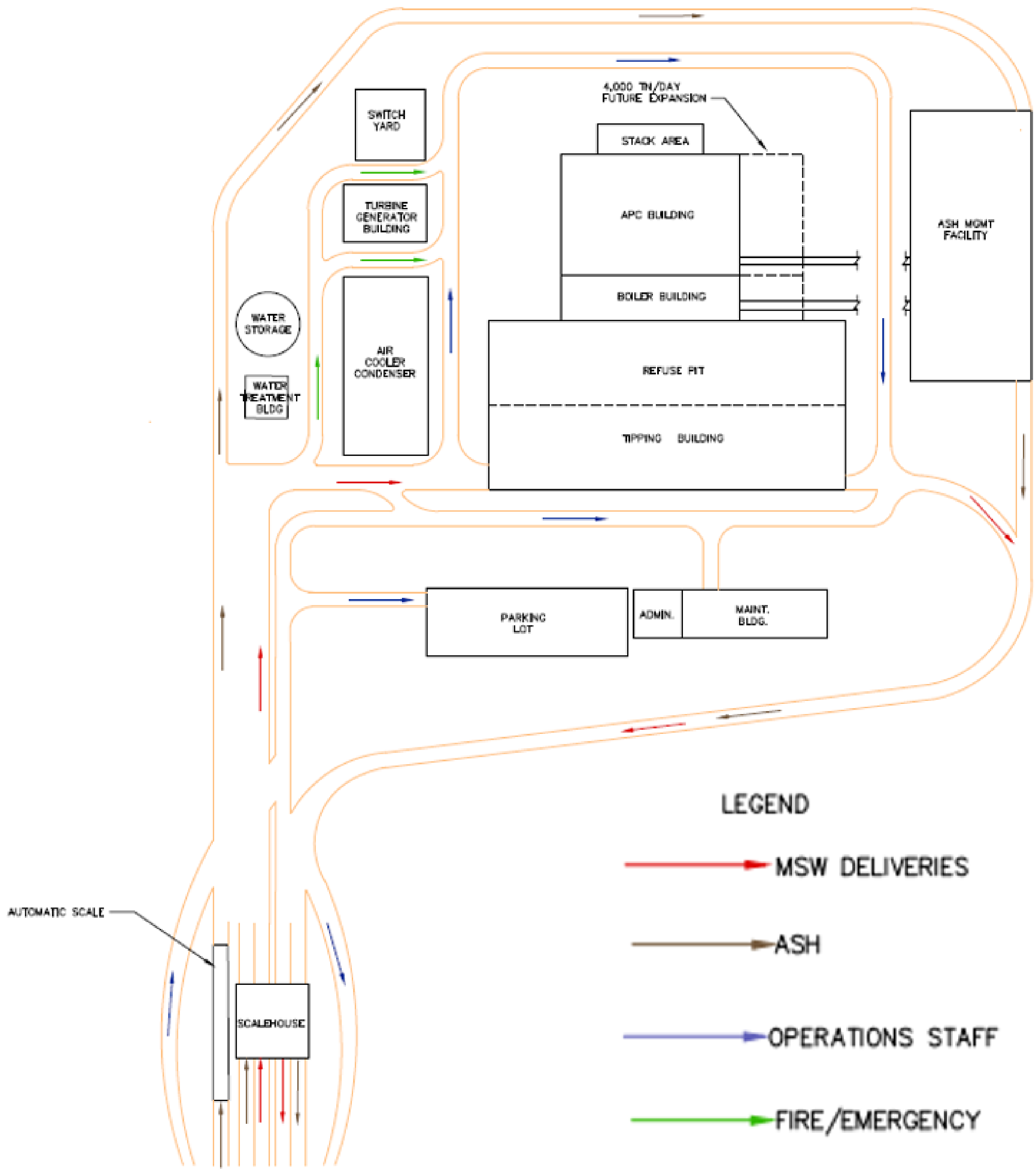


Figure 3-2. Conceptual Layout for Layout Option 1 (Low Bound Forecast)

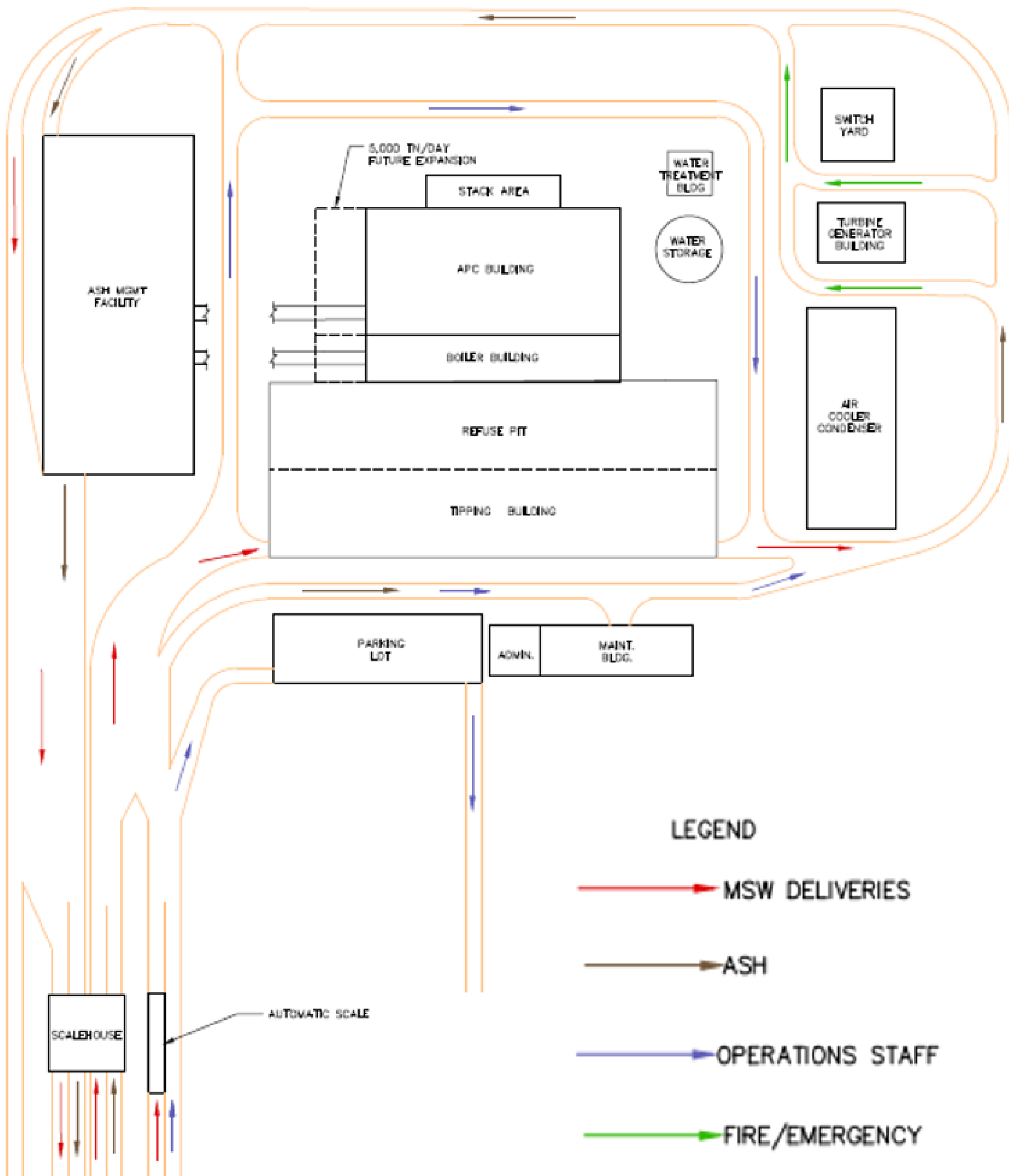


Figure 3-3. Conceptual Layout for Layout Option 2 (High Bound Forecast)

3.3.2.1 Scale House

The Scale House will provide traffic lanes and separate scale facilities for inbound and outbound MSW disposal trucks. The Scale House will be appropriately sized to accommodate the projected volume of MSW for the proposed WTE Facility. The Scale House area would include an automatic scale to facilitate processing of County transfer trailers and reduce queue wait times. Bypass lanes will be available for vehicles not requiring to be weighed on the inbound or outbound directions.

3.3.2.2 Tipping Building

The Tipping Building will provide adequate spacing for transfer trailers to enter the tipping floor and have room to maneuver towards the refuse storage pit while allowing traffic to pass through the building concurrently. The building is sized to allow greater than 30 trucks to tip simultaneously. The entry and exit doors will be 20 feet wide and will be offset 10 feet from the corners of the building. The foundation for the tipping floor will need to be brought to an appropriate elevation above the base elevation of the Facility to allow for sufficient Refuse Storage Pit sizing. The current sizing in the Layout Options assumes that the Tipping Building will be built during initial construction large enough for the expanded facility.

3.3.2.3 Refuse Storage Pit

The Refuse Storage Pit Building will have the required refuse pit capacity to store refuse below the level of the tipping floor. Back stacking of MSW up to the top of the refuse storage pit parapet walls will provide additional storage. The refuse pit dimensions will be calculated assuming a maximum storage capacity of greater than 7 days of material, not accounting for refuse stacked above the tipping floor. The design also includes enough area for each Layout Option for future expansion of the proposed WTE Facility by 1,000 tpd. The current sizing in the Layout Options assumes that the Refuse Storage Pit will be built during initial construction large enough for the expanded facility. Note that cost savings for initial facility construction could be achieved by not building the additional storage capacity, but would need to be recaptured in future expansion costs.

3.3.2.4 Boiler Building

The Boiler Building will house three or four 1,000 tpd boiler units for Layout Options 1 and 2, respectively. The size of each boiler unit is estimated to be 100-feet L x 65-feet W (this size includes the auxiliary equipment directly connected to the side of the boilers such as the sootblowers and auxiliary fuel systems). The area denoted as ‘future’ is allocated for a fourth or fifth 1,000 tpd boiler unit for Layout Options 1 and 2, respectively.

3.3.2.5 Air Pollution Control Building

The APC Building will be located adjacent of the boiler building and will include a continuous emissions monitoring (“CEM”) system enclosure. The size of the APC building is based on vendor information and comparison to the reference facilities in the industry. The APC Building will include the area for the SDA, FFH, SCR, carbon feed, and other miscellaneous equipment. Carbon capture and sequestration is currently assumed to be direct air-capture of CO_2, rather than flue-gas capture of CO_2, so it would be housed in a separate structure.

3.3.2.6 Stack

The Stack will have an approximate 50-foot diameter with an octagonal concrete support pad approximately 5 feet off the stack on all sides. The height of the stack is anticipated to be at least 200 feet based upon 1.5 times the height of the roof of the tallest structure (Boiler Building) of the proposed WTE Facility. The actual stack height will be determined based on detailed design and air emissions modelling in accordance with the Title V air permit requirements. The stack will include flues for the base and expanded facility conditions, so that no stack modifications are required for future expansion.

3.3.2.7 Ash Management Building

The Ash Management Building will be based on the total ash and metal storage requirements with enough room to house an inclined conveyor, ferrous, and non-ferrous metals removal processing systems. Typically, fly ash and bottom ash are combined and managed in this building. The Ash Management Building will be designed to store greater than seven days of combined ash and recovered materials and will recover metals through the ferrous and non-ferrous recovery systems. The Ash Management Building has been sized much larger than typically seen in the industry to account for additional storage and equipment space for advanced metals processing and aggregate separation. Doors are provided on each end to allow drive through truck access.

3.3.2.8 Ash Conveyor Enclosure

The Ash Conveyor Enclosure is a covered enclosure that extends from the Boiler Building to the Ash Management Building and has adequate capacity for an additional boiler unit if installed. Two (2) vibrating pan or slip-stick conveyors will fit into this area to move the boiler bottom ash into the Ash Management Building.

3.3.2.9 Turbine-Generator Building

The T-G Building will be located adjacent to the Boiler Building. The size of the T-G Building will be based upon manufacturer information for turbine-generators as well as the size of the reference facilities in the industry. The proposed site of the T-G Building allows for a T-G unit that can generate up to 100 MW of electric capacity for the Low Bound Case. Additional area in the T-G Building is allocated for the possible expansion of the T-G building and installation of an additional T-G when the additional 1,000 tpd unit is constructed in the future for approximately an additional 30 MW T-G. Sizing for the High Bound Case would include a T-G that could generate up to 130 MW, with room for the installation of approximately an additional 30 MW T-G for the future expansion. In all cases, enough clear space and access is provided around the T-G equipment, inside the building, to allow for layout of materials, tools, and equipment for use in future outages.

3.3.2.10 Air Cooled Condenser

The ACC cools the steam exhaust from the turbine and supplies the condensate water to the boiler feed water pumps and does not require a water source to operate. The ACC will be located adjacent to both the T-G Building and the Boiler Building. While slightly more expensive, an ACC will be utilized rather than a traditional cooling tower to conserve site water usage.

3.3.2.11 Switchyard and Switchgear Room

The Switchyard and Switchgear Room will contain the equipment that connects the facility to the power purchaser and provider. The Switchyard consists of a gravel bed surrounded by barbed wire fence. The location of the Switchyard should be selected to align with connection to the electric grid. The Switchgear Room will be located along the boundary of the Switchyard and will be designed to meet the needs of a 100 MW T-G unit for the Low Bound Case or 130 MW T-G for the High Bound Case with additional capacity for the future power expansion.

3.3.2.12 Water Treatment Building

The Water Treatment Building will be designed to house the demineralizer system, reverse osmosis (“RO”) system, and chemical feeding equipment for creating demineralized water for use in the boilers. The dimensions will be based on projected water makeup and water treatment requirements. A 105-foot diameter Water Storage tank will be located adjacent to the Water Treatment Building to store rainwater runoff from the Facility rooftops to limit the requirements for purchased potable or supply well water.

3.3.2.13 Maintenance and Administration Building

The Maintenance Building and Administration Building are shown co-located in the same structure; however, these buildings could be easily separated based on the site requirements and/or convenience. The Maintenance Building will house the maintenance shop, area for large equipment repair, warehouse and spare parts storage area, and shower and change rooms for maintenance staff. An outage maintenance area may also be incorporated into the Layout Options to serve as a staging area when boiler outages occur.

3.3.2.14 Additional Buildings and Structures.

In addition to the buildings and structures shown on Layout Options 1 and 2, the site will also include the following buildings and structures:

- Fire Pump House and Fire Water Storage Tank
- Wastewater Tank(s)
- Cooling Water Tower and Heat Exchangers
- Settling Basin
- Chemical Storage Area
- Fuel Station
- Guard Shack, if required
- Inbound/Outbound Scale House
- Miscellaneous Pumps and Equipment
- Carbon Capture and Sequestration Equipment

While not shown on the Layout Options, there is ample additional space in the acreage estimates to place these additional buildings throughout each potential Layout Option. As most of these buildings and structures are relatively small and low cost, it is assumed that they would be sized to account for the additional expansion at the time of the initial construction.

3.3.3 **Area Requirements**

When developing an area estimate for a WTE site, the area can change considerably depending on the site conditions, access to utilities and existing infrastructure, and the overall design of the equipment. Therefore, a general proportional rule of thumb is not necessarily the best path forward for developing reasonable site requirement estimates. It is also often possible to condense the buildings and equipment into a slightly smaller footprint (at additional cost). Bearing this in mind, the Arcadis Team has estimated a slightly larger site requirement than may be needed. However, as land cost in the County is at a premium, the additional cost to engineer and construct the structure and footprint into a smaller area will be offset by the reduced cost for land.

To develop the estimates, the Arcadis Team initially took a survey of several 3,000 tpd WTE facilities in the US and Europe to determine the area of those sites. The acreage for a typical 3,000 tpd WTE facility ranges from approximately 25 acres to 35 acres, depending on the site conditions, with the larger acreages showing larger clear spaces around the facilities themselves. As the site could vary considerably, we ruled out using a proportional rule of thumb approach for upsizing the acreages to the necessary requirements for the Low Bound and High Bound Forecasts.

Instead, the Arcadis Team took the building sizes from the most recent greenfield (which refers to construction on a new, previously unused site that is not being modified/retrofitted for use) WTE facility construction of a 3,000 tpd WTE facility in West Palm Beach, Florida and proportionally upsized the buildings on an individual basis to include additional room for advanced metals processing, additional capacity for future expansion, and additional Refuse Pit storage. These revised buildings were developed using AUTOCAD as shown in Section 3.3.2. These Layout Options 1 and 2 also provide proposed roadway and traffic configurations, truck turning radiuses, and follow general industry standard design principles. The designs of both Layout Options utilize grass and gravel wherever possible to reduce the area of impervious surfaces and assume requirements for stormwater outlay.

The total area of the site with the revised building sizes and included roadways was then condensed and measured. Table 3-3 summarizes the enlarged building sizes and the resultant total project areas for each Layout Option.

Table 3-3. WTE Facility Dimension Assumptions

Building	Layout Option 1 (Low Bound)		Layout Option 2 (High Bound)	
	Length	Width	Length	Width
Switch Yard	115’	115’	115’	115’
Turbine Generator Building	140’	95’	140’	95’
Air Cooled Condenser	140’	300’	140’	350’

Building	Layout Option 1 (Low Bound)		Layout Option 2 (High Bound)	
	Length	Width	Length	Width
Air Pollution Control Building	295’	200’	400’	200’
Boiler Building	295’	75’	400’	75’
Refuse Pit	590’	130’	710’	130’
Tipping Building	590’	150’	710’	150’
Ash Management Building	200’	450’	240’	535’
Water Treatment	70’	70’	70’	70’
Water Storage	105’	Diameter	105’	Diameter
Administration Building	80’	80’	80’	80’
Maintenance Building	240’	80’	240’	80’
Total Site Acreage:	**43 Acres**		**55 Acres**	

3.4 Implementation Schedule

A preliminary Project Implementation Schedule (“Schedule”) has been developed based upon long-term implementation plan activities that generally include planning, permitting, procurement and construction-related activities. The Schedule identifies the major tasks, overall start date, duration, and estimated completion date, which are required for the duration of the proposed WTE Facility project.

3.4.1 Long-Term Implementation Plan

Several long-term implementation planning activities have been identified that should be on an accelerated schedule or early start track to take place concurrently with the planning activities. These accelerated activities are outlined in Table 3-4 below.

Table 3-4. Accelerated Schedule Activities

Task
Bond Financing Support
Waste Quantification and Characterization
Site Identification and Land Acquisition (as applicable)
Preliminary Site Preparation
Interlocal Agreement Negotiation/Extension with Partner Cities
Update to Comprehensive Plan

Task
Siting Study and Environmental Impact Statement (“EIS”) (including Human Health and Ecological Risk Assessment (“HHERA”))
Power Purchase Agreement Negotiations
Washington Utilities and Transportation Commission (“UTC”) Need Determination Process
Notice of Construction (“NOC”) Permit (per PSCAA Regulation I, Section 6.03)
Prevention of Significant Deterioration (“PSD”) Air Construction Permit Process
Land Use Determination Confirmation
Procurement Strategy Development and Vendor Procurement

3.4.2 **Regulatory Approval**

The Permitting Requirements section of this Study (Section 3.6) describes the types of permit approvals required for the construction of the proposed WTE Facility. The schedule reflects the permitting processes including the preparation, submission, clarification, and issuance of required permits and approvals. The critical path commences with the update to the Comprehensive Plan, followed by preparation of the Siting Study and EIS, PSD air construction permit, and followed by construction activities. A Human Health and Ecological Risk Assessment (“HHERA”) will be completed as part of the EIS and concurrently with other permitting activities to maintain the overall schedule. It is anticipated that the overall permitting duration is approximately three to five years from preliminary application development through issuance of all required permits.

It should be noted that the fast track schedule presented in Section 3.6.2 below assumes that there are no significant regulatory hurdles or public opposition to the project. The extended schedule allows for up to two years of delay for potential appeals to land use permits or air permits. Should the regulatory agencies present significant objections to or unanticipated requirements for the proposed WTE Facility, there may be one or more constraints created by the additional capital cost, additional regulatory review timeframe, and the potential impacts to the site layout and facility footprint. Public opposition to the project could increase the regulatory review and approval timeframes and thus create one or more constraints to the development of the proposed WTE Facility.

3.4.3 **Anticipated Time Required for Air Permit Approval**

Puget Sound Clean Air Agency (“PSCAA”) has jurisdiction for regulating sources of air pollution in the County. PSCAA Regulation I, Section 6.03 requires a Notice of Construction (“NOC”) application be submitted for all new or modified air pollution sources prior to construction. The proposed WTE Facility will be considered a new major source under the New Source Review (“NSR”) permitting program based on potential emission levels, and as such will be required to complete complex air quality analyses and secure a Prevention of Significant Deterioration (“PSD”) construction permit. In accordance with PSCAA regulations, the Washington Department of Ecology (“WDOE”) is the permitting agency for the PSD program. The PSD permitting process is extensive and includes public participation, USEPA review, and review by Federal Land Managers (“FLM”) responsible for federally protected Class I areas.

The preparation of a PSD permit application to submit to PSCAA and the WDOE will require approximately 18 - 24 months. This estimated time frame includes the completion of required dispersion modeling analyses, control technology review and supporting documentation. After submittal of the permit application, the permitting authority will review the permit application and determine whether the application is complete or if additional information is required. Detailed technical review of the permit application by the permitting agencies and a public review process will follow until final permit issuance. For complex PSD permits, an estimated 12 – 24 months is required for permitting agency review and final permit issuance.

A reasonable time estimate for the entire permit application process, from the development of the air permit application to final permit approval, is approximately 30 – 48 months. Additional time may be required if a permitting authority disagrees with a proposed control technology selection, or if an air quality modeling analysis or challenging public issue needs to be addressed. The extended Siting and Permitting timeline presented in Section 3.4.6 includes a potential delay of 2-years to account for possible appeals to a land use permit or air quality permit or other delays associated with obtaining WTE or WEBR approvals.

3.4.4 **Procurement**

The procurement process currently outlined in the Schedule consists of the following main tasks:

- Procurement strategy development;
- Request for Expressions of Interest ("RFEI") development, response, and response evaluation (depending on procurement strategy this task may not be required);
- Request for Qualifications ("RFQ") development, response, and response evaluation; and
- Request for Proposals ("RFP") development, response, and response evaluation.

It is currently envisioned that the procurement process will consist of issuing two draft RFPs in order to thoroughly incorporate all qualified vendor input into the procurement documents. Award of Contract to the successful vendor is estimated to take approximately one to two years.

The proposed procurement approach will be further refined in the procurement strategy development phase and specific activities may be accelerated or eliminated depending upon the ultimately selected procurement approach. The approach presented herein is based upon the design-build-operate procurement which is typical in this industry; however, there are a variety of alternative delivery methods that could be considered. Procurement is estimated to take approximately one to two years and will be concurrent with the planning, permitting, and siting activities. Thus, it should not affect the critical path of the Schedule.

3.4.5 **Construction-Related Activities**

The construction period outlined in the Schedule is a general overview of the construction process. As the Project moves forward, detailed construction schedules will be developed as part of the planning and procurement process by County consultants and/or the successful vendor. The construction-related activities include:

- Procurement of major equipment;
- Procurement of long lead time items;
- Preliminary site and utilities work;
- Design;
- Construction;
- Commissioning and start-up;
- Acceptance testing and
- Final inspection.

It is currently anticipated that the construction duration is approximately four years from the Notice to Proceed through acceptance testing and commercial operations date (“COD”). The critical path involves design, construction, and procurement of long lead time items. It is estimated that the T-G will need to be purchased at least one year prior to the start of construction. This estimated lead time allows for the T-G to be installed in year 2 of construction for the successful vendor to build around the T-G.

Other activities to consider for the Schedule include Bond Financing and the different approaches available to the County. Financing options are briefly discussed in Section 3.8 Financing Options, but bond financing is the most likely method.

After the equipment procurement and Bond Financing are completed, the next critical path is actual construction activities. It was assumed that the successful vendor will require approximately four years for design, equipment procurement, fabrication, construction and testing to complete the Proposed WTE Facility. Acceptance testing is anticipated to occur in approximately November and December 2027 based upon the Fast-Track preliminary Schedule. This Schedule assumes that there are no issues with market conditions and availability of long-lead time materials and equipment. The Schedule may extend through January 2028 if the permitting and/or siting process is extended beyond the initial four year Fast-Track estimate.

3.4.6 **Project Implementation Schedule Summary**

The preliminary schedule based on long-term implementation plan activities generally includes siting, planning, permitting, procurement and construction-related activities. The schedule represents an eight (8) to eleven (11) year period from the planning stage to the end of acceptance testing, which is longer than similar projects implemented in the past due to siting and permitting requirements in King County. The schedule will be used as a tool to maintain a record of all required activities and will be updated to reflect results of subsequent investigations over the course of the Project implementation period. A summary of the WTE Facility project implementation schedule is provided in Table 3-5 below.

Table 3-5. WTE Facility – Project Implementation Schedule

Task	Activity	Fast-Track Schedule	Extended Siting and/or Permitting Schedule
1	Extend/Negotiate Interlocal Agreements and Update Comprehensive Solid Waste Management Plan	1 to 2 years	2 years
2	Siting / Planning / Permitting	3 years	5 years
3	Procurement (RFQ / draft RFP / Final RFP through selection and Notice of Award)	1 – 2 years (concurrent with Task 2)	2 years (concurrent with Task 2)
4	Design / Build to Commercial Operations Date (COD)	4 years	4 years
Total		8-9 years	11 years
COD Date if Start 1/1/2020		1/1/2028 – 1/1/2029	1/1/2031

Table 3-6 summarizes major activities in the project implementation schedule.

Table 3-6. Major Activities Summary

Task
Interlocal Agreement Negotiation/Extension with Partner Cities
Update to Comprehensive Plan
Site Identification and Land Acquisition (as applicable)
Preliminary Site Preparation
Power Purchase Agreement Negotiations
UTC Process Accelerated Activities
PPSA Process Accelerated Activities
Land Use Determination
Environmental Resource Permitting
PSD Air Construction Permit
Health Risk Assessment
NPDES Stormwater Construction Permit

Task
Procurement
Financing
Design
Construction
Acceptance Testing
Title V Operation Permit
NPDES Stormwater Discharge
Record Drawing Review / Project Closeout

3.5 Cedar Hills Landfill Capacity Impacts

Based on both the high and low bound waste forecast capacity requirement, models were developed to evaluate the disposal capacity required for both excess MSW and residue / ash from 2025 through 2075.

For MSW, disposal options include Cedar Hills and / or WEBR. KCSWD is considering several site development options for Cedar Hills and a preferred option has not been identified. For residue / ash, disposal options include an ash monofill and / or reuse via a cement kiln or similar approved recovery option. This section describes how the disposal forecast would be impacted. At the direction of the County, this Study assumes that Cedar Hills will not be available for ash disposal. In addition, the site development options for the remaining lifetime of Cedar Hills are still under review within the County. Therefore, the effect of different alternatives for MSW disposal was investigated, but not the effect on the landfill remaining useful life.

Variables considered for disposal / reuse capacity requirement were as follows:

- High bound waste forecast.
- Low bound waste forecast.
- Timeline for the WTE facility coming online.
- Timeline for the WTE facility expansion.
- Residue reuse options:
  - Worst Case (No aggregate re-use application) – Residue amount that would need to be landfilled is estimated to be 23% by weight of incoming tonnage. This is a typical residual amount for new WTE technology.
  - Reasonable Case (75% of bottom ash aggregate is re-used in an outside application) – Residue amount that would need to be landfilled is estimated to be 7.5% by weight of incoming tonnage. This assumes bottom and fly ash separation, with the majority of bottom ash re-used in road aggregate application. Many European facilities utilize 100% of bottom ash residual for roads and other applications.

- Best Case (Combined ash re-use application, with only over-sized or larger aggregate pieces remaining) – Residue amount that would need to be landfilled is estimated to be about 2% by weight of incoming tonnage. This assumes combined ash re-use in a cement or asphalt mix scenario and would require WDOE's approval. It is important to note that approval for ash re-use will be subject to regulatory review and constraints and the products will have to comply with provisions in the Washington Administrative Code. This is a manageable process, is utilized widespread in Europe, and has been successfully navigated with regulatory agencies in Florida to allow more widespread re-use over the past 5-10 years.

The following conversion factors were used to convert MSW and residue/ash to cubic yards ("CY") in order to assess landfill capacity requirement, also in CY.

- MSW 1,600 lbs. = 1 cy
- Residue/ash 2,500 lbs. = 1 cy

Tables 3-7 through 3-10 show the effect on total tons of waste to be managed over a 20 and 50-year horizon depending on the waste forecast used and residue reuse options. Ash reuse of 7.5% is a reasonable assumption for this facility and that percentage is used in the primary GHG and financial analysis. However, this is subject to markets being available and willing to take the residue material.

Negative numbers represent overcapacity at the WTE facility (i.e. there is not sufficient waste in the given forecast to meet the treatment capacity of the WTE). This is an opportunity to attract extra external refuse with an associated gate fee.

In addition to advanced metals recycling and ash (aggregate) reuse, another methodology to extend the landfill capacity that the County inquired about was landfill mining. Landfill mining has been performed in few WTE facilities as a fuel in the United States and Europe and only for recently staged waste within 0.5 to 1 year of waste generation in order to maximize waste fuel during period of low waste generation or for increased revenue generation (i.e., heating in winter for WTE facilities connected to heating districts for steam sales). This is primarily because of the low heating content of old MSW which may be further complicated by alternating layers of daily cover and waste that further reduce the quality of waste as a fuel source. This low-quality waste can cause operation and maintenance issues. If the County chooses the WTE option and requires landfill mining, then there should be considerations for only mining waste that is less than one year old and reserved to specific areas of the landfill where waste is placed with intent for recovery (not standard waste storage compared to typical landfill practice). The financial model developed for this study does not include landfill mining.

Complete detailed tables are provided in Appendix A.

Table 3-7. Fast Track WTE Online 2028 – Low Bound Waste Forecast

WTE Online 2028 – 1 million tons. Expansion in 2048 to 1,333,333 tons.																
Year	**Total tons of waste to be managed**	**Worst case: No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled**					**Reasonable Case: 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled**					**Best Case: Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.**				
		Garbage (T)	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**
20-year horizon (2025 - 2045)	20,597,350	2,597,350	3,246,687	4,064,410	5,080,512	8,327,199	2,597,350	3,246,687	1,325,351	1,656,689	4,903,376	2,597,350	3,246,687	353,427	441,784	3,688,471
50-year horizon (2025 -2075)	54,540,180	(2,793,144)	(3,491,430)	11,850,992	14,813,740	11,322,311	(2,793,144)	(3,491,430)	3,864,454	4,830,567	1,339,138)	(2,793,144)	(3,491,430)	1,030,521	1,288,151	(2,203,278)

Table 3-8. Best Case WTE Online 2030 – Low Bound Waste Forecast

WTE Online 2030 – 1 million tons. Expansion in 2048 to 1,333,333 tons.																	
Year	**Total tons of waste to be managed**	**Worst case: No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled**					**Reasonable Case: 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled**					**Best Case: Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.**				
		Garbage (T)	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**
20-year horizon (2025 - 2045)	20,597,350	4,597,350	5,746,687	3,628,809	4,536,011	10,282,698	4,597,350	5,746,687	1,183,307	1,479,134	7,225,821	4,597,350	5,746,687	315,549	394,436	6,141,123
50-year horizon (2025 -2075)	54,540,180	(793,144)	(991,430)	11,415,392	14,269,239	13,277,810	(793,144)	(991,430)	3,722,410	4,653,013	3,661,583	(793,144)	(991,430)	992,643	1,240,803	249,374

Table 3-9. Fast Track WTE Online 2028 – High Bound Waste Forecast

WTE Online 2028 – 1,333,333 million tons. Expansion in 2040 to 1,666,666 tons.																
Year	**Total tons of waste to be managed**	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Reasonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**
20-year horizon (2025 - 2045)	27,830,588	1,830,596	2,288,245	5,576,840	6,971,050	9,259,295	1,830,596	2,288,245	1,818,535	2,273,169	4,561,413	1,830,596	2,288,245	484,943	606,178	2,894,423
50-year horizon (2025 -2075)	76,908,817	908,845	1,136,057	16,717,485	20,896,856	22,032,913	908,845	1,136,057	5,451,354	6,814,192	7,950,249	908,845	1,136,057	1,453,694	1,817,118	2,953,175

Table 3-10. Best Case WTE Online 2030 – High Bound Waste Forecast

WTE Online 2030 – 1,333,333 million tons. Expansion in 2040 to 1,666,666 tons.																
Year	**Total tons of waste to be managed**	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Reasonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**	**Garbage (T)**	**Garbage (cy)**	**Residue/(Ash) (T)**	**Residue/(Ash) (cy)**	**Total disposal capacity required (cy)**
20-year horizon (2025 - 2045)	27,830,588	4,497,262	5,621,577	5,027,540	6,284,425	11,906,003	4,497,262	5,621,577	1,639,415	2,049,269	7,670,847	4,497,262	5,621,577	437,177	546,472	6,168,049
50-year horizon (2025 -2075)	76,908,817	3,575,511	4,469,389	16,168,185	20,210,231	24,679,620	3,575,511	4,469,389	5,272,234	6,590,293	11,059,682	3,575,511	4,469,389	1,405,929	1,757,411	6,226,801

3.6 Permitting Requirements

A preliminary assessment was conducted of the regulatory requirements applicable to the construction and operation of the proposed WTE Facility at an unknown site. Significant permits and approvals that are likely to be required for a WTE Facility were also identified. Information considered in conjunction with this preliminary assessment was obtained from the PSCAA and Washington Administrative Code ("WAC").

Table 3-11 provides a list of potential permit requirements and the associated permitting agency. The list aims to capture all permits that will be or may be required for the construction and operation of a WTE Facility. However, this list may not be exhaustive. The list assumes that the WTE Facility will be located within the County. If the Facility is located outside of County jurisdiction, the local jurisdiction permitting agencies are subject to change. The list of potential permit requirements, with estimated agency permit review periods, coordinating agencies, and supporting documentation required is provided as Appendix B.

Table 3-11. WTE Development Potential Permit Requirements

License, Permit, or Approval Name	Permitting Agency
Planning and State Environmental Policy Act (SEPA) Approvals	
Project-level SEPA Environmental Review and Threshold Determination	KCSWD
Preapplication / Site Plan Review	Permitting Division of King County Department of Local Services
Environmental Impact Statement ("EIS")	KCSWD plus others
Land Use and Related Early Permit Submittals	
Special Use (Land Use) Permit Modification	Permitting Division of King County Department of Local Services
Notice of Intent to Construct a Geotechnical Soil Boring	Washington Department of Ecology ("WDOE")
Notice of Intent for Installing, Modifying, or Removing Piezometers	WDOE
Notice of Intent for Installing, Modifying, or Decommissioning Wells	WDOE
Traffic Control Plan (Traffic Plan / Haul Route)	Roads Services Division of King County Department of Local Services
Stormwater, Grading, and Drainage Control Approval	Permitting Division of King County Department of Local Services (Permitting)
NPDES Construction Stormwater General Permit	WDOE
Street Use Permit(s)	Roads Services Division of King County Department of Local Services

License, Permit, or Approval Name	Permitting Agency
Clean Water Act (CWA) Section 404 permit (Nationwide or Individual)	USACE Seattle District
Environmental Critical Areas Review	Permitting Division of King County Department of Local Services
Endangered Species Act Compliance	US Fish and Wildlife Services ("USFWS") and NOAA Fisheries (jointly, the "Services")
Clean Water Act ("CWA") Section 401 Water Quality Certification	WDOE
Hydraulic Project Approval ("HPA")	Washington Department of Fish and Wildlife ("WDFW")
Air Quality Notice of Construction ("NOC") / Prevention of Significant Deterioration ("PSD") Construction Permit	PSCAA and Washington Department of Ecology
Notice of Construction or Alteration	Federal Aviation Administration ("FAA")
Building and Construction Permits	
Clearing and Grading	Permitting Division of King County Department of Local Services or City
Side Sewer Permit for Temporary Dewatering of Construction Sites, if required	Permitting Division of King County Department of Local Services or City
King County Industrial Wastewater Construction Dewatering Discharge Permit	King County Wastewater Treatment Division, coupled with SPU approval
Building / Construction	Permitting Division of King County Department of Local Services or City
Shoring	Permitting Division of King County Department of Local Services or City
Structural	Permitting Division of King County Department of Local Services or City
Electrical	Washington State Department of Labor and Industries ("L&I")
Mechanical	Permitting Division of King County Department of Local Services or City
Plumbing	Permitting Division of King County Department of Local Services or City
Energy Code	Permitting Division of King County Department of Local Services or City
Water / Sewer / Fire Flow Certificate	Permitting Division of King County Department of Local Services or City

License, Permit, or Approval Name	Permitting Agency
Drainage	Permitting Division of King County Department of Local Services or City
Geotechnical Report	Permitting Division of King County Department of Local Services or City
Utility	Permitting Division of King County Department of Local Services or City
Side Sewer Permit	Permitting Division of King County Department of Local Services or City
Post-Permit Submittals	Permitting Division of King County Department of Local Services or City
On Site Fueling Permit	WDOE
Operating Permits and Approvals	
Solid Waste Permit	Washington Department of Ecology via Public Health Seattle-King County (PHSKC)
Title V Air Operating Permit	PSCAA
Elevator Operating Permit	Permitting Division of King County Department of Local Services and L&I
King County Industrial Wastewater Discharge Permit	King County Wastewater Treatment Division
NPDES Stormwater General Permit Coverage	WDOE
Weighing and Measuring Devices License	Washington Department of Licensing / Department of Agriculture
Fire Department Permits: Motor Vehicle Fueling Station [Above-ground Tanks]; Combustible Liquids/Flammable Liquids; Fuel Dispensing [open use] into Equipment from Above-Ground Tank; Fleet Fueling Site; and Waste Handling)	Permitting Division of King County Department of Local Services
Building Commissioning	Permitting Division of King County Department of Local Services
Certificate of Occupancy	Permitting Division of King County Department of Local Services
On Site Fueling Permit	WDOE

3.6.1 Planning and SEPA Approvals

This is step one of the permitting process. A number of these items can be conducted in parallel once a site has been identified.

3.6.2 Land Use and Related Early Permit Submittals

Several permits must be obtained in relation to land use prior to commencing construction. This is also the stage an ash monofill permit will be applied for, if necessary.

3.6.3 Building and Construction Permits

These permits will be required for the construction period for the WTE facility.

3.6.4 Operating Permits and Approvals

In addition to the permits and regulations above, other permits and approvals may be required for the operation of the proposed WTE Facility, including, but not limited to a NPDES permit if discharging to surface or ground water. An industrial wastewater discharge permit maybe required if the water is going to the County metro system.

3.6.5 Air Construction Permit

One of the critical permits required for the proposed WTE Facility is the air construction permit. The proposed WTE Facility would be considered a new major source of air pollutant emissions and be required to obtain a PSD permit under the NSR permitting program. PSCAA regulations specify that the WDOE is the permitting agency for the PSD program. The PSD permitting process is complex, includes public participation, and requires completion of various air quality analyses. These analyses include BACT analyses for the air pollutants associated with the planned emission units, dispersion modeling analyses to determine air quality impacts at nearby receptors and at receptor locations within federally protected Class I areas, visibility analyses to determine impacts at the Class I areas, and a toxic air contaminant impact analysis. Prior to issuance of a final air construction permit, multiple iterations of these analyses will likely be required to address any adverse impacts and to satisfy concerns of the permitting authorities, FLMs responsible for the Class I areas, and the public.

All sources at the Facility must also comply with applicable federal New Source Performance Standard ("NSPS") established in 40 CFR 60 and National Emission Standards for Hazardous Pollutants ("NESHAP") in 40 CFR 61 and 63. In particular, the municipal waste combustors to be installed at the Facility will be subject to 40 CFR 60, Subpart Eb. This regulation prescribes emission standards, requires monitoring and performance testing, and includes siting requirements. The siting requirements specify that a detailed Materials Separation Plan be completed (preliminary and final draft versions) with a defined public review process.

As a major source, the Facility will also be required to obtain a Title V operating permit. A Title V permit application can be submitted after the PSD construction permit is issued or concurrently with the PSD construction permit application. Considering the complexities associated with the Facility and anticipated construction schedule, it is recommended to prepare and submit the Title V permit application after the PSD construction permit is issued.

3.7 Financial Analysis

The Arcadis Team developed a financial model to estimate the costs for development, construction, operation, and expansion of a WTE facility over the 50-year planning period. This model can be used to compare the costs of a 3,000 tpd facility and a 4,000 tpd facility as well as comparing the estimated WTE costs with the anticipated cost for WEBR.

3.7.1 Development of Cost Estimates

The most recent greenfield WTE facility constructed in the United States was in West Palm Beach, Florida and reached commercial operations in 2015. The West Palm Beach Facility has a 3,000 ton per day capacity, with an annual processing capacity of 1 million tons. A design-build-operate contract method was used, so the contracted entity was responsible for design, construction, and operation of the municipally-owned facility. The size and technology of the West Palm Beach Facility will be similar to a facility developed for the County, and therefore the construction and operations cost for the West Palm Beach Facility was used as a basis for the cost estimates for a County facility. Cost information from other facility refurbishment projects were also used as well as resources with national WTE facility information.

3.7.1.1 Capital Cost

The West Palm Beach Facility construction cost was escalated from 2015 dollars to 2019 dollars. In addition, portions of the West Palm Beach construction cost were adjusted for location. Labor was assumed to be 15% of the construction cost based on known project labor breakdown with adjustments for a greenfield site, which was then adjusted to account for higher labor costs in Seattle compared to Miami based on US Bureau of Labor Statistics location factors. Equipment cost was estimated to be 19% of construction cost based on known project equipment breakdown, which was then adjusted to account for higher sales tax rate in King County (10%) compared to West Palm Beach during construction (6%). Any difference in costs for salaried wages, materials, and subcontractors is considered minimal and likely covered in the project contingency. Additional costs were added for carbon sequestration in anticipation of upcoming greenhouse gas regulations as discussed in Sections 3.9 and 3.11, land acquisition costs estimated at approximately $900,000 per acre, and advanced metal recovery equipment and processing based on the anticipated quantity of ash produced.

A project contingency of 3% of the construction cost was included, as the reference case base construction cost had significant contingency already included, such as $22M in allowances and all change orders included, which represents greater than 2% of the total construction cost. An additional three percent of the construction cost was included for consulting fees, which includes legal fees for contract development and negotiations, engineering fees for owner’s agent services, and other consulting fees that may be needed. It is assumed that bonds will be issued for the contractor design and construction cost. Bond issuance costs are typically 0.6% of the amount needed / principal. We are also including an additional 6.7% for additional bond issuance costs assumed to cover cash flow requirements for a total issuance cost of 7.3%. The bond interest rate is assumed to be 4.0% for a 30-year term.

The modeled 3,000 tpd facility defers to the low-bound tonnage forecast with anticipated 1,000 tpd expansion to be completed in 2048 for total expanded capacity of 4,000 tpd.

The modeled 4,000 tpd facility defers to the high-bound tonnage forecast with anticipated 1,000 tpd expansion to be completed in 2040 for a total expanded capacity of 5,000 tpd. Construction cost estimates for a facility above 3,000 tpd were added as 75% of the base 3,000 tpd facility per tpd above 3,000.

Expansion capital cost estimates are based on 40% of the per tpd construction cost for a 3,000 tpd facility, escalated to the year of the start of design and construction of the expansion. The 40% of per tpd is based on 30% of the original three unit (3,000 tpd) costs because the expansion would be adding one unit to the three existing units for the base case, plus an additional 10% of the original construction cost for general equipment refurbishment due to equipment age and use. It is assumed that design and construction will begin two years before the expanded capacity is required. The cost for additional carbon sequestration equipment for the 1,000 in additional tpd is also included. The estimate assumes land and site work required for expansion was included in initial construction and assumes Advanced Metals Processing (AMP) expansion is not required.

3.7.1.2 Operations and Maintenance Cost

The contract operator Operations and Maintenance (“O&M”) fee cost estimate was based on the West Palm Beach Facility 2019 base annual operating fee of $23.06M, but rounded up to $25M for 2019 because of the additional cost for operation and maintenance of the anticipated additional equipment for carbon sequestration and advanced metal recovery not included in the West Palm Beach Facility. This O&M Fee is based on a 3,000 tpd facility and the cost is 50% of the per tpd cost for a facility with capacity above 3,000 tpd and escalated from 2019 dollars to future year dollars.

Consumables costs for air pollution control reagents including lime, urea (ammonium hydroxide), and carbon are based on the West Palm Beach facility 12-month average usage rate and the third quarter 2018 cost for the reagents. Reagents may escalate more quickly than other costs. The cost model currently uses the common model CPI factor. Additional costs for utilities such as natural gas, water, and wastewater, which are usually pass-through costs from the facility Operator to Owner are also included. Quantities of utilities were estimated based on the usage per tpd capacity of a similar sized facility. Utility costs were based on published information for the Washington area: natural gas price is based on May 2019 US Energy Information Administration (EIA) industrial natural gas price, potable water price is based on Seattle Utility wholesale water customer rates, and wastewater price is based on Seattle Public Utilities commercial sewer rates. Cost for purchased electricity required is not included as it is typically paid for by the Operator.

Ash disposal costs included in the base model assume WEBR using an existing IMF that would have available capacity for the estimated amount of ash. The ash disposal costs also assume higher compaction rate of 30 tons per container, as ash is more dense than MSW without compaction. The WEBR estimated disposal costs including hauling cost to the IMF but excluding capital cost for a new IMF are used. This is due to the smaller total volume of waste being used for WEBR and assumes that an existing IMFs should have capacity to handle this capacity without capital improvements. An additional scenario of ash disposal at Cedar Hills could also be used and would provide reduced disposal costs.

Haul costs for waste transport from existing transfer stations to the WTE Facility were estimated in the WEBR analysis and assume current waste compaction rate and a similar distance from the transfer stations to the current landfill. An additional scenario could assume negligible change in hauling compared to current hauling for both WTE or WEBR disposal, but this cost is highly dependent on the location of the WTE facility or IMF, which are unknown at this time.

Previous analysis by others included significant amounts of bypass waste. Bypass waste is typically defined as waste that can be processed at the WTE facility but is bypassed due to waste storage restrictions. The WTE model includes an input for bypass waste tonnage which is only included as a disposal expense and does not reduce the facility throughput or operational costs. Realistically, there should be limited bypass waste as the facility and expansion timing assume there is more capacity than estimated tonnage with the ability to turn off supplemental waste during high volume periods. Outages can be managed to minimize significant facility capacity reduction, and waste received during facility outages can be stored in the pit for use once the units are operational.

Nonprocessable waste refers to oversized materials that cannot be processed at the WTE facility, such as large appliances, construction and demolition debris, furniture, mattresses, and oversized carpet. Based on the 2015 Waste Characterization and Customer Survey Report, these wastes made up approximately 3.5% of the waste stream, after removing C&D which is no longer accepted after 2018. In the financial model, the estimated quantity of nonprocessable waste was deducted from the waste projections to account for the reduction in facility throughput, operational costs, and added disposal costs as well as allowing for out of County waste disposal up to the WTE facility design capacity.

3.7.1.3 Other Costs and Assumptions

Capital cost escalation rate and annual operating fee escalation are currently modeled at 3.0% based on historic contractual escalation seen at other facilities and review of national CPI information. This escalation rate is also used for other costs and revenues, except for electrical energy revenues, and for WEBR cost escalation. Actual cost escalation can be highly variable based on economic conditions and may also be different for the different facility costs and revenues.

Facility availability is assumed to be approximately 91%, which is low compared with the standard for the industry. This lower availability provides an additional layer of conservatism to ensure all County capacity can be processed. Processable waste processed is assumed to be constant over the term of the model, but facilities can experience fluctuations based on unanticipated outages, major equipment failure, or force majeure events. The model also assumes the annual throughput guarantee (typically an O&M contract value) is equal to the processible waste processed (facility performance), as there are usually additional fees, at a reduced price, paid to the operator for waste processed above the annual throughput guarantee. Because of the reduced price on O&M fees and associated revenues with processing above the facility capacity, additional costs are considered negligible.

HHV of a fuel is the heat released from the complete combustion of the material calculated by returning all the products to pre-combustion temperature and is dependent on the composition of the material being combusted. Because waste composition varies with region and season, the HHV of waste can fluctuate. The Operator can manage the waste in the pit to help homogenize the HHV by mixing and fluffing the waste fed into the boilers. For modelling purposes, the Facility is assumed to have a design HHV of 5,000 BTU per pound and an Annual Average HHV of 5,200 BTU per pound. The HHV values of the waste impact electrical generation rates and therefore electrical energy revenues. Actual HHV variability may impact actual facility capacity which impacts available capacity for outside waste, electrical generation, cost per ton calculations, and facility performance.

Ferrous and non-ferrous estimates are based on the County waste composition numbers indicating 4.7% unrecovered metals in the waste to the landfill. Assuming 28.3% ash generation from the waste, it is estimated that there are approximately 16.6% metals in the ash stream. This is separated into approximately 15% ferrous and 1.5% non-ferrous. The metals recovery rate is estimated at 98% recovery based on West Palm Beach reference facility and experienced increases in recovery with AMP facilities.

The metals market prices used are based on national average pricing, current pricing from other similar facilities, and assume higher price for cleaner metals usually collected from AMP. The current estimated pricing is not escalated to the start year, but used as the input value for the start year to provide some conservatism. The model assumes the County receives all metals revenues with no revenue share to the operator. If an Operator revenue share is included, it would often result in a lower base O&M fee and can incentivize the operator to more efficiently operate the metals recovery system. Aggregate recovery from the ash stream is estimated to be 57% of the total ash residue, which is consistent with the reasonable best-case scenario from the landfill capacity model. The model currently assumes no revenue for the aggregate recovered but does assume that that recipient will pay the costs to haul the aggregate off site, which reduces the quantity of ash requiring disposal at the facility. As aggregate users are identified, revenue from aggregate sales could be realized but is not currently included in the financial model.

The following tables show WTE project costs for an initial 3,000 tpd facility, with 1,000 tpd expansion in 2048 and an initial 4,000 tpd facility, with a 1,000 tpd expansion in 2040. Green cells identify initial costs and purple cells identify expansion costs. Costs shown are less revenues. Revenues are identified and discussed in Section 3.10 Facility Revenue Analysis.

Table 3-12. Initial 3,000 tpd Facility Project Costs Summary

Engineering Procurement Construction (EPC) Contractor Initial Capital Price	$1,053,375,847
Consulting Fees	$31,601,275
Bond Issuance Cost / Interim Financing	$76,896,437
Other Costs - Contingency	$31,601,275
Total Initial Construction Costs	**$1,193,474,835**
EPC Contractor Expansion Capital Price	$255,525,791
Consulting Fees	$7,665,774
Bond Issuance Cost / Interim Financing	$18,653,383
Other Costs - Contingency	$7,665,774
Total Expansion Construction Costs	**$289,510,721**
Total O&M Costs (over 20-Yr O&M Term)	$1,686,825,351
O&M Electrical Sales Revenues	$485,597,009
O&M Metals Recovery Sales Revenues	$212,388,545
O&M Non-County Waste Revenues	$34,281,541
Total O&M Revenues (over 20-Yr O&M Term)	$732,267,096
Total O&M Net Costs (over 20-Yr O&M Term)	**$954,558,255**
Total O&M Costs (over remaining 30-Yr O&M Term)	$6,408,079,190
O&M Electrical Sales Revenues	$1,415,656,506
O&M Metals Recovery Sales Revenues	$905,572,434
O&M Non-County Waste Revenues	$650,807,134
Total O&M Revenues (over remaining 30-Yr O&M Term)	$2,972,036,074
Total O&M Costs (over remaining 30-Yr O&M Term)	**$3,436,043,116**
Total Initial Construction and O&M Costs	**$2,148,033,090**
Total Cost Per Ton (over 20-Yr O&M Term)	**$107.40**
Total Expansion Construction and O&M Costs	**$3,725,553,837**
Total Expansion Cost Per Ton (over remaining 30-Yr O&M Term)	**$372.56**

Table 3-13. Initial 4,000 tpd Facility Project Costs Summary

EPC Contractor Initial Capital Price	$1,317,627,588
Consulting Fees	$39,528,828
Bond Issuance Cost / Interim Financing	$96,186,814
Other Costs - Contingency	$39,528,828
Total Initial Construction Costs	**$1,492,872,058**
EPC Contractor Expansion Capital Price	$203,848,579
Consulting Fees	$6,115,457
Bond Issuance Cost / Interim Financing	$14,880,946
Other Costs - Contingency	$6,115,457
Total Expansion Construction Costs	**$230,960,441**
Total O&M Costs (over 20-Yr O&M Term)	$2,237,584,299
O&M Electrical Sales Revenues	$718,039,869
O&M Metals Recovery Sales Revenues	$316,588,743
O&M Non-County Waste Revenues	$140,878,236
Total O&M Revenues (over 20-Yr O&M Term)	$1,175,506,847
Total O&M Net Costs (over 20-Yr O&M Term)	**$1,062,077,452**
Total O&M Costs (over remaining 30-Yr O&M Term)	$7,934,599,769
O&M Electrical Sales Revenues	$1,769,570,633
O&M Metals Recovery Sales Revenues	$1,131,965,542
O&M Non-County Waste Revenues	$186,020,416
Total O&M Revenues (over remaining 30-Yr O&M Term)	$3,087,556,591
Total O&M Net Costs (over remaining 30-Yr O&M Term)	**$4,847,043,178**
Total Initial Construction and O&M Costs	**$2,554,949,509**
Total Cost Per Ton (over 20-Yr O&M Term)	**$95.81**
Total Expansion Construction and O&M Costs	**$5,078,003,619**
Total Expansion Cost Per Ton (over remaining 30-Yr O&M Term)	**$507.80**

3.7.2 Financial Analysis

Financial analysis of the WTE financial model includes evaluation of costs at approximate 10-year (end of 2037), 20-year (end of 2047) and 50-year (end of 2077) terms assuming construction is completed by the end of 2027. If construction schedule varies, estimates may change due to change in estimated inflation, but should not impact comparison with WEBR on total financials. The WTE financial model was developed to compare costs for WTE facilities of different capacities and for comparison with WEBR estimated costs. Comparison with WEBR is included in Section 5. For comparison purposes, the model assumes WEBR would begin at the same time as Facility commercial operation.

Base model data is provided in this Study and includes several analysis parameters with different modeling options. Base model parameters were often selected to provide a more conservative financial analysis to ensure this study does not over-promise the benefits of the Facility. While all model input values can be modified or adjusted, certain significant scenario parameters and options, the base model option used, and the most realistic option are identified in Table 3-14. When the base model option used in the following analysis differs from an alternate achievable option, that parameter is identified in red font in the Alternate Achievable Option column.

Table 3-14. Financial Analysis Parameters

Scenario Parameters	Options	Base Model	Alternate Achievable Option
Facility Initial Capacity	3,000 tpd with low bound tonnage projection, 4,000 tpd with high bound tonnage projection	Both	3,000 tpd (low bound tonnage projection)
Hauling cost to WTE or WEBR	Include or Exclude for both WTE and WEBR	Include	Exclude (likely same as current hauling cost)
Non-County Waste Processing	Include, Exclude, or Partial	Include	Include (more efficient operation and cost per ton, realistic revenue source)
Land Acquisition Cost	Include or Exclude for both WTE and WEBR	Include	Exclude (highly variable; assumes County property used)
Ash Disposal Cost	WEBR or Existing Landfill	WEBR	Existing Landfill (lower cost and available capacity)
Bypass Waste	Annual Tonnage Bypassed	5,000 tons	0 tons (available storage at facility)
Nonprocessable Waste	Percent of County waste produced but not processible at the WTE facility	3.5%	5% or less (Other analysis assumed 5%, but likely lower based on waste composition data)
Contingency	Percentage of Construction Cost	3%	5% or less, West Palm price already included $22M in allowances (1.9%)

*red font indicates alternate achievable option different from Base Model

Financial model metrics reviewed include the following:

- Total Construction Cost
- Total O&M Costs
- Total O&M Revenues
- Total Net O&M Costs
- Total Costs

- Total Cost Per Ton
- Net Present Value (“NPV”) of Construction
- NPV of Net O&M Costs

Facility revenues are identified and discussed further in Section 3.10, Facility Revenue Analysis.

The modeled 3,000 tpd facility uses the low-bound tonnage forecast with anticipated 1,000 tpd expansion to be completed in 2048 for total expanded capacity of 4,000 tpd. The modeled 4,000 tpd facility uses the high-bound tonnage forecast with anticipated 1,000 tpd expansion to be completed in 2040 for a total expanded capacity of 5,000 tpd. Therefore, the facility capacity selection is dependent on the anticipated waste tonnage.

Table 3-15. Overall Financial Analysis Summary

Term End Year	2028	2037	2047	2077
Term (years)	**Initial Constr. Cost and O&M Term**	**10**	**20**	**50**
3,000 tpd – Low Bound Tonnage Case				
Total Construction Cost	$1,193,474,835	$690,187,680	$1,413,860,228	$2,572,836,051
Total O&M Costs	$1,686,825,351	$717,846,837	$1,686,825,351	$8,094,904,540.78
Total O&M Revenues	$732,267,096	$341,497,157	$732,267,096	$3,704,303,169
Total Net O&M Cost	$954,558,254.92	$376,349,680.65	$954,558,254.92	$4,390,601,371.35
Total Net Costs	$2,148,033,090	$1,066,537,361	$2,368,418,483	$6,963,437,423
Total Net Cost Per Ton	$107.40	$106.65	$118.42	$116.06
4,000 tpd – High Bound Tonnage Case				
Total Construction Cost	$1,492,872,058	$863,329,391	$1,860,223,433	$2,990,682,128
Total O&M Costs	$2,237,584,299	$892,336,917	$2,237,584,299	$10,172,184,068
Total O&M Revenues	$1,175,506,847	$457,653,011	$1,175,506,847	$4,263,063,438
Total Net O&M Cost	$1,062,077,452	$434,683,906	$1,062,077,452	$5,909,120,630
Total Net Costs	$2,554,949,509	$1,298,013,297	$2,922,300,885	$8,899,802,758
Total Net Cost Per Ton	$95.81	$97.35	$99.62	$112.18

The model includes a proforma to show estimated annual costs and escalation which is used to provide the total term costs in the above table. This proforma includes capital cost as amortized annual costs over the term of the bond financing. The proformas for the base 3,000 tpd initial capacity and 4,000 tpd initial capacity scenarios over the 50-year term are provided in Appendix C as the O&M Worksheet.

The financial analysis also includes NPV costs. The NPV analysis uses a 4.5% discount factor as dictated by County policy. It is assumed that the construction costs are fixed from the bid acceptance to the end of construction, so estimated 2023 values equal 2028 values. Then the operations costs are discounted to 2028 values. The NPV cost per ton values are calculated using the total cost NPV divided by the total tons processed during that NPV period. A summary of the NPV analysis is provided in Table 3-16 and Table 3-17.

Table 3-16. Net Present Value 3,000 tpd Facility Project Costs

Net Present Value of Initial EPC Contractor Price and Bond Issuance	$1,014,798,073
Consulting Fees and Contingency	$63,202,551
Total Initial Construction Costs NPV	**$1,078,000,624**
Net Present Value of Initial Operation & Maintenance (20-year term)	$584,014,891
TOTAL Initial Net Present Value	**$1,662,015,514**
Net Present Value of Expansion EPC Contractor Price and Bond Issuance	$261,600,029
Consulting Fees and Contingency	$7,665,774
Total Expansion Constriction Costs NPV	**$269,265,803**
Net Present Value of Expansion Operation & Maintenance (30-year)	$1,614,889,836
TOTAL Expansion Net Present Value	**$1,884,155,639**
Total Capital Cost NPV (over 50 Years)	$1,247,724,761
Total O&M Cost NPV (over 50 Years)	$1,253,617,431
Total Cost NPV (over 50 Years)	**$2,501,342,191**
Total Capital Cost Per Ton NPV (over 50 Years)	$20.80
Total O&M Cost Per Ton NPV (over 50 Years)	$20.89
Total Cost Per Ton (NPV over 50 Years)	**$41.69**

Table 3-17. Net Present Value 4,000 tpd Facility Project Costs

Net Present Value of Initial EPC Contractor Price and Bond Issuance	$1,269,372,125
Consulting Fees and Contingency	$79,057,655
Total Initial Construction Costs NPV	**$1,348,429,780**
Net Present Value of Initial Operation & Maintenance (20-year term)	$652,979,062
TOTAL Initial Net Present Value	**$2,001,408,842**
Net Present Value of Expansion EPC Contractor Price and Bond Issuance	$208,694,372
Consulting Fees and Contingency	$6,115,457
Total Expansion Constriction Costs NPV	**$214,809,829**
Net Present Value of Expansion Operation & Maintenance (30-year)	$2,291,145,439
TOTAL Expansion Net Present Value	**$2,505,955,268**
Total Capital Cost NPV (over 50 Years)	$1,546,361,799
Total O&M Cost NPV (over 50 Years)	$1,602,986,159
Total Cost NPV (over 50 Years)	**$3,149,347,958**
Total Capital Cost Per Ton NPV (over 50 Years)	$19.49
Total O&M Cost Per Ton NPV (over 50 Years)	$20.21
Total Cost Per Ton (NPV over 50 Years)	**$39.70**

The Financial Analysis Model has several worksheets used to perform the analysis. Model worksheets for the base 3,000 tpd initial capacity and 4,000 tpd initial capacity scenarios are included in Appendix C.

3.8 Financing Options

Construction of a large capital project, such as a WTE facility, is most often financed, as most entities do not have the available funds to pay for the capital costs when constructed. There are a limited number of financing options for large capital projects, with the most common being municipal bond financing. Because the KCSWD is an enterprise fund which receives fees for the service provided, the County would likely use a form of long-term revenue bond financing. The bond financing interest rate is dependent on the applicant’s credit rating and is estimated for the purpose of this Study to be 4% based on other recent County financings. It is likely that issuance of General Obligation bonds or revenue bonds with a general obligation guarantee would result in a lower interest rate. Bond financing terms can vary and are determined during agreement development. For the purposes of this Study, a 30-year bond term is being utilized.

Another financing option is for a third-party financing as part of a contract to design, build, and operate a facility. This option typically costs more than the long-term revenue bond financing option as the contracting entity is taking on more risk for the project and the County would not have the advantages of facility ownership. This option was not considered in the financial analysis of this project. Other options are also available but are also likely more costly than the traditional long-term revenue bond financing or are not available to the County. These include commercial paper, bank loans, and inter-fund borrowing.

3.9 Regional Electric Market and Regulatory Structure

Based on the Washington State Energy Profile provided by the U.S. Energy Information Administration, eight of the ten largest power plants in Washington are hydroelectric facilities, making Washington the top U.S. producer of hydroelectric power – routinely contributing more than one-fourth of the nation's total net hydroelectric generation. Hydroelectric power typically accounts for about two-thirds of Washington's electricity generation, and provides lower-cost electricity to the region, compared to power prices in other states. Natural gas-fired power plants, the state's one nuclear power plant, wind turbines, one coal-fired power plant, and biomass-fired power facilities, account for almost all of Washington's remaining net electricity generation. Overall energy consumption in Washington is slightly below the national average on a per capita basis. Because of its significant hydroelectric generating capacity, Washington produces more electricity than it needs to satisfy in-State demand and is an exporter of electricity to the Canadian power grid and supplies power to 14 other western states.

The Grand Coulee Dam on Washington's Columbia River is the sixth largest hydroelectric plant in the world and is the nation's largest electricity generating plant of any kind when measured by capacity. The two largest nonhydroelectric power plants in the State are the Centralia coal-fired power plant and the Columbia nuclear power plant. Centralia produced less than 5% of Washington's net generation in 2017, and both plant’s coal-fired units are scheduled to retire, one in 2020 and the other in 2025. Natural gas or renewable-generated electricity is expected to replace the lost power. The Columbia nuclear power plant has been in operation since 1984 and is the state's third largest generating facility. It is located near the Columbia River in the south-central part of the state on the U. S. Department of Energy's Hanford Site. Wind is the fourth largest source and the state's largest source of non-hydroelectric renewable electricity.

On average, about 80% of the state's net electricity generation originates from renewable energy, making it second in the nation after California. Hydroelectric power represents about nine-tenths of the State's renewable power generation. Wind and biomass account for most of the remaining renewable generation. The State's first utility-scale wind project came online in 2001. Wind resource continues to be developed, particularly along the Columbia Gorge. More than 1,700 turbines with about 3,100 MW of capacity make wind power the second-largest contributor to the State's renewable generation. Solar energy represents a small fraction of the renewable energy generation, with almost all of it coming from rooftop and other small-scale solar power installations. However, the State's largest solar energy project (180 MW) is being constructed at a former coal mine and scheduled to come online in 2020.

In 2006, Washington adopted a renewable portfolio standard (“RPS”) and an energy efficiency resource standard requiring large utility companies to obtain 15% of their electricity from eligible renewable sources by 2020, as well as to undertake cost-effective energy conservation. A wide range of renewables were eligible, including wind, solar, geothermal, landfill gas, wave, ocean or tidal power, methane gas derived from wastewater treatment, and biomass/biodiesel. Hydropower is included if efficiency improvements were met. Waste to Energy is currently not included as a renewable source.

In 2019, Washington passed the Washington Clean Energy Transformation Act (“CETA”), mandating utilities reduce greenhouse gas emissions through several stages, beginning with the elimination of coal power state-wide. Furthermore, CETA dictates that all retail electricity sales in Washington must be carbon neutral by 2030. This goal can be reached through various pathways, including the utilization of renewable resources, non-emitting technologies, or by offsetting emissions through renewable energy credits. By 2045, all utilities in the state are mandated to obtain electricity from sources classified as renewable or non-emitting. Failure to comply with the carbon neutral goals and subsequent renewable or non-emitting goals will require utilities to pay administrative penalties based on the magnitude of the compliance shortfall (i.e., $/non-compliant megawatt-hour).

The single, existing WTE facility within Washington has received specific exemptions and exclusions within the rule but will still need to meet a series of escalating requirements to continue to sell generated electricity. To meet the carbon neutral requirements, new WTE facilities would likely require inclusion of carbon sequestration or carbon capture to offset emissions or require a utility to also purchase renewable energy credits to offset the carbon emissions of the facility. Absent modification of the rule, which can certainly occur over the 25-year compliance period, after 2045 the sale of electricity within Washington from a new WTE facility, even with carbon sequestration or capture, will be difficult. Municipal solid waste, as currently defined in the rule, is not considered biomass and therefore it is our interpretation that, under the current rule, electricity recovered from a WTE facility would not be considered renewable energy. Similarly, as currently defined, "Nonemitting electric generation" means electricity from a generating facility or a resource that provides electric energy, capacity, or ancillary services to an electric utility and that does not emit greenhouse gases as a by-product of energy generation." This non-emitting language could affect all WTE and landfill gas power generation unless revised in the future or the definitions are interpreted by regulators or legislators to allow for flue gas carbon capture that would completely remove all carbon from the stack flue gases.

These factors all affect the potential facility revenue from electrical generation sales as well as the design of the facility. Adoption of the RPS requires large utility companies to obtain an increasing proportion of their energy from renewable sources, which may encourage the local utility to purchase power from the WTE facility or may discourage WTE depending on the evolution of the RPS/CETA and whether or not electricity generated by a WTE facility is redefined to be renewable. The way existing hydropower is considered relative to a utility's compliance with the RPS will also have a significant effect on the overall viability of the sale of electricity that is produced by the WTE facility. Even so, because hydroelectric generated power, which is the source of most of the electric generation in Washington, is one of the lowest price generating types, electricity pricing will likely remain relatively lower and stable over time. Also, because Washington is mandating carbon-neutral electrical sales (and ultimately carbon-free), the capital cost of the facility includes additional estimated costs for carbon sequestration. This and other greenhouse gas impacts are discussed further in Section 3.12 Greenhouse Gas Impacts.

3.10 Facility Revenue Analysis

There are several opportunities for revenue from a WTE facility including electricity sales, materials recovery and tipping fees. Dependent upon the electricity market, revenues from electricity sales can be one of the more significant revenue sources. Additional revenues are often realized through recovery of metals from the waste stream, usually post combustion. More recently with the development of ash reuse methodologies and advanced metals processing equipment, focus has been placed on possible re-use of aggregate materials from the post combustion ash. Recovered WTE aggregate is a developing market with revenues dependent on area market and demand. Another revenue source is from tipping fees for disposal of waste at the facility, and is dependent on the owner of the facility, facility customers, and facility capacity. These revenue sources and applicability to the potential County WTE facility will be discussed in this section.

The revenue estimates use current estimates as Facility Operation Year 1 prices in the WTE financial model, and therefore are conservative estimates for potential facility revenues. Actual revenue experience during the first year of operation, potentially eight years after starting the planning process, may be higher than estimated due to economic inflation.

3.10.1 Energy Revenues

Power Pricing and Escalation

Washington is a net electrical energy exporter and is already about 80% renewable electricity generated if existing hydroelectric is considered. Hydroelectric is one of the lowest price generating types, particularly if debt service has been retired, which will keep electricity pricing relatively lower and stable over time. Many of the largest hydropower facilities are owned / operated by the Federal Government. The plants are as old as 60 years. So, dependent upon reinvestment needs, pricing could be pushed up a bit over time to maintain operability / functionality. The greatest risk over 20 years would be if any of the facilities needed to be decommissioned or if weather changes dramatically enough to have a significant effect on flows and consequently operation and output of the hydropower facilities. A coal plant that provides roughly five percent of the State’s power is being retired. However, excess hydroelectric generation is available. Because the Mid-Columbia Zone serves 14 Western States and ties into the Canadian grid, electricity sales and market conditions are driven by more than just Washington’s in-State energy use / dynamics.

Power prices do not necessarily correlate precisely with inflation. The escalation rate for electricity is influenced by several variables including source makeup within a region, regulatory changes, and market conditions. Electricity pricing for the various sectors in Washington for May 2018 and May 2019 are shown in Table 3-18 below (pricing is in cents/kWh).

Table 3-18. Washington Sector Electricity Pricing

Residential		Commercial		Industrial		Transportation		All Sectors	
May 18	May 19	May 18	May 19	May 18	May 19	May 18	May 19	May 18	May 19
9.81	9.70	8.74	8.62	4.44	4.37	9.32	9.00	7.82	7.69

Based on an evaluation of historic day ahead market ("DAM") pricing since 2008, it appears that pricing is nearly flat with some variability over time, both upward and downward as shown in Figure 3-4 below.

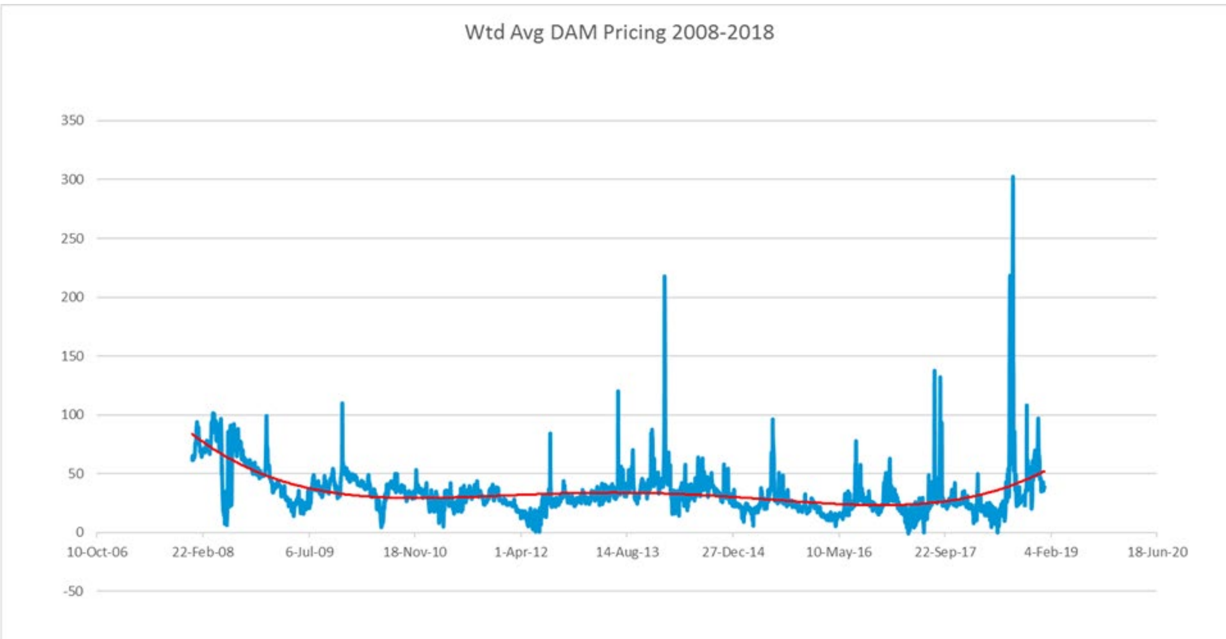


Figure 3-4. Weighted Average Day Ahead Market Pricing for 2008 - 2018

The weighted-average day ahead market pricing for each year during the period is shown below in Table 3-19.

Table 3-19. Weighted Average Day Ahead Market Pricing by Year

Year	Weighted Average $/MWH
2008	61.18
2009	35.85
2010	35.97
2011	29.42
2012	23.03
2013	37.39

Year	Weighted Average $/MWH
2014	38.82
2015	26.05
2016	22.96
2017	26.19
2018	37.40

Since the beginning of 2019, the average weighted day ahead market pricing is $41.71/MWh, but is heavily biased by a price of $890.56 on March 1st. Excluding this data point, the average for the year to date is $35.34/MWh. Recognizing that most of the electricity within Washington is produced by hydroelectric generation, which is not subject to fuel pricing variability, lesser price escalation would be expected over time when compared against regions with greater reliance on natural gas-fired generators. For the purposes of future revenue simulation from electricity sales, a current day ahead market price of $35.00/MWh, escalated at 1.5% annually seems appropriate and is included in the WTE financial model.

The 2019 high price, excluding the March 1st outlier, was $38.68/MWh, which is 10.5 percent higher than the average. The 2019 low price, excluding the March 1st outlier, was $31.67/MWh, which is 9.5% lower than the average. These were also used in the WTE financial model to perform a type of sensitivity analysis of the electrical market price. Over the first ten-year term, the electrical revenues for a 3,000 tpd facility could be $23.6M more or $21.4M less than revenues at the average rate. The electrical revenues for a 4,000 tpd facility could be $31.5M more or $28.5M less than revenues at the average rate. This results in either a decrease in cost per ton of $2.27 if the high rate is realized, or an increase in cost per ton of $2.23 if the low rate is realized. The results are summarized in Table 3-20 below.

Connection Costs and Charges

There are typically connection / tie-in costs with utilities and, dependent upon the approach used for sale of electricity (i.e., Power Purchase Agreement, participation in wholesale market, etc.) wheeling / transmission costs could also be incurred. Unlike smaller, behind the meter distributed electrical generation, relative to the overall costs of a WTE facility, interconnection costs are typically relatively insignificant and are adequately accounted for in the capital costs for substation design. Similarly, while wheeling / transmission costs could be incurred if direct Power Purchase Agreements (“PPA”) are entered, using a value of $35.00/MWh should conservatively reflect any such charges. Retail electricity rates in Washington across all sectors is approximately $78.00/MWh. So, the assumption is that a Power Purchase Agreement would only be entered into if the net value of the electricity sale, reflective of wheeling / transmission costs is greater than the wholesale day ahead market pricing described above.

Other Model Estimates

Other WTE facilities often receive a capacity payment for providing a reliable, baseload electrical supply / capacity to the local electrical system. This capacity payment can be paid up front, monthly, or at the end of the PPA term, depending on negotiations and terms of the agreement. Capacity payments at other facilities vary and are dependent on the PPA negotiation and local utility regulatory requirements. For this WTE financial model, no capacity payment or guarantee has been included. As opposed to other renewable sources like wind and solar, hydroelectric generation provides a stable generation output. This fact, coupled with the low cost of the local hydro-electric power supply and the fact that Washington is a net exporter of electricity, makes it unlikely that the facility will benefit from additional capacity guarantees. If the market changes and a capacity guarantee can be negotiated, it could have a favorable impact on the project financial analysis.

Other WTE facilities also sometimes receive revenues from the sale of green energy credits. This is dependent on the market for green energy credits and development of sales agreements for these credits. As there is no current Federal green energy credit for WTE and no Washington market for sale of these credits, it is unlikely that these credits could be achieved unless legislative changes occur. For this WTE financial model, no green energy credit revenue is included, but as with inclusion of a capacity guarantee, if green energy credits could be sold, it could have a favorable impact on the project financial analysis. With successful carbon capture and sequestration technology, it is likely that carbon credits could be sold for a revenue stream outside of Washington State.

Table 3-20 provides the 10-year total energy revenues for the base 3,000 tpd and 4,000 tpd scenarios.

Table 3-20. Estimated Energy Revenues

10 -year totals	3,000 tpd	4,000 tpd
Average = $35.00 / MWh		
Electrical Capacity Revenues	$0	$0
Average Electrical Energy Revenues	$224,757,000	$299,676,000
Green Energy Credit Revenues	$0	$0
Percent of Revenues	65.8%	65.5%
WTE Facility Total Cost per ton	$106.65	$97.35
High = $38.68 / MWh		
Average Electrical Energy Revenues	$248,389,000	$331,185,000
Percent of Revenues	68.0%	67.7%
WTE Facility Total Cost per ton	$104.29	$94.99
Low = $31.67 / MWh		
Average Electrical Energy Revenues	$203,373,000	$271,164,000
Percent of Revenues	63.5%	63.2%
WTE Facility Total Cost per ton	$108.79	$99.49

3.10.2 Metals and Ash By-products

WTE facilities often recover recyclable metals from the waste stream, often post-combustion, to sell as a revenue source. Many older facilities have added metals recovery systems to their facilities, realizing a return on their capital investment typically within 3-5 years. New facilities include design and construction of metals recovery equipment to realize these revenues immediately. Recently, there is also advancement in metals recovery, where equipment is now able to separate more precious metals with less unwanted residue in the product metals, therefore receiving a premium price for the metals recycled. Inclusion of AMP is included in the capital cost estimate for the County facility and therefore the recovered metal estimates.

Ferrous and non-ferrous estimates are based on the County waste composition numbers indicating 4.7% unrecovered metals in the waste to the landfill. Assuming 28.3% ash generation from the waste, it is estimated that there are approximately 16.6% metals in the ash stream. This is separated into approximately 15% ferrous and 1.5% non-ferrous. The metals recovery rate is estimated at 98% recovery based on West Palm Beach reference facility and experienced increases in recovery with AMP facilities.

Metal market prices can fluctuate monthly. The national index is the direct wholesale price for metals, which is not usually directly achievable from WTE facility recovered metals because the metals are usually sold to a third party for transport and wholesale marketing. Considering ferrous direct wholesale prices of about $300 per ton, national average actual scrap metal prices, and cleaner metals from AMP equipment, the estimated price used for the County to realize as revenues is $120 per ton for ferrous at Year 1 of operations, escalated using the operations CPI. Direct wholesale prices for non-ferrous metals is about $900 per ton, and considering cleaner metals from AMP equipment, the estimated price used for non-ferrous is $700 per ton at Year 1 of operations, escalated using the operations CPI. These revenues are slightly higher than the revenues that are being seen at comparable facilities that do not have AMP.

The WTE financial model assumes no revenue share for metals, but if metals revenue share is negotiated, it would typically result in a lower O&M fee to the operator and incentivizes the operator to operate the AMP to increase recovery and quality.

Aggregate reuse from WTE facility ash is in development at several WTE facilities. Based on the Arcadis Team project knowledge and consistent with reasonable best-case scenario for landfill capacity model, it is assumed that 57% of ash residue is recoverable aggregate. The WTE financial model assumes no revenue for the aggregate recovered, but that recipient will pay hauling costs off site. The recovery of aggregate for reuse also reduces the cost of ash disposal by removing that portion from the ash stream. Therefore, with metals recovery through an AMP and aggregate recovery, it is currently estimated that 74% of the ash residue is reusable.

Table 3-21 provides the 10-year total recovered materials revenues for the base 3,000 tpd and 4,000 tpd scenarios.

Table 3-21. Estimated Recovered Materials Revenues

10-year Totals	3,000 tpd	4,000 tpd
Ferrous Revenues	$57,229,000	$76,305,000
Non-Ferrous Revenues	$33,384,000	$44,511,000
Aggregate Revenues	$0	$0
Total Recovered Materials Revenues	$90,613,000	$120,817,000
Percent of Revenues	27.6%	27.3%

3.10.3 Additional Waste Disposal Capacity Revenues

Privately-owned WTE facilities receive significant revenues from the tipping fees received for the waste delivered and processed. Publicly owned facilities receive revenues from the rates charged to residents and customers for waste disposal, which are usually monthly or annual charges rather than per ton charges. Some publicly owned facilities also accept additional waste or out of area waste for a fee per ton (tipping fee). The West Palm Beach reference facility currently has excess waste disposal capacity, and so marketed that capacity and receives revenues for the out-of-County waste through a fee paid by these customers. The ability to receive other waste is dependent on the capacity of facility constructed and actual tonnage received from the base market or rate payers, which is used to determine the remaining capacity. The revenues will be dependent of the amount of other waste and the tip fee charged for disposal of that waste. There also needs to be a supply or source of additional waste that can be economically delivered to the Facility. In addition, WTE facilities operate more efficiently when they process the design or maximum capacity of waste and therefore, additional benefits in efficiency can also be realized by processing waste at the capacity of the facility.

The WTE financial model currently includes acceptance of non-County waste for remaining facility capacity above the anticipated tonnage forecast and the County receiving revenue for disposal of the out-of-County tonnage. Non-County waste considered here is waste not provided by the partner cities (currently 37 cities) in the current ILA with King County or currently within King County's control, but could be from other municipalities, private haulers, or outside the County. The non-County waste tip fee is competitively estimated at $35 per ton based on approximate $11 per ton cost to transport to facility and current tip fee for disposal by Snohomish County of $50 per ton. The model includes escalation of the tip fee annually based on the operations CPI. The available capacity and the revenue projected depends on the initial facility capacity and the projected waste tonnage. It is important to note that due to the lower fee, these are typically negotiated as on-demand style disposal that can be turned off or cut back by the County at any time. This allows for flexibility in managing waste flows to the facility during outages and limits the amount of bypass waste during scheduled or unscheduled outage events. Table 3-22 provides a summary of non-County waste capacity available and estimated revenues for the 3,000 tpd and 4,000 tpd facility sizes and the corresponding percent that this revenue stream is of the total revenues for the facility.

Table 3-22. Estimated Additional Waste Disposal Capacity Revenues

10-year Totals	3,000 tpd*	4,000 tpd*
Available Non-County Waste	663,171	977,720
Non-County Waste Revenues	$26,127,000	$37,160,000
Percent of Revenues	7.7%	8.1%

*3,000 tpd facility assumes low bound waste tonnage, and 4,000 tpd facility assumes high bound waste tonnage

3.10.4 **Facility Revenue and Expense Summary**

Figure 3-5 and Figure 3-6 display the estimated facility revenues compared with the subtotal of facility expenses, not including annual amortized capital costs. The net O&M cost would be the total of facility O&M expenses less the facility revenues, and is indicated by the grey space between the top of the stacked revenue bars and the top of the expenses shaded area. The costs per ton presented in this report use the net costs, which deducts the estimated facility revenues.

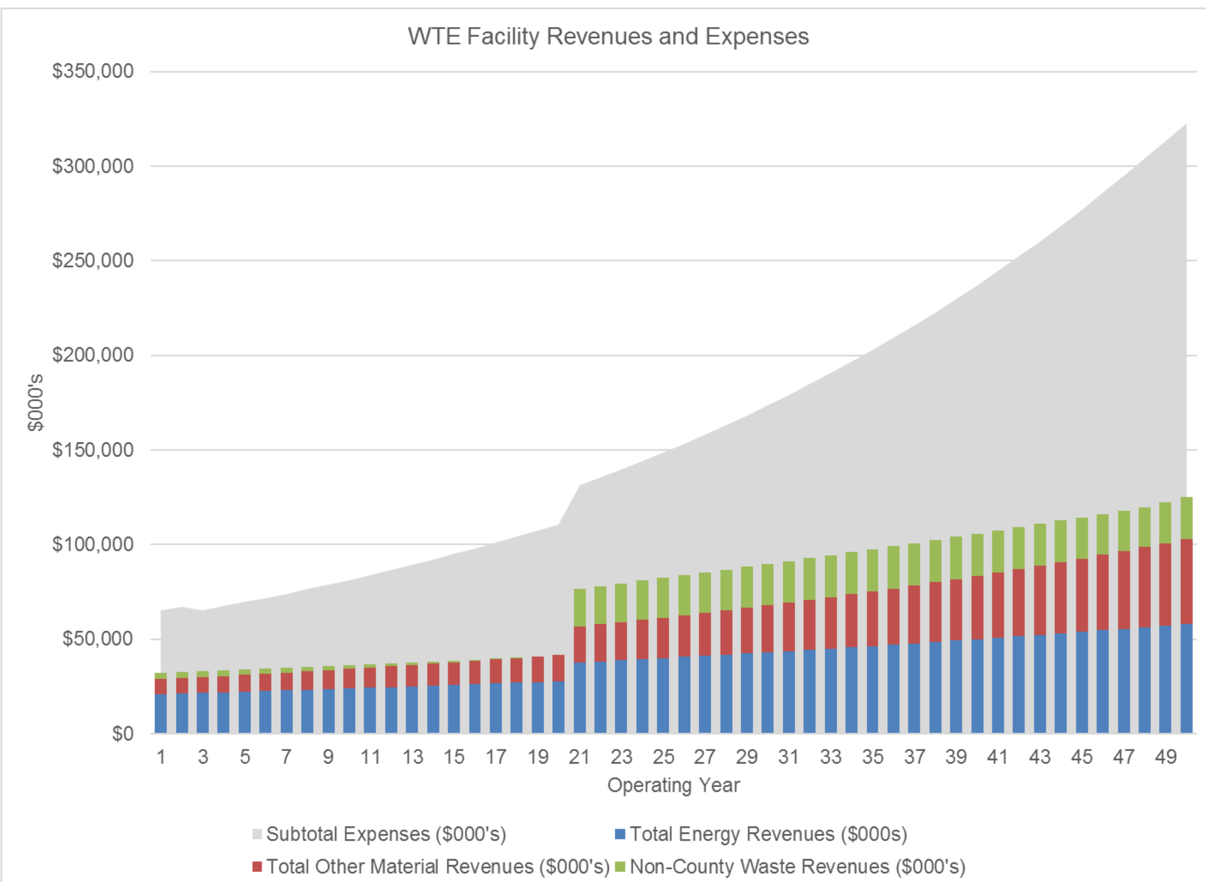


Figure 3-5. Facility Revenue and Expenses – Initial 3,000 tpd Capacity

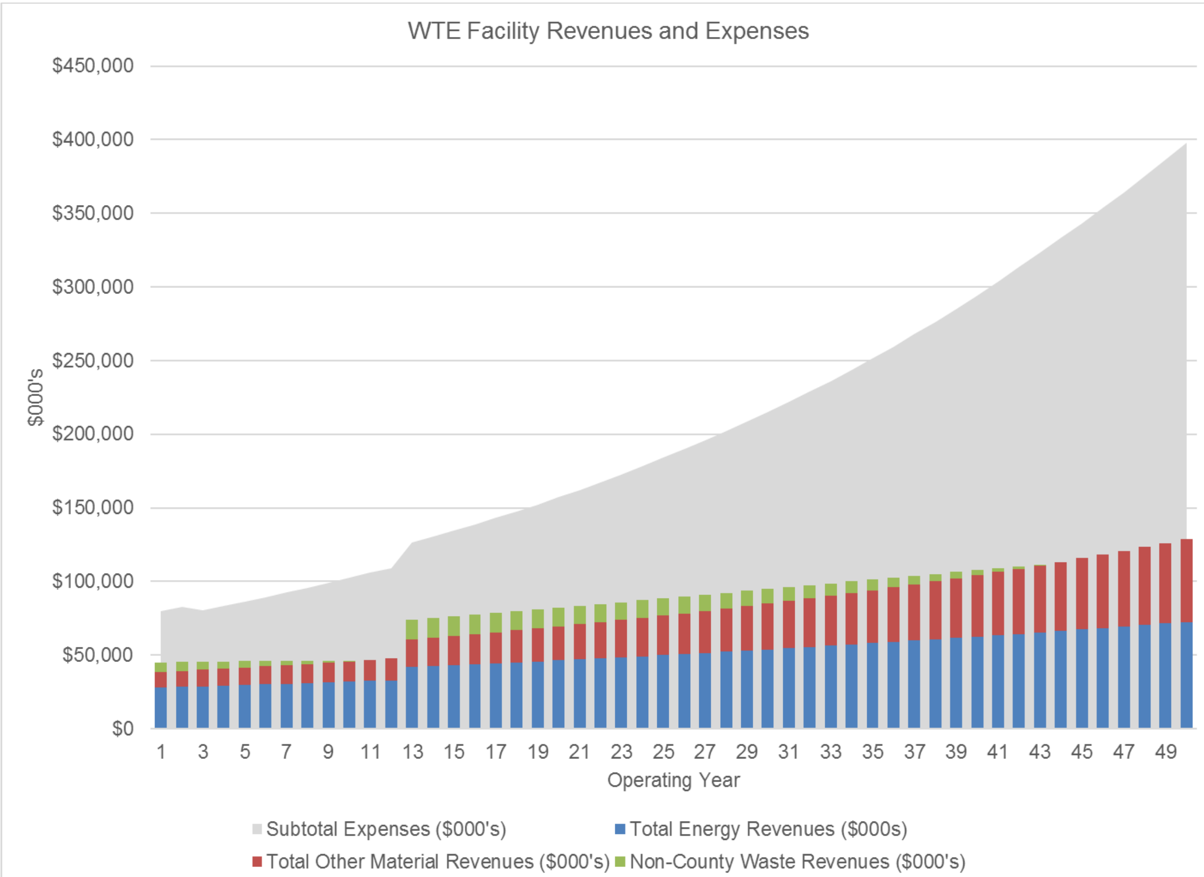


Figure 3-6. Facility Revenue and Expenses – Initial 4,000 tpd Capacity

3.11 Regulatory Environment

The siting, construction, and operation of a WTE facility in the County will involve many regulations, numerous agencies, and extensive public involvement. Table 3-23 identifies the major regulations that are applicable to WTE.

Table 3-23. Major WTE Applicable Regulations

	Citation	Overview	Source
Federal			
The Clean Air Act (CAA)	42 U.S.C. Ch. 85	Describes the comprehensive federal responsibilities for protecting air quality.	https://www.epa.gov/clean-air-act-overview
Resource Conservation and Recovery Act (RCRA)	42 U.S.C. Ch. 82	Dictates the federal requirements for management of hazardous and non-hazardous solid waste, including MSW.	https://www.epa.gov/rcra
Clean Water Act (CWA)	33 U.S.C. Ch. 26	Covers federal responsibilities to regulate water pollution.	https://www.epa.gov/laws-regulations/summary-clean-water-act
State			
State Environmental Policy Act (SEPA)	WAC 197-11	Defines a process to ensure that environmental impacts are considered in state proposals.	https://ecology.wa.gov/regulations-permits/SEPA-environmental-review
Washington Clean Air Act	70.94 R.C.W.	Enforces the federal CAA and further defines air pollution protection standards in WA.	https://app.leg.wa.gov/RCW/default.aspx?cite=70.94
Solid Waste Management Act	70.95 R.C.W.	Outlines solid waste management, specifically reduction and recycling.	https://app.leg.wa.gov/rcw/default.aspx?cite=70.95
Minimal Functional Standards for Solid Waste Handling	WAC 173-304	Describes requirements under 70.95 applicable to waste management, including landfilling and incineration practices.	https://apps.leg.wa.gov/WAC/default.aspx?cite=173-304
Special Incinerator Ash Management Standards	WAC 173-306	Specifies requirements for disposal of ash.	https://apps.leg.wa.gov/WAC/default.aspx?cite=173-306
Water Pollution Control	90.48 R.C.W.	Outlines requirements relevant to the protection of water quality in Washington, including stormwater and wastewater discharge.	https://app.leg.wa.gov/rcw/default.aspx?cite=90.48
Dangerous Waste Regulations	WAC 173-303	Determines requirements for dangerous waste, including residues from WTE facilities.	https://app.leg.wa.gov/wac/default.aspx?cite=173-303

On May 7, 2019, the governor signed into law CETA. As described in Section 3.9, this law requires the following:

- All electric utilities must eliminate from electric rates all costs associated with delivering electricity generated from coal-fired power plants by December 31, 2025.
- All retail sales of electricity must be GHG neutral by January 1, 2030.
- Electric utilities must meet 100 percent of its retail electrical load using non-emitting and renewable resources by January 1, 2045.

New WTE facilities are not exempt under this law and MSW is not included in the definition of “biomass energy”. Therefore, CETA requires that a new WTE facility must be carbon neutral by January 1, 2030 in order to sell the electricity generated from the combustion of MSW on the retail market.

It is currently unclear if emission credits for enhanced recycling of ash using AMP and/or other offsets from improvements in waste collection or recycling can be applied to WTE to demonstrate GHG neutrality for the January 1, 2030 CETA deadline. If recycling or process improvement emission credits are not allowed, then the County may need to employ carbon sequestration technologies to reduce CO_2 by 2030. If recycling credits are allowed and utility credits remain in effect, then the GHG evaluation presented in this Study shows that WTE is at least carbon neutral.

Considering the uncertainties in the operational effectiveness of flue gas carbon sequestration at the scale of a 3,000 tpd to 5,000 tpd WTE facility, Direct Air Capture (“DAC”) technology is considered a more viable option to reduce CO_2 levels at this time. DAC is a technology that captures CO_2 from atmospheric air and provides it in a purified form for sale or storage.

3.12 Greenhouse Gas Impacts

This section discusses GHGs associated with a WTE facility. It identifies the types and sources of GHG emissions; describes the methods, assumptions, and limitations of the GHG evaluation used in this Study; summarizes the results of the GHG evaluation; and discusses factors that may influence GHG estimates. A similar GHG evaluation for landfilling at an out-of-County landfill using WEBR is provided in Section 4.6, and a comparison of GHG evaluation results for WTE and WEBR is included in Section 5.5. Other air quality environmental impacts associated with WTE are discussed in Section 3.13.

3.12.1 Types and Sources of GHG Emissions for WTE

Combustion of MSW in a WTE facility results in the emissions of carbon dioxide (“CO_2”) and nitrous oxide (“N_2O”). Carbon dioxide is the most significant GHG emitted by WTE. Nitrous oxide is produced at much lower concentrations in a WTE facility compared to CO_2, but is a more potent GHG with a global warming potential (“GWP”) 298 times that of CO_2. Carbon dioxide from WTE is primarily emitted as a product of combustion and from transporting the residual waste ash to a landfill. Furthermore, GHG emissions (primarily CO_2) would be generated from WTE facility construction activities (e.g., worker transportation, truck delivery of supplies, raw materials, etc.) and from operations of the WTE facility (e.g., truck deliveries of supplies, worker transportation, etc.).

Construction and miscellaneous operational-GHG emissions (e.g., raw materials, delivery of supplies, worker commute) from a WTE facility are currently difficult to estimate. However, GHG emissions associated with these activities should be a relatively small component of the overall lifetime GHG emissions considering the long-term duration of the WTE facility (e.g. 2075). Likewise, GHG emissions from construction and operation of an IMF associated with the WEBR waste disposal strategy is a minor component compared to the lifetime of WEBR. GHG emissions from construction and operation of a WTE or IMF facility are therefore not quantified in this Study and are not anticipated to be a major factor in the County’s decision regarding the potential selection of WTE or WEBR as the County’s next waste disposal strategy.

3.12.2 Methods and Limitations

GHG emissions were estimated using the default Microsoft Excel version of the WARM model ("Method 1"). Additionally, the emission factors and emission credits in the WARM model documentation were used to provide a more refined GHG estimate ("Method 2"). The WARM model was created by USEPA's Office of Resource Conservation and Recovery to assist municipal waste planners in making better decisions with respect to GHG emission mitigation from waste and uses a life cycle analysis ("LCA") approach. The WARM model was selected for this Study because of its popularity with U.S. regulators and its widespread use in the U.S. solid waste industry. The WARM model was first developed in 1998 and has undergone 15 revisions since this time to keep abreast with current practice and emissions data. The current version of the WARM model was made available to the public in May 2019.

The WARM model uses a streamlined, inventory-focused LCA approach. WARM looks at GHG emissions from a "waste generation reference point" which solely considers GHG emissions that occur once the material has been discarded. This contrasts with many other LCA approaches, which include the full life of a material's emissions, including the extraction of raw materials and the phase in which the materials are in active use. This streamlined approach was determined by the USEPA to be the most appropriate LCA method for comparing alternative waste management strategies in terms of net GHG emissions from non-biogenic carbon. It considers the following GHG emissions and offsets for WTE:

- Gross emissions of CO_2 and N_2O from combustion of MSW
- Gross CO_2 emissions from transportation of ash residuals to a landfill
- Offset for avoided CO_2 emissions from electric generation, and
- Offset for avoided CO_2 emissions from metals recycling of the ash.

Total GHG emissions for a WTE facility such as emissions reported using USEPA's electronic greenhouse gas reporting tool ("eGGRT") are not evaluated in this Study as an LCA approach is considered more appropriate to compare alternative waste management strategies. Due to its streamlined LCA approach, the USEPA WARM model does not quantify annual emissions from a WTE facility, because it does not explicitly model the timing of GHG emissions. Thus, the GHG emissions presented in this Study should only be used to compare the benefits of alternative waste management strategies, not to compare with actual annual GHG emissions reported in traditional GHG inventory tools like eGGRT. As a general note and comparison, the Arcadis Team has seen eGGRT reporting for WTE facilities which breaks down to roughly 0.39 metric tons of anthropogenic CO_2 equivalents per ton of MSW processed. These GHG emissions would need to be directly offset with carbon capture and sequestration technology in order to meet the CETA requirement for 100% renewable or non-emitting electricity by 2045, with no provisions for offsets. Off-sets for avoided emissions for landfilling or for AMP and ash recycling may be sufficient to demonstrate GHG neutrality by 2030 of approved by the Washington State Department of Commerce and the Utilities and Transportation Commission.

The WARM Model compares GHG emissions between alternative waste management strategies using only a few input parameters. These input parameters define the emission factors the model uses to estimate net GHG emissions. For the WTE analysis, the waste composition and the State where the WTE facility is located are important input parameters.

Several emission factors in the Microsoft Excel version of the WARM model cannot be adjusted within the model. For example, the user cannot adjust emission factors to account for rail versus truck transport or increase emission factors to account for advanced recycling of metals (including non-ferrous metals, which are not included in the WARM model) or allow for higher recycling of ash due to advanced metals processing or ash reuse. Due to these limitations, both the Microsoft Excel version of the WARM model ("Method 1") and a County-specific WARM model analysis ("Method 2") were used to estimate GHG emissions. In the later analysis, emission factors in the WARM model documentation were used and sometimes modified to reflect more refined assumptions based on professional judgment. Further information related to the WARM Model emission factors and assumptions underlying these emission factors is provided in Appendix D.

Method 2 refinements to the WARM model emission factors and emission credits included:

- Reduced the emission factor for short haul trucking by 20 percent to account for lower emissions from rail compared to trucks.
- Adjusted transportation emission factor for ash disposal compared to disposal of MSW by WEBR to account for smaller quantities of ash compared to MSW, thus allowing an apples-to-apples comparison of WTE and WEBR.
- Increased the emission factor credit for ash recycling the same amount as Method 1 to account for advanced metals processing and expected future ash reuse.

3.12.3 Assumptions

Key assumptions for the Method 1 GHG emission estimates were as follows:

- GHG emissions from MSW combustion were estimated based on the "Mixed MSW" category in the WARM Model. This composition is based on national MSW characterization studies.
- Washington (Pacific Region) was selected for calculating avoided electricity-related emissions.
- LFG recovery is used for energy recovery.
- Typical operation (Default) of LFG recovery system.
- Dry (MSW decay rate, k= 0.02).
- Travel distance of 20 miles to WTE facility.

The following additional assumptions were made to determine GHG emissions avoided for increased recycling of metals due to AMP:

- An additional 0.014 tons of metals would be recycled per ton of MSW due to AMP. This includes an additional 0.003 tons of ferrous metals and 0.011 tons of non-ferrous metals.
- The 0.014 tons of additional metals recovery was calculated assuming:
    - Metals make up 4.7 percent of the MSW (0.047 tons of metals per ton of MSW)
    - 76% of metals are ferrous (0.036 tons per ton) and 24% of metals are non-ferrous (0.011 tons per ton)

- AMP will increase the amount of ferrous metals recovery from 90% to 98% (increase from 0.032 tons per ton to 0.035 tons per ton for a net difference of 0.003 tons of ferrous metals per ton of MSW)
- AMP will increase the amount of non-ferrous metal recovery from 0% to 98% (net increase of 0.011 tons of non-ferrous metals per ton of MSW)

- Non-ferrous metals were modelled using the WARM model aluminum can category (0.011 tons). Ferrous metals were modelled using the WARM model steel can category (0.003 tons).

The following additional assumptions were made to determine GHG emissions avoided due to ash recycling:

- Ash is 7.5% of MSW (0.075 tons of ash per ton of MSW).
- Ash was modelled using fly ash category.
- Compared landfill 0.075 tons of fly ash versus recycling 0.075 tons of fly ash.

Key assumptions for the GHG analysis using Method 2 for WTE are as follows:

- GHG emissions from MSW combustion were estimated based on the “Mixed MSW” category in the WARM Model.
- GHG emissions for truck transportation of MSW from the point of collection to WTE facility or IMF were assumed to be the same and are therefore not included in the Study.
- Trucking distance from WTE facility to IMF facility is 20 miles (if required for ash disposal).
- Rail distance from IMF to out-of-County landfill is 320 miles.
- 0.075 tons of ash will be recycled per ton of incoming MSW.
- To allow apples-to-apples comparison with WEBR transportation GHG emissions, the emission factor for truck and rail transportation used for WEBR was multiplied by 0.075 for WTE to account for lower tonnage of ash compared to MSW.
- The emission factor used for truck transportation of ash from the WTE facility to the IMF is 0.008 metric tons of CO_2 equivalent per short ton of MSW (MTCO2E/ton). This is 7.5% of the emission factor for trucking all the MSW to an IMF.
- The emission factor per mile used for rail transportation is 0.002 MTCO2E. This assumes that the rail emission factor is 20 percent of the truck emission factor per ton-mile and 7.5% of the MSW in ash requires landfill disposal.
- Utility CO_2 emissions avoided are based on the WARM model emission factor for the mixed MSW category in the Pacific Region (California, Oregon, and Washington). The WARM model uses “non-baseload” emission factors from USEPA’s Emissions and Generation Resource Integrated Database (eGRID). The national average WARM model credit for utility offsets nationally is 0.038 MTCO2E/ton. In contrast, the credit for utility offsets in the Pacific Region is 0.026 MTCO2E per ton of MSW.
- To account for AMP of ferrous and non-ferrous metals and beneficial reuse of the ash, an additional off-set of 0.018 MTCO2E per ton of MSW was credited. The 0.018 MTCO2E per ton credit was determined using Method 1 using the assumptions described above.

3.12.4 Results

The net GHG emissions for WTE per ton of MSW combusted is -0.05 MTCO2E based on the Method 1 calculation method. Results of Method 1 analysis are summarized in Table 3-24.

Table 3-24. GHG Results for WTE using Method 1

Description	WTE (MTCO2E/ton)	WARM V15 Documentation (2)
Net GHG Emissions, excluding ash recycling (2)	0.13	Appendix D, Table D-1
Emission Credit for AMP (3)	-0.11	Appendix D, Table D-2
Emission Credit for Ash Recycling (3)	-0.07	Appendix D, Table D-3
Total Net Emissions	-0.05	

(1) Net GHG emissions assume short haul trucking of 20 miles to WTE facility. Mileage to WTE facility was assumed to be 20-miles.
(2) Emission credit for AMP assumes additional 0.003 tons of ferrous metals and 0.011 tons of non-ferrous metals can be recovered with AMP. This assumes: 4.7% of MSW is metals, 76% of metals is ferrous and 24% is non-ferrous; AMP recovery is 98% ferrous and non-ferrous; non-AMP metals recovery is 90% ferrous and 0% non-ferrous. Non-ferrous metals were assigned to aluminum can WARM category.
(3) The emission credit for ash recycling was calculated using the WARM model Method 1. Inputs: 0.075 tons of ash per ton of MSW; composition: fly ash.

A copy of the WARM Method 1 results and applicable WARM documentation is included in Appendix D.

Following guidance in the WARM model documentation, Method 2 utilized emission factors and emission credits for the following gross emissions and avoided emissions to determine net GHG emissions for WTE. Emission factors and emission credits for the following were obtained from the WARM model documentation.

- Gross CO2 emissions from non-biogenic components of MSW.
- Gross N2O emissions from biogenic and non-biogenic components of MSW.
- Emissions of CO2 from truck and rail transportation of waste ash to an out-of-County landfill.
- Emissions avoided from utility generation in Pacific Region.
- Emissions avoided from increased recycling of metals from AMP.
- Emissions avoided from recycling of ash.

Table 3-25 summarizes the results of the GHG evaluation for WTE. Sources for the GHG emission factors in the USEPA WARM Model are also presented.

Table 3-25. GHG Results for WTE using Method 2

Description	MTCO2E/ton [1]	WARM V15 Documentation [2]
CO_2 and N_2O from MSW Combustion [3]	0.42	Table 5-1(e) minus Table 5-1(d)
Truck transport of ash from WTE to IMF	0.008	7.5% of 0.01 (Table 5-1(d))
Rail transport of ash from IMF to landfill	0.002	7.5% of 0.032 (Table 5-1(d) / 20 x 0.2 x 320)
Avoided Utilities - Washington	-0.26	Table 5-5 (national value is -0.38)
Avoided emissions – steel recovery	-0.04	Table 5-7
Avoided emissions – AMP	-0.11	Appendix D, Table D-2
Avoided emissions – ash recycling	-0.07	Appendix D, Table D-3
Total	-0.05	

Notes:

(1) MTCO2E/ton = metric tons of carbon dioxide equivalent per short ton of MSW
(2) See Appendix D for WARM documentation
(3) The gross GHG emissions from MSW Combustion are based on national average values which include older WTE technologies. The GHG emissions from a new WTE facility would presumably be less due to advances in combustion technology. Additionally, the percentage of plastics in MSW is reportedly higher nationally than in King County (e.g., 18.3% versus 12.2%, suggesting that the WTE GHG emissions for the King County waste composition may be less than national averages).

3.12.5 Factors that Affect Results

Factors that affect the GHG estimates for WTE include:

- Waste composition
- Utility off-set credits
- Ash reuse credits and provision of local ash disposal
- Carbon sequestration credits

Each of these factors are discussed below.

3.12.6 Waste composition

The waste composition primarily affects the GHG calculations for WTE in three ways. First, it defines the emission factors for gross CO_2 and N_2O emissions (e.g., waste compositions with higher amounts of plastics and other non-biogenic carbon, such as synthetic rubber and certain types of textiles, will have higher emission factors). Second, it affects the emission factors for utility off-sets (e.g., wastes with higher heating values such as dimensional lumber, tires, and carpet generate more electricity per ton combusted and therefore have higher utility off-sets). Third, it affects the avoided GHG emissions from recycling of metals in the residual ash. Waste streams with higher amounts of steel cans and metal-containing electronic devices will have higher off-sets for metals recycling of the ash.

As noted above, the amount of petroleum-based plastics in the MSW strongly affects GHG emissions for WTE. The increasing trend on the use of biodegradable plastics could have a dramatic effect on GHG emissions for WTE. If biodegradable plastic were to significantly replace petroleum-based plastics, then GHG emissions for WTE would decrease significantly.

3.12.7 Utility Off-Set Credits

As noted above, the credits for emissions avoided from utility generation are expected to decrease over time as Washington State increases its use of “clean” energy sources. Decreased utility credits may be off-set by increased recycling of ash and metals, or potentially from increased recycling in the solid waste system.

3.12.8 Ash Recycling Off-Set Credits and Local Ash Disposal

The WARM model provides a GHG emission credit for recycling of metals in residual ash. The current credit is 0.04 MTCO2E/ton, which is based on national averages. The USEPA WARM model only provides credits for the recovery of ferrous metals such as steel, and not non-ferrous metals such as copper, bronze, aluminium, and stainless steel or precious metals such as gold and silver. Policies and actions that would increase recycling and reuse of ash could reduce net GHG emissions for WTE by increasing recycling credits.

In the event that the County is able to use a local ash disposal alternative, the GHG emissions for this option will be less by approximately 0.01 MTCO2E/ton.

3.12.9 Carbon Sequestration

Two strategies for achieving GHG neutrality for WTE include CO_2 removal and sequestration and increased off-sets from enhanced recycling of the MSW prior to or after combustion.

The first strategy involves removing and sequestering atmospheric or flue gas CO_2 at the WTE facility to achieve GHG neutrality. There are currently no large-scale proven, commercially available technologies to remove and sequester CO_2 from the flue gas for the size of a WTE facility required by the County. However, these technologies do exist and have been proven on a small scale. Cost have already been included in the WTE financial model based on demonstration technology in Vancouver, Canada for CO_2 removal from air. The cost assumes that the air-cleaning technology would be housed and powered directly onsite and used to directly offset flue gas GHG emissions in lieu of direct flue gas cleaning, which is considerably more complicated. The calcium carbonate tablets removed could either be sold as a revenue stream or directly sequestered if needed to comply with State rules.

The second strategy to achieve GHG neutrality is to increase off-sets by increasing MSW recycling rates. It is unknown whether off-sets of this type would be allowed by the State and County. The USEPA GHG equivalency calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator) was used to estimate an incremental amount of MSW needed to be recycled to off-set the emissions of a WTE facility. The amount of CO_2 reductions required by sequestration and recycling to achieve GHG neutrality based on the analysis conducted in this Study are presented in Table 3-22.

3.13 Transportation Impacts and Needs

Transportation impacts for a WTE facility are anticipated to be similar to those associated with the current landfill practice at Cedar Hills, although the impacts would be shifted from Cedar Hills to the WTE facility location if the WTE facility is not sited at Cedar Hills. As with landfills, MSW is routed from transfer stations to the WTE facility using similar garbage trucks. This Study assumes that the transfer stations would be 20 miles from the WTE facility. A summary of these vehicle trips and mileage is presented inTable 3-26. Additional traffic impacts may arise from ash and bypass waste disposal depending on the ability of the facility to accommodate these wastes. WTE facilities with onsite disposal capabilities will not have additional transportation or traffic impacts from these wastes. If out-of-County disposal of the ash is required; however, the materials would have to be trucked to an IMF before being shipped by rail. For planning purposes, the out-of-County landfill is estimated to be 320 miles from the WTE facility. Ash disposal estimates assume that ash is 23% of total MSW in 2025, decreasing to 7.5% in 2040 and 2075 to account for improvements in recovery and reuse. Bypass waste was set as 5% of annual MSW, which is higher than anticipated by the Arcadis Team. Estimates for anticipated transport requirements between 2025 and 2075 are presented in Appendix E – Transport and Rail-haul Costs.

Other transportation considerations for a WTE facility include the route transport of reagents and metals recycling. Initial facility construction would also account for some traffic impacts in the form of several hundred construction staff vehicles and truck transport for equipment and supplies.

Table 3-26. 2025 WTE Transportation Impacts

Transportation Metric	Out-of-County Ash/Bypass Disposal		Onsite Ash/Bypass Disposal	
	Low Estimate	**High Estimate**	**Low Estimate**	**High Estimate**
Total Vehicle Trips	49,117	57,121	42,002	48,847
Total Vehicle Miles	982,340	1,142,420	840,040	976,940

Note: Assumes 20 miles per trip, 23.2 tons per trip for MSW and bypass waste, and 30 tons per trip for ash disposal.

3.14 Other Environmental Impacts – Air Quality

In addition to GHG emissions and transportation related impacts, a WTE facility will have environmental impacts associated with non-GHG air emissions from the combustion of MSW. The WTE facility will be subject to stringent emission standards and Best Available Control Technology ("BACT") requirements for certain air pollutants. Similar to the Title V Air Operations Permit for the Palm Beach WTE facility, emission criteria will be established for the following air pollutants based on Federal Regulations:

- Ammonia slip (NH_3)

- Cadmium (Cd)
- Carbon monoxide (CO)
- Dioxins/furans
- Hydrogen chloride (HCl)
- Lead (Pb)
- Mercury (Hg)
- Nitrogen oxides (NO_x)
- Particulate matter (PM, filterable)
- Sulfur dioxide (SO_2)
- Visible emissions and opacity
- Volatile organic compounds (VOCs)

The following air pollution control methods are typically used to meet BACT requirements and minimize air emissions:

- Activated Carbon Absorption (Mercury, Dioxin/Furan Control)
- Advanced combustion technologies (VOCs and Other Pollutant Control)
- Fabric Filter Baghouses (Particulate Matter Control)
- Spray Dryer Absorber or equivalent (HCl and Other Pollutant Control)
- Selective Catalytic Reduction (NOx and Dioxin Control)

Table 3-27 identifies air permit limits and emission compliance test results for the Palm Beach County, Florida WTE facility that began operation in 2015. The Palm Beach County, Florida WTE facility is similar in size and pollution controls that would likely be implemented for a County WTE facility and is therefore a good indication of the emissions that could be reasonably anticipated for a WTE facility in the County.

Table 3-27. Example Permit Limits and Emissions from Palm Beach County, Florida WTE Facility

Sample Type	Limit	Units (1)	Test Result		
			Unit #3	**Unit #4**	**Unit #5**
Ammonia Slip (NH_3)	10	ppmvd (3)	2.59	5.01	2.40
	2.76	lb / hr	0.78	1.58	0.77
Particulate Matter (PM) (filterable)	12	mg / dscm (2)	1.93	3.04	2.59
	4.7	lb / hr	0.82	1.32	1.16
Hydrogen Chloride (HCl)	20	ppmvd (3)	6.18	6.78	4.19
	11.9	lb / hr	3.99	4.43	2.85
Volatile Organic Compounds (VOC) (as propane)	7	ppmvd (3)	0.96	0.26	0.18
	5.0	lb / hr	0.74	0.21	0.15
Lead (Pb)	125	µg / dscm (2)	1.20	8.32	1.29
	4.9 E-02	lb / hr	5.14E-04	3.55E-03	5.64E-04
Cadmium (Cd)	10	µg / dscm (2)	<0.50	1.86	0.43
	3.91 E-03	lb / hr	<2.10E-04	7.97E-04	1.88E-04
Mercury (Hg)	25	µg / dscm (2)	<0.67	0.72	1.10
	9.8 E-03	lb / hr	<2.89E-04	3.08E-04	4.81E-04
Outlet Dioxins / Furans (5)	4.2	ng / dscm (4)	0.67	0.21	0.44
Visible Emissions	10	%	0.0	0.0	0.00
Carbon Monoxide	100	ppmvd (3)	31.9	15.5	13.6
	45.5	lb / hr	8.74	6.51	5.64
Nitrogen Oxides	50	ppmvd (3)	36.7	39.9	37.6
	37.4	lb / hr	30.1	26.2	26.3
Sulfur Dioxide	24	ppmvd (3)	20.3	20.7	21.4
	25.0	lb / hr	19.4	20.3	19.9
Opacity	10	%	0.9	2.1	0.8

1. All concentrations are corrected to 7% O_2.
2. Micrograms per cubic meter on a dry basis at standard conditions.
3. Parts per million on a dry volume basis.
4. Nanograms per cubic meter on a dry basis at standard conditions.
5. Based on stack testing performed over the first two full years of commercial operation, the dioxin/furan emission limit was set to 4.2 ng/dscm @ 7% O_2, which is equivalent to 1.7×10^{-6} lb/hr.

It is anticipated that air permit will be require a CEMS for CO, NOx, SO2, and Hg and stack testing for the other pollutants. Additionally, it is anticipated that the air permit will require the operation of a Continuous

Opacity Monitoring System for monitoring opacity as well as continuous monitoring of stream flow, oxygen and CO_2 concentration, flue gas moisture percentage, and flue gas temperature. Due to the small size of the facility, the air modeling required to meet Title V and PSD requirements, and the sophisticated air pollution control systems included, the emissions will not have a measurable effect on local air quality.

4 WASTE EXPORT BY RAIL

This section includes trucking and railroad transport considerations specific to the Pacific Northwest and to the County's planning for management of its MSW.

During the past 30 years, more stringent landfill regulations, public opposition to new landfills (NIMBY), and economic factors have led many communities in the U.S. to ship waste long distances to remote disposal facilities in sparsely populated areas. The Pacific Northwest was an early adopter of long-distance MSW transportation and disposal. Today, numerous large and small communities in Washington and Oregon ship their waste 100-300 miles primarily to three privately-operated landfills along the Columbia River via truck, rail, and barge.

Trucking is a common transport mode for communities that transport waste relatively shorter distances. Trucks have the advantage of being able to travel on the road network which is far more wide ranging than the railroad or barge network. Per mile, trucks burn more fuel and release more GHG emissions than other modes. Challenges related to truck transport of MSW in the Pacific Northwest include traffic congestion in urban areas and along Interstate 5 (I-5) and Interstate 84 (I-84) in the Portland area. Occasionally, service has been negatively affected by weather-related road closures of I-84 and within the urban areas. Trucking companies have also had to deal with an ongoing shortage of drivers[4].

Many communities export and transport their waste by rail, which is more economical for long distance transportation compared to trucking. Per mile, railroad locomotives burn less fuel than trucks. However, the locomotive engines used to power unit trains are large and expensive, and many are older engines that emit more air pollutants such as particulate matter ("PM") and nitrous oxide (NOx) than truck engines.

Challenges related to rail transport of MSW in the Pacific Northwest include service delays resulting from track congestion, intermodal container shortages, (rare) weather-related outages along the I-5 and I-84 corridors, and a lack of flexibility if a shipper wants to change the origin or destination of its cargo.

WEBR programs require more handling of intermodal shipping containers than trucking, since full and empty containers must be loaded or unloaded at both the origin and destination IMFs (see Section 4.3 for more detail). Rail haul typically requires a truck haul (drayage) of intermodal containers from the MSW transfer station to the exporting IMF, as well as from the receiving IMF to the landfill.

Potential candidates to receive the County's MSW are the three Northwest regional landfills that are actively served by rail, either directly (with an IMF at the receiving end), or indirectly (via a truck haul from an IMF). All three collect and beneficially reuse their landfill gas (methane):

- Roosevelt Regional Landfill (owned by Republic Services) – Roosevelt, Washington.
- Columbia Ridge Landfill (owned by Waste Management) - Arlington, Oregon.
- Finley Buttes Landfill (owned by Waste Connections) – Boardman, Oregon. Because this landfill is located farther east along the same Union Pacific Railroad ("UPRR") track that serves Columbia

[4] Seattle Times. 2018. *Shortage of Truckers Causing Prices to Rise.* https://www.seattletimes.com/business/shortage-of-truckers-starting-to-cause-prices-to-rise/. Accessed June 14, 2019.

Ridge, its transportation costs would be higher than Waste Management's. Hence, it was not researched further for this Study.

The Arcadis Team also evaluated several other landfills. However, at this time they either are not served by rail, or they lack landfill gas collection and beneficial reuse systems. Because they would not satisfy the County's anticipated gas collection and beneficial reuse requirements for disposal landfills, they have been excluded from this Study.

4.1 Railroad Company Interviews

The Arcadis Team interviewed the UPRR and the BNSF Railway ("BNSF"), the two Class 1 railroads that serve the major privately-owned landfills in Washington and Oregon. The purpose of these interviews was to obtain information about the companies; to understand their ideas and preferences about transporting and disposing of the County's solid waste; and to discuss their perception of the opportunities and constraints that the County faces in preparing for a potential WEBR program. Prior to the interviews, each company was provided with a list of key questions and operating issues (see Appendix F.) In addition, each railroad was informed that some of the issues discussed might involve their proprietary information, and their information might be included in this Study. This Study contains only summaries of the interview responses.

The following summarizes the feedback of the railroads:

- Both railroads expressed an interest in the County's waste tonnage. Before deciding, each company would require more detailed information and would evaluate the overall economics and operational impacts of adding that tonnage.
- The railroads expect both freight and passenger traffic in the Seattle / Portland corridor to grow. Rail capacity is defined not only by the line haul capacity on the mainline, but the capacity at the railroad's terminal. The ability to get on and off the mainline and in and out of their terminal (IMF) efficiently is critical to their decision.
- Rates are determined largely on supply and demand for the railroad's track capacity, both locally at their terminals and on the mainline. Each railroad has experienced the financial difficulty of being locked into long-term rates and contracts for hauling solid waste. Understandably, they will want to structure their rates to protect their economic interests in the face of rising costs such as fuel and labor. Therefore, they may require shorter contract periods (i.e. five to ten years or less) and/or greater flexibility in adjusting rates to match their costs. They would likely favor an annual rate escalator based on actual rail economics rather than a regional CPI escalator. The annual escalator could in turn influence how long an agreement they would be willing to sign. In addition, they probably would also require a fuel surcharge index that is independent of the annual rate escalator.
- The railroads would like to be involved in the County's choice of an existing IMF, or presumably, in the selection of a new IMF site. Access to an IMF by either / both railroads is a critical consideration for the County.
- Both railroads suggested that the County consider early waste export of a percentage of the annual waste volume, phasing in / ramping up the volume every year thereafter until 100% of the County's

waste is being exported. This phase-in allows the landfill / railroad entity to spread its investment in equipment and over several years.

4.2 Landfill Company Interviews

The Arcadis Team interviewed Republic Services ("RS") and Waste Management ("WM"), owners of the two largest private landfills in Washington and Oregon. Prior to the interviews, each company was provided with a list of key questions and operating issues (see Appendix F). In addition, each company was informed that some of the issues discussed might involve their proprietary information, and their information might be included in this Study. This Study contains only summaries of the interview responses.

The following summarizes the feedback of the landfill companies:

- RS and BNSF would evaluate adding tonnage to the existing BNSF IMF and would have to research other available rail-served real estate if a new site were necessary.
- RS's planning level cost estimate for WEBR from the County to their Roosevelt landfill is approximately $800-$1,300 per container.
- Depending on chassis configuration, RS expects a 32-ton MSW payload per closed top container.
- RS's transport and disposal (T&D) pricing will include supplying MSW intermodal containers.
- For budgetary / exploratory T&D pricing, RS suggested using $23-$30 per ton.
- For comparison, RS's current rate with Snohomish County is $50.56 per ton in total for transport and disposal from RS's private IMF in Everett served by the BNSF Railway.
- WM has identified multiple rail sites in the County that could serve as a viable IMF. The condition of these sites ranges from greenfield (currently undeveloped) to turnkey.
- WM commented that if the County wanted to establish its own IMF, it would need to identify a desirable parcel, then work directly with a rail engineering firm and the respective railroad to go through the processes needed to establish rail service.
- WM has strong partnerships with both UPRR and BNSF and would vet all service options to provide the County with a solution that fits their needs.
- WM is open to offering pricing per load or per ton, whichever method is preferred by the County.
- WM indicated that a 30-ton payload should be attainable and road legal, with the appropriate tractor, chassis, and container configuration.
- Typically, WM's T&D pricing includes supplying intermodal containers. Chassis, tractors, and drayage services can vary by contract, but WM has experience under all scenarios and would tailor the services offered based on the County's preference.
- For budgetary / exploratory T&D pricing, WM referenced the responses to RFPs that it submitted to Snohomish County and (Portland) Metro Regional Government in recent years. Both proposals included comprehensive WasteByRail® solutions, including the development and operation of new

intermodal receiving facilities, with an average T&D price ranging from approximately $45 to $55 per ton.

4.3 WEBR Intermodal Facility

4.3.1 Prototype WEBR Facility

WEBR requires an IMF where shipping containers carrying compacted solid waste are lifted off semi-trucks and placed on a rail car. This is typically accomplished by a “top pick” mobile (wheeled) crane or in some cases, a gantry crane. The container is either placed immediately into a well-type rail car or stored temporarily on the ground for subsequent loading onto a rail car as the train is “built”. The primary infrastructure at an IMF is pavement and tracks.

A hypothetical WEBR IMF model was considered to provide the basis for evaluation and cost estimating, as well as comparison with the conceptual WTE facility. Some of these assumptions are made to allow construction or other costs to be estimated. It should be noted that a fully designed facility sited in an actual location would probably differ from the model in several material aspects. For this Study, the model IMF is assumed to conform to the following:

General IMF Characteristics and Assumptions

- The IMF is sited within the borders of the County.
- The site is intended to receive compacted solid waste that is truck-hauled in closed intermodal shipping containers on chassis. The IMF would accept no waste delivered in KCSWD’s current transfer trailers as they are unsuitable for rail haul.
- Demolition debris would arrive in tarped, open-top intermodal containers since this waste type is typically bulky and cannot be compacted easily.
- 15-25-acre parcel size.
- Parcel shape roughly rectangular and suitable for required facility components.
- Reasonable topography: ground slopes are compatible with vehicle traffic, shipping container storage and potential buildings and structures. Grading and excavation would be minimal.
- Necessary utilities already exist on-site or could be extended from public rights-of-way at a reasonable cost.
- No fatal flaws (such as wetlands), or a few flaws that could be mitigated at a reasonable cost.
- Site has few or no buildings that would require extensive demolition efforts.
- Site avoids extensive or expensive displacement of existing structures, businesses or services.

Land Use/Zoning

- Industrial zoning or zoning as compatible with the intended facility use.
- Preferably in unincorporated part of the County rather than in an incorporated area (city).

Rail and Vehicular Access

- Proximity to either or both BNSF and UPRR mainline tracks, with less than one mile of rail spur needed.
- Must have nearby highway and arterial roadway access.
- Proximity to existing rail support yard infrastructure.

Permitting

- To a certain extent, finding a site in unincorporated County could reduce jurisdictional conflicts during permitting.
- We will assume a cost for public involvement and permitting, e.g. $1 million for WEBR vs. $2-3 million for WTE. Historically, permitting of the former has been less controversial than the latter.

On-site Waste Handling

- Paved roadways for queuing of incoming vehicles carrying intermodal shipping containers of waste.
- Paved areas for temporary staging of containers on the ground and for maneuvering of “top pick” lift trucks that place full containers on outbound railcars and remove empty containers from incoming railcars. Temporary storage of “spare” empty containers for use if the train is delayed.
- Tracks for inbound railcars carrying empties and tracks for loading full containers onto railcars to “build” the outbound train.

Other

- Support building (office, restroom, and break room).
- Assume a cost allowance for demolition of existing site structures (e.g. $250,000 for WEBR).
- Assume a cost allowance for providing / upgrading utilities.

4.3.2 County-Provided Intermodal Facility

Because of each major landfill’s geographic location and the ownership of nearby railroad tracks, the two biggest privately-owned landfills have historically teamed with a particular railroad: Waste Management’s Columbia Ridge Landfill with the UPRR, and Republic Services’ Roosevelt Regional Landfill with the BNSF. These have proven to be successful partnerships in executing WEBR programs for the City of Seattle and Snohomish County, respectively. These relationships would probably remain intact for a County WEBR program.

If the County could secure access to an IMF that is served by both BNSF and UPRR tracks, this could potentially increase competition between the likely WEBR teams. In the future, when it came time to re-bid the contract, neither railroad / landfill team would have an *a priori* advantage with respect to the IMF.

However, similar to WTE, the siting, permitting, designing, and constructing of an IMF would be a risky, costly, and time-consuming venture. Few suitable rail-accessible sites remain in the County. Furthermore, since the County has not historically been in the rail business, it would need to contract out almost all siting, permitting, and engineering services necessary to develop its own IMF. While it would be advantageous for the County to control a rail-neutral (accessible by both railroads) IMF, unless the County can lease such a site from a third party, it would be risky for the County to embark on developing its own IMF. However, failing to do so will substantially increase the risks associated with future negotiations for WEBR, particularly with the rail companies' preference for 5-10 year agreements.

4.4 WEBR Capital and Operating Costs

Besides the cost of an IMF, a waste export program has three major cost components:

- Transport of waste from the transfer stations to the IMF.
- Transport of waste by rail to the landfill.
- Disposal fee at the landfill.

The County currently incurs costs to transport waste from its eight transfer stations to Cedar Hills. However, upgrades to the current system such as installation of compactors and operational improvements could increase payloads and reduce the number of truck trips, thereby reducing operating costs. While transport and disposal are provided by separate companies, regional customers such as the City of Seattle and Snohomish County pay a bundled (transport plus disposal) cost-per-ton rate to WM and RS, respectively.

4.4.1 Transfer Station to IMF Costs

The cost of transporting waste from the transfer stations to a WEBR IMF are an important component of the overall WEBR costs. Transportation costs are roughly proportional to distance and travel time, among other factors. While this Study is not a facility siting study, a theoretical location for the WEBR IMF is needed so that the distance from each transfer station to the WEBR facility can be estimated. Historical transportation costs from each transfer station to Cedar Hills are already known. Therefore, as a starting point for cost calculations, the distances and costs for transporting waste to an IMF were assumed to be the same as those for historical waste transfer to Cedar Hills. This does not imply that the IMF would be located at Cedar Hills, because there is no rail access nearby.

A Transportation Cost Analysis was performed to compare the expected transportation cost components of WTE vs. WEBR disposal alternatives. For simplicity, the analysis assumed that both the WTE Facility and the WEBR IMF would be located the same distance from the transfer stations as Cedar Hills. While the total tonnage from the transfer stations is the same, the transport equipment and resulting payloads for WTE and WEBR are different (see Section 4.4.4). Hence, their transportation costs are different. Based on labor and material estimates developed for this Study, for WTE it would be $9.66 with average payloads of 35 tons; and for WEBR it would be $10.83 with average payloads of 30 tons. Details of this analysis are found in Appendix E – Transport and Rail-haul Costs.

Rail-haul costs for WEBR consist of two components: 1) truck drayage of full / empty containers to / from the receiving landfill's IMF and the working face of the landfill; and 2) the actual railroad transportation costs from the origin IMF to the destination landfill's IMF.

When the train arrives at the landfill IMF, the full containers are removed, placed on trucks, and driven to the landfill's working face. There they are unloaded using a hydraulic tipper. The empty containers are then trucked back to the IMF and placed on the train for the trip back to the customer (in this case, the County).

As stated in Section 4.1, railroad rates are largely determined by the supply and demand for the railroad's track capacity, both locally at their terminals and on the mainline. In their survey responses, both railroads noted the financial difficulty of being locked into long-term rates by waste-disposal contracts. In the future, they will structure their rates to protect their economic interests in the face of rising costs such as fuel, labor, and environmental regulation. For example, they may require shorter contract periods (i.e. five to ten years or less) and / or greater flexibility in adjusting rates to match their costs. They would likely favor an annual rate escalator based on actual rail economics rather than a generic regional CPI escalator. The annual escalator could in turn influence how long an agreement they would be willing to sign with the County. In addition, they will likely require a fuel surcharge index that is independent of the annual rate escalator. During the interviews, the railroads noted that their pricing model involves maximizing the rate at the time of contract negotiation based on then-current market pricing and the traffic volumes on their system. As a result, they were reluctant to provide much assurance about rate levels and related annual rate increases, based on the unpredictability of future key cost drivers to the railroads.

4.4.2 Landfill Disposal Costs

In 2018, WM and RS submitted to Portland Metro their proposed rates for disposal services at their respective rail-served landfills near the Columbia River. The rates ranged from $17.00 to $17.50 per ton. While it may be argued that these rates were set artificially low to win the business, both WM and RS have existing contracts that require a rate match ("Most Favored Nations" clauses) whenever lower rates are contracted. This means that WM and RS are not providing "one-time" exclusive rates just to win new business.

Snohomish County's current rail transport and disposal rate with RS is $53.95 per ton, based on a minimum weight of 26 tons per container. If Snohomish County averages 30 tons per container, the amount invoiced by RS is $1,618.63. The rail transport component is $925 per container regardless of weight. The remaining $693.63, divided by 30 tons, yields a disposal cost of $23.12 per ton.

4.4.3 Waste Equipment and Payload Assumptions

This Study assumes that a preload compactor will be located at each transfer station. Trailers would be driven onto a stand-alone trailer tipper and unloaded at the WTE plant. Walsh Trucking, the subcontractor to Portland's Metro Regional Government, currently averages 35-ton payloads from Metro's two transfer stations to WM's CRLF in Arlington, Oregon. Increased capacity of trucks may require re-routing if bridges reduce weight bearing capacities. This could affect both WTE and WEBR payloads.

Intermodal Container Payloads (WEBR)

The WEBR alternative requires a preload compactor to fully utilize the limited volume capacity in standard 40-48-foot intermodal containers. A light weight, extended wheelbase, quad axle semi-tractor and extended length, quad-axle, intermodal super-chassis combined with the 40- to 48-foot steel intermodal container can accommodate a 28 to 32-ton payloads of compacted waste.

The two railroads anticipate a payload capacity range between 30 and 32 tons, based on their industry experience and the local and state highway restrictions for containers-on-chassis and the use of "Husky Stack" well cars with 40 to 48' long intermodal containers stacked two high.

4.4.4 Assumptions for Total Cost of WEBR

Table 4-1 summarizes the estimated cost of WEBR, based on the following factors:

- Costs (2019 $) from current contracts, interviews with UPRR and BNSF railroads, and WM and RS landfill companies.
- Initial cost assumes an additional fee associated with contractor construction of new IMF. Because of the amount of waste for disposal and approach to not phase in WEBR, it is unlikely that use of current IMF (UPRR Argo Yard and BNSF Interbay Yard) is feasible. Additional add-ons for land acquisition and IMF construction have been added into the WEBR financial model to compare equivalent WEBR and WTE facility scenarios, assuming that the current IMFs are not sized large enough for the volume of waste the County will have available. A capital cost of $5M for IMF construction, $18M for a 20-acre site, with 4% interest rate over a 10-year loan term results in a $2.8M annual loan cost, which is approximately $3.35 per ton. Based on the interviews, a 10-year WEBR contract term seems like the longest term most contractors would allow.
- Rail-haul cost ranges from $900 to $940 per container
  - City of Seattle's cost is $912.09 per container or $30.40 per ton, based on a 30-ton payload.
  - Landfill disposal cost is $17.00 to $17.15 per ton, including intermodal shipping containers provided by landfill company.

Table 4-1. WEBR Transport and Disposal Total Cost Summary

Component	Cost per Container (30 tons/container)	Per Ton
Transfer to Rail Yard (IMF)	$325.03	$10.83
Rail Transport to Landfill	$912.09	$30.40
Landfill Disposal	$510.00	$17.00
IMF Capital Cost / Fee	$100.47	$3.35
Total Cost	$1,847.69	$61.59

4.5 Environmental Impacts

4.5.1 Permitting and Regulations

The Arcadis Team researched environmental regulations related to a new IMF within the County and concluded the following:

1. Siting a new IMF or using an existing IMF in the unincorporated County could reduce jurisdictional conflicts during the permitting process since the County would be the Lead Agency, but it may be more difficult or impossible to site a new IMF in the unincorporated County.
2. WDOE does not require an IMF to have a solid waste handling permit to perform WEBR operations. However, the facility would still be subject to other state environmental regulations such as stormwater control and spill prevention control and countermeasures. The IMF would also be subject to Federal regulations for intermodal and rail facilities.
3. The waste export IMF would likely be subject to Washington state regulation WAC 173-350-300 on-site storage, collection, and transportation standards. These standards apply to the temporary storage of solid waste in a container at an industrial site and the collecting and transporting of solid waste. Because the waste will be totally enclosed in rigid intermodal shipping containers, spillage or leakage of waste is highly unlikely under normal operating conditions. This regulation also has some record-keeping requirements for tracking the "vehicles" (in this case, intermodal containers). Presumably, all containers are already tracked by the railroad and the landfill disposal company.
4. If the County chose to site a new IMF, the process would be subject to State Environmental Protection Act (“SEPA”) requirements, including an EIS.

4.5.2 Construction or Expansion and Operations Impacts

The Arcadis Team evaluated the construction and operations impacts of utilizing IMFs for WEBR of the County’s MSW under the two most likely scenarios.

In one scenario, a WEBR program for the County would utilize an existing IMF operated by either the BNSF or UPRR railroad, though it is likely that the existing IMFs could not accommodate the total volume of County waste without additional expansion or improvements. In general, the environmental impact resulting from the increased number of containers handled at the site would be similar to that caused by economic growth. WEBR could cause the increase in containers handled to occur more quickly than under “normal” economic growth. In addition, tractor-trailer traffic in the vicinity of the IMF would increase, as it would under normal economic growth.

In the other scenario where the County decided to site and develop a new IMF, there would be construction-related environmental impacts. Environmental impacts from operating the IMF would also be experienced at the new location. However, the total environmental impact should be approximately the same, just spread over an additional number of locations.

4.6 Greenhouse Gas Impacts

This section discusses GHGs associated with disposal of MSW at an out of County landfill using WEBR. It identifies the types and sources of GHG emissions; describes the methods, assumptions, and limitations of the GHG evaluation used in this Study; summarizes the results of the GHG evaluation; and discusses factors that may influence these estimates. A similar GHG evaluation for WTE is provided in Section 3.12, and a comparison of GHG evaluation results for WTE and WEBR is included in Section 5.5.

4.6.1 Types and Sources of GHG Emissions for WEBR

The primary GHGs emitted from at a landfill are methane and CO_2. Methane and CO_2 are present in landfill gas at approximately equal concentrations and are produced from the anaerobic decomposition of organic components in the waste. Methane is the most significant GHG emission source at a landfill since it has a GWP of 25 compared to CO_2.

This Study considers the following GHG emissions and avoided GHG emissions for MSW landfills:

1. Methane emissions from anaerobic decomposition of biogenic carbon that are not captured by a landfill gas recovery system.
2. Transportation CO_2 emissions from landfill equipment.
3. Rail transportation CO_2 emissions for transport of MSW using WEBR.
4. Biogenic carbon stored in the landfill (see Section 4.6.2 below).
5. CO_2 emissions avoided through landfill gas-to-energy.

As noted above, the uncaptured methane produced from anaerobic decomposition of MSW is counted in the USEPA WARM model as an anthropogenic GHG because degradation would not result in methane emissions if not for deposition in the landfill. The methane that is captured by the landfill gas recovery system and converted to CO_2 is not counted since the CO_2 is of biogenic origin. Methane and CO_2 generation from the decomposition of non-biogenic carbon (e.g., plastics) is not considered a significant GHG source by the WARM model in a landfill and is therefore not counted. The recent trend of increasing compostable plastics in the waste stream are not currently addressed by the WARM model and represent potential additional methane emissions.

4.6.2 Methods and Limitations

Similar to the WTE GHG analysis, GHG emissions for WEBR were evaluated using the WARM model in two ways. First, GHG emissions were evaluated by Method 1, which used default WARM model Microsoft Excel spreadsheet. Second, the emission factors and emission credits in the WARM model documentation were used in Method 2. In some cases, the emission factors were refined using professional judgment to account for lower emission rates for rail transportation compared to truck transportation, and high LFG recovery efficiency.

The methods and limitations of the WARM model were described previously in Section 3.12.2. An important consideration in the GHG analysis for WEBR is the issue of off-set credits for carbon sequestration in a landfill. Under landfill conditions, biogenic carbon in wastes such as wood, yard waste, paper and certain other wastes derived from biomass will not significantly anaerobically degrade compared to the aerobic degradation that would otherwise occur if these wastes were not landfilled.

While CO_2 emissions from biodegradation of biogenic carbon are not counted, the WARM model subtracts the amount of CO_2 that would have been generated if these wastes were allowed to naturally biodegrade under aerobic conditions. Considering utility offsets and carbon sequestration credits, the WARM model may show negative net GHG emissions for certain waste compositions at landfills (e.g., wastes with high percentages of dimensional lumber, yard waste, and paper if landfill gas recovery is implemented). The IPCC guidance recommends that landfill carbon sequestration credits be identified for information purposes.

Consistent with IPCC guidance, the carbon sequestration credit is identified so that the user can decide whether this credit should be applied to the landfill or not. This Study does not include GHG emissions from potential landfill fires which are difficult to predict and quantify. Presumably, a landfill fire would emit CO_2 from the combustion of the carbon that is sequestered in the landfill (as well as potentially non-biogenic sources of carbon) and would therefore erode the value of the carbon sequestration credit proportional to the percentage of the biogenic waste material that is burned.

Given that the landfill must sequester carbon indefinitely to maintain sequestration credits, it is plausible that the waste may be disturbed in the future (albeit long-term) by natural disaster (e.g., fires, geological disturbance) or for anthropogenic reasons (e.g., future landfill mining to recover land). If disturbed in this manner, the sequestered carbon in the landfill could be oxidized and released as CO_2.

4.6.3 **Assumptions**

The assumptions used for the GHG evaluation of WEBR included the following:

- The WARM model mixed MSW composition was used to estimate GHG emissions for WTE and WEBR. National average waste composition is considered appropriate given the single-year of waste composition data available for the County.
- CO2 emissions for transporting MSW from the point of collection to the IMF were assumed to be the same as transporting MSW from the point of collection to the WTE facility and were therefore not included.
- Rail distance from IMF to out-of-County landfill is 320 miles.
- Rail emission factor is 20 percent of the trucking emission factor on a per mile basis.
- Initial biogenic carbon content of MSW is 42%.
- Adjusted yield of methane as a proportion of initial carbon is 16%.
- Methane generation of waste is 1.62 MTCO2E/ton.
- The LFG recovery system will capture 80 percent of the methane generated by the landfill.
- The landfill will be sited in a dry climate with MSW decay rate of 0.02/year corresponding to landfills receiving fewer than 20 inches of annual precipitation.
- Amount of carbon stored is 0.21 MTCO2E/ton based on mixed MSW.
- Utility off-sets for avoided CO2 emissions for landfill gas electricity is 0.08MTCO2E/ton.
- GHG estimates do not include landfill fires or potential future oxidation of buried waste.

4.6.4 **Results**

Results of the GHG evaluation for disposal of MSW at an out-of-county landfill using WEBR are summarized in Table 4-2 and Table 4-3, for the WARM model Method 1 and Method 2, respectively.

Inputs and outputs of the Method 1 analysis and the emission factors used in the Method 2 analysis are included in Appendix D.

Table 4-2. GHG Evaluation for Disposal of MSW at Out-Of-County Landfill Using WEBR WARM Method 1

Description	WEBR (MTCO2E/ton)[1]	Comment
Net GHG Emissions, excluding ash recycling [2]	0.12 to 0.33	See Table D.2 in Appendix D

The WARM model spreadsheet does not allow explicitly show carbon sequestration credits for landfilling. The lower emission estimate assumes a carbon sequestration credit of 0.21 MTCO2E/ton based on emission credits in the WARM model documentation (see Appendix D).

Table 4-3. GHG Evaluation for Disposal of MSW at Out-Of-County Landfill Using WEBR WARM Method 2

Description	MTCO2E/ton (1)	WARM V15 Documentation (2)
Methane not captured by LFG recovery [3]	0.32	Assumed 80% methane captured.
Landfill equipment operation	0.02	Table 6-16, Appendix D
Rail transport of ash from IMF to landfill	0.03	320 miles x 0.0001 MTCO2E/ton-mile
Avoided Utilities - Washington	-0.08	Table 6-15 equation, Appendix D
Avoided emissions – carbon sequestration	-0.21	Table 6-16, Appendix D
Total	0.08 – 0.29	

Notes:

(1) Methane not captured by LFG recovery system assumes methane generation from anaerobic generation is 1.62MTCO2E per ton of MSW (see Table 6-6 of WARM Model documentation in Appendix D) and 80% LFG recovery. The 80% is based on professional judgment and EPA efficiency testing performed in 2012 and assumes aggressive landfill gas capture.

(2) MTCO2E/ton = metric tons of carbon dioxide equivalent per short ton of MSW

(3) See Appendix D for WARM documentation

4.6.5 Factors that Affect Results

Factors that affect the GHG estimates for WEBR include:

- Waste composition
- Distance to out of county landfill and emission efficiency
- Landfill gas recovery system efficiency
- Carbon sequestration credits

Each of these factors are discussed below.

4.6.5.1 Waste Composition

Waste composition affects the amount of degradable carbon in a landfill, which in turn impacts the amount of methane that is produced from anaerobic decomposition of the waste. Wastes that contain relatively large amounts of organics such as food waste produce a relatively large amount of methane compared to other wastes. To a lesser extent than food, other organic wastes such as paper and yard waste can decompose anaerobically and produce methane, although the methane generated from these wastes may be off-set by carbon sequestration of the fraction of carbon in these wastes that do not anaerobically decompose. As an example, the USEPA WARM model may show that newspaper and wood are net GHG sinks (e.g. negative net GHG emissions) when placed in a landfill with a gas recovery (e.g., the amount of CO_2 avoided by carbon sequestration outweighs the amount of methane that is generated from the anaerobic degradation and is not captured by the landfill gas recovery system).

4.6.5.2 Distance to Landfill and Transportation Energy Source

The distance to the landfill and the fuel source of the trains will affect GHG emissions for WEBR. Landfills that are closer to the County will have lower GHG emissions compared to more distant landfills for the same fuel supply. The increased use of electric trains supplied from GHG neutral energy or non-fossil fuel such as biodiesel will lower GHG emissions for WEBR.

4.6.5.3 Landfill Gas Recovery

The largest factor that will affect GHG emissions at a landfill is the efficiency of the landfill gas recovery system. Greater landfill gas recovery efficiency will reduce GHG emissions. The County may want to consider landfill gas recovery efficiency (based on empirical emissions data) as a factor in selecting a future potential landfill. As indicated above, an efficient landfill gas recovery system can make the difference if a waste in a net GHG source or sink (e.g., paper). The Arcadis Team has performed research at other landfill sites showing methane capture percentages between 32% and 86% in mature, capped cells with gas collection. In Method 1, the WARM model defaults for landfill gas recovery were used. In Method 2, we assumed an overall 80% landfill gas recovery, which is considered aggressive.

4.6.5.4 Carbon Sequestration

This Study includes the landfill carbon sequestration credit based on USEPA WARM model guidance. As noted above, IPCC guidance for landfill emissions does not provide this credit. The applicability of the landfill carbon sequestration credit should be carefully considered when comparing WEBR with WTE, recognizing that comparative landfill emissions would be significantly higher if IPCC guidance was used to estimate landfill GHG emissions rather than the USEPA WARM model guidance. If the carbon sequestration emission factor were eliminated, the data used in this Study indicate that net GHG emissions from landfilling using WEBR would increase from approximately 0.08 MTCO2E/ton to 0.29 MTCO2E/ton.

4.7 Railroad and Truck Fuel Use and Emissions

This section describes the railroad and truck fuel use and emissions expected for the WEBR option. Data was obtained from the EPA website data (https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-locomotives) regarding the three-part program that dramatically reduced emissions from diesel locomotives of all types -- line-haul, switch, and passenger rail. Based on interviews with the railroad companies, at present, some locomotives (nine in the UPRR's entire system) are being "tested" with alternative engine technology and diesel particulate devices; however, the railroads cannot guarantee or offer dedicated "green" locomotives to the County if a waste train were to be developed. Additionally, the USEPA does not currently mandate or require specific reduced emissions or alternative fuel engine for the railroads and their locomotives. The emissions estimates used in this Study for the mode for various time periods follow in Table 4-4.

Table 4-4. Emissions Estimates for Mode of Operation

Mode of Operation	NOx (grams/mile)	PM (grams/mile)
2010-2012 (Low Sulfur Diesel)	916	23
2013-2019 (Ultra Low Sulfur Diesel)	847	22

The USEPA has adopted more stringent standards for marine diesel engines and locomotives that changed the standards for locomotive engines but the timeline for implementation by each railroad is uncertain.

4.7.1 Rail Fuel Use and Emissions

Based on input from industry representatives, rail fuel use was assumed to be 6,000 gallons total for three locomotives per round trip for a 6,000-foot train. Fuel use was adjusted so that every 1 percent reduction in tonnage results in a 0.33 percent reduction in fuel use.

NOx and particulate matter emissions from the use of locomotives were calculated using the methodology from USEPA's *Technical Highlights, Emission Factors for Locomotives,* USEPA420-F-97-051*, December 1997*. Emission factors vary according to the age of the locomotive with Tier 0 standards applying to locomotives originally manufactured between 1973 and 2001, Tier 1 standards applying to locomotives manufactured from 2002 through 2004 and Tier 2 standards applying to locomotives manufactured in 2005 and later.

The average age of the locomotives was assumed to be 10 years each year of the project. Therefore, Tier 0 standards were used for the first year of the project; Tier 1 standards were used for the latter years and Tier 2 standards were used for the remaining years.

Equation 3 presents the calculation of NO_x and particulate matter emissions in grams per mile:

$$\text{Emissions } (NO_x \text{ and PM}) = F \times EF / M \qquad (3)$$

Where

F = annual fuel consumption, gallons

EF = Emission factor (gram per gallon, g/gal)

M= annual miles traveled

Emission factors are presented below in Table 4-5.

Table 4-5. Locomotive Emission Factors – Grams per Gallon

Tier	NOx	Particulate Matter
0	155.8	6.0
1	121.6	6.0
2	83.4	3.1

4.7.2 Truck Fuel Use and Emissions

The following fuel economy was assumed for different types of trucks:

- Long-haul with new engines: 5.5 mpg
- Local drayage with new engines: 4.5 mpg

NOx, particulate matter and CO_2 emissions from the use of trucks were calculated using the Freight Logistics Environmental and Energy Tracking Performance Model (FLEET). The model is available at http://www.epa.gov/smartway/smartway_fleets_software.htm. Inputs included number of trucks, payload, vehicle class, fuel consumption and idling hours.

The FLEET model accounts for the mandated changes in truck technology and for the use of ultra-low sulfur diesel in 2007. Additional inputs include truck model year and the year emissions are to be calculated. The model does not account for upgrades to engines in 2010. These upgrades affect NO_x emissions. NO_x emissions were reduced by 80 percent consistent with USEPA estimates.

4.7.3 Fuel Use and Emissions Considerations

4.7.3.1 Emissions in the Columbia River Gorge Scenic Area

As discussed in a variety of publications including the *Columbia River Gorge Visibility Project, 2006 Annual Report*, Oregon Department of Environmental Quality, Southwest Clean Air Agency, September 12, 2006, there is heightened sensitivity about air pollution that is causing visibility and other concerns in the Columbia River Gorge Scenic Area along I-84 in Oregon. Because of a lack of available emissions data, diesel fuel use was used as a proxy for SOx emissions.

4.7.3.2 Uncertainty Associated with Emissions Estimates

There is considerable uncertainty surrounding the emissions estimates shown in this Study. Considerably more research has been done to model emissions from trucks than has been done for rail. In addition, emissions are inherently difficult to estimate because they depend on many factors such as fuel sulfur content, engine loading, wind, currents, tare weights, and aerodynamic drag. Thus, conclusions made based on the estimates provided in this Study should be viewed with caution.

4.8 Cost Comparisons to Other Regional WEBR Programs

A review of the existing waste-by-rail transport and disposal agreements for both the City of Seattle and Snohomish County is summarized in Table 4-6. Details of the two programs are found in Appendix G.

Table 4-6. Comparable Pacific Northwest WEBR

Jurisdiction	IMF	Contractor	Serving Railroad	Containers Provided by Disposal Contractor?	Average Payload (in tons)	Current Rate /Ton (T&D)
Snohomish County	County-owned Republic operated	Republic Services	BNSF	Yes – 48’ long	28.5	$53.95
City of Seattle	UPRR ARGO	Waste Management	UPRR	Yes – 40’ long	25.7	$41.49

Data Sources: Snohomish County / Republic Services & City of Seattle

Using Seattle’s current cost for rail transport and expected transport cost increases, Table 4-7 shows the estimated cost for the County to dispose of waste by rail for a 40-foot intermodal container with a 30-ton payload and at the County’s average of 23.2 tons per haul.

Table 4-7. Waste-by-Rail Disposal Cost

Component	Total Cost per container	Cost per Ton @ 30 tons per container	Cost per Ton @ the County’s 23.2 tons per haul
Transfer to Rail Yard	$325.03	$10.83	$14.17
Rail Haul Cost	$912.09	$30.40	$39.32
Disposal Cost	$510.00	$17.00	$17.00
IMF Capital Cost/Fee	$100.47	$3.35	$3.35
Total Cost	$1,847.59	$61.59	$73.84

4.9 Regional Transportation Impacts

Implementation of a WEBR project will impact traffic on regional transportation networks – i.e. roads and railroads. Current MSW-related truck traffic flows to / from County transfer stations to Cedar Hills. Under WEBR, those trucks would be re-directed to the IMF. Because the County has not selected one of the existing IMFs nor sited a new IMF, detailed, localized analysis of traffic impacts at the IMF are not feasible. Traffic impacts will be shifted from the vicinity of Cedar Hills to the vicinity of the IMF. Because trucking operations from the transfer stations to the IMF are like those at the landfill, traffic impacts at the IMF are expected to be similar to those seen at Cedar Hills.

Increased rail congestion will increase traffic delays at grade crossings. Railroads are often able to minimize negative impacts from increased rail traffic by scheduling trains overnight, but this mitigation strategy is dependent on sufficiently low rail demand, and therefore cannot be guaranteed for the coming decades. In the past decade, and largely driven by railroad safety mandates, the railroads are attempting to minimize and eliminate highway-railroad at grade crossings. This could further affect both regional traffic impacts and the ability to site an IMF.

Table 4-8 provides information on the anticipated rail and truck traffic and truck and rail transport mileages for WEBR. The table is based on the low and high tonnage forecasts discussed in Section 2.4 and assumes an average driving distance of 20 miles from the transfer stations to an IMF and 320 miles rail distance from the IMF to the out of county landfill.

Table 4-8. 2025 Waste-by-Rail Transportation Impacts

	Low Estimate	High Estimate
Total Vehicle Trips(1)	40,002	46,521
Total Vehicle Miles(2)	800,040	930,420
Total Vehicle Ton-Miles(3)	18,560,920	21,585,360
Total Rail Ton-Miles	296,974,720	345,365,760

(1)Assume 23.2 tons per trip
(2)Assume 20 miles per trip
(3)See tonnage forecast in Section 2.4
(4)Assume 320 miles for rail haul distance

4.9.1 **Future Railroad Capacity**

4.9.1.1 Railroad Capacity Research

WEBR from Washington municipalities is well-established, having performed successfully since the 1990s. Most rail-hauled solid waste travels south from metropolitan areas over the Seattle Subdivision, the track spanning Seattle to Portland that roughly parallels Interstate-5 (I-5). Some of the waste quantity splits off in Vancouver, Washington, traveling east along the Columbia River on BNSF tracks to the Republic Services Roosevelt Regional Landfill. The remaining waste quantity continues south to Portland and then east on UPRR tracks to Waste Management’s Columbia Ridge Landfill.

Since the mid-2000’s, numerous studies of the capacity of Washington’s railroads have been performed, many on behalf of the Washington State Department of Transportation (“WSDOT”). These studies have looked at factors such as the inherent physical capacity of the track system; the location of bottlenecks;

growth in demand for shipment by rail as well as by truck or barge; the effects of climate change[5]; proposed capital improvement projects; and related public and private investment.

The *Statewide Rail Capacity and System Needs Study* (Cambridge Systematics, 2006)[6] was prepared for the Washington State Transportation Commission. The cover letter to the report states “The study concludes that the economic vitality of Washington State requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. However, it also concludes that the rail system is nearing capacity. Service quality is strained, and rail rates are going up for many Washington State businesses. The pressure on the rail system will increase as the Washington State economy grows. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent between 2005 and 2025. The State’s role is necessarily shaped by the fact that nearly all freight railroads are privately-owned for-profit companies. The major freight railroads are investing to add capacity and improve service in Washington State, but their business practices and investment priorities are understandably driven primarily by the railroads’ national-level needs and competition.

The needs of Washington State businesses and communities are just one part of the railroads’ considerations. Additional investment and incentives for investment are needed to ensure a robust rail system that meets Washington State’s economic needs, as well as the railroads’ business needs.”

Selected findings of the Cambridge Systematics 2006 report include:

- In 2004, Washington shipped more coal via rail than “waste or scrap”, but by 2025 the latter was projected to exceed the former. (Waste or scrap may include recyclable materials as well as solid waste).
- The track between Seattle and Portland is subject to frequent stoppages, with trains tying up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. While most of the track is owned by the BNSF, it shares operating rights with UPRR, Amtrak, and Sounder commuter trains. The line operates at between 40 and 60 percent of practical capacity, which is itself about 60 percent of theoretical capacity.
- Major choke points / bottlenecks include Seattle, Tacoma, Centralia, Kalama, and Vancouver.
- While the railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines, the operational changes may not be enough to satisfy the future needs of Washington shippers.

Technical Memo 3 (HDR 2006) to *Statewide Rail Capacity Needs and Constraints* (Cambridge Systematics, 2006)[7] provides a comprehensive analysis of how rail capacity is affected by many factors

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[5] WSDOT. 2011. Climate Impacts Vulnerability Assessment. Prepared for Federal Highway Administration. November.

[6] Cambridge Systematics et al. 2006. Statewide Rail Capacity and System Needs Study, Final Report. Prepared for Washington State Transportation Commission. December.

[7] HDR et al. 2006. Statewide Rail Capacity Needs and Constraints, Technical Memorandum Task-3 Rail Capacity Needs and Constraints. Prepared for Washington State Transportation Commission. July.

including physical bottlenecks, capacity of rail yards, and speed constraints on bridges and various sections of track. Findings of relevance to WEBR included:

- BNSF yards and terminals considered to be operating at or over capacity (in 2006) include Interbay (in Seattle), Seattle, Centralia, Vancouver, and Wishram. Wishram is located just west of Roosevelt, the final rail destination for solid waste headed to Republic Services' landfill.
- UPRR's Argo Yard (Seattle) is over capacity (in 2006) because it is used for both domestic and international intermodal traffic, solid waste, and general merchandise.
- TM-3 identified almost 100 capital projects (40 funded, 58 unfunded) to improve rail capacity in Washington state. Some of these improve passenger train capacity, while others improve freight train capacity.

The 2014 *Washington State Rail Plan -- Integrated Freight and Passenger Rail Plan 2013-2035* (WSDOT Rail Division, 2014)[8] describes the state's interest in the rail system and identified potential public actions to improve the rail system consistent with transportation policy goals of economic vitality, preservation, safety, mobility, environment and stewardship. Significant observations include:

- Rapid growth in volume due to coal (or any commodity) would mean demand would exceed capacity sooner than 2035.
- Rail volume trends will also be addressed in the Freight Mobility Plan and reassessed in the next rail plan update (anticipated 2018).
- It is anticipated the Class I railroads (BNSF and UPRR) and other infrastructure owners will likely address key capacity issues as they emerge.
- Washington's rail system is expected to handle more than 260 million tons of cargo by 2035 — more than double the volume carried on the system in 2010. This represents a compound annual growth rate of 3.4 percent for all commodities carried on the rail system.
- Seattle-Portland is projected to be near the 100 percent utilization mark, which would make it difficult to handle variations or additional traffic without adding excessive delays.
- Factors that could significantly affect future rail volumes include:
  - New bulk exports such as coal.
  - Volatility in global sourcing.
  - Use of larger container ships, reducing the number of ports on-call.
  - Shifting modal economics between rail and truck.
  - Fluctuating fuel costs and potential conversion to alternative sources of energy.

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[8] WSDOT Rail Division. 2014a. Washington State Rail Plan -- Integrated Freight and Passenger Rail Plan 2013-2035. Prepared by and for Washington State Dept. of Transportation. March.

- It is important to understand that rail capacity is not static. The volume of traffic that can be accommodated depends not only on infrastructure, but also on the railroad's operating strategies, traffic mix, use of technology and many other business decisions.
- Railroads typically respond to growth in freight demand with concurrent impacts on their infrastructure through a mix of operational strategies and capital improvements including:
    - Operation of longer trains.
    - Schedule and train speed adjustments.
    - Segregation of traffic by direction and / or type (e.g. separate bulk from intermodal, etc.), where multiple routes are available.
    - Application of advanced traffic management systems that improve meet/pass planning, management of train speeds and a reduction in headways.
    - Construction of additional main track, new and/or lengthened passing sidings.
    - Expansion of industry, yard and terminal facilities.
    - Installation of signals and / or improvements to existing signal systems.
- As private businesses, railroads seek a return on investment on their capital investments that exceeds a threshold, which varies based on the cost and availability of capital at the time the investment is being considered. Often, the risks associated with a new investment exceed the likely benefits, and the railroads will choose to make business adjustments instead. These include selective price and service level changes, which directly impact capacity needs. Most commonly, these take the form of pricing actions, service frequency and provisioning of cars for loading, if they are supplied by the railroad. The impact of these decisions can negatively affect shippers and short-line connections by increasing their direct and indirect costs.

The 2014 *Washington State Freight Mobility Plan* (WSDOT 2014b)[9] reiterated many of the points covered by the *State Rail Plan*. Additional observations include:

- Several rail segments are expected to require operational changes and / or capital improvements to manage anticipated freight rail volume by 2035. Seattle-to-Portland is projected to be near the 100 percent utilization mark, which would make it difficult to handle variations or additional traffic without adding excessive delays [Freight Analysis Framework Version 3 (FAF3) forecast].
- Multimodal (e.g. combined truck and rail) shipping of waste / scrap is predicted to grow by 217 percent from 2011 to 2030.
- The next update to the Freight Mobility Plan is due out in 2019.

[9] WSDOT. 2014b. Washington State Freight Mobility Plan. Prepared by and for Washington State Dept. of Transportation. October.

The 2017 *State Freight Plan* (WSDOT 2017) was a Technical Update to the 2014 *Freight Mobility Plan*[10].

Interesting findings include:

- The Freight Analysis Framework Version 4 (FAF4) forecast projects that the freight tonnage moved by multiple modes (e.g. truck and rail) and mail will increase from 21.7 million tons in 2015 to 32.6 million tons in 2035. This translates into a total increase of 50 percent over a 20-year period, and an annual growth rate at 2.1 percent. The multiple modes and mail category also include small shipments sent via postal and courier services and is not limited to containerized or trailer-on-flat car shipments. The total ton-miles moved by multiple modes and mail is anticipated to increase from 25.2 billion in 2015 to 42.9 billion in 2035 (a total increase of 70 percent) at an annual growth rate of 2.7 percent.
- Outbound freight tonnage is projected to grow faster than intrastate tonnage during the 2015 to 2035 period. The County waste headed to the Columbia Ridge Landfill (Waste Management) or Finley Butte Landfill (Waste Connections) would be outbound freight, while waste going to the Roosevelt Regional Landfill (Republic Services) would be intrastate.
- To enhance the capacity of the rail system, railroads typically implement operational changes before pursuing major capital investments. Operational changes include operation of longer trains, schedule and train speed adjustments, and application of advanced operational management systems and signaling systems. Typical capital improvements include construction of additional main track, and new and/or lengthened passing sidings, or expansion of yard and terminal facilities.

In addition to the State studies noted above, The County performed its own an analysis of WEBR: *Solid Waste Transfer and Waste Management Plan* (KCSWD 2006)[11]. Notable points include:

- The County should decide about WEBR no more than 5 years before waste export is implemented.
- KCSWD evaluated a phased approach to WEBR, anticipated shipping 20% of its waste stream to start. WEBR would include 4 trains / week; require 480 containers / week without spares; and cause a “negligible increase in overall rail traffic”.
- The benefits of a privately owned and operated IMF include:
  - The County would avoid up-front capital costs of developing the IMF. Those costs, however, would still be reflected in the cost of service to ratepayers.
  - The County would not be responsible for siting of the IMF.
  - The County would expect the cost-competitive bundling of services between the IMF operation and long-haul and disposal to drive down costs to the lowest possible level.

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[10] WSDOT. 2017. Washington State Freight System Plan, Technical Update to the 2014 Freight Mobility Plan. Prepared by and for Washington State Dept. of Transportation.

[11] King County Solid Waste Division (KCSWD). 2006. Solid Waste Transfer and Waste Management Plan (formerly Solid Waste Transfer and Waste Export System Plan). September.

- If operation of the IMF is bundled with long-haul responsibility, the County could require the operating contractor to provide backup transportation and reserve containers in the event of a rail system disruption.
- The contractor would have the responsibility for facility maintenance.
- The contractor would work directly with the serving railroad.

- The drawbacks include:
  - The County would lack the guaranteed intermodal capacity under its exclusive control and could find itself without such service or access to the rail system in the future.
  - The County would have much less flexibility to coordinate all elements of the solid waste system and would need to rely on contract terms to ensure that its interests and waste export needs are addressed.
  - The County could likely enable a single, vertically integrated company to handle all aspects of waste export and disposal, which could discourage future competition in the region.
- KCSWD also evaluated a publicly owned and operated IMF as well as publicly owned but privately operated IMF.

4.9.1.2 Rail Capacity Analysis

The studies summarized above recognized the need to maintain and upgrade the rail system in Washington State through coordinated public and private sector efforts. The major railroads (BNSF and UPRR), the State, and the Federal government are all making investments in infrastructure. However, the success and timing of these efforts in providing adequate rail capacity is difficult to predict, especially almost two decades in the future (2035). Four major types of change can affect the amount of available rail capacity in 2035:

- Global economic changes: e.g. tariffs can decrease the amount of American agricultural products being exported and foreign goods being imported.
- Political change: e.g. recently cancellation of a major planned coal export terminal, and widespread opposition to a proposed liquefied natural gas (LNG) terminal.
- Climate change: e.g. the type and quantity of crops grown; flooding and washouts of track; wildfires and extreme heat.
- Regulatory change: e.g. more (or less) stringent emissions limits from diesel locomotives; other greenhouse gas measures.

Even at a million tpy, the County's solid waste would represent a small fraction of the 260 million tons of cargo anticipated to be rail-hauled in Washington in 2045.

As of summer 2019, there appears to be enough rail capacity to ship an additional 1.2 million tpy to either of the two private landfills that currently serve city and county governments in Washington and Oregon. We can reasonably conclude that absent a major catastrophe such as a landslide or earthquake that destroys a significant portion of the Seattle-Portland track, there will continue to be some rail capacity.

If in 2035 there is not enough capacity to carry an additional 1.2 million tpy, then the question becomes who gets to use the available capacity. The answer depends on how much each entity is willing to pay to move its products. It seems likely that each railroad will select and prioritize what commodities it will haul based on its own economic self-interest: that is, which combination of total tons and rate / ton provides the highest economic benefit for the railroad. Other considerations could be length of contract, stability and / or growth in tonnage of a commodity being shipped, other factors from outside the region, etc. If the County solicits bids for WEBR, its Request for Proposals should ask for a $/ton or $/railcar pricing for MSW delivered to the landfill with a minimum payload guarantee per intermodal container. This would allow a comparison with other modes of transportation and with rates paid by other rail customers shipping other products.

An important takeaway from the interviews with the railroads and landfill companies is their suggestion that the County consider phasing-in waste export rather than starting shipment of the full County waste stream at once. The County already considered this over a decade ago (KCSWD 2006). An updated potential scenario is described below:

- The County would begin by exporting 100,000-200,000 tons/year (approximately 10 to 20% of tonnage going to Cedar Hills), increasing the amount yearly.
  - This would allow the railroads and landfill companies to phase-in their investment and delivery of rolling stock (locomotives and rail cars, top picks, shipping containers, etc.).
  - It would use the existing UPRR Argo or BNSF Magnolia IMF. No additional permitting should be required, since each IMF has already been shipping MSW for many years.
  - This export would save approximately 10-20% of the annual airspace, thereby extending the life of Cedar Hills slightly.
  - Independently and concurrently with the phase-in, there may be improvements in physical rail capacity due to state and private investment in rail infrastructure. However, the gains may be offset somewhat by increases in shipping demand or changes in cargo destinations and/or commodities being shipped.
- The primary drawback of phasing-in waste export is that the County's fixed costs of operating Cedar Hills, plus the cost of partial waste export, would likely exceed the value of nominally increasing the life of Cedar Hills.

4.10 Project Implementation Schedule

The most critical component for rail haul is locating an IMF within the County for loading and unloading the intermodal containers onto rail cars. At present, the UPRR is the only railroad that can directly serve the Columbia Ridge and Finley Buttes landfills and the BNSF is the only railroad that directly can serve Republic Service's Roosevelt Regional landfill. Therefore, it is preferable that the County find a "reciprocally served" (i.e. dual access) site within the County.

4.10.1 Intermodal Facility Implementation Schedule

Total implementation time for a WEBR program is likely to range from as low as 24 months to as high as 72 months, based on the tasks and activities outlined in Table 4-9.

Table 4-9. IMF Facility – Project Implementation Schedule

Task	Activity	Preliminary Schedule (new IMF)	Preliminary Schedule (existing IMF)
1	Extend/Negotiate Interlocal Agreements and Update Comprehensive Solid Waste Management Plan	1 to 2 years	2 years
2	Siting / Planning / Permitting	2 years	1-2 years
3	Procurement (RFQ / draft RFP / Final RFP) through selection and Notice of Award	1-2 years (concurrent with Task 2)	1-2 years (concurrent with Task 2)
4	Design / Build to Commercial Operations Date (COD)	1 - 2 years	0 years
Total		4 - 6 years	3 – 4 years
COD Date if Start 1/1/2020		1/1/2020 – 1/1/2026	1/1/2020 – 1/1/2024

4.10.2 WEBR Equipment Implementation Schedule

A wide range of equipment is necessary for a successful WEBR program and Table 4-10 summarizes the minimum needed equipment, their respective manufacturing lead times, and the impacts to the WEBR implementation schedule.

Table 4-10. WEBR Equipment Availability and Manufacturing Lead Times

Equipment Type	Lead Time (in months)	Comments
Class 8 Tractors	3 to 6	Lead times vary slightly by manufacturer.
Chassis Trailers	6 to 9	Lead times vary slightly by manufacturer.
Intermodal Containers	4 to 6	Lead times vary slightly by manufacturer.
Railroad Locomotives	18+	If new engines meeting latest USEPA emission standards (Tier 4) are required.
Railroad Railcars	9-12+	Assumes Husky double stack well cars.
Container- lifting Equipment (Top Picks)	6+	Also known as “Top Picks”; lead times vary slightly by manufacturer.
Yard Goats / Hostlers	4 to 6	Also known as “trailer hostlers”; lead times vary by manufacturer.
Trailer Tippers	9 to 12	Lead times vary slightly by manufacturer.

5 WASTE-TO-ENERGY AND WASTE EXPORT BY RAIL COMPARISON

The purpose of this section is to provide a comparison of using WTE versus WEBR as the County's next MSW disposal method. The elements to be compared between the two options include the following:

- Timeline to fully adopt either disposal method
- Financial impact to the disposal cost per ton of either method
- Required permitting, and from which agencies, to fully adopt either method
- Regulatory environment required to fully adopt either method
- Environmental impact to fully adopt either method
- Transportation needs and traffic impacts required to fully adopt either method

5.1 Project Implementation Schedule

The project implementation schedule for a new WTE facility is estimated to take approximately eight to 11 years, as compared to an estimated three to six years for an IMF facility. The most significant difference in the project implementation schedules are for the siting / permitting and the design / build to commercial operation phases.

As shown in Table 5-1 below, for the IMF facility, the siting / planning / permitting phase and the procurement phase are estimated to take one to two years each. For the WTE facility, the siting / planning / permitting phase may take three to five years; and the procurement phase is estimated to take one to two years. The critical path in the permitting process for a WTE facility contains preparation of the PSD permit for air quality control. As discussed in Section 3.6.5, the PSD permitting process is complex, requires various air quality analyses, and will require rounds of public participation. Detailed review of the air pollution control technology will be performed to ensure that it meets BACT, and concern over the technology used for air pollution control may require additional modeling or equipment design, extending the scheduled further. It is for this reason that the permitting phase is substantially longer than that for an IMF Facility. However, the procurement phase for the WTE facility can occur simultaneously during the siting / planning / permitting phase, which may mitigate, in part, this longer implementation schedule.

The most significant difference in schedule comes from the design / build to commercial operation phase estimates. As a more complex facility, this phase for the WTE facility is estimated to take approximately four years; whereas the IMF facility may take less than a year if using an existing facility to two years to build a new facility. Refer to Table 5-1 for a comparison of the project implementation schedules.

Table 5-1. Project Implementation Schedule Comparison

Task	Activity	Preliminary Schedule WTE Facility	Preliminary Schedule IMF Facility
1	Extend/Negotiate Interlocal Agreements and Update Comprehensive Solid Waste Management Plan	1 - 2 years	1 - 2 years
2	Siting / Planning / Permitting	3 - 5 years	1 – 2 years
3	Procurement (RFQ / draft RFP / Final RFP through selection and Notice of Award)	1 – 2 years (concurrent with Task 2)	1 – 2 years (concurrent with Task 2)
4	Design / Build to Commercial Operations Date (COD)	4 years	0 – 2 years
Total		8 – 11 years	3 – 6 years
COD Date if Start 1/1/2020		1/1/2028 – 1/1/2031	1/1/2023 – 1/1/2026

5.2 Financial Comparison

The financial comparison between WTE facility disposal and WEBR is highly dependent on the different variables and assumptions made in the financial models. These assumptions are discussed in the WTE (Section 3.0) and WEBR (Section 4.0) sections of this Study. For comparison purposes, land acquisition and capital cost or fee charged by rail operator for a new IMF facility is included for WEBR since land acquisition and capital cost for WTE facility are included in the WTE financial model. A new IMF will likely be required because of the large anticipated tonnage of waste projected for disposal. The WEBR IMF capital cost / fee is included as a per ton cost over the first 10 years of the projections. The WTE capital costs are included as annual amortized costs over 30 years of each bond issuance. Phasing of the WEBR waste tonnage was not considered for this comparison. Estimates developed in past or current dollar values for both WEBR and WTE facility disposal were escalated to the anticipated first year of WTE facility operations, estimated to be 2028. Also, hauling costs from the County transfer stations to either the WTE facility or WEBR IMF are also included, assuming similar distances to WTE or IMF as it is to Cedar Hills. The hauling cost comparison is further discussed in previous Section 4.4.1 Transfer Station to IMF Costs.

The WTE and WEBR total and costs per ton for the identified term using the low bound tonnage forecast for the 10-year term, 20-year term, and 50-year term are summarized in Table 5-2. Note that negative values in the Difference column indicate savings if WTE is utilized rather than WEBR.

Table 5-2. Cost Comparison between WTE and WEBR – 3,000 Expanded to 4,000 tpd

Total Cost and Average Cost per Ton	10-year Term	20-year Term	50-Year Term
Waste-to-Energy (WTE) – 3,000 expanded to 4,000 tpd			
Total Cost	$1,066,537,361	$2,368,418,483	$6,963,437,423
Cost Per Ton	$106.65	$118.42	$116.06
WEBR Low Bound			
Total Cost	$1,026,526,133	$2,424,490,647	$11,251,567,071
Cost Per Ton	$109.94	$126.35	$215.15
Difference (WTE-WEBR)			
Total Cost	$40,011,228	($56,072,165)	($4,288,129,649)
Cost Per Ton	($3.29)	($7.93)	($99.09)

The WTE and WEBR total and costs per ton for the identified term using the high bound tonnage forecast for the 10-year term, 20-year term, and 50-year term are summarized in Table 5-3. Note that negative values in the Difference column indicate savings if WTE is utilized rather than WEBR.

Table 5-3. Cost Comparison between WTE and WEBR – 4,000 Expanded to 5,000 tpd

Total Cost and Average Cost per Ton	10-year Term	20-year Term	50-Year Term
Waste-to-Energy (WTE) – 4,000 expanded to 5,000 tpd			
Total Cost	$1,298,013,297	$2,922,300,885	$8,899,802,758
Cost Per Ton	$97.35	$99.62	$112.18
WEBR High Bound			
Total Cost	$1,362,187,218	$3,376,330,508	$16,140,955,031
Cost Per Ton	$110.25	$127.19	$216.90
Difference (WTE-WEBR)			
Total Cost	($64,173,921)	($454,029,622)	($7,241,152,273)
Cost Per Ton	($12.90)	($27.57)	($104.72)

In some cases, the difference in cost per ton and total costs do not match, such as the low bound scenario difference in WTE to WEBR for the 10-year term, because WEBR is truly a cost per ton of waste where WTE has an annual cost regardless of total processed. The WEBR total cost is only for the quantity of waste projected. The WTE total cost and cost per ton assumes a fixed quantity of waste processed (up to the facility capacity). The WTE analysis includes tonnage and revenues from tipping fees for outside-County waste to meet the facility capacity and does not include cost for disposal of County waste above the facility design capacity. WTE cost per ton would be 9% higher if excess waste capacity is not successfully sold; however, is still less than the WEBR cost per ton over the 50-year term. In some scenarios, the total projected tonnage exceeds the facility design capacity, but it is assumed that the WTE facility can operate up to 10% above the design capacity, based on historic experience and industry standard. The planned facility expansion occurs before the projected waste tonnage exceeds the 110% design capacity.

Both options cost over $1 billion in the near term (10-years) and over $6 billion in the long term (50-years) but the WTE facility disposal option could cost up to $104.72 per ton less than WEBR over the long term (50-years). For the low bound tonnage estimates and 10-year term, the WEBR total cost is $40M less than WTE facility disposal, but actually costs $3.29 more per ton because the WTE facility disposal option assumes acceptance of more waste to reach facility design capacity than disposed of by WEBR. In additional, past the first 10-year term, the WEBR cost, capacity, and availability could be drastically different, with even higher prices than projected due to low supply and high demand. For the 20-year term and beyond, WTE facility disposal is lower than projected WEBR costs for both total cost and cost per ton.

In addition, the WTE and WEBR cost per ton at years 1, 10, 20, and 50 are summarized in Table 5-4 and provide a snapshot of the cost per ton at those years:

Table 5-4. Cost Per Ton Comparison between WTE and WEBR

Cost per Ton*	Year 1	Year 10	Year 20	Year 50
Waste-to-Energy (WTE) - 3,000 expanded to 4,000 tpd	$102.19	$109.85	$154.81	$148.08
Waste-to-Energy (WTE) - 4,000 expanded to 5000 tpd	$90.67	$107.46	$104.83	$161.54
Waste Export by Rail (WEBR)	$96.34	$124.38	$161.28	$391.46
Difference (WTE-WEBR) Low Bound	$5.85	($8.84)	($6.47)	($243.37)
Difference (WTE-WEBR) High Bound	($5.67)	($16.92)	($56.44)	($229.92)

*costs are net cost and deduct revenues received

For the low bound tonnage forecast assuming a 3,000 tpd WTE facility, the Year 1 cost per ton for WEBR is lower than WTE facility disposal, but in Year 5, the cost per ton for WEBR exceeds the cost per ton for WTE facility disposal, and so continues for the 50-year term. For all the high bound tonnage forecasts terms, the WTE facility disposal costs less per ton after accounting for expected WTE energy revenues.

Figure 5-1 and Figure 5-2 show the various cost per ton over the 50-year term for both low bound (initial 3,000 tpd WTE facility) and high bound (initial 4,000 tpd WTE facility) scenarios. WTE revenues, expenses not including annual amortized capital cost, and net facility cost which includes expenses, annual amortized capital cost, less revenues are included to compare with WEBR cost per ton. The

WEBR cost per ton drops slightly after year 10 because the additional capital cost for the IMF facility or additional IMF capacity is assumed to be completed year 10. The WTE net facility cost per ton changes significantly various years, with timing depending on which scenario, high bound or low bound, is shown. For the low bound scenario (initial 3,000 tpd facility): the increase in Years 18, 19, and 20 are due to cost for facility expansion before the facility can accept the additional waste; the drop after Year 30 is due to the completion of the annual amortized initial capital payment at the end of the 30 year term; and the drop in Year 49 is due to the completion of the annual amortized expansion capital payment at the end of the 30 year term.

Figure 5-1. Cost Per Ton Comparison between WTE and WEBR – Initial 3000 tpd Facility

For the high bound scenario (initial 4,000 tpd facility): the increase in Years 11, 12, and 12 are due to cost for facility expansion before the facility can accept the additional waste; the drop after Year 30 is due to the completion of the annual amortized initial capital payment at the end of the 30 year term; and the drop in Year 41 is due to the completion of the annual amortized expansion capital payment at the end of the 30 year term.

Figure 5-2. Cost Per Ton Comparison between WTE and WEBR – Initial 4000 tpd Facility

As mentioned previously, there are several risks or assumptions included in both the WTE and WEBR financial models which, if different, can significantly impact the projected cost in the short term and long term. The top 5 risks or assumptions impacting the financial models for both the WTE and WEBR are identified in Table 5-5:

Table 5-5. Top 5 Risks or Assumptions Impacting WTE and WEBR Financial Models

Waste-to-Energy	Waste Export by Rail
Facility capacity and tonnage projections. If the larger facility capacity option is selected and the actual waste processed is significantly lower, the cost per ton of waste will significantly increase. This could occur either because King County tonnage is below forecast, or because excess capacity is not successfully sold.	Short term contracts, which may result in large fluctuations in fees long term.
Electrical sales revenues. Current estimates are conservative with conservative escalation (1.5% annually). If revenues are higher, the cost per ton for WTE facility disposal will further decrease creating a larger difference from WEBR.	Rail capacity limited presently and likely in the future, which can result in increased costs as demand increases.
Carbon sequestration (carbon neutral and carbon free). Carbon neutral requirements can likely be met by carbon sequestration equipment, but if carbon free requirements are enacted, exceptions would have to be made for WTE facilities.	Congestion or service interruption (i.e., snowstorm, earthquake) of rail system may result in lower reliability and additional costs for expansion or improvements or need to road-haul waste to landfill..
Escalation Rate. Current CPI estimate is 3%. All costs except electrical revenues use this CPI, but actual CPI can vary over time and expense type. This risk is also true for WEBR, but was not identified as one of its top five.	Compaction of waste per container. Current estimate is conservatively based on current County waste compaction. Variances will impact hauling and disposal costs per ton.
Materials Recovery. Quantity of metals and aggregate recovery, revenues, and reduction of ash for disposal all impact costs and revenues for the facility.	Captive shipper landfills make it more difficult to switch landfills and rail hauler at end of initial contract. Therefore, they have the power to increase rates without competition.

Based on the financial models developed, WTE facility disposal costs less per ton of waste and provides the County more financial control of long-term waste disposal costs than WEBR and could result in approximately $4.3 to $7.2 billion in savings over the 50-year term. When compared to WEBR, the risks or assumptions for the WTE facility disposal option can be mitigated earlier in the life of the project, such as with development of a PPA to control electrical revenues for a longer period of time, or carbon sequestration requirements and permitting which should be determined at the time of facility development. Therefore, the costs for WTE facility disposal are likely lower and more reliable than the potentially volatile WEBR market.

5.3 Permitting

The construction of either a new WTE facility or IMF facility will require many of the same licenses, permits and / or approvals related to a new construction project. Such permits are listed in Table 3-10 in Section 3.6 and in Appendix B. However, due to the handling and combustion of solid waste, the permitting requirements for a new WTE facility are significantly more robust than for an IMF facility. Permits required for a WTE facility that are not required for an IMF facility include a PSD air construction permit and visibility impact analysis prior to construction, and a Title V operating permit and solid waste handling permit once the facility is operational. Both types of facilities will still be subject to other environmental regulations such as stormwater control and other Federal regulations for their respective facility types. Refer to Table 5-6 for a comparison of permitting requirements. Procuring the Title V operating permit and solid waste handling will take place during the construction phase, and will not affect the critical path of the schedule.

Table 5-6. Permitting Comparison

Permit	WTE Facility	IMF Facility
Planning and SEPA Approvals, including EIS	✓	✓
Land Use and Related Early Permit Submittals	✓	✓
Building and Construction Permits	✓	✓
Operating Permits and Approvals	✓	✓
PSD Air Construction Permit	✓	-
Title V Operating Permit (or additional requirements of RCW 80.50 if >350 MW)	✓	-
Visibility Impact Analysis	✓	-
Solid Waste Handling Permit	✓	-

5.4 Regulatory Environment

WTE and WEBR waste management strategies will involve many of the same regulatory agencies and involve many of the same regulatory processes. For example, both alternatives will require an extensive public participation and approval process under the State Environmental Policy Act (“SEPA”). The SEPA process will require that a comprehensive Environmental Impact Statement (“EIS”) be prepared to evaluate environmental impacts associated with the County’s preferred strategy. A site for an IMF or WTE facility will need to be selected by the County such that site-specific environmental impacts and mitigation measures can be evaluated in the EIS. The EIS will also need to discuss GHG emissions.

Regulatory considerations for WTE and WEBR are summarized below:

- WTE may be less familiar to regulators than WEBR, requiring additional time and effort to address agency questions or concerns. However, as Spokane City does have a WTE permitted in Washington, it should be manageable with some education of the local regulators.

- WTE may be less familiar to the public than WEBR and may require higher public participation efforts compared to WTE. This could be managed with a proactive public campaign early in the planning process.
- Siting a WTE facility may be more challenging than siting an IMF in the County due to familiarity and possibly adverse public perceptions. This is a true challenge that will take time and public education to understand the limited impact. However, siting either an IMF or a WTE within the County limits will require early public interaction to help avoid the “Not in my backyard” affect.
- WTE permitting may be more difficult and time consuming compared to WEBR due to complexities in air permitting. This is complex and somewhat time consuming, but from a regulatory standpoint is easily achievable. WEBR permitting will be significantly more streamlined.

Public acceptance of the County’s proposed disposal strategy may strongly affect the timing and difficulty of the SEPA / EIS approvals as well as the ability for the County to site a WTE facility or IMF. WEBR is currently being implemented by the City of Seattle and other communities in Washington and is therefore likely to be familiar and less challenged. Washington has some familiarity with WTE from the Spokane City WTE facility; however, the Spokane City facility is much older than a new WTE facility and emissions and safety technology has improved since Spokane City’s facility was built.

5.5 Environmental Impacts

The following sections summarize environmental impacts of the WTE and WEBR disposal methods, which are compared based on the greenhouse gas impacts.

5.5.1 Greenhouse Gas Impacts

The GHG evaluations for WTE and WEBR disposal strategies are discussed in Sections 3.12 and 4.6, respectively. Table 5-7 compares net GHG emissions for WTE and WEBR using the EPA WARM Model Microsoft Excel spreadsheet method.

Table 5-7. Comparison of Net GHG Emissions for WTE and WEBR, WARM Method 1

Description	WTE (MTCO2E/ton)	WEBR (MTCO2E/ton) (1)
Net GHG Emissions, excluding ash recycling (2)	0.13	0.12 to 0.33
Emission Credit for AMP (3)	-0.11	0.00
Emission Credit for Ash Recycling (4)	-0.07	0.00
Total Net Emissions	-0.05	0.12 to 0.33

(1) The WARM model Excel spreadsheet does not explicitly show or allow changes to carbon sequestration credits for landfilling. The lower emission estimate assumes a carbon sequestration credit of 0.21 MTCO2E/ton based on emission credits in the WARM model documentation (see Appendix D).

(2) Net GHG emissions assume short haul trucking of 20 miles to WTE facility. Mileage to landfill was assumed to be 20 miles for trucking to IMF and 320 miles of rail mileage to out of county landfill. The rail mileage was reduced by 80 percent to account

for assumed 20-percent lower emission factor for rail versus truck transport. The adjusted WEBR mileage used in this analysis was 84 miles (20 miles + 320/5 miles = 84 miles).

(3) Emission credit assumes additional 0.003 tons of ferrous metals and 0.011 tons of non-ferrous metals can be recovered with AMP compared to WARM model default estimates.

(4) The emission credit for ash recycling was calculated using WARM Method 1. Inputs: 0.075 tons of ash per ton of MSW; composition: fly ash.

Table 5-8 summarizes the WARM model results using the emission factors and emission credits in the WARM model documentation, with refinements to the emission factors to account for lower rail emissions compared to truck transportation on a per mile basis, increased emission credits for AMP and ash reuse, and increased LFG recovery.

Table 5-8. Comparison of Net GHG Emissions for WTE and WEBR, WARM Method 2

Description	WTE (MTCO2E/ton)	WEBR (MTCO2E/ton)
Facility Sources	0.42	0.34
Transportation Sources	0.01	0.03
Utility Credits	-0.26	-0.08
Other Credits (1)	-0.22	-0.21
Total Net GHG Emissions (2)	-0.05	0.08 to 0.29

(1) Other credits for WTE are associated with increased offsets for AMP and ash reuse. Other credits for WEBR are associated with carbon sequestration of non-anaerobically biodegradable biogenic wastes.

(2) The higher emission value does not include the carbon sequestration credit.

As indicated in Table 5-7, WARM Method 1 indicates that a net difference of 0.17 MTCO2E/ton of GHGs can be avoided by WTE compared to waste disposal at an out of county landfill using WEBR. If carbon sequestration emission credits are not applied to the landfill, then a net difference of 0.38 MTCO2E/ton of GHG can be avoided by WTE compared to WEBR, assuming a carbon sequestration credit of 0.21 MTCO2E/ton.

As indicated in Table 5-8, a net difference of 0.13 MTCO2E/ton of GHGs can be avoided by WTE compared to waste disposal at an out of county landfill using WEBR if emission credits for AMP and ash reuse are factored into the analysis. If carbon sequestration emission credits are not applied to the landfill, then a net difference of 0.34 MTCO2E/ton of GHG can be avoided by WTE compared to WEBR, assuming a landfill carbon sequestration credit of 0.21 MTCO2E/ton.

In 2008, the City of Vancouver, BC conducted a similar study that compared GHG emissions between WTE and a landfill. The Vancouver, BC study evaluated GHG emissions using IPCC guidance rather than the USEPA WARM model. The Vancouver, BC study did not include transportation GHG emissions or GHG emission off-set credits for electric generation, ash recycling, or carbon sequestration.

The Vancouver, BC study calculated net GHG emissions for two waste composition scenarios. The first scenario was based on 2008 waste composition data (52 percent recycling rate) and the second scenario was based on predicted 2016 waste composition. The second scenario assumed that the city achieved its recycling goal of 70% in 2016.

The waste compositions used in the Vancouver, BC study are summarized in the Table 5-9. U.S. National waste composition and 2015 County waste composition data are also included for comparison. Professional judgement was used to cross-reference national and the County composition into the categories used in the 2008 Vancouver, BC study.

Table 5-9. Waste Compositions Comparison

Composition	Vancouver 2008	Vancouver 2016	National 2015	King County 2015
Wood	22.9	13.3	8	13
Paper and Paperboard	14.6	10.0	13	12
Food	12.5	10.0	22	19
Yard and Garden	4.2	0.0	8	5
Plastics	8.3	10.0	19	18
Non-Compostable Organics	8.3	13.3	0	2
Inorganics	6.3	10	14	6
Other	22.9	33.4	16	25
Totals	**100**	**100**	**100**	**100**

As indicated in Table 5-10 the results from the Vancouver, BC study and the County Study were similar for GHG generated from waste combustion and landfilling. Emission credits were not evaluated in the Vancouver study, so no comparison can be made regarding off set credits for avoided CO_2 emissions.

Table 5-10. Comparison of Vancouver and County GHG Emission Estimates

Vancouver GHG Study Results				County GHG Study Results	
2008		**2016**		**2019**	
WTE	**Landfill**	**WTE**	**Landfill**	**WTE**	**Landfill**
0.30	0.35	0.42	0.22	0.42	0.32

The relatively high emissions for WTE in the County compared to Vancouver may be explained by the relatively high percentage of plastic in the waste stream used in this Study. The percentage of plastics in the national waste composition is similar to the plastics composition in the County waste stream, suggesting that the GHG emissions for the County should be similar to national averages.

The percentage of food waste in the national and the County waste composition data is higher than the Vancouver composition data. Since food waste produces relatively large amounts of methane compared to other waste categories, this suggests that landfill GHG emissions for this Study should be higher than emissions from a Vancouver landfill. This could be partially offset by higher moisture conditions in Vancouver compared to an out of county landfill considered in this Study. Higher moisture conditions promote faster and more complete anaerobic decomposition of the waste. Overall, the comparison of the Vancouver study and this Study suggest similar results.

5.6 Transportation Needs and Traffic Impacts

Both WTE and WEBR require centralized facilities for reception of waste from the transfer stations (the WTE facility or the IMF). Transportation impacts from trucking at these locations are therefore expected to be comparable to those seen at regional landfills. Additional transportation requirements and traffic impacts at the WTE facility are strongly dependent on the siting of the plant, specifically as it relates to the disposal of ash and bypass wastes. In contrast, additional impacts of WEBR caused by increased rail congestion will be regional rather than localized around the IMF, but the degree of congestion and possible mitigation are depending on siting and future rail use.

Quantitatively, the most direct comparison between a WTE facility and WEBR solution is through examination of vehicle and rail “ton-miles”, or the transport of one ton of MSW for one mile. Thus, in 2025 a WTE facility would have similar or slightly higher vehicle traffic as WEBR, but considerably less rail traffic. As discussed above, a key factor in determining transportation requirements for WTE is the disposal of ash and bypass waste, which is reliant on facility siting. As MSW tonnage and transport requirements increase in future decades, this trend is projected to remain constant. A full accounting of transportation projects through 2075 is provided in Appendix H.

Table 5-11. Transportation Needs of WTE vs. WEBR in 2025

Transportation Metric	WTE Onsite Ash/Bypass Disposal		WTE Out of County Ash/Bypass Disposal		WEBR	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Total Vehicle Ton-Miles	18,560,920	21,585,360	23,757,960	27,629,260	18,560,920	21,585,360
Total Rail Ton-Miles	--	--	83,152,640	96,702,400	296,974,720	345,365,760

5.7 Summary Comparison

The following subsections provide the advantages and disadvantages identified within this Study for using either WTE or WEBR as the County’s next MSW disposal method.

5.7.1 WTE Advantages and Disadvantages

Advantages and disadvantages associated with constructing a WTE facility to dispose of MSW within the County are as follows:

Advantages

- Lower long-term net cost for waste transportation and disposal per ton than WEBR.
- Control of waste disposal is independent of available landfill and rail capacity (not at the discretion of contracted haulers and disposal facilities that have control of the fees charged).
- Long term waste disposal (at least 20-year contract term with options for extension and expansion).

- More environmentally responsible than landfilling
    - Less potential for groundwater and surface water impacts.
    - Less impact for total land usage and species disruption
    - Lower net GHG emissions
    - Higher recycling rates and power generation
    - Listed as a higher priority on the waste hierarchy for USEPA and as listed in WAC 173-303-140
- Resource recovery including electricity generation, metals recovery, and potential aggregate reuse.

Disadvantages

- Significant capital investment and ongoing costs for maintenance.
- Regulatory – carbon neutral to zero carbon requirements. If zero carbon electrical generation is mandated, an exception for WTE facilities would have to included or sophisticated carbon flue gas capture would be required.
- Lower electricity sales revenues in region compared to other national waste-to-energy facilities due to large use of hydroelectricity.
- Set capacity based on facility size resulting in fixed costs regardless of actual waste tonnage available. This is pertinent as the County may not know if actual waste tonnages match the low or high bound projections or if excess capacity can be sold until well into the planning / design process.
- Facility will likely face significant opposition for siting and establishing a location due to public “not in my backyard” concerns.

5.7.2 WEBR Advantages and Disadvantages

Advantages and disadvantages associated with implementing WEBR as an MSW disposal system within the County are as follows:

Advantages

- Lower fuel consumption and emissions than the County’s current truck transportation system, although truck drayage of intermodal containers to the IMF is anticipated to be roughly equal to the County’s current trucking from transfer stations to Cedar Hills.
- Less interfacing with the motoring public at an IMF than at or near Cedar Hills.
- In the event of a rail line outage or blockage, containerized waste could be transported by truck / chassis over alternate routes to the landfill. In an emergency, the waste companies could also make alternative disposal landfills available such as the Greater Wenatchee Landfill (WM) and Coffin Butte (RS) in Oregon.
- Some possibility of improving regional freight mobility and spurring economic development if an IMF can be developed for materials that would move better by rail rather than by truck.

Disadvantages

- Although the railroads, the State, and the Federal government continue to invest in upgrading rail infrastructure, present and future capacity is limited. Unless a major catastrophe such as a landslide or earthquake wipes out a significant portion of the Seattle-Portland track, there will continue to be some rail capacity. The question becomes one of affordability, i.e., how much is each customer willing to pay the railroad to move its products. It seems likely that each railroad will select and prioritize what commodities it will haul based on its own economic self-interest: that is, which combination of total tons and rate/ton provides the highest economic benefit for the railroad. Other considerations could be length of contract; stability and/or change in tonnage of certain commodities (e.g. coal); other factors from outside the region, etc.
- Siting a new IMF (if required) requires a large piece of land with or adjacent to existing tracks.
- To minimize their risk, in the interviews, railroads indicated that they typically want contracts of five years or less. This will affect future pricing projections and expose the County to much higher disposal risk.
- Rarely, if ever, do the railroads offer liquidated damages or agree to service performance criteria.
- WEBR option is at risk of a potential derailment that scatters several rail cars and loaded or empty containers (depending on the direction of the train: Loaded=south and east; empty=west and north) and spillage of waste could occur. This differs from a truck spillage incident where typically only one truck is involved, spilling significantly less waste than a train carrying 80 to 100 intermodal containers
- A new IMF may be required to accommodate the additional capacity for the County's waste. At present, railroad traffic is highly congested in and around the greater Seattle and Portland areas and the railroads are limited in what they can offer the County for dedicated intermodal service and yard space for building trains. Thus, it is possible that an independent terminal operator, or the County, would need to provide the railroad a facility with rail access to connect and transport loaded railroad cars to the landfill.
- "Captive shipper" landfills are served by one railroad each: Republic Services' Roosevelt landfill is served only by the BNSF; WM's CRLF and Waste Connections' Finley Buttes are served only by the UPRR. If the County wants to keep using the same landfill when the initial contract expires, then there is no choice of railroads because only one railroad serves that landfill. Conversely, if the County wants to change landfills, then it has to change railroads.

6 CONCLUSIONS

The Arcadis Team has performed a review of the relevant information and developed comprehensive financial models and GHG analyses for both WTE and WEBR scenarios. As these evaluations and the limitations of our scope heavily impact the proposed conclusions, the conclusions should be directly reviewed in conjunction with the Arcadis Team’s scope of services, direction received from the County during the Study development, and the complete text of this Study for a clear understanding of the limitations of review and the comprehensive summaries, assumptions, and comparisons for each topic.

6.1 Tonnage Forecast and Landfill Capacity Conclusions

Review of the various tonnage estimates, developed in conjunction with the County, settled on a low and a high bound tonnage forecast that ranges a large span of MSW volume for disposal, from 1,035,239 tons in 2045 on the low bound, to 1,496,171 in 2045 on the high bound. This large swing of over 450,000 tons between the scenarios greatly impacts not only the future costs borne by the County, but what design decisions must occur, primarily for initial WTE construction capacity and expansion dates. As the County may not know which forecast will be more accurate in the upcoming years until several years have passed, it is important that the County move forward in a manner to allow for the greatest flexibility in changing future decisions to accommodate waste conditions. For WEBR options, the impact is limited to ensuring sufficient IMF capacity is available for all future options. However, for WTE, it is critical that the County look for site options that would allow for larger facility sizes when performing initial siting and location evaluation so that the opportunity to increase the size of the facility during the proposal stage is possible.

Additionally, the large range of forecasting will significantly impact remaining landfill air space at Cedar Hills. Based on current available airspace and proposed future permitted capacity, the Arcadis Team has estimated that even with WTE ash disposal (assuming a reasonable ash re-use case), Cedar Hills would have remaining air space well into the WTE facility commercial operation period, assuming a COD date of 2028. If the County is able to permit an additional lined cell for use as an ash monofill, the County could save significant costs for hauling and disposal of the remaining WTE ash during the operating period. If the County maintained sufficient airspace to provide for ash disposal at Cedar Hills for the entire 50-year term with a cost of disposal at Cedar Hills of half the cost of WEBR, the Arcadis Team estimates a 50-year savings to the County of over $350 million or a total sum cost per ton reduction of $6/ton for the entire 50-year period. If the actual landfill operation cost for small volumes of ash disposal is less than half of the predicted WEBR price, which is likely, the cost savings to the County would increase.

6.2 WTE Conclusions

After review of the appropriate data and models, it is apparent that due to the stability of operational costs and revenue streams, WTE will provide a gross savings of approximately $4.3 to $7.2 billion (low bound to high bound tonnage forecast) when compared to WEBR over the 50-year planning period and WTE has a significant advantage on improving recycling rates and energy recovery when compared to WEBR. While the short-term, 10-year, cost-per-ton differential between WTE and WEBR is nearly even due to the large construction cost for WTE, WTE’s multiple revenue streams significantly lower escalation and inflation impacts and protect against future price increases as the County moves further into the planning period.

WTE has a long development period and is estimated to take eight (8) to ten (10) years before the County could begin commercial operations, with significant concern for the timeliness of the public comment period and submission and review of the PSD air permitting documents with the regulatory agencies, as well as the potential lengthy timeframe associated with identifying and acquiring a new site, in a worst case scenario. Analysis of the remaining air space in the current and proposed future landfill cells show that the County has sufficient time and disposal capacity to use the landfill during the long-lead time required for project development.

Modelling lifecycle GHG emissions for a WTE facility is complex and depends heavily on the assumptions utilized for offsets due to recovered materials and energy generation. However, without offsets, WTE has known anthropogenic GHG emissions for every ton of MSW combusted. Even with offsets for recovered materials, WTE will likely require carbon capture and sequestration technology installed in order to remain viable past deadlines in 2030 and 2045 for carbon neutral and non-emitting utility sources mandated by the Washington State legislature. These GHG capture systems are on the cusp of commercial viability, but would be the first of its kind installed in a commercial fashion on a WTE facility in the US. If complications arise with installation or operation of the system, or if regulators do not approve use of such a system to be compliant, it could have associated long-term risk of non-compliance with State law, if the law remains unchanged.

Prior to completion of this Report, the Arcadis Team requested Ramboll to conduct a peer review of the Report related to the waste-to-energy content with a particular emphasis on European best practices. Appendix I contains their review with our response to their comments embedded in their document in ***bold italicized orange font*** text.

6.3 WEBR Conclusions

After review of the appropriate data and models, it is apparent that because of the short-term nature of a negotiated WEBR contract (5-10 years before renegotiations) and the difficulty in sourcing an IMF accessible by both rail carriers, the County would have a higher risk of price increases over the life of the planning period. WEBR costs have a high potential for future escalation due to the limitations in existing rail capacity and the potential monopoly effect if there is no IMF served by both rail lines to spur competition during future negotiations. These risks are not built-in to the current pricing comparison and represent a large unknown that the County will be at risk for in future disposal cost and solid waste rate impacts.

It is unlikely that any existing IMF could handle the addition of all of the County's currently available waste, but expansions or additions to existing IMFs or construction of a new IMF is a relatively easier task than the permitting, review, and construction process for a WTE facility. If necessary, the County could begin using WEBR for future disposal in two (2) to six (6) years, depending on what siting and construction is ultimately required. If the County moves forward with WEBR for the total volume of waste, it is likely that the current rail haulers will require or request that the waste be implemented in a phased approach over time.

GHG estimates of WEBR show that due to the propensity for a landfill to be a carbon sink for certain anthropogenic plastics, landfill gas energy recovery, and the lowered GHG emissions due to rail haul; WEBR would be a negative GHG source if landfill gas collection efficiency is as high as assumed in the WARM model. However, because actual landfill gas collection efficiency is lower than WARM model estimates, GHG emissions for WEBR is closer to net-neutral or slightly positive due to the high global warming potential of methane emissions. Additionally, WEBR provides no additional ability to recover or re-use certain materials such as metal and aggregate, which will lower the volume of total recyclables collected in the County when compared to WTE.

6.4 Summary

Based on these conclusions and the broader discussion throughout this Study, the Arcadis Team recommends that the County consider pursuing additional preliminary evaluation, permitting and siting considerations, and other steps necessary to move forward with WTE facility disposal over WEBR. Due to the long-term cost savings, improved recycling rates, and potential for net negative GHG emissions with the inclusion of carbon capture technology, WTE facility disposal will provide a significant financial and environmental benefit to the County over WEBR. Additionally, even with the potential for hurdles during the permitting and siting process, WTE represents a much more stable long-term financial profile over WEBR to protect the County's solid waste rate structure against future inflation and escalation.

Because of the timeframe expected to update the County's Comprehensive Plan for Solid Waste Management for any future change to disposal options, the Arcadis Team recommends the County evaluate the opportunity to perform simultaneous siting and planning studies for WTE in parallel with updates to the Comprehensive Plan. This would improve the critical path schedule to allow for the WTE facility to enter commercial operation at an earlier date and to maximize available landfill airspace for future risk aversion.

Finally, concurrently with the existing County activities to maximize capacity at the Cedar Hills landfill, the Arcadis Team recommends that the County evaluate opportunities at Cedar Hills for future ash monofill development and long-term disposal, as well as opportunity to either purchase additional adjacent property or use the buffer space as a potential siting location for the WTE facility. The WTE financial model evaluated within this Study utilized assumptions that were site neutral in an effort to provide the best comparison case, and added conservatism, when comparing against WEBR. If the County utilizes a current County-owned property for development of the WTE facility and maintains air space at Cedar Hills for future ash disposal, the County could save an additional $100 million in avoidance of land purchase and $350 million in ash disposal and hauling costs over the 50-year planning period. These combined savings would reduce the total cost per ton for the 50-year period by approximately $6/ton. If the County wishes to maximize future landfill airspace at Cedar Hills or waste forecast tonnages are significantly higher in the short term than expected, the Arcadis Team recommends that the County consider short-term, partial WEBR of a portion of available MSW during the long planning process. Smaller tonnage amounts should be easily implemented with existing IMFs. This would allow for the County to maximize future airspace available or perform long-term expansions or additions of the Cedar Hills landfill for future use as an ash monofill.

APPENDIX A

Cedar Hills Landfill Capacity Impacts

Fast Track - Low Bound Waste Forecast

WTE online 2028 - 1 million tonnes. Expansion in 2048 to 1,333,333 tonnes.																
Year	Total tons of waste to be managed	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
2025	928,046	928,046	1,160,058			1,160,058	928,046	928,046	1160057.728			1,160,058	928,046	928046.1821	1160057.728	
2026	933,450	933,450	1,166,812			1,166,812	933,450	933,450	1,166,812			1,166,812	933,450	933,450	1,166,812	
2027	938,853	938,853	1,173,566			1,173,566	938,853	938,853	1,173,566			1,173,566	938,853	938,853	1,173,566	
2028	944,256	(55,744)	(69,680)	217,179	271,474	201,794	(55,744)	(69,680)	70,819	88,524	18,844	(55,744)	(69,680)	18,885	23,606	(46,073)
2029	949,660	(50,340)	(62,925)	218,422	273,027	210,102	(50,340)	(62,925)	71,224	89,031	26,105	(50,340)	(62,925)	18,993	23,741	(39,184)
2030	955,063	(44,937)	(56,171)	219,665	274,581	218,410	(44,937)	(56,171)	71,630	89,537	33,366	(44,937)	(56,171)	19,101	23,877	(32,294)
2031	960,075	(39,925)	(49,906)	220,817	276,022	226,115	(39,925)	(49,906)	72,006	90,007	40,101	(39,925)	(49,906)	19,201	24,002	(25,904)
2032	965,087	(34,913)	(43,642)	221,970	277,462	233,821	(34,913)	(43,642)	72,382	90,477	46,835	(34,913)	(43,642)	19,302	24,127	(19,514)
2033	970,099	(29,901)	(37,377)	223,123	278,903	241,527	(29,901)	(37,377)	72,757	90,947	53,570	(29,901)	(37,377)	19,402	24,252	(13,124)
2034	975,110	(24,890)	(31,112)	224,275	280,344	249,232	(24,890)	(31,112)	73,133	91,417	60,305	(24,890)	(31,112)	19,502	24,378	(6,734)
2035	980,122	(19,878)	(24,847)	225,428	281,785	256,938	(19,878)	(24,847)	73,509	91,886	67,039	(19,878)	(24,847)	19,602	24,503	(344)
2036	985,373	(14,627)	(18,283)	226,636	283,295	265,012	(14,627)	(18,283)	73,903	92,379	74,096	(14,627)	(18,283)	19,707	24,634	6,351
2037	990,625	(9,375)	(11,719)	227,844	284,805	273,086	(9,375)	(11,719)	74,297	92,871	81,152	(9,375)	(11,719)	19,812	24,766	13,047
2038	995,876	(4,124)	(5,155)	229,051	286,314	281,159	(4,124)	(5,155)	74,691	93,363	88,208	(4,124)	(5,155)	19,918	24,897	19,742
2039	1,001,127	1,127	1,409	230,000	287,500	288,909	1,127	1,409	75,000	93,750	95,159	1,127	1,409	20,000	25,000	26,409
2040	1,006,379	6,379	7,973	230,000	287,500	295,473	6,379	7,973	75,000	93,750	101,723	6,379	7,973	20,000	25,000	32,973
2041	1,012,086	12,086	15,107	230,000	287,500	302,607	12,086	15,107	75,000	93,750	108,857	12,086	15,107	20,000	25,000	40,107
2042	1,017,825	17,825	22,281	230,000	287,500	309,781	17,825	22,281	75,000	93,750	116,031	17,825	22,281	20,000	25,000	47,281
2043	1,023,597	23,597	29,496	230,000	287,500	316,996	23,597	29,496	75,000	93,750	123,246	23,597	29,496	20,000	25,000	54,496
2044	1,029,402	29,402	36,752	230,000	287,500	324,252	29,402	36,752	75,000	93,750	130,502	29,402	36,752	20,000	25,000	61,752
2045	1,035,239	35,239	44,049	230,000	287,500	331,549	35,239	44,049	75,000	93,750	137,799	35,239	44,049	20,000	25,000	69,049
2046	1,041,110	41,110	51,387	230,000	287,500	338,887	41,110	51,387	75,000	93,750	145,137	41,110	51,387	20,000	25,000	76,387
2047	1,047,014	47,014	58,767	230,000	287,500	346,267	47,014	58,767	75,000	93,750	152,517	47,014	58,767	20,000	25,000	83,767
2048	1,052,951	(280,382)	(350,477)	242,179	302,724	(47,753)	(280,382)	(350,477)	78,971	98,714	(251,763)	(280,382)	(350,477)	21,059	26,324	(324,153)
2049	1,058,923	(274,410)	(343,013)	243,552	304,440	(38,573)	(274,410)	(343,013)	79,419	99,274	(243,739)	(274,410)	(343,013)	21,178	26,473	(316,540)
2050	1,064,928	(268,405)	(335,507)	244,933	306,167	(29,340)	(268,405)	(335,507)	79,870	99,837	(235,670)	(268,405)	(335,507)	21,299	26,623	(308,884)
2051	1,070,967	(262,366)	(327,958)	246,322	307,903	(20,055)	(262,366)	(327,958)	80,323	100,403	(227,555)	(262,366)	(327,958)	21,419	26,774	(301,184)
2052	1,077,040	(256,293)	(320,366)	247,719	309,649	(10,717)	(256,293)	(320,366)	80,778	100,972	(219,394)	(256,293)	(320,366)	21,541	26,926	(293,440)
2053	1,083,148	(250,185)	(312,732)	249,124	311,405	(1,327)	(250,185)	(312,732)	81,236	101,545	(211,186)	(250,185)	(312,732)	21,663	27,079	(285,653)
2054	1,089,290	(244,043)	(305,054)	250,537	313,171	8,117	(244,043)	(305,054)	81,697	102,121	(202,933)	(244,043)	(305,054)	21,786	27,232	(277,821)
2055	1,095,467	(237,866)	(297,332)	251,957	314,947	17,615	(237,866)	(297,332)	82,160	102,700	(194,632)	(237,866)	(297,332)	21,909	27,387	(269,945)
2056	1,101,680	(231,653)	(289,567)	253,386	316,733	27,166	(231,653)	(289,567)	82,626	103,282	(186,284)	(231,653)	(289,567)	22,034	27,542	(262,025)
2057	1,107,927	(225,406)	(281,757)	254,823	318,529	36,772	(225,406)	(281,757)	83,095	103,868	(177,889)	(225,406)	(281,757)	22,159	27,698	(254,059)
2058	1,114,210	(219,123)	(273,904)	256,268	320,335	46,432	(219,123)	(273,904)	83,566	104,457	(169,447)	(219,123)	(273,904)	22,284	27,855	(246,049)
2059	1,120,529	(212,804)	(266,006)	257,722	322,152	56,146	(212,804)	(266,006)	84,040	105,050	(160,956)	(212,804)	(266,006)	22,411	28,013	(237,992)
2060	1,126,883	(206,450)	(258,063)	259,183	323,979	65,916	(206,450)	(258,063)	84,516	105,645	(152,417)	(206,450)	(258,063)	22,538	28,172	(229,891)
2061	1,133,273	(200,060)	(250,075)	260,653	325,816	75,741	(200,060)	(250,075)	84,995	106,244	(143,830)	(200,060)	(250,075)	22,665	28,332	(221,743)
2062	1,139,700	(193,633)	(242,041)	262,131	327,664	85,622	(193,633)	(242,041)	85,477	106,847	(135,194)	(193,633)	(242,041)	22,794	28,492	(213,549)
2063	1,146,163	(187,170)	(233,962)	263,617	329,522	95,559	(187,170)	(233,962)	85,962	107,453	(126,510)	(187,170)	(233,962)	22,923	28,654	(205,308)
2064	1,152,663	(180,670)	(225,838)	265,112	331,391	105,553	(180,670)	(225,838)	86,450	108,062	(117,776)	(180,670)	(225,838)	23,053	28,817	(197,021)
2065	1,159,199	(174,134)	(217,667)	266,616	333,270	115,603	(174,134)	(217,667)	86,940	108,675	(108,992)	(174,134)	(217,667)	23,184	28,980	(188,687)
2066	1,165,773	(167,560)	(209,450)	268,128	335,160	125,710	(167,560)	(209,450)	87,433	109,291	(100,159)	(167,560)	(209,450)	23,315	29,144	(180,306)
2067	1,172,384	(160,949)	(201,186)	269,648	337,060	135,874	(160,949)	(201,186)	87,929	109,911	(91,275)	(160,949)	(201,186)	23,448	29,310	(171,877)
2068	1,179,032	(154,301)	(192,876)	271,177	338,972	146,096	(154,301)	(192,876)	88,427	110,534	(82,341)	(154,301)	(192,876)	23,581	29,476	(163,400)
2069	1,185,719	(147,614)	(184,518)	272,715	340,894	156,376	(147,614)	(184,518)	88,929	111,161	(73,357)	(147,614)	(184,518)	23,714	29,643	(154,875)
2070	1,192,443	(140,890)	(176,113)	274,262	342,827	166,714	(140,890)	(176,113)	89,433	111,791	(64,321)	(140,890)	(176,113)	23,849	29,811	(146,302)
2071	1,199,205	(134,128)	(167,660)	275,817	344,771	177,111	(134,128)	(167,660)	89,940	112,425	(55,235)	(134,128)	(167,660)	23,984	29,980	(137,680)
2072	1,206,005	(127,328)	(159,160)	277,381	346,727	187,567	(127,328)	(159,160)	90,450	113,063	(46,097)	(127,328)	(159,160)	24,120	30,150	(129,009)
2073	1,212,844	(120,489)	(150,611)	278,954	348,693	198,082	(120,489)	(150,611)	90,963	113,704	(36,907)	(120,489)	(150,611)	24,257	30,321	(120,290)
2074	1,219,722	(113,611)	(142,013)	280,536	350,670	208,657	(113,611)	(142,013)	91,479	114,349	(27,664)	(113,611)	(142,013)	24,394	30,493	(111,520)
2075	1,226,639	(106,694)	(133,367)	282,127	352,659	219,292	(106,694)	(133,367)	91,998	114,997	(18,370)	(106,694)	(133,367)	24,533	30,666	(102,701)

Fast Track - Low Bound Waste Forecast

WTE online 2028 - 1 million tonnes. Expansion in 2048 to 1,333,333 tonnes.																
Year	**Total tons of waste to be managed**	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
20 year horizon (2025 - 2045)	20,597,350	2,597,350	3,246,687	4,064,410	5,080,512	8,327,199	2,597,350	2,546,600	4,825,787	1,656,689	1,402,940	3,297,437	2,546,600	3,153,776	3,942,220	188,035
50 year horizon (2025 -2075)	54,540,180	(2,793,144)	(3,491,430)	11,850,992	14,813,740	11,322,311	(2,793,144)	(4,191,517)	7,364,890	4,830,567	(2,161,298)	(2,093,057)	(4,191,517)	3,830,870	4,788,587	(5,703,714)

Best Case - Low Bound Waste Forecast

WTE online 2030 - 1 million tonnes. Expansion in 2048 to 1,333,333 tonnes.																
Year	Total tons of waste to be managed	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
2025	928,046	928,046	1,160,058			1,160,058	928,046	1,160,058			1,160,058	928,046	1,160,058			1,160,058
2026	933,450	933,450	1,166,812			1,166,812	933,450	1,166,812			1,166,812	933,450	1,166,812			1,166,812
2027	938,853	938,853	1,173,566			1,173,566	938,853	1,173,566			1,173,566	938,853	1,173,566			1,173,566
2028	944,256	944,256	1,180,320			1,180,320	944,256	1,180,320			1,180,320	944,256	1,180,320			1,180,320
2029	949,660	949,660	1,187,075			1,187,075	949,660	1,187,075			1,187,075	949,660	1,187,075			1,187,075
2030	955,063	(44,937)	(56,171)	219,665	274,581	218,410	(44,937)	(56,171)	71,630	89,537	33,366	(44,937)	(56,171)	19,101	23,877	(32,294)
2031	960,075	(39,925)	(49,906)	220,817	276,022	226,115	(39,925)	(49,906)	72,006	90,007	40,101	(39,925)	(49,906)	19,201	24,002	(25,904)
2032	965,087	(34,913)	(43,642)	221,970	277,462	233,821	(34,913)	(43,642)	72,382	90,477	46,835	(34,913)	(43,642)	19,302	24,127	(19,514)
2033	970,099	(29,901)	(37,377)	223,123	278,903	241,527	(29,901)	(37,377)	72,757	90,947	53,570	(29,901)	(37,377)	19,402	24,252	(13,124)
2034	975,110	(24,890)	(31,112)	224,275	280,344	249,232	(24,890)	(31,112)	73,133	91,417	60,305	(24,890)	(31,112)	19,502	24,378	(6,734)
2035	980,122	(19,878)	(24,847)	225,428	281,785	256,938	(19,878)	(24,847)	73,509	91,886	67,039	(19,878)	(24,847)	19,602	24,503	(344)
2036	985,373	(14,627)	(18,283)	226,636	283,295	265,012	(14,627)	(18,283)	73,903	92,379	74,096	(14,627)	(18,283)	19,707	24,634	6,351
2037	990,625	(9,375)	(11,719)	227,844	284,805	273,086	(9,375)	(11,719)	74,297	92,871	81,152	(9,375)	(11,719)	19,812	24,766	13,047
2038	995,876	(4,124)	(5,155)	229,051	286,314	281,159	(4,124)	(5,155)	74,691	93,363	88,208	(4,124)	(5,155)	19,918	24,897	19,742
2039	1,001,127	1,127	1,409	230,000	287,500	288,909	1,127	1,409	75,000	93,750	95,159	1,127	1,409	20,000	25,000	26,409
2040	1,006,379	6,379	7,973	230,000	287,500	295,473	6,379	7,973	75,000	93,750	101,723	6,379	7,973	20,000	25,000	32,973
2041	1,012,086	12,086	15,107	230,000	287,500	302,607	12,086	15,107	75,000	93,750	108,857	12,086	15,107	20,000	25,000	40,107
2042	1,017,825	17,825	22,281	230,000	287,500	309,781	17,825	22,281	75,000	93,750	116,031	17,825	22,281	20,000	25,000	47,281
2043	1,023,597	23,597	29,496	230,000	287,500	316,996	23,597	29,496	75,000	93,750	123,246	23,597	29,496	20,000	25,000	54,496
2044	1,029,402	29,402	36,752	230,000	287,500	324,252	29,402	36,752	75,000	93,750	130,502	29,402	36,752	20,000	25,000	61,752
2045	1,035,239	35,239	44,049	230,000	287,500	331,549	35,239	44,049	75,000	93,750	137,799	35,239	44,049	20,000	25,000	69,049
2046	1,041,110	41,110	51,387	230,000	287,500	338,887	41,110	51,387	75,000	93,750	145,137	41,110	51,387	20,000	25,000	76,387
2047	1,047,014	47,014	58,767	230,000	287,500	346,267	47,014	58,767	75,000	93,750	152,517	47,014	58,767	20,000	25,000	83,767
2048	1,052,951	(280,382)	(350,477)	242,179	302,724	(47,753)	(280,382)	(350,477)	78,971	98,714	(251,763)	(280,382)	(350,477)	21,059	26,324	(324,153)
2049	1,058,923	(274,410)	(343,013)	243,552	304,440	(38,573)	(274,410)	(343,013)	79,419	99,274	(243,739)	(274,410)	(343,013)	21,178	26,473	(316,540)
2050	1,064,928	(268,405)	(335,507)	244,933	306,167	(29,340)	(268,405)	(335,507)	79,870	99,837	(235,670)	(268,405)	(335,507)	21,299	26,623	(308,884)
2051	1,070,967	(262,366)	(327,958)	246,322	307,903	(20,055)	(262,366)	(327,958)	80,323	100,403	(227,555)	(262,366)	(327,958)	21,419	26,774	(301,184)
2052	1,077,040	(256,293)	(320,366)	247,719	309,649	(10,717)	(256,293)	(320,366)	80,778	100,972	(219,394)	(256,293)	(320,366)	21,541	26,926	(293,440)
2053	1,083,148	(250,185)	(312,732)	249,124	311,405	(1,327)	(250,185)	(312,732)	81,236	101,545	(211,186)	(250,185)	(312,732)	21,663	27,079	(285,653)
2054	1,089,290	(244,043)	(305,054)	250,537	313,171	8,117	(244,043)	(305,054)	81,697	102,121	(202,933)	(244,043)	(305,054)	21,786	27,232	(277,821)
2055	1,095,467	(237,866)	(297,332)	251,957	314,947	17,615	(237,866)	(297,332)	82,160	102,700	(194,632)	(237,866)	(297,332)	21,909	27,387	(269,945)
2056	1,101,680	(231,653)	(289,567)	253,386	316,733	27,166	(231,653)	(289,567)	82,626	103,282	(186,284)	(231,653)	(289,567)	22,034	27,542	(262,025)
2057	1,107,927	(225,406)	(281,757)	254,823	318,529	36,772	(225,406)	(281,757)	83,095	103,868	(177,889)	(225,406)	(281,757)	22,159	27,698	(254,059)
2058	1,114,210	(219,123)	(273,904)	256,268	320,335	46,432	(219,123)	(273,904)	83,566	104,457	(169,447)	(219,123)	(273,904)	22,284	27,855	(246,049)
2059	1,120,529	(212,804)	(266,006)	257,722	322,152	56,146	(212,804)	(266,006)	84,040	105,050	(160,956)	(212,804)	(266,006)	22,411	28,013	(237,992)
2060	1,126,883	(206,450)	(258,063)	259,183	323,979	65,916	(206,450)	(258,063)	84,516	105,645	(152,417)	(206,450)	(258,063)	22,538	28,172	(229,891)
2061	1,133,273	(200,060)	(250,075)	260,653	325,816	75,741	(200,060)	(250,075)	84,995	106,244	(143,830)	(200,060)	(250,075)	22,665	28,332	(221,743)
2062	1,139,700	(193,633)	(242,041)	262,131	327,664	85,622	(193,633)	(242,041)	85,477	106,847	(135,194)	(193,633)	(242,041)	22,794	28,492	(213,549)
2063	1,146,163	(187,170)	(233,962)	263,617	329,522	95,559	(187,170)	(233,962)	85,962	107,453	(126,510)	(187,170)	(233,962)	22,923	28,654	(205,308)
2064	1,152,663	(180,670)	(225,838)	265,112	331,391	105,553	(180,670)	(225,838)	86,450	108,062	(117,776)	(180,670)	(225,838)	23,053	28,817	(197,021)
2065	1,159,199	(174,134)	(217,667)	266,616	333,270	115,603	(174,134)	(217,667)	86,940	108,675	(108,992)	(174,134)	(217,667)	23,184	28,980	(188,687)
2066	1,165,773	(167,560)	(209,450)	268,128	335,160	125,710	(167,560)	(209,450)	87,433	109,291	(100,159)	(167,560)	(209,450)	23,315	29,144	(180,306)
2067	1,172,384	(160,949)	(201,186)	269,648	337,060	135,874	(160,949)	(201,186)	87,929	109,911	(91,275)	(160,949)	(201,186)	23,448	29,310	(171,877)
2068	1,179,032	(154,301)	(192,876)	271,177	338,972	146,096	(154,301)	(192,876)	88,427	110,534	(82,341)	(154,301)	(192,876)	23,581	29,476	(163,400)
2069	1,185,719	(147,614)	(184,518)	272,715	340,894	156,376	(147,614)	(184,518)	88,929	111,161	(73,357)	(147,614)	(184,518)	23,714	29,643	(154,875)
2070	1,192,443	(140,890)	(176,113)	274,262	342,827	166,714	(140,890)	(176,113)	89,433	111,791	(64,321)	(140,890)	(176,113)	23,849	29,811	(146,302)
2071	1,199,205	(134,128)	(167,660)	275,817	344,771	177,111	(134,128)	(167,660)	89,940	112,425	(55,235)	(134,128)	(167,660)	23,984	29,980	(137,680)
2072	1,206,005	(127,328)	(159,160)	277,381	346,727	187,567	(127,328)	(159,160)	90,450	113,063	(46,097)	(127,328)	(159,160)	24,120	30,150	(129,009)
2073	1,212,844	(120,489)	(150,611)	278,954	348,693	198,082	(120,489)	(150,611)	90,963	113,704	(36,907)	(120,489)	(150,611)	24,257	30,321	(120,290)
2074	1,219,722	(113,611)	(142,013)	280,536	350,670	208,657	(113,611)	(142,013)	91,479	114,349	(27,664)	(113,611)	(142,013)	24,394	30,493	(111,520)
2075	1,226,639	(106,694)	(133,367)	282,127	352,659	219,292	(106,694)	(133,367)	91,998	114,997	(18,370)	(106,694)	(133,367)	24,533	30,666	(102,701)

Best Case - Low Bound Waste Forecast

WTE online 2030 - 1 million tonnes. Expansion in 2048 to 1,333,333 tonnes.																	
Year	**Total tons of waste to be managed**	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
20 year horizon (2025 - 2045)	20,597,350	4,597,350	5,746,687	3,628,809	4,536,011	10,282,698	4,597,350	5,746,687	1,183,307	1,479,134	7,225,821	4,597,350	5,746,687	315,549	394,436	6,141,123
50 year horizon (2025 -2075)	54,540,180	(793,144)	(991,430)	11,415,392	14,269,239	13,277,810	(793,144)	(991,430)	3,722,410	4,653,013	3,661,583	(793,144)	(991,430)	992,643	1,240,803	249,374

Fast Track - High Bound Waste Forecast																
WTE online 2028 - 1,333,333 million tonnes. Expansion in 2040 to 1,666,666 tonnes.																
Year	Total tons of waste to be managed	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
2025	1,079,268	1,079,268	1,349,085			1,349,085	1,079,268	1,349,085			1,349,085	1,079,268	1,349,085			1,349,085
2026	1,117,042	1,117,042	1,396,303			1,396,303	1,117,042	1,396,303			1,396,303	1,117,042	1,396,303			1,396,303
2027	1,144,968	1,144,968	1,431,210			1,431,210	1,144,968	1,431,210			1,431,210	1,144,968	1,431,210			1,431,210
2028	1,183,897	(149,436)	(186,795)	272,296	340,370	153,576	(149,436)	(186,795)	88,792	110,990	(75,805)	(149,436)	(186,795)	23,678	29,597	(157,197)
2029	1,204,364	(128,969)	(161,211)	277,004	346,255	185,043	(128,969)	(161,211)	90,327	112,909	(48,302)	(128,969)	(161,211)	24,087	30,109	(131,102)
2030	1,225,184	(108,149)	(135,186)	281,792	352,241	217,055	(108,149)	(135,186)	91,889	114,861	(20,325)	(108,149)	(135,186)	24,504	30,630	(104,556)
2031	1,246,365	(86,968)	(108,710)	286,664	358,330	249,620	(86,968)	(108,710)	93,477	116,847	8,137	(86,968)	(108,710)	24,927	31,159	(77,551)
2032	1,267,912	(65,421)	(81,777)	291,620	364,525	282,748	(65,421)	(81,777)	95,093	118,867	37,090	(65,421)	(81,777)	25,358	31,698	(50,079)
2033	1,289,831	(43,502)	(54,378)	296,661	370,826	316,448	(43,502)	(54,378)	96,737	120,922	66,544	(43,502)	(54,378)	25,797	32,246	(22,132)
2034	1,312,129	(21,204)	(26,505)	301,790	377,237	350,732	(21,204)	(26,505)	98,410	123,012	96,507	(21,204)	(26,505)	26,243	32,803	6,298
2035	1,334,812	1,479	1,849	306,667	383,333	385,182	1,479	1,849	100,000	125,000	126,849	1,479	1,849	26,667	33,333	35,183
2036	1,357,888	24,555	30,694	306,667	383,333	414,027	24,555	30,694	100,000	125,000	155,694	24,555	30,694	26,667	33,333	64,027
2037	1,381,363	48,030	60,037	306,667	383,333	443,370	48,030	60,037	100,000	125,000	185,037	48,030	60,037	26,667	33,333	93,370
2038	1,405,243	71,910	89,888	306,667	383,333	473,221	71,910	89,888	100,000	125,000	214,888	71,910	89,888	26,667	33,333	123,221
2039	1,429,536	96,203	120,254	306,667	383,333	503,588	96,203	120,254	100,000	125,000	245,254	96,203	120,254	26,667	33,333	153,588
2040	1,454,250	(212,416)	(265,520)	334,477	418,097	152,576	(212,416)	(265,520)	109,069	136,336	(129,184)	(212,416)	(265,520)	29,085	36,356	(229,164)
2041	1,462,539	(204,127)	(255,159)	336,384	420,480	165,321	(204,127)	(255,159)	109,690	137,113	(118,046)	(204,127)	(255,159)	29,251	36,563	(218,595)
2042	1,470,875	(195,791)	(244,738)	338,301	422,877	178,138	(195,791)	(244,738)	110,316	137,895	(106,844)	(195,791)	(244,738)	29,418	36,772	(207,966)
2043	1,479,259	(187,407)	(234,258)	340,230	425,287	191,029	(187,407)	(234,258)	110,944	138,681	(95,578)	(187,407)	(234,258)	29,585	36,981	(197,277)
2044	1,487,691	(178,975)	(223,719)	342,169	427,711	203,993	(178,975)	(223,719)	111,577	139,471	(84,247)	(178,975)	(223,719)	29,754	37,192	(186,526)
2045	1,496,171	(170,495)	(213,119)	344,119	430,149	217,030	(170,495)	(213,119)	112,213	140,266	(72,853)	(170,495)	(213,119)	29,923	37,404	(175,714)
2046	1,504,699	(161,967)	(202,459)	346,081	432,601	230,142	(161,967)	(202,459)	112,852	141,066	(61,393)	(161,967)	(202,459)	30,094	37,617	(164,841)
2047	1,513,276	(153,390)	(191,738)	348,053	435,067	243,329	(153,390)	(191,738)	113,496	141,870	(49,868)	(153,390)	(191,738)	30,266	37,832	(153,906)
2048	1,521,902	(144,764)	(180,955)	350,037	437,547	256,591	(144,764)	(180,955)	114,143	142,678	(38,277)	(144,764)	(180,955)	30,438	38,048	(142,908)
2049	1,530,576	(136,090)	(170,112)	352,033	440,041	269,929	(136,090)	(170,112)	114,793	143,492	(26,620)	(136,090)	(170,112)	30,612	38,264	(131,847)
2050	1,539,301	(127,365)	(159,207)	354,039	442,549	283,342	(127,365)	(159,207)	115,448	144,309	(14,897)	(127,365)	(159,207)	30,786	38,483	(120,724)
2051	1,548,075	(118,591)	(148,239)	356,057	445,071	296,832	(118,591)	(148,239)	116,106	145,132	(3,107)	(118,591)	(148,239)	30,961	38,702	(109,537)
2052	1,556,899	(109,767)	(137,209)	358,087	447,608	310,399	(109,767)	(137,209)	116,767	145,959	8,750	(109,767)	(137,209)	31,138	38,922	(98,287)
2053	1,565,773	(100,893)	(126,116)	360,128	450,160	324,044	(100,893)	(126,116)	117,433	146,791	20,675	(100,893)	(126,116)	31,315	39,144	(86,972)
2054	1,574,698	(91,968)	(114,960)	362,181	452,726	337,766	(91,968)	(114,960)	118,102	147,628	32,668	(91,968)	(114,960)	31,494	39,367	(75,593)
2055	1,583,674	(82,992)	(103,740)	364,245	455,306	351,566	(82,992)	(103,740)	118,776	148,469	44,729	(82,992)	(103,740)	31,673	39,592	(64,148)
2056	1,592,701	(73,965)	(92,457)	366,321	457,901	365,445	(73,965)	(92,457)	119,453	149,316	56,859	(73,965)	(92,457)	31,854	39,818	(52,639)
2057	1,601,779	(64,887)	(81,109)	368,409	460,512	379,403	(64,887)	(81,109)	120,133	150,167	69,058	(64,887)	(81,109)	32,036	40,044	(41,064)
2058	1,610,909	(55,757)	(69,696)	370,509	463,136	393,441	(55,757)	(69,696)	120,818	151,023	81,327	(55,757)	(69,696)	32,218	40,273	(29,423)
2059	1,620,091	(46,575)	(58,218)	372,621	465,776	407,558	(46,575)	(58,218)	121,507	151,884	93,665	(46,575)	(58,218)	32,402	40,502	(17,716)
2060	1,629,326	(37,340)	(46,675)	374,745	468,431	421,756	(37,340)	(46,675)	122,199	152,749	106,074	(37,340)	(46,675)	32,587	40,733	(5,942)
2061	1,638,613	(28,053)	(35,066)	376,881	471,101	436,035	(28,053)	(35,066)	122,896	153,620	118,554	(28,053)	(35,066)	32,772	40,965	5,899
2062	1,647,953	(18,713)	(23,391)	379,029	473,787	450,396	(18,713)	(23,391)	123,596	154,496	131,105	(18,713)	(23,391)	32,959	41,199	17,808
2063	1,657,347	(9,319)	(11,649)	381,190	476,487	464,838	(9,319)	(11,649)	124,301	155,376	143,727	(9,319)	(11,649)	33,147	41,434	29,784
2064	1,666,793	127	159	383,333	479,166	479,326	127	159	125,000	156,250	156,409	127	159	33,333	41,667	41,826
2065	1,676,294	9,628	12,035	383,333	479,166	491,202	9,628	12,035	125,000	156,250	168,285	9,628	12,035	33,333	41,667	53,702
2066	1,685,849	19,183	23,979	383,333	479,166	503,145	19,183	23,979	125,000	156,250	180,229	19,183	23,979	33,333	41,667	65,645
2067	1,695,458	28,792	35,990	383,333	479,166	515,157	28,792	35,990	125,000	156,250	192,240	28,792	35,990	33,333	41,667	77,657
2068	1,705,123	38,457	48,071	383,333	479,166	527,237	38,457	48,071	125,000	156,250	204,321	38,457	48,071	33,333	41,667	89,737
2069	1,714,842	48,176	60,220	383,333	479,166	539,386	48,176	60,220	125,000	156,250	216,470	48,176	60,220	33,333	41,667	101,886
2070	1,724,616	57,950	72,438	383,333	479,166	551,604	57,950	72,438	125,000	156,250	228,688	57,950	72,438	33,333	41,667	114,105

Fast Track - High Bound Waste Forecast																	
WTE online 2028 - 1,333,333 million tonnes. Expansion in 2040 to 1,666,666 tonnes.																	
Year	**Total tons of waste to be managed**	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
2071	1,734,447	67,781	84,726	383,333	479,166	563,892	67,781	84,726	125,000	156,250	240,976	67,781	84,726	33,333	41,667	126,392
2072	1,744,333	77,667	97,084	383,333	479,166	576,250	77,667	97,084	125,000	156,250	253,334	77,667	97,084	33,333	41,667	138,750
2073	1,754,276	87,610	109,512	383,333	479,166	588,679	87,610	109,512	125,000	156,250	265,762	87,610	109,512	33,333	41,667	151,179
2074	1,764,275	97,609	122,011	383,333	479,166	601,178	97,609	122,011	125,000	156,250	278,261	97,609	122,011	33,333	41,667	163,678
2075	1,774,331	107,665	134,582	383,333	479,166	613,748	107,665	134,582	125,000	156,250	290,832	107,665	134,582	33,333	41,667	176,248

20 year horizon (2025 - 2045)	27,830,588	1,830,596	2,288,245	5,576,840	6,971,050	9,259,295	1,830,596	2,288,245	1,818,535	2,273,169	4,561,413	1,830,596	2,288,245	484,943	606,178	2,894,423
50 year horizon (2025 -2075)	76,908,817	908,845	1,136,057	16,717,485	20,896,856	22,032,913	908,845	1,136,057	5,451,354	6,814,192	7,950,249	908,845	1,136,057	1,453,694	1,817,118	2,953,175

Best Case - High Bound Waste Forecast																
WTE online 2030 - 1,333,333 million tonnes. Expansion in 2040 to 1,666,666 tonnes.																
Year	Total tons of waste to be managed	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
2025	1,079,268	1,079,268	1,349,085			1,349,085	1,079,268	1,349,085			1,349,085	1,079,268	1,349,085			1,349,085
2026	1,117,042	1,117,042	1,396,303			1,396,303	1,117,042	1,396,303			1,396,303	1,117,042	1,396,303			1,396,303
2027	1,144,968	1,144,968	1,431,210			1,431,210	1,144,968	1,431,210			1,431,210	1,144,968	1,431,210			1,431,210
2028	1,183,897	1,183,897	1,479,871			1,479,871	1,183,897	1,479,871			1,479,871	1,183,897	1,479,871			1,479,871
2029	1,204,364	1,204,364	1,505,455			1,505,455	1,204,364	1,505,455			1,505,455	1,204,364	1,505,455			1,505,455
2030	1,225,184	(108,149)	(135,186)	281,792	352,241	217,055	(108,149)	(135,186)	91,889	114,861	(20,325)	(108,149)	(135,186)	24,504	30,630	(104,556)
2031	1,246,365	(86,968)	(108,710)	286,664	358,330	249,620	(86,968)	(108,710)	93,477	116,847	8,137	(86,968)	(108,710)	24,927	31,159	(77,551)
2032	1,267,912	(398,754)	(498,443)	291,620	364,525	(133,918)	(65,421)	(81,777)	95,093	118,867	37,090	(65,421)	(81,777)	25,358	31,698	(50,079)
2033	1,289,831	1,289,831	1,612,288	296,661	370,826	1,983,115	(43,502)	(54,378)	96,737	120,922	66,544	(43,502)	(54,378)	25,797	32,246	(22,132)
2034	1,312,129	1,312,129	1,640,161	301,790	377,237	2,017,398	(21,204)	(26,505)	98,410	123,012	96,507	(21,204)	(26,505)	26,243	32,803	6,298
2035	1,334,812	1,334,812	1,668,515	306,667	383,333	2,051,849	1,479	1,849	100,000	125,000	126,849	1,479	1,849	26,667	33,333	35,183
2036	1,357,888	1,357,888	1,697,360	306,667	383,333	2,080,693	24,555	30,694	100,000	125,000	155,694	24,555	30,694	26,667	33,333	64,027
2037	1,381,363	1,381,363	1,726,703	306,667	383,333	2,110,037	48,030	60,037	100,000	125,000	185,037	48,030	60,037	26,667	33,333	93,370
2038	1,405,243	1,405,243	1,756,554	306,667	383,333	2,139,887	71,910	89,888	100,000	125,000	214,888	71,910	89,888	26,667	33,333	123,221
2039	1,429,536	1,429,536	1,786,921	306,667	383,333	2,170,254	96,203	120,254	100,000	125,000	245,254	96,203	120,254	26,667	33,333	153,588
2040	1,454,250	(212,416)	(265,520)	334,477	418,097	152,576	(212,416)	(265,520)	109,069	136,336	(129,184)	(212,416)	(265,520)	29,085	36,356	(229,164)
2041	1,462,539	(204,127)	(255,159)	336,384	420,480	165,321	(204,127)	(255,159)	109,690	137,113	(118,046)	(204,127)	(255,159)	29,251	36,563	(218,595)
2042	1,470,875	(195,791)	(244,738)	338,301	422,877	178,138	(195,791)	(244,738)	110,316	137,895	(106,844)	(195,791)	(244,738)	29,418	36,772	(207,966)
2043	1,479,259	(187,407)	(234,258)	340,230	425,287	191,029	(187,407)	(234,258)	110,944	138,681	(95,578)	(187,407)	(234,258)	29,585	36,981	(197,277)
2044	1,487,691	(178,975)	(223,719)	342,169	427,711	203,993	(178,975)	(223,719)	111,577	139,471	(84,247)	(178,975)	(223,719)	29,754	37,192	(186,526)
2045	1,496,171	(170,495)	(213,119)	344,119	430,149	217,030	(170,495)	(213,119)	112,213	140,266	(72,853)	(170,495)	(213,119)	29,923	37,404	(175,714)
2046	1,504,699	(161,967)	(202,459)	346,081	432,601	230,142	(161,967)	(202,459)	112,852	141,066	(61,393)	(161,967)	(202,459)	30,094	37,617	(164,841)
2047	1,513,276	(153,390)	(191,738)	348,053	435,067	243,329	(153,390)	(191,738)	113,496	141,870	(49,868)	(153,390)	(191,738)	30,266	37,832	(153,906)
2048	1,521,902	(144,764)	(180,955)	350,037	437,547	256,591	(144,764)	(180,955)	114,143	142,678	(38,277)	(144,764)	(180,955)	30,438	38,048	(142,908)
2049	1,530,576	(136,090)	(170,112)	352,033	440,041	269,929	(136,090)	(170,112)	114,793	143,492	(26,620)	(136,090)	(170,112)	30,612	38,264	(131,847)
2050	1,539,301	(127,365)	(159,207)	354,039	442,549	283,342	(127,365)	(159,207)	115,448	144,309	(14,897)	(127,365)	(159,207)	30,786	38,483	(120,724)
2051	1,548,075	(118,591)	(148,239)	356,057	445,071	296,832	(118,591)	(148,239)	116,106	145,132	(3,107)	(118,591)	(148,239)	30,961	38,702	(109,537)
2052	1,556,899	(109,767)	(137,209)	358,087	447,608	310,399	(109,767)	(137,209)	116,767	145,959	8,750	(109,767)	(137,209)	31,138	38,922	(98,287)
2053	1,565,773	(100,893)	(126,116)	360,128	450,160	324,044	(100,893)	(126,116)	117,433	146,791	20,675	(100,893)	(126,116)	31,315	39,144	(86,972)
2054	1,574,698	(91,968)	(114,960)	362,181	452,726	337,766	(91,968)	(114,960)	118,102	147,628	32,668	(91,968)	(114,960)	31,494	39,367	(75,593)
2055	1,583,674	(82,992)	(103,740)	364,245	455,306	351,566	(82,992)	(103,740)	118,776	148,469	44,729	(82,992)	(103,740)	31,673	39,592	(64,148)
2056	1,592,701	(73,965)	(92,457)	366,321	457,901	365,445	(73,965)	(92,457)	119,453	149,316	56,859	(73,965)	(92,457)	31,854	39,818	(52,639)
2057	1,601,779	(64,887)	(81,109)	368,409	460,512	379,403	(64,887)	(81,109)	120,133	150,167	69,058	(64,887)	(81,109)	32,036	40,044	(41,064)
2058	1,610,909	(55,757)	(69,696)	370,509	463,136	393,441	(55,757)	(69,696)	120,818	151,023	81,327	(55,757)	(69,696)	32,218	40,273	(29,423)
2059	1,620,091	(46,575)	(58,218)	372,621	465,776	407,558	(46,575)	(58,218)	121,507	151,884	93,665	(46,575)	(58,218)	32,402	40,502	(17,716)
2060	1,629,326	(37,340)	(46,675)	374,745	468,431	421,756	(37,340)	(46,675)	122,199	152,749	106,074	(37,340)	(46,675)	32,587	40,733	(5,942)
2061	1,638,613	(28,053)	(35,066)	376,881	471,101	436,035	(28,053)	(35,066)	122,896	153,620	118,554	(28,053)	(35,066)	32,772	40,965	5,899
2062	1,647,953	(18,713)	(23,391)	379,029	473,787	450,396	(18,713)	(23,391)	123,596	154,496	131,105	(18,713)	(23,391)	32,959	41,199	17,808
2063	1,657,347	(9,319)	(11,649)	381,190	476,487	464,838	(9,319)	(11,649)	124,301	155,376	143,727	(9,319)	(11,649)	33,147	41,434	29,784
2064	1,666,793	127	159	383,333	479,166	479,326	127	159	125,000	156,250	156,409	127	159	33,333	41,667	41,826
2065	1,676,294	9,628	12,035	383,333	479,166	491,202	9,628	12,035	125,000	156,250	168,285	9,628	12,035	33,333	41,667	53,702
2066	1,685,849	19,183	23,979	383,333	479,166	503,145	19,183	23,979	125,000	156,250	180,229	19,183	23,979	33,333	41,667	65,645
2067	1,695,458	28,792	35,990	383,333	479,166	515,157	28,792	35,990	125,000	156,250	192,240	28,792	35,990	33,333	41,667	77,657
2068	1,705,123	38,457	48,071	383,333	479,166	527,237	38,457	48,071	125,000	156,250	204,321	38,457	48,071	33,333	41,667	89,737
2069	1,714,842	48,176	60,220	383,333	479,166	539,386	48,176	60,220	125,000	156,250	216,470	48,176	60,220	33,333	41,667	101,886
2070	1,724,616	57,950	72,438	383,333	479,166	551,604	57,950	72,438	125,000	156,250	228,688	57,950	72,438	33,333	41,667	114,105

Best Case - High Bound Waste Forecast																
WTE online 2030 - 1,333,333 million tonnes. Expansion in 2040 to 1,666,666 tonnes.																
Year	Total tons of waste to be managed	**Worst case:** No aggregate re-use application. Residue @ 23% by weight of incoming tonnage to be landfilled					**Resonable Case:** 75% of bottom ash is re-used. Residue @ 7.5% by weight of incoming tonnage to be landfilled					**Best Case:** Combined ash re-use. Residue @ 2% by weight of incoming tonnage to be landfilled.				
		Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)	Garbage (T)	Garbage (cy)	Residue/(Ash) (T)	Residue/(Ash) (cy)	Total disposal capacity required (cy)
2071	1,734,447	67,781	84,726	383,333	479,166	563,892	67,781	84,726	125,000	156,250	240,976	67,781	84,726	33,333	41,667	126,392
2072	1,744,333	77,667	97,084	383,333	479,166	576,250	77,667	97,084	125,000	156,250	253,334	77,667	97,084	33,333	41,667	138,750
2073	1,754,276	87,610	109,512	383,333	479,166	588,679	87,610	109,512	125,000	156,250	265,762	87,610	109,512	33,333	41,667	151,179
2074	1,764,275	97,609	122,011	383,333	479,166	601,178	97,609	122,011	125,000	156,250	278,261	97,609	122,011	33,333	41,667	163,678
2075	1,774,331	107,665	134,582	383,333	479,166	613,748	107,665	134,582	125,000	156,250	290,832	107,665	134,582	33,333	41,667	176,248

20 year horizon (2025 - 2045)	27,830,588	13,497,260	16,871,575	5,027,540	6,284,425	23,156,000	4,497,262	5,621,577	1,639,415	2,049,269	7,670,847	4,497,262	5,621,577	437,177	546,472	6,168,049
50 year horizon (2025 - 2075)	76,908,817	12,575,509	15,719,387	16,168,185	20,210,231	35,929,618	3,575,511	4,469,389	5,272,234	6,590,293	11,059,682	3,575,511	4,469,389	1,405,929	1,757,411	6,226,801

APPENDIX B

WTE Development Potential Permit Matrix

Appendix B
KC WTE Development Permit Matrix
Potential Permit Requirements*

License, Permit, or Approval Name	Permitting Agency	Months – Agency Permit Review Period: Low	Medium	High	Coordinating Agencies	Supporting Documents Required	Comments
Planning and SEPA Approvals							
Comp. Plan Update	King County Solid Waste Division (KCSWD)	12	20	24	WDOE, Partner Cities	Updates to EIS/Public Review	
Siting Study and Preferred Site Selection	KCSWD + others	6	12	24 or more		Site plans; preliminary traffic plans	
Project-level SEPA Environmental Review and Threshold Determination	KCSWD + Others	2	3	4	Puget Sound Clean Air Agency (PSCAA)	Greenhouse gas emissions worksheet Air Quality / Odor Emissions Evaluation	
Preapplication / Site Plan Review	Permitting Division of King County Department of Local Services or City	1	1	2	KCSWD	Pre-Application Meeting Request Form Preliminary Site Plan Project Description	
EIS	KCSWD plus others		12	24 or more	PSCAA, WDOE, PHSKC	Environmental Impact Statement and SEPA Checklist	
Land Use and Related Early Permit Submittals							
Special Use (land use) Permit Modification	Permitting Division of King County Department of Local Services or City		18	24		SEPA Checklist - Land use Zoning data sheet Additional plot plan information Site cross section Notes and calculations Tree and vegetation plan Geotechnical report DPD Geotechnical Inspections Certified survey Site elevations Landscape Plan	
Landfill Ash Monofill (for CHRL or other non-permitted facility)	Washington Department of Ecology (WDOE)	12	24	>24	KCSWD, PHSKC, PSCAA	Monofill cell preliminary design	
Notice Of Intent To Construct A Geotechnical Soil Boring	WDOE		1			Boring locations, size (diamter), use	
Notice of Intent for installing, modifying, or removing piezometers	WDOE		1			Groundwater monitoring locations	
Notice of Intent for installing, modifying, or decommissioning wells	WDOE		1			Boring locations, size (diamter), use	
Traffic Control Plan (Traffic Plan/Haul Route)	Roads Services Division of King County Department of Local Services or City		2				
Stormwater, Grading, and Drainage Control Approval	Permitting Division of King County Department of Local Services or City	1	2	3		TESC	

Appendix B
KC WTE Development Permit Matrix
Potential Permit Requirements*

License, Permit, or Approval Name	Permitting Agency	Months Agency Permit Review Period Low	Medium	High	Coordinating Agencies	Supporting Documents Required	Comments
NPDES Construction Stormwater General Permit	WDOE		8	12		Water storage plans TESC SWPP SPCC Monitoring Plan Soil and Groundwater Management Plan. The application must include certification that the public notice and SEPA requirements ahave been met. The SWPPP needs to be prepared prior to construction, but is not neccessary for the permit application.	
Street Use Permit(s)	Roads Services Division of King County Department of Local Services or City	2	4	6	Permitting Division of King County Department of Local Services or City	Project Scope and Details Form Base Map Checklist (Required for 30% + plan submittal) Two (2) paper copies of plans One (1) electronic copy of plan in PDF format CADD file (if available) % completeness of plans	
Clean Water Act (CWA) Section 404 permit (Nationwide or Individual)	US Army Corps of Engineers (USACE) Seattle District		4		WDOE	Joint Aquatic Resources Permit Application (JARPA) Form Design drawings (to USACE standards) Cultural Resources documentation Endangered Species Act compliance documentation Wetland and Stream Delineation Report/Critical Areas Report Wetland/Stream Mitigation Plan	May not be required
Environmental Critical Areas Review	Permitting Division of King County Department of Local Services or City	2		3		Critical Areas Report (wetlands, streams, and habitat; geotechnical)	
Endangered Species Act Compliance	US Fish and Wildlife Service (USFWS) and NOAA Fisheries (jointly, the Services)		4	6		No Effect Letter (NEL) or Biological Evaluation (BE)	May not be required
Clean Water Act (CWA) Section 401 Water Quality Certification	WDOE		4			JARPA Form Critical Areas Report (wetlands and streams) Wetland/Stream Mitigation Plan	May not be required
Hydraulic Project Approval (HPA)	Washington Department of Fish and Wildlife (WDFW)		2			Online application via Aquatic Protection Permitting System (APPS) Critical Areas Report (wetlands and streams) SEPA Determination Design drawings	Most likely not required
Air Quality Notice of Construction (NOC)	Puget Sound Clean Air Agency (PSCAA)				WDOE		
Notice of Construction or Alteration	Federal Aviation Administration (FAA)	1	4	6	Permitting Division of King County Department of Local Services or City		Depends on airport proximity

Appendix B
KC WTE Development Permit Matrix
Potential Permit Requirements*

License, Permit, or Approval Name	Permitting Agency	Months Agency Permit Review Period Low	Medium	High	Coordinating Agencies	Supporting Documents Required	Comments
Building and Construction Permits							
Clearing and Grading	Permitting Division of King County Department of Local Services or City		1			30% plans (submit updated signed/dated plans later for final review and approval) Affidavit of Application Form Certification of Applicant Status Form Clearing and Grading Permit Application Worksheet Clearing and Grading Application Fee Worksheet Site plan including temporary and permanent erosion control plans Geotechnical/Soils Report SEPA Determination	
Side Sewer Permit for Temporary Dewatering of Construction Sites, if required	Permitting Division of King County Department of Local Services or City		1		King County Metro	Geotechnical Report Analysis of influence of temporary dewatering activities adjacent to street ROW Point of discharge and proposed rate of discharge for temporary dewatering flows Temporary Dewatering Plan Phase I or Phase II Environmental Site Assessment (if available) Proof of Construction Stormwater Permit was obtained from DOE.	
King County Industrial Wastewater Construction Dewatering Discharge Permit	King County Wastewater Treatment Division, coupled with Seattle Public Utilities approval	2	4	6		Construction Dewatering Plan Schematic flow diagram Site layout Planned changes in pretreatment or waste disposal practices Analytical or historical data SPCC Tank capacities and concentrations Hydrogeologic reports for groundwater remediation Engineering report of wastewater treatment systems Documentation of water balance calculations Description of contamination sources and chemical characteristics of soil and water Engineering justification that permit effluent limitations will be met TESC plan to minimize solids in dewatering effluent Activities leading to unavoidable contamination of stormwater Methods to reduce stormwater volume and contamination	
Building/Construction	Permitting Division of King County Department of Local Services or City	5	7	10		Site plan; building plans, elevations, and details; erosion control plans; structural, drainage, and energy calculations. Components of the building permit include electrical permit, mechanical permits, fire approvals, energy code, etc.	
Shoring	Permitting Division of King County Department of Local Services or City		4			Various applications	
Structural	Permitting Division of King County Department of Local Services or City		2			Various applications	

Appendix B
KC WTE Development Permit Matrix
Potential Permit Requirements*

License, Permit, or Approval Name	Permitting Agency	Months Agency Permit Review Period Low	Medium	High	Coordinating Agencies	Supporting Documents Required	Comments
Electrical	Washington State Department of Labor and Industries (L&I)		2			Various applications	
Mechanical	Permitting Division of King County Department of Local Services or City		2			Various applications	
Plumbing	Permitting Division of King County Department of Local Services or City		2				
Energy Code	Permitting Division of King County Department of Local Services or City		2		Puget Sound Energy (PSE)	Various applications	
Water/Sewer/Fire Flow Certificate	Permitting Division of King County Department of Local Services or City		2			Various applications	
Drainage	Permitting Division of King County Department of Local Services or City		8	12		Various applications	
Geotechnical Report	Permitting Division of King County Department of Local Services or City		2			Various applications	
Utility	Permitting Division of King County Department of Local Services or City		2			Various applications	
Side Sewer Permit	Permitting Division of King County Department of Local Services or City	1	1	2			
Post-Permit Submittals	Permitting Division of King County Department of Local Services or City						
On site fuelling permit	WDOE						

Appendix B
KC WTE Development Permit Matrix
Potential Permit Requirements*

License, Permit, or Approval Name	Permitting Agency	Months Agency Permit Review Period Low	Medium	High	Coordinating Agencies	Supporting Documents Required	Comments
Operating Permits and Approvals							
Solid Waste Permit	Washington Department of Ecology via Public Health Seattle-King County (PHSKC)		4	12	PHSKC		
Air operating Permit (AOP)	Puget Sound Clean Air Agency (PSCAA)	36	48	60			
Elevator Operating Permit	L&I						
King County Industrial Wastewater Discharge Permit	King County Wastewater Treatment Division	2	4	6		Schematic flow diagram Site layout Planned changes in pretreatment or waste disposal practices Analytical or historical data SPCC Tank capacities and concentrations Hydrogeologic reports for groundwater remediation Engineering report of wastewater treatment systems Documentation of water balance calculations Description of contamination sources and chemical characteristics of soil and water Engineering justification that permit effluent limitations will be met TESC plan to minimize solids in dewatering effluent Activities leading to unavoidable contamination of stormwater Methods to reduce stormwater volume and contamination	
NPDES Stormwater General Permit Coverage	WDOE	2	3	4		Discharge information Sampling points SIC Code Receiving water information and location	
Weighing and Measuring Devices License	Washington Department of Licensing / Department of Agriculture		1	4	L&I		
Fire Department Permits Motor Vehicle Fueling Station [Above-ground Tanks]; Combustible Liquids/Flammable Liquids; Fuel Dispensing [open use] into Equipment from Above-Ground Tank; Fleet Fueling Site; and Waste Handling)	Permitting Division of King County Department of Local Services or City		1	4			
Building Commissioning	Permitting Division of King County Department of Local Services or City		1	4			
Certificate of Occupancy	Permitting Division of King County Department of Local Services or City		1	4			
On site fuelling permit	WDOE		1	4			

*This list aims to capture all those permits that will be or maybe required for the construction and operation of a Waste to Energy Facility, but may not be exhaustive. All times are estimates and may vary outside what is documented here. This list assumes King County is the permitting authority. If the Waste to Energy facility is located outside of King County juristiction, the local juristiction permitting agencies will be the permitting agency in charge.

APPENDIX C

WTE Financial Model

Overall Financial Summary

Term End Year	2028	2037	2047	2077
	Term (years)	**10**	**20**	**50**
	Initial Constr. and O&M Term			
Low Tonnage Bound Case - 3000 TPD				
Total Construction Cost	$1,193,474,835	$690,187,680	$1,413,860,228	$2,572,836,051
Total O&M Costs	$1,686,825,351	$717,846,837	$1,686,825,351	$8,094,904,540.78
Total O&M Revenues	$732,267,096	$341,497,157	$732,267,096	$3,704,303,169
Total Net O&M Cost	$954,558,254.92	$376,349,680.65	$954,558,254.92	$4,390,601,371.35
Total Costs	$2,148,033,090	$1,066,537,361	$2,368,418,483	$6,963,437,423
Total Cost Per Ton	$107.40	$106.65	$118.42	$116.06
Waste-by-Rail Export Low Tonnage Bound Case - 3000 TPD				
Costs		$1,026,526,133	$2,424,490,647	$11,251,567,071
Revenues		$0	$0	$0
Total Net Costs		$1,026,526,133	$2,424,490,647	$11,251,567,071
Total Net Cost Per Ton		$109.94	$126.35	$215.15
Difference between WTE and WEBR (Total Net Cost)		$40,011,228	($56,072,165)	($4,288,129,649)
Difference between WTE and WEBR (Total Cost Per Ton)		($3.29)	($7.93)	($99.09)
High Tonnage Bound Case - 4000 TPD				
Total Construction Cost	$1,492,872,058	$863,329,391	$1,860,223,433	$2,990,682,128
Total O&M Costs	$2,237,584,299	$892,336,917	$2,237,584,299	$10,172,184,068
Total O&M Revenues	$1,175,506,847	$457,653,011	$1,175,506,847	$4,263,063,438
Total Net O&M Cost	$1,062,077,452	$434,683,906	$1,062,077,452	$5,909,120,630
Total Costs	$2,554,949,509	$1,298,013,297	$2,922,300,885	$8,899,802,758
Total Cost Per Ton	$95.81	$97.35	$99.62	$112.18
Waste-by-Rail Export High Tonnage Bound Case - 4000 TPD				
Costs		$1,362,187,218	$3,376,330,508	$16,140,955,031
Revenues		$0	$0	$0
Total Net Costs		$1,362,187,218	$3,376,330,508	$16,140,955,031
Total Net Cost Per Ton		$110.25	$127.19	$216.90
Difference between WTE and WEBR (Total Net Cost)		($64,173,921)	($454,029,622)	($7,241,152,273)
Difference between WTE and WEBR (Total Cost Per Ton)		($12.90)	($27.57)	($104.72)

Scenarios

Low Tonnage Bound Case - 3000 TPD		
Initial Capacity TPD, TPY	3000	1,000,000
Expansion	2048	
Expanded Size TPD, TPY	4000	1,333,333
Hauling Cost to WTE Facility ($/ton)	$14.17	
Out of County Waste Accepted (Year 1, TPY)	88,793	
Land Acquisition Costs ($/TPD)	$12,563	
Bypass Waste Annual Tonnage (tons)	5000	
Hauling Cost to IMF	Included	
Construction Cost of New IMF	Included	
High Tonnage Bound Case - 4000 TPD		
Initial Capacity TPD, TPY	4000	1,333,333
Expansion	2040	
Expanded Size TPD, TPY	5000	1,666,667
Hauling Cost to WTE Facility ($/ton)	$14.17	
Out of County Waste Accepted (Year 1, TPY)	190,873	
Land Acquisition Costs ($/TPD)	$12,563	
Bypass Waste Annual Tonnage (tons)	5000	
Hauling Cost to IMF	Included	
Construction Cost of New IMF	Included	

Waste to Energy Option - Assumptions / Inputs

Blue font indicates an input value

Schedule

	Start Date/Duration (Years)	
Planning / Permitting / Siting	3	Years
Develop Bid Package	1	Years
Procurement to Notice of Award	1	Years
D/B to COD	5	Years
Cost Estimate Date	6/1/2019	Date
Permitting/Planning/Siting Start Date	1/1/2020	Date
Development of Design Criteria and Bid Package	1/1/2020	Date
Procurement of EPC Contractor	1/1/2022	Date
Contractor Notice to Proceed Date	1/1/2023	Date
Contractor NTP Check (Permitting/Siting complete)	1/1/2023	Date
Commercial Operation Date	1/1/2028	Date
1,000 TPD Future Expansion Completion	2048	Year
Future Expansion Design and Construction Duration	2	Years

Costs and Escalation Factors

Initial Design and Construction Price	$1,053,375,847	$
Initial Consulting Fees	$31,601,275	$
Initial Annual Operation Fee (2019)	$25,000,000	$/yr
Annual Initial Construction Cost (Payments over 30 year bond term)	$69,018,768	$/yr
Expansion Design and Construction Price	$255,525,791	$
Expansion Consulting Fees	$7,665,774	$
Expansion Annual Operation Fee (Expansion Year)	$67,626,217	$/yr
Annual Expansion Construction Cost (Payments over 30 year bond term)	$16,742,434	$/yr
Consulting Fees Percentage of Construction Cost	3.0%	Percent (%)
Bond Financing Cost as Percentage of Construction Cost	0.6%	Percent (%)
Additional Bond Issuance Cost as a Percentage of Construction Cost	6.7%	Percent (%)
Bond Financing Rate	4.0%	Percent (%)
Bond Financing Term	30	Years
Capital Cost Escalation Rate	3.0%	% per year
Annual Operating Fee Escalation / CPI	3.0%	% per year
Net Present Value (NPV) Discount Factor - Construction	4.5%	% per year
NPV Discount Factor for O&M	4.5%	% per year
Term of Initial Operation and Maintenance Agreement	20	Years
Term of Interim Operation and Maintenance Agreement	5	Years
Term of 2nd Operation and Maintenance Agreement	25	Years
Land Acquisition Cost	$12,563	$/TPD

Waste Processing

Initial Facility Throughput	3,000	tpd
Initial Annual Throughput Guarantee	1,000,000	tpy
Facility Availability (Daily to Annual Throughput Factor)	91%	Percent (%)
Initial Processible Waste Processed	1,000,000	tpy
Expansion Additional Capacity	1,000	tpd
Expansion Additional Throughput	333,333.33	tpy
Expanded Facility Throughput	4,000	tpd
Expanded Facility Throughput Guarantee	1,333,333	tpy
Processible Waste Delivered Escalation Rate	0.00%	% per year
Residue Generation Rate	28.3%	% of processed tons
Ash Disposal Cost (Year 1)	$58.23	$/ton
Annual Average Higher Heating Value of Waste Processed	5,200	Btu per Pound
Design HHV Waste Assumption	5,000	Btu per Pound
Out of County Waste Accepted (Year 1)	88,793	tpy
Out of County Waste Tip Fee (Year 1)	$35.00	$/ton
Percentage of Remaining Capacity use for Out of County Waste	100%	Percent (%)
Bypass Waste Tonnage	5,000	tpy
Nonprocessible Waste Percentage	3.5%	Percent (%)
Transport Cost to WTE Facility	$14.17	$/ton

Electrical Generation

Gross Electric Generation Rate	675	kWh/ton
Electric Generation Guarantee	600	kWh/ton
Electric Capacity Guarantee	0	MW Month
Electric Capacity Factor	90%	Percent (%)
Electric Capacity Payment (Year 1)	$0	$/MW month
Electric Capacity Payment Escalation Rate	1.90%	% per year
Electric Energy Escalation Rate	3.00%	Percent (%)
Average Electrical Energy Revenue	$0.0350	$/kWh
Green Energy Credit	$0.0000	$/kWh
Operator Energy Rev Share Above Net kWh/T	60%	Percent (%)
Operator kWh/Ton Achieved	600	kWh/Ton

Metals Recovery

Ferrous Metal Recovery Guarantee	98.0%	Percent Recovered
Non-Ferrous Metal Recovery Guarantee	98.0%	Percent Recovered
Recovered Ferrous Market Price (Year 1)	$120.00	$/ton
Recovered Non-Ferrous Market Price (Year 1)	$700.00	$/ton
Ferrous Metal In Ash	15.0%	% in Ash Residue
Non-Ferrous Metal In Ash	1.5%	% in Ash Residue
Operator Material Revenue Share	0%	Percent (%)
Aggregate Production	57%	% in Ash Residue
Aggregate Price (Year 1)	$0.00	$/ton

Air Pollution Control Reagents

Pebble Lime Usage Rate	21.00	Lbs/ton of waste
Ammonium Hydroxide Usage Rate	3.50	Lbs/ton of waste
Carbon Usage Rate	0.40	Lbs/ton of waste
Pebble Lime Unit Cost	0.147	$/lb
Pebble Lime Cost per Ton of Waste	3.08	$/ton
Ammonium Hydroxide Unit Cost	0.076	$/lb
Ammonium Hydroxide Cost per Ton of Waste	0.27	$/ton
Carbon Unit Price	0.70	$/lb
Carbon Price per Ton Waste	0.28	$/ton

Project Costs Summary

EPC Contractor Initial Capital Price	$1,053,375,847	
Consulting Fees	$31,601,275	
Bond Issuance Cost / Interim Financing	$76,896,437	
Other Costs - Contingency	$31,601,275	3%
Total Initial Construction Costs	**$1,193,474,835**	
EPC Contractor Expansion Capital Price	$255,525,791	
Consulting Fees	$7,665,774	
Bond Issuance Cost / Interim Financing	$18,653,383	
Other Costs - Contingency	$7,665,774	3%
Total Expansion Construction Costs	**$289,510,721**	
Total O&M Costs (over 20-Yr O&M Term)	$1,686,825,351	
O&M Electrical Sales Revenues	$485,597,009	
O&M Metals Recovery Sales Revenues	$212,388,545	
O&M Non-County Waste Revenues	$34,281,541	
Total O&M Revenues (over 20-Yr O&M Term)	$732,267,096	
Total O&M Net Costs (over 20-Yr O&M Term)	**$954,558,255**	
Total O&M Costs (over remaining 30-Yr O&M Term)	$6,408,079,190	
O&M Electrical Sales Revenues	$1,415,656,506	
O&M Metals Recovery Sales Revenues	$905,572,434	
O&M Non-County Waste Revenues	$650,807,134	
Total O&M Revenues (over remaining 30-Yr O&M Term)	$2,972,036,074	
Total O&M Net Costs (over remaining 30-Yr O&M Term)	**$3,436,043,116**	
Total Initial Construction and O&M Costs	**$2,148,033,090**	
Total Cost Per Ton (over 20-Yr O&M Term)	**$107.40**	
Total Expansion Construction and O&M Costs	**$3,725,553,837**	
Total Expansion Cost Per Ton (over remaining 30-Yr O&M Term)	**$372.56**	
Net Present Value of Initial EPC Contractor Price and Bond Issuance	$1,014,798,073	
Consulting Fees and Contingency	$63,202,551	
Total Initial Construction Costs NPV	**$1,078,000,624**	
Net Present Value of Initial Operation & Maintenance (20-year term)	$584,014,891	
TOTAL Initial Net Present Value	**$1,662,015,514**	
Net Present Value of Expansion EPC Contractor Price and Bond Issuance	$261,600,029	
Consulting Fees and Contingency	$7,665,774	
Total Expansion Constriction Costs NPV	**$269,265,803**	
Net Present Value of Expansion Operation & Maintenance (30-year)	$1,614,889,836	
TOTAL Expansion Net Present Value	**$1,884,155,639**	
Total Capital Cost NPV (over 50 Years)	$1,247,724,761	
Total O&M Cost NPV (over 50 Years)	$1,253,617,431	
Total Cost NPV (over 50 Years)	**$2,501,342,191**	
Total Capital Cost Per Ton NPV (over 50 Years)	$20.80	
Total O&M Cost Per Ton NPV (over 50 Years)	$20.89	
Total Cost Per Ton (NPV over 50 Years)	**$41.69**	
Total Cost Per Ton (O&M Year 1)	**$102.19**	
Total Cost Per Ton (Year 20)	**$154.81**	
Total Cost Per Ton (Year 50)	**$148.08**	
Average Cost Per Ton over initial period (20 years)	**$118.42**	
Average Cost Per Ton over planning period (50 years)	**$116.29**	

Waste Export By Rail (WEBR)	
Total Cost (First Year)	**$87,789,776**
Total Cost (20 Year Term)	**$2,424,490,647**
Total Cost (50 Year Term)	**$11,251,567,071**
Total Cost Per Ton (O&M Year 1)	**$96.34**
Total Cost Per Ton (Year 20)	**$161.28**
Total Cost Per Ton (Year 50)	**$391.46**

Color Code:
Initial Term
Expansion Term
WEBR

Metals Recovery Estimates

47,000	Metals in waste stream (4.7% from Waste
42,450	Ferrous Metals in Ash Residue
4,245	Non-Ferrous Metals in Ash Residue
46,695	Total Metals in Ash Residue

King County Solid Waste Division
Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value 2019	Estimated Costs for NTP Year to COD Year 2023	Estimated Expansion Cost 2046	
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$245,392	
Additional Items Not Included in PBREF 2		$0.00	$0.00	
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134	
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00	Could consider this as included in PBREF 2 optional costs (aesthetics, spare parts, etc)
Land Acquisition Costs	$12,563	$14,139.20	$0.00	Currently assumed land neede for expansion purchased with initial construction. \
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00	
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$255,526	
Facility Capacity (TPD)	3000	3000	1000	
	$926,232,197	$1,042,482,498	$255,525,791	
Advanced Metals Recovery (AMR) System				
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A	assumed no expansion required
Facility Ash Production (TPD)	849	849	N/A	
Estimated Construction Price of AMR	$9,678,600	$10,893,350		
Total Estimated Construction Price (EPC)	**$935,910,797**	**$1,053,375,847**	**$255,525,791**	

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost	Drawdown Schedule (months from NTP)										
				Construction Estimated Date	1/31/2023	3/3/2023	4/2/2023	5/3/2023	6/2/2023	7/3/2023	8/2/2023	9/2/2023	10/2/2023	11/2/2023	12/2/2023
					1	2	3	4	5	6	7	8	9	10	11
1.	Construction Price	**$1,053,375,847**	**60**	**$76,896,436.86**	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264
2.	Expansion Price	**$255,525,791**	**24**	**$18,653,382.73**	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908
				Expansion Estimated Date	1/1/2046	2/1/2046	3/3/2046	4/3/2046	5/3/2046	6/3/2046	7/3/2046	8/3/2046	9/2/2046	10/3/2046	11/2/2046

Net Present Value of Construction Costs		**0.38%**	**$1,014,798,073**
Net Present Value of Expansion Costs		**0.38%**	**$261,600,029**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2046
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$245,392
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$255,526
Facility Capacity (TPD)	3000	3000	1000
	$926,232,197	$1,042,482,498	$255,525,791
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	849	849	N/A
Estimated Construction Price of AMR	$9,678,600	$10,893,350	
Total Estimated Construction Price (EPC)	**$935,910,797**	**$1,053,375,847**	**$255,525,791**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost	12	13	14	15	16	17	18	19	20	21	22	23
				Construction Estimated Date	1/2/2024	2/1/2024	3/3/2024	4/2/2024	5/3/2024	6/2/2024	7/3/2024	8/2/2024	9/2/2024	10/2/2024	11/2/2024	12/2/2024
1.	Construction Price	**$1,053,375,847**	**60**	**$76,896,436.86**	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264
2.	Expansion Price	**$255,525,791**	**24**	**$18,653,382.73**	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908	$10,646,908
				Expansion Estimated Date	12/3/2046	1/2/2047	2/2/2047	3/4/2047	4/4/2047	5/4/2047	6/4/2047	7/4/2047	8/4/2047	9/3/2047	10/4/2047	11/3/2047

Net Present Value of Construction Costs		**0.38%**	**$1,014,798,073**
Net Present Value of Expansion Costs		**0.38%**	**$261,600,029**

King County Solid Waste Division
Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2046
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$245,392
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$255,526
Facility Capacity (TPD)	3000	3000	1000
	$926,232,197	$1,042,482,498	$255,525,791
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	849	849	N/A
Estimated Construction Price of AMR	$9,678,600	$10,893,350	
Total Estimated Construction Price (EPC)	**$935,910,797**	**$1,053,375,847**	**$255,525,791**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost	24	25	26	27	28	29	30	31	32	33	34	35
				Construction Estimated Date	1/2/2025	2/1/2025	3/4/2025	4/3/2025	5/4/2025	6/3/2025	7/4/2025	8/3/2025	9/3/2025	10/3/2025	11/3/2025	12/3/2025
1.	Construction Price	**$1,053,375,847**	**60**	**$76,896,436.86**	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264
2.	Expansion Price	**$255,525,791**	**24**	**$18,653,382.73**	$10,646,908	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
				Expansion Estimated Date	12/4/2047	1/3/2048	2/3/2048	3/4/2048	4/4/2048	5/4/2048	6/4/2048	7/4/2048	8/4/2048	9/3/2048	10/4/2048	11/3/2048

Net Present Value of Construction Costs		**0.38%**	**$1,014,798,073**
Net Present Value of Expansion Costs		**0.38%**	**$261,600,029**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2046
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$245,392
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$255,526
Facility Capacity (TPD)	3000	3000	1000
	$926,232,197	$1,042,482,498	$255,525,791
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	849	849	N/A
Estimated Construction Price of AMR	$9,678,600	$10,893,350	
Total Estimated Construction Price (EPC)	**$935,910,797**	**$1,053,375,847**	**$255,525,791**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost												
				Construction Estimated Date	1/3/2026	2/2/2026	3/5/2026	4/4/2026	5/5/2026	6/4/2026	7/5/2026	8/4/2026	9/4/2026	10/4/2026	11/4/2026	12/4/2026
					36	37	38	39	40	41	42	43	44	45	46	47
1.	Construction Price	**$1,053,375,847**	**60**	**$76,896,436.86**	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264
2.	Expansion Price	**$255,525,791**	**24**	**$18,653,382.73**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
				Expansion Estimated Date	12/4/2048	1/3/2049	2/3/2049	3/5/2049	4/5/2049	5/5/2049	6/5/2049	7/5/2049	8/5/2049	9/4/2049	10/5/2049	11/4/2049

Net Present Value of Construction Costs		**0.38%**	**$1,014,798,073**
Net Present Value of Expansion Costs		**0.38%**	**$261,600,029**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2046
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$245,392
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$255,526
Facility Capacity (TPD)	3000	3000	1000
	$926,232,197	$1,042,482,498	$255,525,791
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	849	849	N/A
Estimated Construction Price of AMR	$9,678,600	$10,893,350	
Total Estimated Construction Price (EPC)	**$935,910,797**	**$1,053,375,847**	**$255,525,791**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost												
				Construction Estimated Date	1/4/2027	2/3/2027	3/6/2027	4/5/2027	5/6/2027	6/5/2027	7/6/2027	8/5/2027	9/5/2027	10/5/2027	11/5/2027	12/5/2027
					48	49	50	51	52	53	54	55	56	57	58	59
1.	Construction Price	**$1,053,375,847**	**60**	**$76,896,436.86**	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264	$17,556,264
2.	Expansion Price	**$255,525,791**	**24**	**$18,653,382.73**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
				Expansion Estimated Date	12/5/2049	1/4/2050	2/4/2050	3/6/2050	4/6/2050	5/6/2050	6/6/2050	7/6/2050	8/6/2050	9/5/2050	10/6/2050	11/5/2050

Net Present Value of Construction Costs		**0.38%**	**$1,014,798,073**
Net Present Value of Expansion Costs		**0.38%**	**$261,600,029**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2046
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$245,392
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$255,526
Facility Capacity (TPD)	3000	3000	1000
	$926,232,197	$1,042,482,498	$255,525,791
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	849	849	N/A
Estimated Construction Price of AMR	$9,678,600	$10,893,350	
Total Estimated Construction Price (EPC)	**$935,910,797**	**$1,053,375,847**	**$255,525,791**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost		Total
				Construction Estimated Date	1/5/2028	
					60	
1.	Construction Price	**$1,053,375,847**	**60**	**$76,896,436.86**	$17,556,264	**$1,053,375,847**
2.	Expansion Price	**$255,525,791**	**24**	**$18,653,382.73**	$0	**$255,525,791**
				Expansion Estimated Date	12/6/2050	

Net Present Value of Construction Costs		**0.38%**	**$1,014,798,073**
Net Present Value of Expansion Costs		**0.38%**	**$261,600,029**

Waste to Energy Option - O&M Cost Estimate	Year Based on COD	2028	2029	2030	2031	2032	2033
ECONOMIC EVALUATION	Escalation Rates or Values	1	2	3	4	5	6
Waste Processing							
1. Processible Waste Delivered	0.00%	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
2. Processible Waste Processed (tons)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
3. Bypass Waste (tons)		5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)		33,049	33,238	33,427	33,603	33,778	33,953
5. Ash Generation (tons)	28.30%	283,000	283,000	283,000	283,000	283,000	283,000
6. Ferrous Recovered (tons)		41,601	41,601	41,601	41,601	41,601	41,601
7. Non-Ferrous Recovered (tons)		4,160	4,160	4,160	4,160	4,160	4,160
8. Aggregate Recovered (tons)	57.00%	161,310	161,310	161,310	161,310	161,310	161,310
9. Ash Disposal (tons)		75,929	75,929	75,929	75,929	75,929	75,929
10. Ash Disposal as a percentage of Waste Processed		7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)		600,000	600,000	600,000	600,000	600,000	600,000
14. Capacity Factor Achieved		N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	1.90%	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	90%	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	1.50%	$0.0350	$0.0355	$0.0361	$0.0366	$0.0371	$0.0377
18. Electrical Energy Revenues ($000s)		$21,000	$21,315	$21,635	$21,959	$22,289	$22,623
19. Green Energy Credits ($/kWh)	3.00%	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)		$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)		$21,000	$21,315	$21,635	$21,959	$22,289	$22,623
22. Operator Energy Revenue Share ($000s)	60%	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	3.00%	$120.00	$123.60	$127.31	$131.13	$135.06	$139.11
24. Recovered Ferrous Revenues ($000's)		$4,992	$5,142	$5,296	$5,455	$5,619	$5,787
25. Recovered Non-Ferrous Market Price ($/ton)	3.00%	$700	$721	$743	$765	$788	$811
25. Recovered Non-Ferrous Revenues ($000's)		$2,912	$2,999	$3,089	$3,182	$3,278	$3,376
26. Recovered Aggregate Market Price ($/ton)	3.00%	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)		$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)		$7,904	$8,141	$8,386	$8,637	$8,896	$9,163
29. Operator Material Revenue Share ($000s)	0%	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	100%	88,793	83,578	78,364	73,528	68,691	63,855
31. Non-County Waste Tip Fee ($/ton)	3.00%	$35.00	$36.05	$37.13	$38.25	$39.39	$40.57
32. Non-County Waste Revenues ($000's)		$3,108	$3,013	$2,910	$2,812	$2,706	$2,591
33. **Subtotal County Revenues**		$32,012	$32,469	$32,930	$33,408	$33,891	$34,377
Revenues per ton ($/ton)		$32.01	$32.47	$32.93	$33.41	$33.89	$34.38
County Expenses							
34. Base O&M Fee ($000s/yr)	3.00%	$32,228	$33,195	$34,191	$35,217	$36,273	$37,361
35. Excess O&M Fee ($/ton)		N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)		N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	3.00%	$3.97	$4.09	$4.21	$4.34	$4.47	$4.60
39. Pebble Lime Usage Cost ($000s)		$3,972	$4,091	$4,214	$4,340	$4,471	$4,605
40. Ammonium Hydroxide Unit Cost ($/ton waste)	3.00%	$0.34	$0.35	$0.36	$0.38	$0.39	$0.40
41. Ammonium Hydroxide Usage Cost ($000)		$344	$354	$365	$376	$387	$399
42. Carbon Unit Price ($/ton)	3.00%	$0.36	$0.37	$0.38	$0.39	$0.41	$0.42
43. Carbon Usage Costs ($000s)		$361	$372	$383	$395	$406	$419
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)		$611	$633	$656	$679	$703	$728
46. Non Processible Waste WEBR Disposal including Haul Cos	$70.49	$91.97	$94.73	$97.57	$100.50	$103.52	$106.62
47. Non Processible Waste WEBR Disposal including Haul Cost ($000's)		$3,040	$3,149	$3,262	$3,377	$3,497	$3,620
48. Ash Disposal Fee ($/ton)	3.00%	$75.98	78.26	80.60	83.02	85.51	88.08
49. Ash Disposal Expenses ($000's)		$5,769	$5,942	$6,120	$6,304	$6,493	$6,688
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$1.25	$1.63	$1.68	$1.73	$1.78	$1.84	$1.89
52. Utilities Pass Through ($000's)		$1,631	$1,680	$1,731	$1,782	$1,836	$1,891
53. Haul Cost to WTE Facility ($/ton)	$14.17	$18.49	$19.04	$19.61	$20.20	$20.81	$21.43
54. Haul Cost to WTE Facility ($000's)		$16,847	$17,452	$18,078	$18,718	$19,380	$20,065
55. Bypass Waste Disposal ($000's)		$380	$391	$403	$415	$428	$440
56. **Subtotal Expenses ($000's)**		$65,183	$67,259	$65,484	$67,546	$69,673	$71,867
Expenses per ton ($/ton)		$65.18	$67.26	$65.48	$67.55	$69.67	$71.87
FACILITY EXPENSES LESS REVENUES ($000's)		$33,171	$34,790	$32,554	$34,138	$35,782	$37,490
NET O&M COST PER TON OF WASTE		$33.17	$34.79	$32.55	$34.14	$35.78	$37.49
Amortized Annual Initial Capital Cost ($000's)		$69,019	$69,019	$69,019	$69,019	$69,019	$69,019
Amortized Initial Capital Cost Per Ton of Waste		$69.02	$69.02	$69.02	$69.02	$69.02	$69.02
Amortized Annual Expansion Cost ($000's)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Amortized Expansion Cost Per Ton of Waste		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Amortized Capital Cost ($000's)		$69,019	$69,019	$69,019	$69,019	$69,019	$69,019
Net Facility Cost ($000's)		$102,190	$103,808	$101,573	$103,156	$104,801	$106,509
Net Facility Cost Per Ton of Waste ($/ton)		$102.19	$103.81	$101.57	$103.16	$104.80	$106.51
WEBR Year	2019	2028					
Disposal by Rail Capital Cost IMF ($/ton)	$3.35	$4.37	$4.37	$4.37	$4.37	$4.37	$4.37
Disposal by Rail Haul to IMF Cost ($/ton)	$14.17	$18.49	$19.04	$19.61	$20.20	$20.81	$21.43
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$56.32	$73.48	$75.69	$77.96	$80.30	$82.71	$85.19
Disposal By Rail less Hauling to IMF ($/ton)	$59.67	$77.86	$80.06	$82.33	$84.67	$87.08	$89.56
Disposal By Rail ($/ton)	$73.84	$96.34	$99.10	$101.95	$104.87	$107.89	$110.99
Disposal Tonnage Required		911,207	916,422	921,636	926,472	931,309	936,145
Disposal By Rail ($000's)		$87,790	$90,821	$93,957	$97,162	$100,477	$103,906
Difference between WTE and Rail Disposal (cost per ton)		$5.85	$4.70	($0.37)	($1.72)	($3.09)	($4.48)
Difference between WTE and Rail Disposal ($000's)		$14,400	$12,988	$7,616	$5,995	$4,324	$2,603

Waste to Energy Option - O&M Cost Estimate	2034	2035	2036	2037	2038	2039	2040
ECONOMIC EVALUATION	7	8	9	10	11	12	13
Waste Processing							
1. Processible Waste Delivered	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
2. Processible Waste Processed (tons)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	34,129	34,304	34,488	34,672	34,856	35,039	35,223
5. Ash Generation (tons)	283,000	283,000	283,000	283,000	283,000	283,000	283,000
6. Ferrous Recovered (tons)	41,601	41,601	41,601	41,601	41,601	41,601	41,601
7. Non-Ferrous Recovered (tons)	4,160	4,160	4,160	4,160	4,160	4,160	4,160
8. Aggregate Recovered (tons)	161,310	161,310	161,310	161,310	161,310	161,310	161,310
9. Ash Disposal (tons)	75,929	75,929	75,929	75,929	75,929	75,929	75,929
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	600,000	600,000	600,000	600,000	600,000	600,000	600,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0383	$0.0388	$0.0394	$0.0400	$0.0406	$0.0412	$0.0418
18. Electrical Energy Revenues ($000s)	$22,962	$23,307	$23,656	$24,011	$24,371	$24,737	$25,108
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$22,962	$23,307	$23,656	$24,011	$24,371	$24,737	$25,108
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$143.29	$147.58	$152.01	$156.57	$161.27	$166.11	$171.09
24. Recovered Ferrous Revenues ($000's)	$5,961	$6,140	$6,324	$6,514	$6,709	$6,910	$7,118
25. Recovered Non-Ferrous Market Price ($/ton)	$836	$861	$887	$913	$941	$969	$998
25. Recovered Non-Ferrous Revenues ($000's)	$3,477	$3,581	$3,689	$3,800	$3,914	$4,031	$4,152
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$9,438	$9,721	$10,013	$10,313	$10,623	$10,941	$11,269
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	59,018	54,182	49,115	44,047	38,980	33,912	28,845
31. Non-County Waste Tip Fee ($/ton)	$41.79	$43.05	$44.34	$45.67	$47.04	$48.45	$49.90
32. Non-County Waste Revenues ($000's)	$2,466	$2,332	$2,178	$2,012	$1,833	$1,643	$1,439
33. **Subtotal County Revenues**	$34,867	$35,360	$35,847	$36,336	$36,827	$37,321	$37,817
Revenues per ton ($/ton)	$34.87	$35.36	$35.85	$36.34	$36.83	$37.32	$37.82
County Expenses							
34. Base O&M Fee ($000s/yr)	$38,482	$39,636	$40,826	$42,050	$43,312	$44,611	$45,950
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$4.74	$4.89	$5.03	$5.18	$5.34	$5.50	$5.66
39. Pebble Lime Usage Cost ($000s)	$4,743	$4,885	$5,032	$5,183	$5,338	$5,498	$5,663
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.41	$0.42	$0.44	$0.45	$0.46	$0.48	$0.49
41. Ammonium Hydroxide Usage Cost ($000)	$411	$423	$436	$449	$462	$476	$490
42. Carbon Unit Price ($/ton)	$0.43	$0.44	$0.46	$0.47	$0.49	$0.50	$0.51
43. Carbon Usage Costs ($000s)	$431	$444	$458	$471	$485	$500	$515
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$753	$780	$808	$836	$866	$897	$928
46. Non Processible Waste WEBR Disposal including Haul Cos	$109.82	$113.12	$116.51	$120.00	$123.60	$127.31	$131.13
47. Non Processible Waste WEBR Disposal including Haul Cos	$3,748	$3,880	$4,018	$4,161	$4,308	$4,461	$4,619
48. Ash Disposal Fee ($/ton)	90.72	93.44	96.25	99.13	102.11	105.17	108.32
49. Ash Disposal Expenses ($000's)	$6,888	$7,095	$7,308	$7,527	$7,753	$7,985	$8,225
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$1.95	$2.01	$2.07	$2.13	$2.19	$2.26	$2.33
52. Utilities Pass Through ($000's)	$1,948	$2,006	$2,066	$2,128	$2,192	$2,258	$2,326
53. Haul Cost to WTE Facility ($/ton)	$22.08	$22.74	$23.42	$24.12	$24.85	$25.59	$26.36
54. Haul Cost to WTE Facility ($000's)	$20,773	$21,507	$22,271	$23,061	$23,879	$24,725	$25,600
55. Bypass Waste Disposal ($000's)	$454	$467	$481	$496	$511	$526	$542
56. **Subtotal Expenses ($000's)**	$74,130	$76,464	$78,876	$81,365	$83,932	$86,579	$89,310
Expenses per ton ($/ton)	$74.13	$76.46	$78.88	$81.36	$83.93	$86.58	$89.31
FACILITY EXPENSES LESS REVENUES ($000's)	$39,263	$41,104	$43,030	$45,029	$47,104	$49,258	$51,493
NET O&M COST PER TON OF WASTE	$39.26	$41.10	$43.03	$45.03	$47.10	$49.26	$51.49
Amortized Annual Initial Capital Cost ($000's)	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019
Amortized Initial Capital Cost Per Ton of Waste	$69.02	$69.02	$69.02	$69.02	$69.02	$69.02	$69.02
Amortized Annual Expansion Cost ($000's)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0
Amortized Expansion Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Amortized Capital Cost ($000's)	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019
Net Facility Cost ($000's)	$108,282	$110,122	$112,048	$114,048	$116,123	$118,277	$120,512
Net Facility Cost Per Ton of Waste ($/ton)	$108.28	$110.12	$112.05	$114.05	$116.12	$118.28	$120.51
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$4.37	$4.37	$4.37	$4.37	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$22.08	$22.74	$23.42	$24.12	$24.85	$25.59	$26.36
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$87.74	$90.38	$93.09	$95.88	$98.76	$101.72	$104.77
Disposal By Rail less Hauling to IMF ($/ton)	$92.12	$94.75	$97.46	$100.25	$98.76	$101.72	$104.77
Disposal By Rail ($/ton)	$114.19	$117.49	$120.88	$124.38	$123.60	$127.31	$131.13
Disposal Tonnage Required	940,982	945,818	950,885	955,953	961,020	966,088	971,155
Disposal By Rail ($000's)	$107,453	$111,121	$114,943	$118,897	$118,787	$122,995	$127,350
Difference between WTE and Rail Disposal (cost per ton)	($5.91)	($7.36)	($8.83)	($10.33)	($7.48)	($9.04)	($10.62)
Difference between WTE and Rail Disposal ($000's)	$829	($999)	($2,895)	($4,849)	($2,664)	($4,718)	($6,838)

Waste to Energy Option - O&M Cost Estimate	2041	2042	2043	2044	2045	2046	2047
ECONOMIC EVALUATION	14	15	16	17	18	19	20
Waste Processing							
1. Processible Waste Delivered	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
2. Processible Waste Processed (tons)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	35,423	35,624	35,826	36,029	36,233	36,439	36,645
5. Ash Generation (tons)	283,000	283,000	283,000	283,000	283,000	283,000	283,000
6. Ferrous Recovered (tons)	41,601	41,601	41,601	41,601	41,601	41,601	41,601
7. Non-Ferrous Recovered (tons)	4,160	4,160	4,160	4,160	4,160	4,160	4,160
8. Aggregate Recovered (tons)	161,310	161,310	161,310	161,310	161,310	161,310	161,310
9. Ash Disposal (tons)	75,929	75,929	75,929	75,929	75,929	75,929	75,929
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	600,000	600,000	600,000	600,000	600,000	600,000	600,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0425	$0.0431	$0.0438	$0.0444	$0.0451	$0.0458	$0.0464
18. Electrical Energy Revenues ($000s)	$25,485	$25,867	$26,255	$26,649	$27,048	$27,454	$27,866
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$25,485	$25,867	$26,255	$26,649	$27,048	$27,454	$27,866
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$176.22	$181.51	$186.96	$192.56	$198.34	$204.29	$210.42
24. Recovered Ferrous Revenues ($000's)	$7,331	$7,551	$7,778	$8,011	$8,251	$8,499	$8,754
25. Recovered Non-Ferrous Market Price ($/ton)	$1,028	$1,059	$1,091	$1,123	$1,157	$1,192	$1,227
25. Recovered Non-Ferrous Revenues ($000's)	$4,276	$4,405	$4,537	$4,673	$4,813	$4,958	$5,106
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$11,608	$11,956	$12,314	$12,684	$13,064	$13,456	$13,860
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	23,337	17,799	12,229	6,627	994	0	0
31. Non-County Waste Tip Fee ($/ton)	$51.40	$52.94	$54.53	$56.16	$57.85	$59.59	$61.37
32. Non-County Waste Revenues ($000's)	$1,200	$942	$667	$372	$58	$0	$0
33. **Subtotal County Revenues**	$38,292	$38,765	$39,236	$39,705	$40,170	$40,911	$41,726
Revenues per ton ($/ton)	$38.29	$38.76	$39.24	$39.70	$40.17	$40.91	$41.73
County Expenses							
34. Base O&M Fee ($000s/yr)	$47,328	$48,748	$50,210	$51,717	$53,268	$54,866	$56,512
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$5.83	$6.01	$6.19	$6.37	$6.57	$6.76	$6.96
39. Pebble Lime Usage Cost ($000s)	$5,833	$6,008	$6,188	$6,374	$6,565	$6,762	$6,965
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.51	$0.52	$0.54	$0.55	$0.57	$0.59	$0.60
41. Ammonium Hydroxide Usage Cost ($000)	$505	$520	$536	$552	$568	$585	$603
42. Carbon Unit Price ($/ton)	$0.53	$0.55	$0.56	$0.58	$0.60	$0.61	$0.63
43. Carbon Usage Costs ($000s)	$530	$546	$563	$580	$597	$615	$633
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$962	$996	$1,032	$1,069	$1,107	$1,147	$1,188
46. Non Processible Waste WEBR Disposal including Haul Cos	$135.07	$139.12	$143.29	$147.59	$152.02	$156.58	$161.28
47. Non Processible Waste WEBR Disposal including Haul Cos	$4,784	$4,956	$5,134	$5,318	$5,508	$5,706	$5,910
48. Ash Disposal Fee ($/ton)	111.57	114.92	118.37	121.92	125.58	129.35	133.23
49. Ash Disposal Expenses ($000's)	$8,472	$8,726	$8,988	$9,257	$9,535	$9,821	$10,116
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$2.40	$2.47	$2.54	$2.62	$2.70	$2.78	$2.86
52. Utilities Pass Through ($000's)	$2,395	$2,467	$2,541	$2,618	$2,696	$2,777	$2,860
53. Haul Cost to WTE Facility ($/ton)	$27.15	$27.97	$28.80	$29.67	$30.56	$31.48	$32.42
54. Haul Cost to WTE Facility ($000's)	$26,518	$27,468	$28,452	$29,472	$30,529	$31,476	$32,420
55. Bypass Waste Disposal ($000's)	$558	$575	$592	$610	$628	$647	$666
56. **Subtotal Expenses ($000's)**	$92,139	$95,058	$98,070	$101,179	$104,386	$107,549	$110,776
Expenses per ton ($/ton)	$92.14	$95.06	$98.07	$101.18	$104.39	$107.55	$110.78
FACILITY EXPENSES LESS REVENUES ($000's)	$53,847	$56,293	$58,834	$61,474	$64,216	$66,639	$69,050
NET O&M COST PER TON OF WASTE	$53.85	$56.29	$58.83	$61.47	$64.22	$66.64	$69.05
Amortized Annual Initial Capital Cost ($000's)	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019
Amortized Initial Capital Cost Per Ton of Waste	$69.02	$69.02	$69.02	$69.02	$69.02	$69.02	$69.02
Amortized Annual Expansion Cost ($000's)	$0	$0	$0	$0	$0	$16,742	$16,742
Amortized Expansion Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$0.00	$50.23	$50.23
Total Amortized Capital Cost ($000's)	$69,019	$69,019	$69,019	$69,019	$69,019	$85,761	$85,761
Net Facility Cost ($000's)	$122,866	$125,312	$127,853	$130,493	$133,235	$152,400	$154,811
Net Facility Cost Per Ton of Waste ($/ton)	$122.87	$125.31	$127.85	$130.49	$133.23	$152.40	$154.81
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$27.15	$27.97	$28.80	$29.67	$30.56	$31.48	$32.42
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$107.91	$111.15	$114.49	$117.92	$121.46	$125.10	$128.86
Disposal By Rail less Hauling to IMF ($/ton)	$107.91	$111.15	$114.49	$117.92	$121.46	$125.10	$128.86
Disposal By Rail ($/ton)	$135.07	$139.12	$143.29	$147.59	$152.02	$156.58	$161.28
Disposal Tonnage Required	976,663	982,201	987,771	993,373	999,006	1,004,671	1,010,368
Disposal By Rail ($000's)	$131,914	$136,642	$141,539	$146,612	$151,867	$157,310	$162,948
Difference between WTE and Rail Disposal (cost per ton)	($12.20)	($13.81)	($15.44)	($17.10)	($18.78)	($4.18)	($6.47)
Difference between WTE and Rail Disposal ($000's)	($9,048)	($11,330)	($13,686)	($16,120)	($18,632)	($4,910)	($8,137)

King County

King County Solid Waste Division
Waste to Energy Feasibility Study
Operations and Maintenance

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Waste to Energy Option - O&M Cost Estimate	2048	2049	2050	2051	2052	2053	2054
ECONOMIC EVALUATION	21	22	23	24	25	26	27
Waste Processing							
1. Processible Waste Delivered	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
2. Processible Waste Processed (tons)	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	36,853	37,062	37,272	37,484	37,696	37,910	38,125
5. Ash Generation (tons)	377,333	377,333	377,333	377,333	377,333	377,333	377,333
6. Ferrous Recovered (tons)	55,468	55,468	55,468	55,468	55,468	55,468	55,468
7. Non-Ferrous Recovered (tons)	5,547	5,547	5,547	5,547	5,547	5,547	5,547
8. Aggregate Recovered (tons)	215,080	215,080	215,080	215,080	215,080	215,080	215,080
9. Ash Disposal (tons)	101,239	101,239	101,239	101,239	101,239	101,239	101,239
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	800,000	800,000	800,000	800,000	800,000	800,000	800,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0471	$0.0478	$0.0486	$0.0493	$0.0500	$0.0508	$0.0515
18. Electrical Energy Revenues ($000s)	$37,712	$38,278	$38,852	$39,435	$40,026	$40,626	$41,236
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$37,712	$38,278	$38,852	$39,435	$40,026	$40,626	$41,236
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$216.73	$223.24	$229.93	$236.83	$243.94	$251.25	$258.79
24. Recovered Ferrous Revenues ($000's)	$12,022	$12,382	$12,754	$13,137	$13,531	$13,937	$14,355
25. Recovered Non-Ferrous Market Price ($/ton)	$1,264	$1,302	$1,341	$1,382	$1,423	$1,466	$1,510
25. Recovered Non-Ferrous Revenues ($000's)	$7,013	$7,223	$7,440	$7,663	$7,893	$8,130	$8,374
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$19,034	$19,605	$20,194	$20,799	$21,423	$22,066	$22,728
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	317,235	311,473	305,678	299,850	293,990	288,096	282,168
31. Non-County Waste Tip Fee ($/ton)	$63.21	$65.11	$67.06	$69.08	$71.15	$73.28	$75.48
32. Non-County Waste Revenues ($000's)	$20,054	$20,280	$20,500	$20,712	$20,917	$21,112	$21,298
33. **Subtotal County Revenues**	$76,800	$78,163	$79,545	$80,946	$82,366	$83,805	$85,262
Revenues per ton ($/ton)	$57.60	$58.62	$59.66	$60.71	$61.77	$62.85	$63.95
County Expenses							
34. Base O&M Fee ($000s/yr)	$67,626	$69,655	$71,745	$73,897	$76,114	$78,397	$80,749
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$7.17	$7.39	$7.61	$7.84	$8.07	$8.32	$8.57
39. Pebble Lime Usage Cost ($000s)	$9,565	$9,852	$10,148	$10,452	$10,766	$11,089	$11,421
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.62	$0.64	$0.66	$0.68	$0.70	$0.72	$0.74
41. Ammonium Hydroxide Usage Cost ($000)	$828	$853	$879	$905	$932	$960	$989
42. Carbon Unit Price ($/ton)	$0.65	$0.67	$0.69	$0.71	$0.73	$0.76	$0.78
43. Carbon Usage Costs ($000s)	$870	$896	$923	$950	$979	$1,008	$1,039
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$1,231	$1,275	$1,320	$1,368	$1,417	$1,468	$1,520
46. Non Processible Waste WEBR Disposal including Haul Cos	$166.11	$171.10	$176.23	$181.52	$186.96	$192.57	$198.35
47. Non Processible Waste WEBR Disposal including Haul Cos	$6,122	$6,341	$6,569	$6,804	$7,048	$7,300	$7,562
48. Ash Disposal Fee ($/ton)	137.22	141.34	145.58	149.95	154.45	159.08	163.85
49. Ash Disposal Expenses ($000's)	$13,892	$14,309	$14,738	$15,180	$15,636	$16,105	$16,588
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$2.95	$3.03	$3.13	$3.22	$3.32	$3.42	$3.52
52. Utilities Pass Through ($000's)	$3,928	$4,046	$4,167	$4,292	$4,421	$4,554	$4,690
53. Haul Cost to WTE Facility ($/ton)	$33.39	$34.39	$35.43	$36.49	$37.58	$38.71	$39.87
54. Haul Cost to WTE Facility ($000's)	$33,930	$35,146	$36,406	$37,711	$39,062	$40,462	$41,913
55. Bypass Waste Disposal ($000's)	$686	$707	$728	$750	$772	$795	$819
56. **Subtotal Expenses ($000's)**	$131,326	$135,464	$139,733	$144,138	$148,682	$153,371	$158,208
Expenses per ton ($/ton)	$98.49	$101.60	$104.80	$108.10	$111.51	$115.03	$118.66
FACILITY EXPENSES LESS REVENUES ($000's)	$54,526	$57,301	$60,188	$63,191	$66,316	$69,566	$72,946
NET O&M COST PER TON OF WASTE	$40.89	$42.98	$45.14	$47.39	$49.74	$52.17	$54.71
Amortized Annual Initial Capital Cost ($000's)	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019	$69,019
Amortized Initial Capital Cost Per Ton of Waste	$51.76	$51.76	$51.76	$51.76	$51.76	$51.76	$51.76
Amortized Annual Expansion Cost ($000's)	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742
Amortized Expansion Cost Per Ton of Waste	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23
Total Amortized Capital Cost ($000's)	$85,761	$85,761	$85,761	$85,761	$85,761	$85,761	$85,761
Net Facility Cost ($000's)	$140,287	$143,062	$145,949	$148,953	$152,077	$155,327	$158,707
Net Facility Cost Per Ton of Waste ($/ton)	$105.22	$107.30	$109.46	$111.71	$114.06	$116.50	$119.03
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$33.39	$34.39	$35.43	$36.49	$37.58	$38.71	$39.87
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$132.72	$136.70	$140.80	$145.03	$149.38	$153.86	$158.48
Disposal By Rail less Hauling to IMF ($/ton)	$132.72	$136.70	$140.80	$145.03	$149.38	$153.86	$158.48
Disposal By Rail ($/ton)	$166.11	$171.10	$176.23	$181.52	$186.96	$192.57	$198.35
Disposal Tonnage Required	1,016,098	1,021,860	1,027,655	1,033,483	1,039,344	1,045,238	1,051,165
Disposal By Rail ($000's)	$168,788	$174,838	$181,104	$187,595	$194,319	$201,283	$208,498
Difference between WTE and Rail Disposal (cost per ton)	($60.90)	($63.80)	($66.77)	($69.80)	($72.91)	($76.08)	($79.32)
Difference between WTE and Rail Disposal ($000's)	($28,501)	($31,776)	($35,155)	($38,643)	($42,242)	($45,956)	($49,791)

King County

King County Solid Waste Division
Waste to Energy Feasibility Study
Operations and Maintenance

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Waste to Energy Option - O&M Cost Estimate	2055	2056	2057	2058	2059	2060	2061
ECONOMIC EVALUATION	28	29	30	31	32	33	34
Waste Processing							
1. Processible Waste Delivered	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
2. Processible Waste Processed (tons)	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	38,341	38,559	38,777	38,997	39,218	39,441	39,665
5. Ash Generation (tons)	377,333	377,333	377,333	377,333	377,333	377,333	377,333
6. Ferrous Recovered (tons)	55,468	55,468	55,468	55,468	55,468	55,468	55,468
7. Non-Ferrous Recovered (tons)	5,547	5,547	5,547	5,547	5,547	5,547	5,547
8. Aggregate Recovered (tons)	215,080	215,080	215,080	215,080	215,080	215,080	215,080
9. Ash Disposal (tons)	101,239	101,239	101,239	101,239	101,239	101,239	101,239
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	800,000	800,000	800,000	800,000	800,000	800,000	800,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0523	$0.0531	$0.0539	$0.0547	$0.0555	$0.0564	$0.0572
18. Electrical Energy Revenues ($000s)	$41,854	$42,482	$43,119	$43,766	$44,423	$45,089	$45,765
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$41,854	$42,482	$43,119	$43,766	$44,423	$45,089	$45,765
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$266.55	$274.55	$282.79	$291.27	$300.01	$309.01	$318.28
24. Recovered Ferrous Revenues ($000's)	$14,785	$15,229	$15,686	$16,156	$16,641	$17,140	$17,654
25. Recovered Non-Ferrous Market Price ($/ton)	$1,555	$1,602	$1,650	$1,699	$1,750	$1,803	$1,857
25. Recovered Non-Ferrous Revenues ($000's)	$8,625	$8,883	$9,150	$9,424	$9,707	$9,998	$10,298
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$23,410	$24,112	$24,836	$25,581	$26,348	$27,139	$27,953
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	276,207	270,213	264,184	258,121	252,023	245,891	239,725
31. Non-County Waste Tip Fee ($/ton)	$77.75	$80.08	$82.48	$84.95	$87.50	$90.13	$92.83
32. Non-County Waste Revenues ($000's)	$21,474	$21,638	$21,790	$21,928	$22,053	$22,162	$22,254
33. **Subtotal County Revenues**	$86,738	$88,232	$89,745	$91,275	$92,824	$94,389	$95,972
Revenues per ton ($/ton)	$65.05	$66.17	$67.31	$68.46	$69.62	$70.79	$71.98
County Expenses							
34. Base O&M Fee ($000s/yr)	$83,172	$85,667	$88,237	$90,884	$93,610	$96,419	$99,311
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$8.82	$9.09	$9.36	$9.64	$9.93	$10.23	$10.54
39. Pebble Lime Usage Cost ($000s)	$11,764	$12,117	$12,480	$12,855	$13,241	$13,638	$14,047
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.76	$0.79	$0.81	$0.83	$0.86	$0.89	$0.91
41. Ammonium Hydroxide Usage Cost ($000)	$1,019	$1,049	$1,081	$1,113	$1,146	$1,181	$1,216
42. Carbon Unit Price ($/ton)	$0.80	$0.83	$0.85	$0.88	$0.90	$0.93	$0.96
43. Carbon Usage Costs ($000s)	$1,070	$1,102	$1,135	$1,169	$1,204	$1,240	$1,277
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$1,575	$1,631	$1,690	$1,750	$1,813	$1,878	$1,945
46. Non Processible Waste WEBR Disposal including Haul Cos	$204.30	$210.43	$216.74	$223.24	$229.94	$236.84	$243.94
47. Non Processible Waste WEBR Disposal including Haul Cos	$7,833	$8,114	$8,405	$8,706	$9,018	$9,341	$9,676
48. Ash Disposal Fee ($/ton)	168.77	173.83	179.04	184.42	189.95	195.65	201.52
49. Ash Disposal Expenses ($000's)	$17,086	$17,598	$18,126	$18,670	$19,230	$19,807	$20,401
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$3.62	$3.73	$3.84	$3.96	$4.08	$4.20	$4.33
52. Utilities Pass Through ($000's)	$4,831	$4,976	$5,125	$5,279	$5,437	$5,601	$5,769
53. Haul Cost to WTE Facility ($/ton)	$41.07	$42.30	$43.57	$44.88	$46.22	$47.61	$49.04
54. Haul Cost to WTE Facility ($000's)	$43,415	$44,971	$46,583	$48,252	$49,981	$51,773	$53,628
55. Bypass Waste Disposal ($000's)	$844	$869	$895	$922	$950	$978	$1,008
56. **Subtotal Expenses ($000's)**	$163,199	$168,349	$173,662	$179,144	$184,800	$190,636	$196,658
Expenses per ton ($/ton)	$122.40	$126.26	$130.25	$134.36	$138.60	$142.98	$147.49
FACILITY EXPENSES LESS REVENUES ($000's)	$76,461	$80,116	$83,917	$87,869	$91,976	$96,247	$100,685
NET O&M COST PER TON OF WASTE	$57.35	$60.09	$62.94	$65.90	$68.98	$72.19	$75.51
Amortized Annual Initial Capital Cost ($000's)	$69,019	$69,019	$69,019	$0	$0	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$51.76	$51.76	$51.76	$0.00	$0.00	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742
Amortized Expansion Cost Per Ton of Waste	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23
Total Amortized Capital Cost ($000's)	$85,761	$85,761	$85,761	$16,742	$16,742	$16,742	$16,742
Net Facility Cost ($000's)	$162,222	$165,878	$169,678	$104,611	$108,719	$112,989	$117,428
Net Facility Cost Per Ton of Waste ($/ton)	$121.67	$124.41	$127.26	$78.46	$81.54	$84.74	$88.07
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$41.07	$42.30	$43.57	$44.88	$46.22	$47.61	$49.04
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$163.23	$168.13	$173.17	$178.37	$183.72	$189.23	$194.91
Disposal By Rail less Hauling to IMF ($/ton)	$163.23	$168.13	$173.17	$178.37	$183.72	$189.23	$194.91
Disposal By Rail ($/ton)	$204.30	$210.43	$216.74	$223.24	$229.94	$236.84	$243.94
Disposal Tonnage Required	1,057,126	1,063,121	1,069,150	1,075,213	1,081,310	1,087,442	1,093,609
Disposal By Rail ($000's)	$215,970	$223,711	$231,729	$240,034	$248,638	$257,549	$266,780
Difference between WTE and Rail Disposal (cost per ton)	($82.63)	($86.02)	($89.48)	($144.79)	($148.40)	($152.10)	($155.87)
Difference between WTE and Rail Disposal ($000's)	($53,748)	($57,833)	($62,051)	($135,424)	($139,919)	($144,560)	($149,352)

King County

King County Solid Waste Division
Waste to Energy Feasibility Study
Operations and Maintenance

ARCADIS

Waste to Energy Option - O&M Cost Estimate	2062	2063	2064	2065	2066	2067	2068
ECONOMIC EVALUATION	35	36	37	38	39	40	41
Waste Processing							
1. Processible Waste Delivered	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
2. Processible Waste Processed (tons)	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	39,889	40,116	40,343	40,572	40,802	41,033	41,266
5. Ash Generation (tons)	377,333	377,333	377,333	377,333	377,333	377,333	377,333
6. Ferrous Recovered (tons)	55,468	55,468	55,468	55,468	55,468	55,468	55,468
7. Non-Ferrous Recovered (tons)	5,547	5,547	5,547	5,547	5,547	5,547	5,547
8. Aggregate Recovered (tons)	215,080	215,080	215,080	215,080	215,080	215,080	215,080
9. Ash Disposal (tons)	101,239	101,239	101,239	101,239	101,239	101,239	101,239
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	800,000	800,000	800,000	800,000	800,000	800,000	800,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0581	$0.0589	$0.0598	$0.0607	$0.0616	$0.0626	$0.0635
18. Electrical Energy Revenues ($000s)	$46,452	$47,149	$47,856	$48,574	$49,302	$50,042	$50,793
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$46,452	$47,149	$47,856	$48,574	$49,302	$50,042	$50,793
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$327.83	$337.66	$347.79	$358.23	$368.97	$380.04	$391.44
24. Recovered Ferrous Revenues ($000's)	$18,184	$18,730	$19,291	$19,870	$20,466	$21,080	$21,713
25. Recovered Non-Ferrous Market Price ($/ton)	$1,912	$1,970	$2,029	$2,090	$2,152	$2,217	$2,283
25. Recovered Non-Ferrous Revenues ($000's)	$10,607	$10,926	$11,253	$11,591	$11,939	$12,297	$12,666
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$28,791	$29,655	$30,545	$31,461	$32,405	$33,377	$34,378
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	233,523	227,286	221,014	214,706	208,362	201,983	195,567
31. Non-County Waste Tip Fee ($/ton)	$95.62	$98.49	$101.44	$104.48	$107.62	$110.85	$114.17
32. Non-County Waste Revenues ($000's)	$22,329	$22,384	$22,420	$22,433	$22,423	$22,389	$22,328
33. **Subtotal County Revenues**	$97,572	$99,188	$100,820	$102,468	$104,131	$105,808	$107,499
Revenues per ton ($/ton)	$73.18	$74.39	$75.62	$76.85	$78.10	$79.36	$80.62
County Expenses							
34. Base O&M Fee ($000s/yr)	$102,291	$105,359	$108,520	$111,776	$115,129	$118,583	$122,140
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$10.85	$11.18	$11.51	$11.86	$12.21	$12.58	$12.96
39. Pebble Lime Usage Cost ($000s)	$14,468	$14,902	$15,349	$15,810	$16,284	$16,773	$17,276
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.94	$0.97	$1.00	$1.03	$1.06	$1.09	$1.12
41. Ammonium Hydroxide Usage Cost ($000)	$1,253	$1,290	$1,329	$1,369	$1,410	$1,452	$1,496
42. Carbon Unit Price ($/ton)	$0.99	$1.02	$1.05	$1.08	$1.11	$1.14	$1.18
43. Carbon Usage Costs ($000s)	$1,316	$1,355	$1,396	$1,438	$1,481	$1,525	$1,571
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$2,015	$2,087	$2,162	$2,239	$2,320	$2,403	$2,489
46. Non Processible Waste WEBR Disposal including Haul Cos	$251.26	$258.80	$266.56	$274.56	$282.80	$291.28	$300.02
47. Non Processible Waste WEBR Disposal including Haul Cos	$10,023	$10,382	$10,754	$11,140	$11,539	$11,952	$12,381
48. Ash Disposal Fee ($/ton)	207.56	213.79	220.20	226.81	233.61	240.62	247.84
49. Ash Disposal Expenses ($000's)	$21,013	$21,644	$22,293	$22,962	$23,651	$24,360	$25,091
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$4.46	$4.59	$4.73	$4.87	$5.02	$5.17	$5.32
52. Utilities Pass Through ($000's)	$5,942	$6,120	$6,303	$6,493	$6,687	$6,888	$7,095
53. Haul Cost to WTE Facility ($/ton)	$50.51	$52.02	$53.59	$55.19	$56.85	$58.55	$60.31
54. Haul Cost to WTE Facility ($000's)	$55,551	$57,542	$59,604	$61,740	$63,953	$66,245	$68,619
55. Bypass Waste Disposal ($000's)	$1,038	$1,069	$1,101	$1,134	$1,168	$1,203	$1,239
56. **Subtotal Expenses ($000's)**	$202,871	$209,281	$215,896	$222,721	$229,763	$237,029	$244,527
Expenses per ton ($/ton)	$152.15	$156.96	$161.92	$167.04	$172.32	$177.77	$183.40
FACILITY EXPENSES LESS REVENUES ($000's)	$105,299	$110,093	$115,075	$120,253	$125,632	$131,221	$137,028
NET O&M COST PER TON OF WASTE	$78.97	$82.57	$86.31	$90.19	$94.22	$98.42	$102.77
Amortized Annual Initial Capital Cost ($000's)	$0	$0	$0	$0	$0	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742
Amortized Expansion Cost Per Ton of Waste	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23
Total Amortized Capital Cost ($000's)	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742
Net Facility Cost ($000's)	$122,041	$126,835	$131,818	$136,995	$142,375	$147,964	$153,771
Net Facility Cost Per Ton of Waste ($/ton)	$91.53	$95.13	$98.86	$102.75	$106.78	$110.97	$115.33
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$50.51	$52.02	$53.59	$55.19	$56.85	$58.55	$60.31
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$200.75	$206.78	$212.98	$219.37	$225.95	$232.73	$239.71
Disposal By Rail less Hauling to IMF ($/ton)	$200.75	$206.78	$212.98	$219.37	$225.95	$232.73	$239.71
Disposal By Rail ($/ton)	$251.26	$258.80	$266.56	$274.56	$282.80	$291.28	$300.02
Disposal Tonnage Required	1,099,810	1,106,047	1,112,320	1,118,627	1,124,971	1,131,351	1,137,766
Disposal By Rail ($000's)	$276,341	$286,246	$296,505	$307,132	$318,140	$329,543	$341,354
Difference between WTE and Rail Disposal (cost per ton)	($159.73)	($163.67)	($167.70)	($171.82)	($176.02)	($180.31)	($184.69)
Difference between WTE and Rail Disposal ($000's)	($154,300)	($159,410)	($164,687)	($170,137)	($175,765)	($181,579)	($187,583)

Waste to Energy Option - O&M Cost Estimate	2069	2070	2071	2072	2073	2074	2075
ECONOMIC EVALUATION	42	43	44	45	46	47	48
Waste Processing							
1. Processible Waste Delivered	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
2. Processible Waste Processed (tons)	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	41,500	41,735	41,972	42,210	42,450	42,690	42,932
5. Ash Generation (tons)	377,333	377,333	377,333	377,333	377,333	377,333	377,333
6. Ferrous Recovered (tons)	55,468	55,468	55,468	55,468	55,468	55,468	55,468
7. Non-Ferrous Recovered (tons)	5,547	5,547	5,547	5,547	5,547	5,547	5,547
8. Aggregate Recovered (tons)	215,080	215,080	215,080	215,080	215,080	215,080	215,080
9. Ash Disposal (tons)	101,239	101,239	101,239	101,239	101,239	101,239	101,239
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	800,000	800,000	800,000	800,000	800,000	800,000	800,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0644	$0.0654	$0.0664	$0.0674	$0.0684	$0.0694	$0.0705
18. Electrical Energy Revenues ($000s)	$51,554	$52,328	$53,113	$53,909	$54,718	$55,539	$56,372
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$51,554	$52,328	$53,113	$53,909	$54,718	$55,539	$56,372
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$403.19	$415.28	$427.74	$440.57	$453.79	$467.41	$481.43
24. Recovered Ferrous Revenues ($000's)	$22,364	$23,035	$23,726	$24,438	$25,171	$25,926	$26,704
25. Recovered Non-Ferrous Market Price ($/ton)	$2,352	$2,422	$2,495	$2,570	$2,647	$2,727	$2,808
25. Recovered Non-Ferrous Revenues ($000's)	$13,046	$13,437	$13,840	$14,255	$14,683	$15,124	$15,577
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$35,410	$36,472	$37,566	$38,693	$39,854	$41,050	$42,281
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	189,115	182,626	176,101	169,538	162,938	156,301	149,627
31. Non-County Waste Tip Fee ($/ton)	$117.60	$121.12	$124.76	$128.50	$132.36	$136.33	$140.42
32. Non-County Waste Revenues ($000's)	$22,239	$22,120	$21,970	$21,786	$21,566	$21,308	$21,010
33. **Subtotal County Revenues**	$109,203	$110,920	$112,649	$114,388	$116,138	$117,896	$119,663
Revenues per ton ($/ton)	$81.90	$83.19	$84.49	$85.79	$87.10	$88.42	$89.75
County Expenses							
34. Base O&M Fee ($000s/yr)	$125,805	$129,579	$133,466	$137,470	$141,594	$145,842	$150,217
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$13.35	$13.75	$14.16	$14.58	$15.02	$15.47	$15.94
39. Pebble Lime Usage Cost ($000s)	$17,794	$18,328	$18,878	$19,444	$20,028	$20,628	$21,247
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$1.16	$1.19	$1.23	$1.26	$1.30	$1.34	$1.38
41. Ammonium Hydroxide Usage Cost ($000)	$1,541	$1,587	$1,634	$1,683	$1,734	$1,786	$1,840
42. Carbon Unit Price ($/ton)	$1.21	$1.25	$1.29	$1.33	$1.37	$1.41	$1.45
43. Carbon Usage Costs ($000s)	$1,618	$1,666	$1,716	$1,768	$1,821	$1,876	$1,932
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$2,578	$2,670	$2,766	$2,865	$2,968	$3,074	$3,184
46. Non Processible Waste WEBR Disposal including Haul Cos	$309.02	$318.29	$327.84	$337.68	$347.81	$358.24	$368.99
47. Non Processible Waste WEBR Disposal including Haul Cos	$12,824	$13,284	$13,760	$14,253	$14,764	$15,293	$15,842
48. Ash Disposal Fee ($/ton)	255.27	262.93	270.82	278.95	287.31	295.93	304.81
49. Ash Disposal Expenses ($000's)	$25,844	$26,619	$27,418	$28,240	$29,087	$29,960	$30,859
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$5.48	$5.65	$5.81	$5.99	$6.17	$6.35	$6.54
52. Utilities Pass Through ($000's)	$7,307	$7,527	$7,752	$7,985	$8,225	$8,471	$8,726
53. Haul Cost to WTE Facility ($/ton)	$62.12	$63.98	$65.90	$67.88	$69.92	$72.01	$74.17
54. Haul Cost to WTE Facility ($000's)	$71,079	$73,626	$76,265	$78,999	$81,830	$84,763	$87,801
55. Bypass Waste Disposal ($000's)	$1,276	$1,315	$1,354	$1,395	$1,437	$1,480	$1,524
56. **Subtotal Expenses ($000's)**	$252,264	$260,247	$268,484	$276,984	$285,755	$294,806	$304,145
Expenses per ton ($/ton)	$189.20	$195.19	$201.36	$207.74	$214.32	$221.10	$228.11
FACILITY EXPENSES LESS REVENUES ($000's)	$143,060	$149,327	$155,836	$162,596	$169,617	$176,910	$184,482
NET O&M COST PER TON OF WASTE	$107.30	$111.99	$116.88	$121.95	$127.21	$132.68	$138.36
Amortized Annual Initial Capital Cost ($000's)	$0	$0	$0	$0	$0	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742
Amortized Expansion Cost Per Ton of Waste	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23	$50.23
Total Amortized Capital Cost ($000's)	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742	$16,742
Net Facility Cost ($000's)	$159,803	$166,069	$172,578	$179,338	$186,360	$193,652	$201,225
Net Facility Cost Per Ton of Waste ($/ton)	$119.85	$124.55	$129.43	$134.50	$139.77	$145.24	$150.92
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$62.12	$63.98	$65.90	$67.88	$69.92	$72.01	$74.17
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$246.90	$254.31	$261.94	$269.80	$277.89	$286.23	$294.81
Disposal By Rail less Hauling to IMF ($/ton)	$246.90	$254.31	$261.94	$269.80	$277.89	$286.23	$294.81
Disposal By Rail ($/ton)	$309.02	$318.29	$327.84	$337.68	$347.81	$358.24	$368.99
Disposal Tonnage Required	1,144,218	1,150,707	1,157,233	1,163,795	1,170,395	1,177,032	1,183,707
Disposal By Rail ($000's)	$353,588	$366,261	$379,388	$392,986	$407,071	$421,661	$436,773
Difference between WTE and Rail Disposal (cost per ton)	($189.17)	($193.74)	($198.41)	($203.17)	($208.04)	($213.00)	($218.07)
Difference between WTE and Rail Disposal ($000's)	($193,785)	($200,192)	($206,810)	($213,647)	($220,711)	($228,009)	($235,549)

Waste to Energy Option - O&M Cost Estimate	2076	2077
ECONOMIC EVALUATION	49	50
Waste Processing		
1. Processible Waste Delivered	1,333,333	1,333,333
2. Processible Waste Processed (tons)	1,333,333	1,333,333
3. Bypass Waste (tons)	5,000	5,000
4. Nonprocessible Waste (tons)	42,932	42,932
5. Ash Generation (tons)	377,333	377,333
6. Ferrous Recovered (tons)	55,468	55,468
7. Non-Ferrous Recovered (tons)	5,547	5,547
8. Aggregate Recovered (tons)	215,080	215,080
9. Ash Disposal (tons)	101,239	101,239
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%
Energy Revenues		
11. Gross Electrical Rate (kWh/ton)	675	675
12. Net Electrical Rate (kWh/ton)	600	600
13. Net Electrical Generation (mwh/yr)	800,000	800,000
14. Capacity Factor Achieved	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0715	$0.0726
18. Electrical Energy Revenues ($000s)	$57,217	$58,076
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0
21. Total Energy Revenues ($000s)	$57,217	$58,076
22. Operator Energy Revenue Share ($000s)	$0	$0
Other Material Revenues		
23. Recovered Ferrous Market Price ($/ton)	$495.87	$510.75
24. Recovered Ferrous Revenues ($000's)	$27,505	$28,330
25. Recovered Non-Ferrous Market Price ($/ton)	$2,893	$2,979
25. Recovered Non-Ferrous Revenues ($000's)	$16,045	$16,526
26. Recovered Aggregate Market Price ($/ton)	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0
28. Total Other Material Revenues ($000's)	$43,549	$44,856
29. Operator Material Revenue Share ($000s)	N/A	N/A
Other Revenues		
30. Non-County Waste Accepted (tons)	149,627	149,627
31. Non-County Waste Tip Fee ($/ton)	$144.63	$148.97
32. Non-County Waste Revenues ($000's)	$21,640	$22,290
33. **Subtotal County Revenues**	$122,407	$125,221
Revenues per ton ($/ton)	$91.81	$93.92
County Expenses		
34. Base O&M Fee ($000s/yr)	$154,724	$159,366
35. Excess O&M Fee ($/ton)	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A
37. Consumable Costs		
38. Pebble Lime Unit Cost ($/ton waste)	$16.41	$16.91
39. Pebble Lime Usage Cost ($000s)	$21,885	$22,541
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$1.42	$1.46
41. Ammonium Hydroxide Usage Cost ($000)	$1,895	$1,952
42. Carbon Unit Price ($/ton)	$1.49	$1.54
43. Carbon Usage Costs ($000s)	$1,990	$2,050
44. Nonprocessible Waste		
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$3,280	$3,378
46. Non Processible Waste WEBR Disposal including Haul Cos	$380.06	$391.46
47. Non Processible Waste WEBR Disposal including Haul Cos	$16,317	$16,806
48. Ash Disposal Fee ($/ton)	313.96	323.37
49. Ash Disposal Expenses ($000's)	$31,784	$32,738
50. Other Expenses ($000's)		
51. Utilities Pass Through ($/ton)	$6.74	$6.94
52. Utilities Pass Through ($000's)	$8,987	$9,257
53. Haul Cost to WTE Facility ($/ton)	$76.40	$78.69
54. Haul Cost to WTE Facility ($000's)	$90,435	$93,148
55. Bypass Waste Disposal ($000's)	$1,570	$1,617
56. **Subtotal Expenses ($000's)**	$313,269	$322,668
Expenses per ton ($/ton)	$234.95	$242.00
FACILITY EXPENSES LESS REVENUES ($000's)	$190,862	$197,446
NET O&M COST PER TON OF WASTE	$143.15	$148.08
Amortized Annual Initial Capital Cost ($000's)	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$0	$0
Amortized Expansion Cost Per Ton of Waste	$0.00	$0.00
Total Amortized Capital Cost ($000's)	$0	$0
Net Facility Cost ($000's)	$190,862	$197,446
Net Facility Cost Per Ton of Waste ($/ton)	$143.15	$148.08
WEBR Year		
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$76.40	$78.69
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$303.66	$312.77
Disposal By Rail less Hauling to IMF ($/ton)	$303.66	$312.77
Disposal By Rail ($/ton)	$380.06	$391.46
Disposal Tonnage Required	1,183,707	1,183,707
Disposal By Rail ($000's)	$449,877	$463,373
Difference between WTE and Rail Disposal (cost per ton)	($236.91)	($243.37)
Difference between WTE and Rail Disposal ($000's)	($259,014)	($265,927)

Initial Facility Capacity Options Modeled	3,000	TPD
	4,000	TPD
Expansion Capacity Modeled	1,000	TPD

EPC Construction Cost	
PBREF 2 B&W Bid Price	$667,981,128
Year of Bid Price	2010
PBREF 2 EPC Price (including COs)	$672,284,230
Year of Final EPC Price (COD)	2015
Average Annual Escalation	3.00%
Year PBREF 2 Construction Price Escalated To	2019
PBREF 2 Final EPC Escalated Price	$756,661,824
Assumed Labor Cost as Percentage of Construction Price	15%
Seattle Labor Cost Increase Compared to Miami (BLS)	50%
Additional Labor Cost for Project Location	$56,749,636.78
Assumed Equipment and Materials Cost as Percentage of Construction Price	50%
Sales Tax WPB in 2015	6%
Sales Tax King County	10.0%
Additional Cost for HIgher Sales Tax Rate	$15,133,236
PBREF 2 Final EPC Escalated Price Including Location Adjustment	$828,544,697
PBREF 2 Facility Capacity (TPD)	3000
PBREF 2 Facility Capacity (TPY)	1000000
PBREF 2 Final EPC Escalated Price per TPD	$276,181.57
Aesthetic Treatment Allowance (2010)	$12,000,000
Spare Parts Allowance (2010)	$10,000,000
Percentage of EPC Price Increase for Tonnage above 3000 tpd	75%
Percentage of EPC Price for 1000 TPD Expansion	40%
Additional Items Not Included in PBREF 2	
AMR Unit Cost ($/tpd ash processed)	$11,400
Carbon Sequestration of Flue Gas (GHG Regulations) ($/tpd)	$20,000
Land Acquisition Cost per Acre ($/Acre)	$900,000
Acres Needed for 3000 TPD Facility Site (Acres)	30
Acres Needed for 4000 TPD Facility Site (Acres)	43
Acres Needed for 5000 TPD Facility Site (Acres)	55
Estimated Land Acquisition Cost ($/TPD) for 3000 TPD (end 4000 TPD)	$12,750
Estimated Land Acquisition Cost ($/TPD) for 4000 TPD (end 5000 TPD)	$12,375
Estimated Land Acquisiton Cost ($/TPD) Average	$12,563

O&M Costs

PBREF 2 Base O&M Fee (2015)		$20,490,000
PBREF 2 Base O&M Fee (2019)		$23,061,676
Assumed Base O&M Fee for 3000 tpd Facility (2019)		$25,000,000
Assumed Base O&M Fee per TPD (2019)		$8,333.33
Percentage of Base O&M Fee Increase for Tonnage above 3000 tpd		50%
Percentage of Base O&M Fee for renegotiation of O&M term		100%
Natural Gas Usage at PBREF 2 (ccf/year)		703,000
Natural Gas Price ($/mcf)	$	6.61
Annual Natural Gas Cost ($/ton)		$0.465
Potable Water Usage (gallons/year)		92,500,000
Potable Water Price ($/ccf)	$	2.36
Annual Potable Water Cost ($/ton)		$0.292
Wastewater Disposal (gallons/year)		25,500,000
Wastewater Disposal Price ($/ccf)	$	14.48
Annual Wastewater Disposal Cost ($/ton)		$0.494
Total Utilties Pass Through Cost ($/ton)		$1.25
WEBR Cost Per Ton (includes capital, excludes haul to IMF)		$59.67
Haul Cost to IMF ($/ton)		$14.17
Intermodal Facility Land + Capital Cost ($/ton)		$3.35
WEBR Cost Per Ton (excludes capital and haul to IMF)		$56.32
Intermodal Facility Land + Capital Cost Payment Term (years)		10
Ash Disposal WEBR - Includes hauling to existing IMF ($/ton)		$58.23
Ash Disposal at Landfill ($/ton)		$17.00

Revenues

Electrical Energy Revenue - Average 2019 WA ($/kWh)	$	0.0353
Electrical Energy Revenue - HIgh 2019 WA ($/kWh)	$	0.0387
Electrical Energy Revenue - Low 2019 WA ($/kWh)	$	0.0317

PBREF 2 System:

Mass Burn
Ferrous and Non Ferrous Recovery from Ash
ACC
SCR
Carbon Injection

PBREF 2 EPC Contract

Design-Build-Operate

PBREF 2 O&M Contact

Base O&M Fee up to Throughput Guarantee
Excess O&M Fee for waste over Throughput Guarantee
Electrical revenue shared for electrical generation above Electrical Generation Guarantee
60% Operator Energy Rev Share Above Net kWh/T
Operator does not receive a share of metals revenues

Nonprocessible Waste % 3.50%

Facility Capacity Modeled | Facility Capacity Modeled 1,000,000 | - | only works for initial 3000 TPD | only works for initial 4000 tpd

Year	Estimate Amount of Waste (tons) Low Bound	Estimate Amount of Non-processible Waste (tons) Low Bound	Estimate Amount of Processible Waste (tons) Low Bound	Facility Capacity Available for Outside Waste Low Bound	Estimate Amount of Waste (tons) High Bound	Estimate Amount of Non-processible Waste (tons) High Bound	Estimate Amount of Processible Waste (tons) High Bound	Facility Capacity Available for Outside Waste High Bound	Expansion Low Bound Low Bound	Expansion High Bound High Bound
2018	888,513	31,098	857,415	142,585	888,513	31,098	857,415	142,585	0	0
2019	888,988	31,115	857,874	142,126	895,673	31,349	864,324	135,676	0	0
2020	898,180	31,436	866,744	133,256	936,563	32,780	903,783	96,217	0	0
2021	904,153	31,645	872,508	127,492	958,103	33,534	924,569	75,431	0	0
2022	910,126	31,854	878,272	121,728	994,511	34,808	959,703	40,297	0	0
2023	916,100	32,063	884,036	115,964	1,012,412	35,434	976,978	23,022	0	0
2024	922,073	32,273	889,800	110,200	1,049,871	36,745	1,013,126	0	0	0
2025	928,046	32,482	895,565	104,435	1,079,268	37,774	1,041,493	0	0	0
2026	933,450	32,671	900,779	99,221	1,117,042	39,096	1,077,946	0	0	0
2027	938,853	32,860	905,993	94,007	1,144,968	40,074	1,104,894	0	0	0
2028	944,256	33,049	911,207	88,793	1,183,897	41,436	1,142,461	0	0	0
2029	949,660	33,238	916,422	83,578	1,204,364	42,153	1,162,211	0	0	0
2030	955,063	33,427	921,636	78,364	1,225,184	42,881	1,182,303	0	0	0
2031	960,075	33,603	926,472	73,528	1,246,365	43,623	1,202,742	0	0	0
2032	965,087	33,778	931,309	68,691	1,267,912	44,377	1,223,535	0	0	0
2033	970,099	33,953	936,145	63,855	1,289,831	45,144	1,244,687	0	0	0
2034	975,110	34,129	940,982	59,018	1,312,129	45,925	1,266,204	0	0	0
2035	980,122	34,304	945,818	54,182	1,334,812	46,718	1,288,094	0	0	0
2036	985,373	34,488	950,885	49,115	1,357,888	47,526	1,310,362	0	0	0
2037	990,625	34,672	955,953	44,047	1,381,363	48,348	1,333,015	0	0	0
2038	995,876	34,856	961,020	38,980	1,405,243	49,184	1,356,060	0	0	0
2039	1,001,127	35,039	966,088	33,912	1,429,536	50,034	1,379,503	0	0	0
2040	1,006,379	35,223	971,155	28,845	1,454,250	50,899	1,403,351	0	0	0
2041	1,012,086	35,423	976,663	23,337	1,462,539	51,189	1,411,350	0	0	0
2042	1,017,825	35,624	982,201	17,799	1,470,875	51,481	1,419,395	0	0	0
2043	1,023,597	35,826	987,771	12,229	1,479,259	51,774	1,427,485	0	0	0
2044	1,029,402	36,029	993,373	6,627	1,487,691	52,069	1,435,622	0	0	0
2045	1,035,239	36,233	999,006	994	1,496,171	52,366	1,443,805	0	0	0
2046	1,041,110	36,439	1,004,671	0	1,504,699	52,664	1,452,035	0	0	0
2047	1,047,014	36,645	1,010,368	0	1,513,276	52,965	1,460,311	0	0	0
2048	1,052,951	36,853	1,016,098	0	1,521,902	53,267	1,468,635	0	317,235	-135,302
2049	1,058,923	37,062	1,021,860	0	1,530,576	53,570	1,477,006	0	311,473	-143,673
2050	1,064,928	37,272	1,027,655	0	1,539,301	53,876	1,485,425	0	305,678	-152,092
2051	1,070,967	37,484	1,033,483	0	1,548,075	54,183	1,493,892	0	299,850	-160,559

	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Expansion Low Bound	Expansion High Bound
2052	1,077,040	37,696	1,039,344	0	1,556,899	54,491	1,502,407	0	293,990	-169,074
2053	1,083,148	37,910	1,045,238	0	1,565,773	54,802	1,510,971	0	288,096	-177,638
2054	1,089,290	38,125	1,051,165	0	1,574,698	55,114	1,519,584	0	282,168	-186,250
2055	1,095,467	38,341	1,057,126	0	1,583,674	55,429	1,528,245	0	276,207	-194,912
2056	1,101,680	38,559	1,063,121	0	1,592,701	55,745	1,536,956	0	270,213	-203,623
2057	1,107,927	38,777	1,069,150	0	1,601,779	56,062	1,545,717	0	264,184	-212,384
2058	1,114,210	38,997	1,075,213	0	1,610,909	56,382	1,554,527	0	258,121	-221,194
2059	1,120,529	39,218	1,081,310	0	1,620,091	56,703	1,563,388	0	252,023	-230,055
2060	1,126,883	39,441	1,087,442	0	1,629,326	57,026	1,572,300	0	245,891	-238,966
2061	1,133,273	39,665	1,093,609	0	1,638,613	57,351	1,581,262	0	239,725	-247,928
2062	1,139,700	39,889	1,099,810	0	1,647,953	57,678	1,590,275	0	233,523	-256,942
2063	1,146,163	40,116	1,106,047	0	1,657,347	58,007	1,599,339	0	227,286	-266,006
2064	1,152,663	40,343	1,112,320	0	1,666,793	58,338	1,608,456	0	221,014	-275,122
2065	1,159,199	40,572	1,118,627	0	1,676,294	58,670	1,617,624	0	214,706	-284,291
2066	1,165,773	40,802	1,124,971	0	1,685,849	59,005	1,626,844	0	208,362	-293,511
2067	1,172,384	41,033	1,131,351	0	1,695,458	59,341	1,636,117	0	201,983	-302,784
2068	1,179,032	41,266	1,137,766	0	1,705,123	59,679	1,645,443	0	195,567	-312,110
2069	1,185,719	41,500	1,144,218	0	1,714,842	60,019	1,654,822	0	189,115	-321,489
2070	1,192,443	41,735	1,150,707	0	1,724,616	60,362	1,664,255	0	182,626	-330,921
2071	1,199,205	41,972	1,157,233	0	1,734,447	60,706	1,673,741	0	176,101	-340,408
2072	1,206,005	42,210	1,163,795	0	1,744,333	61,052	1,683,281	0	169,538	-349,948
2073	1,212,844	42,450	1,170,395	0	1,754,276	61,400	1,692,876	0	162,938	-359,543
2074	1,219,722	42,690	1,177,032	0	1,764,275	61,750	1,702,525	0	156,301	-369,192
2075	1,226,639	42,932	1,183,707	0	1,774,331	62,102	1,712,230	0	149,627	-378,896

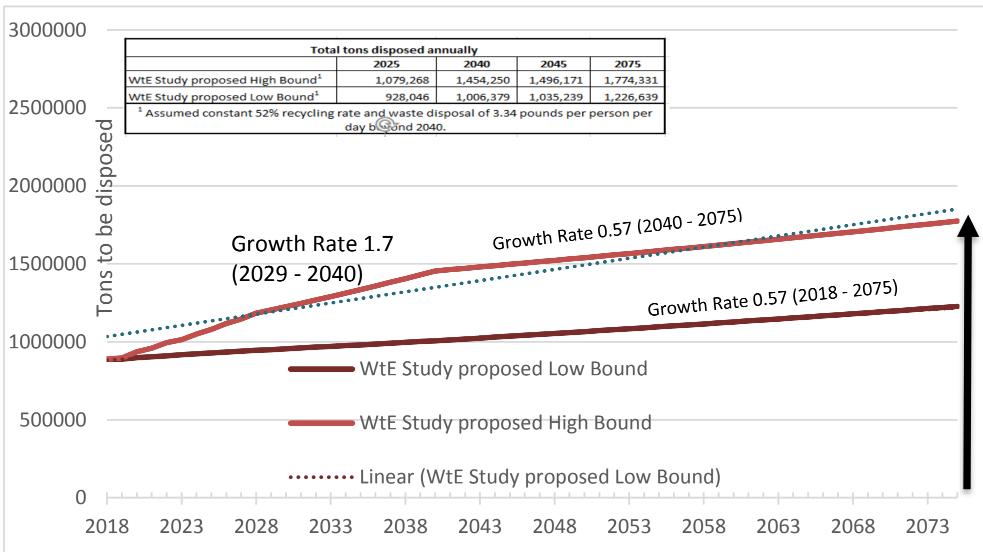
Notes:

yellow highlight indicates likely expansion tonnage and therefore expansion year used in model

green highlight indicates 30 year initial bond payoff date

blue highlight indicates possible delayed expansion tonnage and expansion year

Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Expansion Low Bound	Expansion High Bound



Overall Financial Summary

Term End Year	2028	2037	2047	2077
	Term (years)	**10**	**20**	**50**
	Initial Constr. and O&M Term			
Low Tonnage Bound Case - 3000 TPD				
Total Construction Cost	$1,193,474,835	$690,187,680	$1,413,860,228	$2,572,836,051
Total O&M Costs	$1,686,825,351	$717,846,837	$1,686,825,351	$8,094,904,540.78
Total O&M Revenues	$732,267,096	$341,497,157	$732,267,096	$3,704,303,169
Total Net O&M Cost	$954,558,254.92	$376,349,680.65	$954,558,254.92	$4,390,601,371.35
Total Costs	$2,148,033,090	$1,066,537,361	$2,368,418,483	$6,963,437,423
Total Cost Per Ton	$107.40	$106.65	$118.42	$116.06
Waste-by-Rail Export Low Tonnage Bound Case - 3000 TPD				
Costs		$1,026,526,133	$2,424,490,647	$11,251,567,071
Revenues		$0	$0	$0
Total Net Costs		$1,026,526,133	$2,424,490,647	$11,251,567,071
Total Net Cost Per Ton		$109.94	$126.35	$215.15
Difference between WTE and WEBR (Total Net Cost)		$40,011,228	($56,072,165)	($4,288,129,649)
Difference between WTE and WEBR (Total Cost Per Ton)		($3.29)	($7.93)	($99.09)
High Tonnage Bound Case - 4000 TPD				
Total Construction Cost	$1,492,872,058	$863,329,391	$1,860,223,433	$2,990,682,128
Total O&M Costs	$2,237,584,299	$892,336,917	$2,237,584,299	$10,172,184,068
Total O&M Revenues	$1,175,506,847	$457,653,011	$1,175,506,847	$4,263,063,438
Total Net O&M Cost	$1,062,077,452	$434,683,906	$1,062,077,452	$5,909,120,630
Total Costs	$2,554,949,509	$1,298,013,297	$2,922,300,885	$8,899,802,758
Total Cost Per Ton	$95.81	$97.35	$99.62	$112.18
Waste-by-Rail Export High Tonnage Bound Case - 4000 TPD				
Costs		$1,362,187,218	$3,376,330,508	$16,140,955,031
Revenues		$0	$0	$0
Total Net Costs		$1,362,187,218	$3,376,330,508	$16,140,955,031
Total Net Cost Per Ton		$110.25	$127.19	$216.90
Difference between WTE and WEBR (Total Net Cost)		($64,173,921)	($454,029,622)	($7,241,152,273)
Difference between WTE and WEBR (Total Cost Per Ton)		($12.90)	($27.57)	($104.72)

Scenarios

Low Tonnage Bound Case - 3000 TPD		
Initial Capacity TPD, TPY	3000	1,000,000
Expansion	2048	
Expanded Size TPD, TPY	4000	1,333,333
Hauling Cost to WTE Facility ($/ton)	$14.17	
Out of County Waste Accepted (Year 1, TPY)	88,793	
Land Acquisition Costs ($/TPD)	$12,563	
Bypass Waste Annual Tonnage (tons)	5000	
Hauling Cost to IMF	Included	
Construction Cost of New IMF	Included	
High Tonnage Bound Case - 4000 TPD		
Initial Capacity TPD, TPY	4000	1,333,333
Expansion	2040	
Expanded Size TPD, TPY	5000	1,666,667
Hauling Cost to WTE Facility ($/ton)	$14.17	
Out of County Waste Accepted (Year 1, TPY)	190,873	
Land Acquisition Costs ($/TPD)	$12,563	
Bypass Waste Annual Tonnage (tons)	5000	
Hauling Cost to IMF	Included	
Construction Cost of New IMF	Included	

Waste to Energy Option - Assumptions / Inputs

Blue font indicates an input value

Schedule

	Start Date/Duration (Years)	
Planning / Permitting / Siting	3	Years
Develop Bid Package	1	Years
Procurement to Notice of Award	1	Years
D/B to COD	5	Years
Cost Estimate Date	6/1/2019	Date
Permitting/Planning/Siting Start Date	1/1/2020	Date
Development of Design Criteria and Bid Package	1/1/2020	Date
Procurement of EPC Contractor	1/1/2022	Date
Contractor Notice to Proceed Date	1/1/2023	Date
Contractor NTP Check (Permitting/Siting complete)	1/1/2023	Date
Commercial Operation Date	1/1/2028	Date
1,000 TPD Future Expansion Completion	2040	Year
Future Expansion Design and Construction Duration	2	Years

Costs and Escalation Factors

Initial Design and Construction Price	$1,317,627,588	$
Initial Consulting Fees	$39,528,828	$
Initial Annual Operation Fee (2019)	$29,166,667	$/yr
Annual Initial Construction Cost (Payments over 30 year bond term)	$86,332,939	$/yr
Expansion Design and Construction Price	$203,848,579	$
Expansion Consulting Fees	$6,115,457	$
Expansion Annual Operation Fee (Expansion Year)	$60,113,619	$/yr
Annual Expansion Construction Cost (Payments over 30 year bond term)	$13,356,465	$/yr
Consulting Fees Percentage of Construction Cost	3.0%	Percent (%)
Bond Financing Cost as Percentage of Construction Cost	0.6%	Percent (%)
Additional Bond Issuance Cost as a Percentage of Construction Cost	6.7%	Percent (%)
Bond Financing Rate	4.0%	Percent (%)
Bond Financing Term	30	Years
Capital Cost Escalation Rate	3.0%	% per year
Annual Operating Fee Escalation / CPI	3.0%	% per year
Net Present Value (NPV) Discount Factor - Construction	4.5%	% per year
NPV Discount Factor for O&M	4.5%	% per year
Term of Initial Operation and Maintenance Agreement	20	Years
Term of Interim Operation and Maintenance Agreement	5	Years
Term of 2nd Operation and Maintenance Agreement	25	Years
Land Acquisition Cost	$12,563	$/TPD

Waste Processing

Initial Facility Throughput	4,000	tpd
Initial Annual Throughput Guarantee	1,333,333	tpy
Facility Availability (Daily to Annual Throughput Factor)	91%	Percent (%)
Initial Processible Waste Processed	1,333,333	tpy
Expansion Additional Capacity	1,000	tpd
Expansion Additional Throughput	333,333.33	tpy
Expanded Facility Throughput	5,000	tpd
Expanded Facility Throughput Guarantee	1,666,667	tpy
Processible Waste Delivered Escalation Rate	0.00%	% per year
Residue Generation Rate	28.3%	% of processed tons
Ash Disposal Cost (Year 1)	$58.23	$/ton
Annual Average Higher Heating Value of Waste Processed	5,200	Btu per Pound
Design HHV Waste Assumption	5,000	Btu per Pound
Out of County Waste Accepted (Year 1)	190,873	tpy
Out of County Waste Tip Fee (Year 1)	$35.00	$/ton
Percentage of Remaining Capacity use for Out of County Waste	100%	Percent (%)
Bypass Waste Tonnage	5,000	tpy
Nonprocessible Waste Percentage	3.5%	Percent (%)
Transport Cost to WTE Facility	$14.17	$/ton

Electrical Generation

Gross Electric Generation Rate	675	kWh/ton
Electric Generation Guarantee	600	kWh/ton
Electric Capacity Guarantee	0	MW Month
Electric Capacity Factor	90%	Percent (%)
Electric Capacity Payment (Year 1)	$0	$/MW month
Electric Capacity Payment Escalation Rate	1.90%	% per year
Electric Energy Escalation Rate	3.00%	Percent (%)
Average Electrical Energy Revenue	$0.0350	$/kWh
Green Energy Credit	$0.0000	$/kWh
Operator Energy Rev Share Above Net kWh/T	60%	Percent (%)
Operator kWh/Ton Achieved	600	kWh/Ton

Metals Recovery

Ferrous Metal Recovery Guarantee	98.0%	Percent Recovered
Non-Ferrous Metal Recovery Guarantee	98.0%	Percent Recovered
Recovered Ferrous Market Price (Year 1)	$120.00	$/ton
Recovered Non-Ferrous Market Price (Year 1)	$700.00	$/ton
Ferrous Metal In Ash	15.0%	% in Ash Residue
Non-Ferrous Metal In Ash	1.5%	% in Ash Residue
Operator Material Revenue Share	0%	Percent (%)
Aggregate Production	57%	% in Ash Residue
Aggregate Price (Year 1)	$0.00	$/ton

Air Pollution Control Reagents

Pebble Lime Usage Rate	21.00	Lbs/ton of waste
Ammonium Hydroxide Usage Rate	3.50	Lbs/ton of waste
Carbon Usage Rate	0.40	Lbs/ton of waste
Pebble Lime Unit Cost	0.147	$/lb
Pebble Lime Cost per Ton of Waste	3.08	$/ton
Ammonium Hydroxide Unit Cost	0.076	$/lb
Ammonium Hydroxide Cost per Ton of Waste	0.27	$/ton
Carbon Unit Price	0.70	$/lb
Carbon Price per Ton Waste	0.28	$/ton

Project Costs Summary

EPC Contractor Initial Capital Price	$1,317,627,588	
Consulting Fees	$39,528,828	
Bond Issuance Cost / Interim Financing	$96,186,814	
Other Costs - Contingency	$39,528,828	3%
Total Initial Construction Costs	**$1,492,872,058**	
EPC Contractor Expansion Capital Price	$203,848,579	
Consulting Fees	$6,115,457	
Bond Issuance Cost / Interim Financing	$14,880,946	
Other Costs - Contingency	$6,115,457	3%
Total Expansion Construction Costs	**$230,960,441**	
Total O&M Costs (over 20-Yr O&M Term)	$2,237,584,299	
O&M Electrical Sales Revenues	$718,039,869	
O&M Metals Recovery Sales Revenues	$316,588,743	
O&M Non-County Waste Revenues	$140,878,236	
Total O&M Revenues (over 20-Yr O&M Term)	$1,175,506,847	
Total O&M Net Costs (over 20-Yr O&M Term)	**$1,062,077,452**	
Total O&M Costs (over remaining 30-Yr O&M Term)	$7,934,599,769	
O&M Electrical Sales Revenues	$1,769,570,633	
O&M Metals Recovery Sales Revenues	$1,131,965,542	
O&M Non-County Waste Revenues	$186,020,416	
Total O&M Revenues (over remaining 30-Yr O&M Term)	$3,087,556,591	
Total O&M Net Costs (over remaining 30-Yr O&M Term)	**$4,847,043,178**	
Total Initial Construction and O&M Costs	**$2,554,949,509**	
Total Cost Per Ton (over 20-Yr O&M Term)	**$95.81**	
Total Expansion Construction and O&M Costs	**$5,078,003,619**	
Total Expansion Cost Per Ton (over remaining 30-Yr O&M Term)	**$507.80**	
Net Present Value of Initial EPC Contractor Price and Bond Issuance	$1,269,372,125	
Consulting Fees and Contingency	$79,057,655	
Total Initial Construction Costs NPV	**$1,348,429,780**	
Net Present Value of Initial Operation & Maintenance (20-year term)	$652,979,062	
TOTAL Initial Net Present Value	**$2,001,408,842**	
Net Present Value of Expansion EPC Contractor Price and Bond Issuance	$208,694,372	
Consulting Fees and Contingency	$6,115,457	
Total Expansion Constriction Costs NPV	**$214,809,829**	
Net Present Value of Expansion Operation & Maintenance (30-year)	$2,291,145,439	
TOTAL Expansion Net Present Value	**$2,505,955,268**	
Total Capital Cost NPV (over 50 Years)	$1,546,361,799	
Total O&M Cost NPV (over 50 Years)	$1,602,986,159	
Total Cost NPV (over 50 Years)	**$3,149,347,958**	
Total Capital Cost Per Ton NPV (over 50 Years)	$19.49	
Total O&M Cost Per Ton NPV (over 50 Years)	$20.21	
Total Cost Per Ton (NPV over 50 Years)	**$39.70**	
Total Cost Per Ton (O&M Year 1)	**$90.67**	
Total Cost Per Ton (Year 20)	**$104.83**	
Total Cost Per Ton (Year 50)	**$161.54**	
Average Cost Per Ton over initial period (20 years)	**$99.80**	
Average Cost Per Ton over planning period (50 years)	**$111.65**	

Waste Export By Rail (WEBR)	
Total Cost (First Year)	**$110,069,751**
Total Cost (20 Year Term)	**$3,376,330,508**
Total Cost (50 Year Term)	**$16,140,955,031**
Total Cost Per Ton (O&M Year 1)	**$96.34**
Total Cost Per Ton (Year 20)	**$161.28**
Total Cost Per Ton (Year 50)	**$391.46**

Color Code:
- Initial Term
- Expansion Term
- WEBR

Metals Recovery Estimates

62,667	Metals in waste stream (4.7% from Waste
56,600	Ferrous Metals in Ash Residue
5,660	Non-Ferrous Metals in Ash Residue
62,260	Total Metals in Ash Residue

King County Solid Waste Division
Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost	
	2019	2023	2038	
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$193,714	
Additional Items Not Included in PBREF 2		$0.00	$0.00	
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134	
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00	Could consider this as included in PBREF 2 optional costs (aesthetics, spare parts, etc)
Land Acquisition Costs	$12,563	$14,139.20	$0.00	Currently assumed land neede for expansion purchased with initial construction. \
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00	
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$203,849	
Facility Capacity (TPD)	4000	4000	1000	
	$1,234,976,263	$1,303,103,122	$203,848,579	
Advanced Metals Recovery (AMR) System				
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A	assumed no expansion required
Facility Ash Production (TPD)	1132	1132	N/A	
Estimated Construction Price of AMR	$12,904,800	$14,524,466		
Total Estimated Construction Price (EPC)	**$1,247,881,063**	**$1,317,627,588**	**$203,848,579**	

				Construction Estimated Date	1/31/2023	3/3/2023	4/2/2023	5/3/2023	6/2/2023	7/3/2023	8/2/2023	9/2/2023	10/2/2023	11/2/2023	12/2/2023
	Component Description	**Construction Price**	**Commercial Operations (months from proposal)**	**Bond Issuance Cost**	**Drawdown Schedule (months from NTP)**										
					1	2	3	4	5	6	7	8	9	10	11
1.	Construction Price	**$1,317,627,588**	**60**	**$96,186,813.95**	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460
2.	Expansion Price	**$203,848,579**	**24**	**$14,880,946.30**	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691
				Expansion Estimated Date	1/1/2038	2/1/2038	3/3/2038	4/3/2038	5/3/2038	6/3/2038	7/3/2038	8/3/2038	9/2/2038	10/3/2038	11/2/2038

Net Present Value of Construction Costs		**0.38%**	**$1,269,372,125**
Net Present Value of Expansion Costs		**0.38%**	**$208,694,372**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2038
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$193,714
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$203,849
Facility Capacity (TPD)	4000	4000	1000
	$1,234,976,263	$1,303,103,122	$203,848,579
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	1132	1132	N/A
Estimated Construction Price of AMR	$12,904,800	$14,524,466	
Total Estimated Construction Price (EPC)	**$1,247,881,063**	**$1,317,627,588**	**$203,848,579**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost
1.	Construction Price	**$1,317,627,588**	**60**	**$96,186,813.95**
2.	Expansion Price	**$203,848,579**	**24**	**$14,880,946.30**

	12	13	14	15	16	17
Construction Estimated Date	1/2/2024	2/1/2024	3/3/2024	4/2/2024	5/3/2024	6/2/2024
1. Construction Price	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460
2. Expansion Price	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691
Expansion Estimated Date	12/3/2038	1/2/2039	2/2/2039	3/4/2039	4/4/2039	5/4/2039

	18	19	20	21	22	23
Construction Estimated Date	7/3/2024	8/2/2024	9/2/2024	10/2/2024	11/2/2024	12/2/2024
1. Construction Price	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460
2. Expansion Price	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691	$8,493,691
Expansion Estimated Date	6/4/2039	7/4/2039	8/4/2039	9/3/2039	10/4/2039	11/3/2039

Net Present Value of Construction Costs		**0.38%**	**$1,269,372,125**
Net Present Value of Expansion Costs		**0.38%**	**$208,694,372**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2038
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$193,714
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$203,849
Facility Capacity (TPD)	4000	4000	1000
	$1,234,976,263	$1,303,103,122	$203,848,579
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	1132	1132	N/A
Estimated Construction Price of AMR	$12,904,800	$14,524,466	
Total Estimated Construction Price (EPC)	**$1,247,881,063**	**$1,317,627,588**	**$203,848,579**

				Construction Estimated Date	1/2/2025	2/1/2025	3/4/2025	4/3/2025	5/4/2025	6/3/2025	7/4/2025	8/3/2025	9/3/2025	10/3/2025	11/3/2025	12/3/2025
	Component Description	**Construction Price**	**Commercial Operations (months from proposal)**	**Bond Issuance Cost**												
					24	25	26	27	28	29	30	31	32	33	34	35
1.	Construction Price	**$1,317,627,588**	**60**	**$96,186,813.95**	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460
2.	Expansion Price	**$203,848,579**	**24**	**$14,880,946.30**	$8,493,691	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
				Expansion Estimated Date	12/4/2039	1/3/2040	2/3/2040	3/4/2040	4/4/2040	5/4/2040	6/4/2040	7/4/2040	8/4/2040	9/3/2040	10/4/2040	11/3/2040

Net Present Value of Construction Costs		**0.38%**	**$1,269,372,125**
Net Present Value of Expansion Costs		**0.38%**	**$208,694,372**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2038
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$193,714
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$203,849
Facility Capacity (TPD)	4000	4000	1000
	$1,234,976,263	$1,303,103,122	$203,848,579
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	1132	1132	N/A
Estimated Construction Price of AMR	$12,904,800	$14,524,466	
Total Estimated Construction Price (EPC)	**$1,247,881,063**	**$1,317,627,588**	**$203,848,579**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost												
				Construction Estimated Date	1/3/2026	2/2/2026	3/5/2026	4/4/2026	5/5/2026	6/4/2026	7/5/2026	8/4/2026	9/4/2026	10/4/2026	11/4/2026	12/4/2026
					36	37	38	39	40	41	42	43	44	45	46	47
1.	Construction Price	**$1,317,627,588**	**60**	**$96,186,813.95**	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460
2.	Expansion Price	**$203,848,579**	**24**	**$14,880,946.30**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
				Expansion Estimated Date	12/4/2040	1/3/2041	2/3/2041	3/5/2041	4/5/2041	5/5/2041	6/5/2041	7/5/2041	8/5/2041	9/4/2041	10/5/2041	11/4/2041

Net Present Value of Construction Costs		**0.38%**	**$1,269,372,125**
Net Present Value of Expansion Costs		**0.38%**	**$208,694,372**

King County Solid Waste Division

Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2038
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$193,714
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$203,849
Facility Capacity (TPD)	4000	4000	1000
	$1,234,976,263	$1,303,103,122	$203,848,579
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	1132	1132	N/A
Estimated Construction Price of AMR	$12,904,800	$14,524,466	
Total Estimated Construction Price (EPC)	**$1,247,881,063**	**$1,317,627,588**	**$203,848,579**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost	48	49	50	51	52	53	54	55	56	57	58	59
				Construction Estimated Date	1/4/2027	2/3/2027	3/6/2027	4/5/2027	5/6/2027	6/5/2027	7/6/2027	8/5/2027	9/5/2027	10/5/2027	11/5/2027	12/5/2027
1.	Construction Price	**$1,317,627,588**	**60**	**$96,186,813.95**	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460	$21,960,460
2.	Expansion Price	**$203,848,579**	**24**	**$14,880,946.30**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
				Expansion Estimated Date	12/5/2041	1/4/2042	2/4/2042	3/6/2042	4/6/2042	5/6/2042	6/6/2042	7/6/2042	8/6/2042	9/5/2042	10/6/2042	11/5/2042

Net Present Value of Construction Costs		**0.38%**	**$1,269,372,125**
Net Present Value of Expansion Costs		**0.38%**	**$208,694,372**

King County Solid Waste Division
Waste to Energy Feasibility Study

Waste to Energy Option - Capital Cost Estimate	Escalated to 2019 Value	Estimated Costs for NTP Year to COD Year	Estimated Expansion Cost
	2019	2023	2038
PBREF 2 Final EPC Escalated Price per TPD	$276,182	$310,845	$193,714
Additional Items Not Included in PBREF 2		$0.00	$0.00
Carbon Sequestration of Flue Gas (GHG Regulations)	$20,000	$22,510	$10,134
Initial Construction of Unit Site Work For Expansion Space		$0.00	$0.00
Land Acquisition Costs	$12,563	$14,139.20	$0.00
Potential Deduction for Electrical Equipment from Electric Company		$0.00	$0.00
Estimated Construction Price Per TPD Waste	$308,744	$347,494	$203,849
Facility Capacity (TPD)	4000	4000	1000
	$1,234,976,263	$1,303,103,122	$203,848,579
Advanced Metals Recovery (AMR) System			
AMR Unit Cost ($/tpd ash processed)	$11,400	$12,831	N/A
Facility Ash Production (TPD)	1132	1132	N/A
Estimated Construction Price of AMR	$12,904,800	$14,524,466	
Total Estimated Construction Price (EPC)	**$1,247,881,063**	**$1,317,627,588**	**$203,848,579**

	Component Description	Construction Price	Commercial Operations (months from proposal)	Bond Issuance Cost		Total
				Construction Estimated Date	1/5/2028	
					60	
1.	Construction Price	**$1,317,627,588**	**60**	**$96,186,813.95**	$21,960,460	**$1,317,627,588**
2.	Expansion Price	**$203,848,579**	**24**	**$14,880,946.30**	$0	**$203,848,579**
				Expansion Estimated Date	12/6/2042	

Net Present Value of Construction Costs		**0.38%**	**$1,269,372,125**
Net Present Value of Expansion Costs		**0.38%**	**$208,694,372**

Waste to Energy Option - O&M Cost Estimate	Year Based on COD	2028	2029	2030	2031	2032	2033
ECONOMIC EVALUATION	Escalation Rates or Values	1	2	3	4	5	6
Waste Processing							
1. Processible Waste Delivered	0.00%	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
2. Processible Waste Processed (tons)	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333
3. Bypass Waste (tons)		5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)		41,436	42,153	42,881	43,623	44,377	45,144
5. Ash Generation (tons)	28.30%	377,333	377,333	377,333	377,333	377,333	377,333
6. Ferrous Recovered (tons)		55,468	55,468	55,468	55,468	55,468	55,468
7. Non-Ferrous Recovered (tons)		5,547	5,547	5,547	5,547	5,547	5,547
8. Aggregate Recovered (tons)	57.00%	215,080	215,080	215,080	215,080	215,080	215,080
9. Ash Disposal (tons)		101,239	101,239	101,239	101,239	101,239	101,239
10. Ash Disposal as a percentage of Waste Processed		7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)		800,000	800,000	800,000	800,000	800,000	800,000
14. Capacity Factor Achieved		N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	1.90%	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	90%	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	1.50%	$0.0350	$0.0355	$0.0361	$0.0366	$0.0371	$0.0377
18. Electrical Energy Revenues ($000s)		$28,000	$28,420	$28,846	$29,279	$29,718	$30,164
19. Green Energy Credits ($/kWh)	3.00%	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)		$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)		$28,000	$28,420	$28,846	$29,279	$29,718	$30,164
22. Operator Energy Revenue Share ($000s)	60%	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	3.00%	$120.00	$123.60	$127.31	$131.13	$135.06	$139.11
24. Recovered Ferrous Revenues ($000's)		$6,656	$6,856	$7,062	$7,273	$7,492	$7,716
25. Recovered Non-Ferrous Market Price ($/ton)	3.00%	$700	$721	$743	$765	$788	$811
25. Recovered Non-Ferrous Revenues ($000's)		$3,883	$3,999	$4,119	$4,243	$4,370	$4,501
26. Recovered Aggregate Market Price ($/ton)	3.00%	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)		$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)		$10,539	$10,855	$11,181	$11,516	$11,862	$12,217
29. Operator Material Revenue Share ($000s)	0%	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	100%	190,873	171,122	151,030	130,591	109,799	88,647
31. Non-County Waste Tip Fee ($/ton)	3.00%	$35.00	$36.05	$37.13	$38.25	$39.39	$40.57
32. Non-County Waste Revenues ($000's)		$6,681	$6,169	$5,608	$4,995	$4,325	$3,597
33. **Subtotal County Revenues**		$45,219	$45,444	$45,635	$45,790	$45,905	$45,978
Revenues per ton ($/ton)		$33.91	$34.08	$34.23	$34.34	$34.43	$34.48
County Expenses							
34. Base O&M Fee ($000s/yr)	3.00%	$37,599	$38,727	$39,889	$41,086	$42,319	$43,588
35. Excess O&M Fee ($/ton)		N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)		N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	3.00%	$3.97	$4.09	$4.21	$4.34	$4.47	$4.60
39. Pebble Lime Usage Cost ($000s)		$5,296	$5,455	$5,619	$5,787	$5,961	$6,140
40. Ammonium Hydroxide Unit Cost ($/ton waste)	3.00%	$0.34	$0.35	$0.36	$0.38	$0.39	$0.40
41. Ammonium Hydroxide Usage Cost ($000)		$459	$472	$486	$501	$516	$532
42. Carbon Unit Price ($/ton)	3.00%	$0.36	$0.37	$0.38	$0.39	$0.41	$0.42
43. Carbon Usage Costs ($000s)		$482	$496	$511	$526	$542	$558
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)		$766	$803	$841	$881	$923	$968
46. Non Processible Waste WEBR Disposal including Haul Co:	$70.49	$91.97	$94.73	$97.57	$100.50	$103.52	$106.62
47. Non Processible Waste WEBR Disposal including Haul Cost ($000's)		$3,811	$3,993	$4,184	$4,384	$4,594	$4,813
48. Ash Disposal Fee ($/ton)	3.00%	$75.98	78.26	80.60	83.02	85.51	88.08
49. Ash Disposal Expenses ($000's)		$7,692	$7,923	$8,160	$8,405	$8,657	$8,917
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$1.25	$1.63	$1.68	$1.73	$1.78	$1.84	$1.89
52. Utilities Pass Through ($000's)		$2,175	$2,240	$2,307	$2,377	$2,448	$2,521
53. Haul Cost to WTE Facility ($/ton)	$14.17	$18.49	$19.04	$19.61	$20.20	$20.81	$21.43
54. Haul Cost to WTE Facility ($000's)		$21,123	$22,132	$23,190	$24,299	$25,461	$26,678
55. Bypass Waste Disposal ($000's)		$380	$391	$403	$415	$428	$440
56. **Subtotal Expenses ($000's)**		$79,782	$82,633	$80,566	$83,396	$86,331	$89,374
Expenses per ton ($/ton)		$59.84	$61.97	$60.42	$62.55	$64.75	$67.03
FACILITY EXPENSES LESS REVENUES ($000's)		$34,562	$37,189	$34,931	$37,606	$40,426	$43,396
NET O&M COST PER TON OF WASTE		$25.92	$27.89	$26.20	$28.20	$30.32	$32.55
Amortized Annual Initial Capital Cost ($000's)		$86,333	$86,333	$86,333	$86,333	$86,333	$86,333
Amortized Initial Capital Cost Per Ton of Waste		$64.75	$64.75	$64.75	$64.75	$64.75	$64.75
Amortized Annual Expansion Cost ($000's)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Amortized Expansion Cost Per Ton of Waste		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Amortized Capital Cost ($000's)		$86,333	$86,333	$86,333	$86,333	$86,333	$86,333
Net Facility Cost ($000's)		$120,895	$123,522	$121,264	$123,939	$126,758	$129,729
Net Facility Cost Per Ton of Waste ($/ton)		$90.67	$92.64	$90.95	$92.95	$95.07	$97.30
WEBR Year	2019	2028					
Disposal by Rail Capital Cost IMF ($/ton)	$3.35	$4.37	$4.37	$4.37	$4.37	$4.37	$4.37
Disposal by Rail Haul to IMF Cost ($/ton)	$14.17	$18.49	$19.04	$19.61	$20.20	$20.81	$21.43
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$56.32	$73.48	$75.69	$77.96	$80.30	$82.71	$85.19
Disposal By Rail less Hauling to IMF ($/ton)	$59.67	$77.86	$80.06	$82.33	$84.67	$87.08	$89.56
Disposal By Rail ($/ton)	$73.84	$96.34	$99.10	$101.95	$104.87	$107.89	$110.99
Disposal Tonnage Required		1,142,461	1,162,211	1,182,303	1,202,742	1,223,535	1,244,687
Disposal By Rail ($000's)		$110,070	$115,179	$120,531	$126,135	$132,005	$138,152
Difference between WTE and Rail Disposal (cost per ton)		($5.67)	($6.46)	($11.00)	($11.92)	($12.82)	($13.70)
Difference between WTE and Rail Disposal ($000's)		$10,826	$8,342	$733	($2,196)	($5,246)	($8,423)

Waste to Energy Option - O&M Cost Estimate	2034	2035	2036	2037	2038	2039	2040
ECONOMIC EVALUATION	7	8	9	10	11	12	13
Waste Processing							
1. Processible Waste Delivered	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,666,667
2. Processible Waste Processed (tons)	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,333,333	1,666,667
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	45,925	46,718	47,526	48,348	49,184	50,034	50,899
5. Ash Generation (tons)	377,333	377,333	377,333	377,333	377,333	377,333	471,667
6. Ferrous Recovered (tons)	55,468	55,468	55,468	55,468	55,468	55,468	69,335
7. Non-Ferrous Recovered (tons)	5,547	5,547	5,547	5,547	5,547	5,547	6,934
8. Aggregate Recovered (tons)	215,080	215,080	215,080	215,080	215,080	215,080	268,850
9. Ash Disposal (tons)	101,239	101,239	101,239	101,239	101,239	101,239	126,548
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	800,000	800,000	800,000	800,000	800,000	800,000	1,000,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0383	$0.0388	$0.0394	$0.0400	$0.0406	$0.0412	$0.0418
18. Electrical Energy Revenues ($000s)	$30,616	$31,076	$31,542	$32,015	$32,495	$32,983	$41,847
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$30,616	$31,076	$31,542	$32,015	$32,495	$32,983	$41,847
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$143.29	$147.58	$152.01	$156.57	$161.27	$166.11	$171.09
24. Recovered Ferrous Revenues ($000's)	$7,948	$8,186	$8,432	$8,685	$8,945	$9,214	$11,863
25. Recovered Non-Ferrous Market Price ($/ton)	$836	$861	$887	$913	$941	$969	$998
25. Recovered Non-Ferrous Revenues ($000's)	$4,636	$4,775	$4,919	$5,066	$5,218	$5,375	$6,920
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$12,584	$12,962	$13,350	$13,751	$14,163	$14,588	$18,782
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	67,129	45,239	22,971	318	0	0	263,316
31. Non-County Waste Tip Fee ($/ton)	$41.79	$43.05	$44.34	$45.67	$47.04	$48.45	$49.90
32. Non-County Waste Revenues ($000's)	$2,805	$1,947	$1,018	$15	$0	$0	$13,140
33. **Subtotal County Revenues**	$46,006	$45,985	$45,911	$45,780	$46,659	$47,571	$73,769
Revenues per ton ($/ton)	$34.50	$34.49	$34.43	$34.34	$34.99	$35.68	$44.26
County Expenses							
34. Base O&M Fee ($000s/yr)	$44,896	$46,243	$47,630	$49,059	$50,531	$52,046	$60,114
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$4.74	$4.89	$5.03	$5.18	$5.34	$5.50	$5.66
39. Pebble Lime Usage Cost ($000s)	$6,324	$6,513	$6,709	$6,910	$7,117	$7,331	$9,439
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.41	$0.42	$0.44	$0.45	$0.46	$0.48	$0.49
41. Ammonium Hydroxide Usage Cost ($000)	$548	$564	$581	$598	$616	$635	$817
42. Carbon Unit Price ($/ton)	$0.43	$0.44	$0.46	$0.47	$0.49	$0.50	$0.51
43. Carbon Usage Costs ($000s)	$575	$592	$610	$628	$647	$667	$858
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$1,014	$1,062	$1,113	$1,166	$1,222	$1,280	$1,342
46. Non Processible Waste WEBR Disposal including Haul Cos	$109.82	$113.12	$116.51	$120.00	$123.60	$127.31	$131.13
47. Non Processible Waste WEBR Disposal including Haul Cos	$5,043	$5,285	$5,537	$5,802	$6,079	$6,370	$6,674
48. Ash Disposal Fee ($/ton)	90.72	93.44	96.25	99.13	102.11	105.17	108.32
49. Ash Disposal Expenses ($000's)	$9,184	$9,460	$9,744	$10,036	$10,337	$10,647	$13,708
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$1.95	$2.01	$2.07	$2.13	$2.19	$2.26	$2.33
52. Utilities Pass Through ($000's)	$2,597	$2,675	$2,755	$2,838	$2,923	$3,011	$3,876
53. Haul Cost to WTE Facility ($/ton)	$22.08	$22.74	$23.42	$24.12	$24.85	$25.59	$26.36
54. Haul Cost to WTE Facility ($000's)	$27,953	$29,290	$30,690	$32,157	$33,130	$34,123	$36,993
55. Bypass Waste Disposal ($000's)	$454	$467	$481	$496	$511	$526	$542
56. **Subtotal Expenses ($000's)**	$92,530	$95,804	$99,199	$102,722	$105,811	$108,986	$126,347
Expenses per ton ($/ton)	$69.40	$71.85	$74.40	$77.04	$79.36	$81.74	$75.81
FACILITY EXPENSES LESS REVENUES ($000's)	$46,524	$49,819	$53,289	$56,942	$59,153	$61,415	$52,578
NET O&M COST PER TON OF WASTE	$34.89	$37.36	$39.97	$42.71	$44.36	$46.06	$31.55
Amortized Annual Initial Capital Cost ($000's)	$86,333	$86,333	$86,333	$86,333	$86,333	$86,333	$86,333
Amortized Initial Capital Cost Per Ton of Waste	$64.75	$64.75	$64.75	$64.75	$64.75	$64.75	$51.80
Amortized Annual Expansion Cost ($000's)	$0.00	$0.00	$0.00	$0.00	$13,356.47	$13,356.47	$13,356
Amortized Expansion Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$40.07	$40.07	$40.07
Total Amortized Capital Cost ($000's)	$86,333	$86,333	$86,333	$86,333	$99,689	$99,689	$99,689
Net Facility Cost ($000's)	$132,857	$136,152	$139,622	$143,274	$158,842	$161,104	$152,267
Net Facility Cost Per Ton of Waste ($/ton)	$99.64	$102.11	$104.72	$107.46	$119.13	$120.83	$91.36
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$4.37	$4.37	$4.37	$4.37	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$22.08	$22.74	$23.42	$24.12	$24.85	$25.59	$26.36
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$87.74	$90.38	$93.09	$95.88	$98.76	$101.72	$104.77
Disposal By Rail less Hauling to IMF ($/ton)	$92.12	$94.75	$97.46	$100.25	$98.76	$101.72	$104.77
Disposal By Rail ($/ton)	$114.19	$117.49	$120.88	$124.38	$123.60	$127.31	$131.13
Disposal Tonnage Required	1,266,204	1,288,094	1,310,362	1,333,015	1,356,060	1,379,503	1,403,351
Disposal By Rail ($000's)	$144,591	$151,334	$158,397	$165,794	$167,615	$175,628	$184,024
Difference between WTE and Rail Disposal (cost per ton)	($14.55)	($15.37)	($16.16)	($16.92)	($4.47)	($6.48)	($39.77)
Difference between WTE and Rail Disposal ($000's)	($11,733)	($15,182)	($18,775)	($22,520)	($8,773)	($14,524)	($31,757)

King County

King County Solid Waste Division
Waste to Energy Feasibility Study
Operations and Maintenance

ARCADIS

Waste to Energy Option - O&M Cost Estimate	2041	2042	2043	2044	2045	2046	2047
ECONOMIC EVALUATION	14	15	16	17	18	19	20
Waste Processing							
1. Processible Waste Delivered	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
2. Processible Waste Processed (tons)	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	51,189	51,481	51,774	52,069	52,366	52,664	52,965
5. Ash Generation (tons)	471,667	471,667	471,667	471,667	471,667	471,667	471,667
6. Ferrous Recovered (tons)	69,335	69,335	69,335	69,335	69,335	69,335	69,335
7. Non-Ferrous Recovered (tons)	6,934	6,934	6,934	6,934	6,934	6,934	6,934
8. Aggregate Recovered (tons)	268,850	268,850	268,850	268,850	268,850	268,850	268,850
9. Ash Disposal (tons)	126,548	126,548	126,548	126,548	126,548	126,548	126,548
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0425	$0.0431	$0.0438	$0.0444	$0.0451	$0.0458	$0.0464
18. Electrical Energy Revenues ($000s)	$42,474	$43,111	$43,758	$44,414	$45,081	$45,757	$46,443
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$42,474	$43,111	$43,758	$44,414	$45,081	$45,757	$46,443
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$176.22	$181.51	$186.96	$192.56	$198.34	$204.29	$210.42
24. Recovered Ferrous Revenues ($000's)	$12,218	$12,585	$12,963	$13,351	$13,752	$14,165	$14,590
25. Recovered Non-Ferrous Market Price ($/ton)	$1,028	$1,059	$1,091	$1,123	$1,157	$1,192	$1,227
25. Recovered Non-Ferrous Revenues ($000's)	$7,127	$7,341	$7,562	$7,788	$8,022	$8,263	$8,511
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$19,346	$19,926	$20,524	$21,140	$21,774	$22,427	$23,100
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	255,317	247,272	239,181	231,045	222,862	214,632	206,355
31. Non-County Waste Tip Fee ($/ton)	$51.40	$52.94	$54.53	$56.16	$57.85	$59.59	$61.37
32. Non-County Waste Revenues ($000's)	$13,123	$13,091	$13,042	$12,977	$12,892	$12,789	$12,665
33. **Subtotal County Revenues**	$74,943	$76,129	$77,325	$78,531	$79,747	$80,973	$82,208
Revenues per ton ($/ton)	$44.97	$45.68	$46.39	$47.12	$47.85	$48.58	$49.32
County Expenses							
34. Base O&M Fee ($000s/yr)	$61,917	$63,775	$65,688	$67,658	$69,688	$71,779	$73,932
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$5.83	$6.01	$6.19	$6.37	$6.57	$6.76	$6.96
39. Pebble Lime Usage Cost ($000s)	$9,722	$10,013	$10,314	$10,623	$10,942	$11,270	$11,608
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.51	$0.52	$0.54	$0.55	$0.57	$0.59	$0.60
41. Ammonium Hydroxide Usage Cost ($000)	$842	$867	$893	$920	$947	$976	$1,005
42. Carbon Unit Price ($/ton)	$0.53	$0.55	$0.56	$0.58	$0.60	$0.61	$0.63
43. Carbon Usage Costs ($000s)	$884	$910	$938	$966	$995	$1,025	$1,055
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$1,390	$1,440	$1,491	$1,545	$1,600	$1,658	$1,717
46. Non Processible Waste WEBR Disposal including Haul Cos	$135.07	$139.12	$143.29	$147.59	$152.02	$156.58	$161.28
47. Non Processible Waste WEBR Disposal including Haul Cos	$6,914	$7,162	$7,419	$7,685	$7,961	$8,246	$8,542
48. Ash Disposal Fee ($/ton)	111.57	114.92	118.37	121.92	125.58	129.35	133.23
49. Ash Disposal Expenses ($000's)	$14,120	$14,543	$14,979	$15,429	$15,892	$16,368	$16,860
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$2.40	$2.47	$2.54	$2.62	$2.70	$2.78	$2.86
52. Utilities Pass Through ($000's)	$3,992	$4,112	$4,236	$4,363	$4,493	$4,628	$4,767
53. Haul Cost to WTE Facility ($/ton)	$27.15	$27.97	$28.80	$29.67	$30.56	$31.48	$32.42
54. Haul Cost to WTE Facility ($000's)	$38,320	$39,694	$41,118	$42,593	$44,121	$45,704	$47,343
55. Bypass Waste Disposal ($000's)	$558	$575	$592	$610	$628	$647	$666
56. **Subtotal Expenses ($000's)**	$130,354	$134,490	$138,758	$143,162	$147,707	$152,397	$157,237
Expenses per ton ($/ton)	$78.21	$80.69	$83.25	$85.90	$88.62	$91.44	$94.34
FACILITY EXPENSES LESS REVENUES ($000's)	$55,411	$58,361	$61,433	$64,631	$67,959	$71,424	$75,029
NET O&M COST PER TON OF WASTE	$33.25	$35.02	$36.86	$38.78	$40.78	$42.85	$45.02
Amortized Annual Initial Capital Cost ($000's)	$86,333	$86,333	$86,333	$86,333	$86,333	$86,333	$86,333
Amortized Initial Capital Cost Per Ton of Waste	$51.80	$51.80	$51.80	$51.80	$51.80	$51.80	$51.80
Amortized Annual Expansion Cost ($000's)	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356
Amortized Expansion Cost Per Ton of Waste	$40.07	$40.07	$40.07	$40.07	$40.07	$40.07	$40.07
Total Amortized Capital Cost ($000's)	$99,689	$99,689	$99,689	$99,689	$99,689	$99,689	$99,689
Net Facility Cost ($000's)	$155,100	$158,051	$161,122	$164,320	$167,649	$171,113	$174,718
Net Facility Cost Per Ton of Waste ($/ton)	$93.06	$94.83	$96.67	$98.59	$100.59	$102.67	$104.83
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$27.15	$27.97	$28.80	$29.67	$30.56	$31.48	$32.42
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$107.91	$111.15	$114.49	$117.92	$121.46	$125.10	$128.86
Disposal By Rail less Hauling to IMF ($/ton)	$107.91	$111.15	$114.49	$117.92	$121.46	$125.10	$128.86
Disposal By Rail ($/ton)	$135.07	$139.12	$143.29	$147.59	$152.02	$156.58	$161.28
Disposal Tonnage Required	1,411,350	1,419,395	1,427,485	1,435,622	1,443,805	1,452,035	1,460,311
Disposal By Rail ($000's)	$190,626	$197,464	$204,547	$211,884	$219,485	$227,358	$235,513
Difference between WTE and Rail Disposal (cost per ton)	($42.01)	($44.29)	($46.62)	($49.00)	($51.43)	($53.91)	($56.44)
Difference between WTE and Rail Disposal ($000's)	($35,525)	($39,413)	($43,424)	($47,564)	($51,836)	($56,245)	($60,795)

Waste to Energy Option - O&M Cost Estimate	2048	2049	2050	2051	2052	2053	2054
ECONOMIC EVALUATION	21	22	23	24	25	26	27
Waste Processing							
1. Processible Waste Delivered	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
2. Processible Waste Processed (tons)	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	53,267	53,570	53,876	54,183	54,491	54,802	55,114
5. Ash Generation (tons)	471,667	471,667	471,667	471,667	471,667	471,667	471,667
6. Ferrous Recovered (tons)	69,335	69,335	69,335	69,335	69,335	69,335	69,335
7. Non-Ferrous Recovered (tons)	6,934	6,934	6,934	6,934	6,934	6,934	6,934
8. Aggregate Recovered (tons)	268,850	268,850	268,850	268,850	268,850	268,850	268,850
9. Ash Disposal (tons)	126,548	126,548	126,548	126,548	126,548	126,548	126,548
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0471	$0.0478	$0.0486	$0.0493	$0.0500	$0.0508	$0.0515
18. Electrical Energy Revenues ($000s)	$47,140	$47,847	$48,565	$49,293	$50,033	$50,783	$51,545
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$47,140	$47,847	$48,565	$49,293	$50,033	$50,783	$51,545
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$216.73	$223.24	$229.93	$236.83	$243.94	$251.25	$258.79
24. Recovered Ferrous Revenues ($000's)	$15,027	$15,478	$15,942	$16,421	$16,913	$17,421	$17,943
25. Recovered Non-Ferrous Market Price ($/ton)	$1,264	$1,302	$1,341	$1,382	$1,423	$1,466	$1,510
25. Recovered Non-Ferrous Revenues ($000's)	$8,766	$9,029	$9,300	$9,579	$9,866	$10,162	$10,467
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$23,793	$24,507	$25,242	$25,999	$26,779	$27,583	$28,410
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	198,032	189,660	181,241	172,775	164,259	155,696	147,083
31. Non-County Waste Tip Fee ($/ton)	$63.21	$65.11	$67.06	$69.08	$71.15	$73.28	$75.48
32. Non-County Waste Revenues ($000's)	$12,518	$12,349	$12,155	$11,934	$11,687	$11,410	$11,102
33. **Subtotal County Revenues**	$83,451	$84,703	$85,962	$87,227	$88,499	$89,776	$91,057
Revenues per ton ($/ton)	$50.07	$50.82	$51.58	$52.34	$53.10	$53.87	$54.63
County Expenses							
34. Base O&M Fee ($000s/yr)	$76,150	$78,435	$80,788	$83,211	$85,708	$88,279	$90,927
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$7.17	$7.39	$7.61	$7.84	$8.07	$8.32	$8.57
39. Pebble Lime Usage Cost ($000s)	$11,957	$12,315	$12,685	$13,065	$13,457	$13,861	$14,277
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.62	$0.64	$0.66	$0.68	$0.70	$0.72	$0.74
41. Ammonium Hydroxide Usage Cost ($000)	$1,035	$1,066	$1,098	$1,131	$1,165	$1,200	$1,236
42. Carbon Unit Price ($/ton)	$0.65	$0.67	$0.69	$0.71	$0.73	$0.76	$0.78
43. Carbon Usage Costs ($000s)	$1,087	$1,120	$1,153	$1,188	$1,224	$1,260	$1,298
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$1,779	$1,843	$1,909	$1,977	$2,048	$2,121	$2,198
46. Non Processible Waste WEBR Disposal including Haul Cos	$166.11	$171.10	$176.23	$181.52	$186.96	$192.57	$198.35
47. Non Processible Waste WEBR Disposal including Haul Cos	$8,848	$9,166	$9,495	$9,835	$10,188	$10,553	$10,932
48. Ash Disposal Fee ($/ton)	137.22	141.34	145.58	149.95	154.45	159.08	163.85
49. Ash Disposal Expenses ($000's)	$17,365	$17,886	$18,423	$18,976	$19,545	$20,131	$20,735
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$2.95	$3.03	$3.13	$3.22	$3.32	$3.42	$3.52
52. Utilities Pass Through ($000's)	$4,910	$5,057	$5,209	$5,365	$5,526	$5,692	$5,863
53. Haul Cost to WTE Facility ($/ton)	$33.39	$34.39	$35.43	$36.49	$37.58	$38.71	$39.87
54. Haul Cost to WTE Facility ($000's)	$49,041	$50,801	$52,623	$54,511	$56,466	$58,491	$60,589
55. Bypass Waste Disposal ($000's)	$686	$707	$728	$750	$772	$795	$819
56. **Subtotal Expenses ($000's)**	$162,232	$167,387	$172,707	$178,197	$183,863	$189,710	$195,745
Expenses per ton ($/ton)	$97.34	$100.43	$103.62	$106.92	$110.32	$113.83	$117.45
FACILITY EXPENSES LESS REVENUES ($000's)	$78,781	$82,684	$86,745	$90,970	$95,364	$99,935	$104,688
NET O&M COST PER TON OF WASTE	$47.27	$49.61	$52.05	$54.58	$57.22	$59.96	$62.81
Amortized Annual Initial Capital Cost ($000's)	$86,333	$86,333	$86,333	$86,333	$86,333	$86,333	$86,333
Amortized Initial Capital Cost Per Ton of Waste	$51.80	$51.80	$51.80	$51.80	$51.80	$51.80	$51.80
Amortized Annual Expansion Cost ($000's)	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356
Amortized Expansion Cost Per Ton of Waste	$40.07	$40.07	$40.07	$40.07	$40.07	$40.07	$40.07
Total Amortized Capital Cost ($000's)	$99,689	$99,689	$99,689	$99,689	$99,689	$99,689	$99,689
Net Facility Cost ($000's)	$178,470	$182,374	$186,435	$190,659	$195,054	$199,624	$204,377
Net Facility Cost Per Ton of Waste ($/ton)	$107.08	$109.42	$111.86	$114.40	$117.03	$119.77	$122.63
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$33.39	$34.39	$35.43	$36.49	$37.58	$38.71	$39.87
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$132.72	$136.70	$140.80	$145.03	$149.38	$153.86	$158.48
Disposal By Rail less Hauling to IMF ($/ton)	$132.72	$136.70	$140.80	$145.03	$149.38	$153.86	$158.48
Disposal By Rail ($/ton)	$166.11	$171.10	$176.23	$181.52	$186.96	$192.57	$198.35
Disposal Tonnage Required	1,468,635	1,477,006	1,485,425	1,493,892	1,502,407	1,510,971	1,519,584
Disposal By Rail ($000's)	$243,961	$252,712	$261,777	$271,168	$280,895	$290,971	$301,408
Difference between WTE and Rail Disposal (cost per ton)	($59.03)	($61.67)	($64.37)	($67.12)	($69.93)	($72.80)	($75.72)
Difference between WTE and Rail Disposal ($000's)	($65,491)	($70,339)	($75,343)	($80,508)	($85,841)	($91,347)	($97,031)

Waste to Energy Option - O&M Cost Estimate	2055	2056	2057	2058	2059	2060	2061
ECONOMIC EVALUATION	28	29	30	31	32	33	34
Waste Processing							
1. Processible Waste Delivered	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
2. Processible Waste Processed (tons)	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	55,429	55,745	56,062	56,382	56,703	57,026	57,351
5. Ash Generation (tons)	471,667	471,667	471,667	471,667	471,667	471,667	471,667
6. Ferrous Recovered (tons)	69,335	69,335	69,335	69,335	69,335	69,335	69,335
7. Non-Ferrous Recovered (tons)	6,934	6,934	6,934	6,934	6,934	6,934	6,934
8. Aggregate Recovered (tons)	268,850	268,850	268,850	268,850	268,850	268,850	268,850
9. Ash Disposal (tons)	126,548	126,548	126,548	126,548	126,548	126,548	126,548
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0523	$0.0531	$0.0539	$0.0547	$0.0555	$0.0564	$0.0572
18. Electrical Energy Revenues ($000s)	$52,318	$53,103	$53,899	$54,708	$55,528	$56,361	$57,207
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$52,318	$53,103	$53,899	$54,708	$55,528	$56,361	$57,207
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$266.55	$274.55	$282.79	$291.27	$300.01	$309.01	$318.28
24. Recovered Ferrous Revenues ($000's)	$18,482	$19,036	$19,607	$20,195	$20,801	$21,425	$22,068
25. Recovered Non-Ferrous Market Price ($/ton)	$1,555	$1,602	$1,650	$1,699	$1,750	$1,803	$1,857
25. Recovered Non-Ferrous Revenues ($000's)	$10,781	$11,104	$11,437	$11,781	$12,134	$12,498	$12,873
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$29,262	$30,140	$31,045	$31,976	$32,935	$33,923	$34,941
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	138,421	129,710	120,950	112,139	103,278	94,367	85,405
31. Non-County Waste Tip Fee ($/ton)	$77.75	$80.08	$82.48	$84.95	$87.50	$90.13	$92.83
32. Non-County Waste Revenues ($000's)	$10,762	$10,387	$9,976	$9,527	$9,037	$8,505	$7,928
33. **Subtotal County Revenues**	$92,342	$93,630	$94,920	$96,210	$97,501	$98,790	$100,076
Revenues per ton ($/ton)	$55.41	$56.18	$56.95	$57.73	$58.50	$59.27	$60.05
County Expenses							
34. Base O&M Fee ($000s/yr)	$93,655	$96,465	$99,359	$102,339	$105,410	$108,572	$111,829
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$8.82	$9.09	$9.36	$9.64	$9.93	$10.23	$10.54
39. Pebble Lime Usage Cost ($000s)	$14,705	$15,146	$15,601	$16,069	$16,551	$17,047	$17,559
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.76	$0.79	$0.81	$0.83	$0.86	$0.89	$0.91
41. Ammonium Hydroxide Usage Cost ($000)	$1,273	$1,311	$1,351	$1,391	$1,433	$1,476	$1,520
42. Carbon Unit Price ($/ton)	$0.80	$0.83	$0.85	$0.88	$0.90	$0.93	$0.96
43. Carbon Usage Costs ($000s)	$1,337	$1,377	$1,418	$1,461	$1,505	$1,550	$1,597
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$2,276	$2,358	$2,443	$2,530	$2,621	$2,715	$2,812
46. Non Processible Waste WEBR Disposal including Haul Cos	$204.30	$210.43	$216.74	$223.24	$229.94	$236.84	$243.94
47. Non Processible Waste WEBR Disposal including Haul Cos	$11,324	$11,730	$12,151	$12,587	$13,038	$13,506	$13,991
48. Ash Disposal Fee ($/ton)	168.77	173.83	179.04	184.42	189.95	195.65	201.52
49. Ash Disposal Expenses ($000's)	$21,357	$21,998	$22,658	$23,338	$24,038	$24,759	$25,502
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$3.62	$3.73	$3.84	$3.96	$4.08	$4.20	$4.33
52. Utilities Pass Through ($000's)	$6,039	$6,220	$6,407	$6,599	$6,797	$7,001	$7,211
53. Haul Cost to WTE Facility ($/ton)	$41.07	$42.30	$43.57	$44.88	$46.22	$47.61	$49.04
54. Haul Cost to WTE Facility ($000's)	$62,763	$65,014	$67,346	$69,762	$72,265	$74,857	$77,542
55. Bypass Waste Disposal ($000's)	$844	$869	$895	$922	$950	$978	$1,008
56. **Subtotal Expenses ($000's)**	$201,973	$208,401	$215,035	$221,881	$228,947	$236,240	$243,766
Expenses per ton ($/ton)	$121.18	$125.04	$129.02	$133.13	$137.37	$141.74	$146.26
FACILITY EXPENSES LESS REVENUES ($000's)	$109,631	$114,771	$120,115	$125,671	$131,446	$137,450	$143,690
NET O&M COST PER TON OF WASTE	$65.78	$68.86	$72.07	$75.40	$78.87	$82.47	$86.21
Amortized Annual Initial Capital Cost ($000's)	$86,333	$86,333	$86,333	$0	$0	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$51.80	$51.80	$51.80	$0.00	$0.00	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356
Amortized Expansion Cost Per Ton of Waste	$40.07	$40.07	$40.07	$40.07	$40.07	$40.07	$40.07
Total Amortized Capital Cost ($000's)	$99,689	$99,689	$99,689	$13,356	$13,356	$13,356	$13,356
Net Facility Cost ($000's)	$209,320	$214,460	$219,804	$139,027	$144,803	$150,806	$157,047
Net Facility Cost Per Ton of Waste ($/ton)	$125.59	$128.68	$131.88	$83.42	$86.88	$90.48	$94.23
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$41.07	$42.30	$43.57	$44.88	$46.22	$47.61	$49.04
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$163.23	$168.13	$173.17	$178.37	$183.72	$189.23	$194.91
Disposal By Rail less Hauling to IMF ($/ton)	$163.23	$168.13	$173.17	$178.37	$183.72	$189.23	$194.91
Disposal By Rail ($/ton)	$204.30	$210.43	$216.74	$223.24	$229.94	$236.84	$243.94
Disposal Tonnage Required	1,528,245	1,536,956	1,545,717	1,554,527	1,563,388	1,572,300	1,581,262
Disposal By Rail ($000's)	$312,220	$323,420	$335,021	$347,039	$359,487	$372,382	$385,740
Difference between WTE and Rail Disposal (cost per ton)	($78.71)	($81.75)	($84.86)	($139.83)	($143.06)	($146.36)	($149.72)
Difference between WTE and Rail Disposal ($000's)	($102,900)	($108,959)	($115,217)	($208,012)	($214,684)	($221,576)	($228,693)

King County

King County Solid Waste Division
Waste to Energy Feasibility Study
Operations and Maintenance

ARCADIS

Waste to Energy Option - O&M Cost Estimate	2062	2063	2064	2065	2066	2067	2068
ECONOMIC EVALUATION	35	36	37	38	39	40	41
Waste Processing							
1. Processible Waste Delivered	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
2. Processible Waste Processed (tons)	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	57,678	58,007	58,338	58,670	59,005	59,341	59,679
5. Ash Generation (tons)	471,667	471,667	471,667	471,667	471,667	471,667	471,667
6. Ferrous Recovered (tons)	69,335	69,335	69,335	69,335	69,335	69,335	69,335
7. Non-Ferrous Recovered (tons)	6,934	6,934	6,934	6,934	6,934	6,934	6,934
8. Aggregate Recovered (tons)	268,850	268,850	268,850	268,850	268,850	268,850	268,850
9. Ash Disposal (tons)	126,548	126,548	126,548	126,548	126,548	126,548	126,548
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0581	$0.0589	$0.0598	$0.0607	$0.0616	$0.0626	$0.0635
18. Electrical Energy Revenues ($000s)	$58,065	$58,936	$59,820	$60,717	$61,628	$62,552	$63,491
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$58,065	$58,936	$59,820	$60,717	$61,628	$62,552	$63,491
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$327.83	$337.66	$347.79	$358.23	$368.97	$380.04	$391.44
24. Recovered Ferrous Revenues ($000's)	$22,730	$23,412	$24,114	$24,838	$25,583	$26,350	$27,141
25. Recovered Non-Ferrous Market Price ($/ton)	$1,912	$1,970	$2,029	$2,090	$2,152	$2,217	$2,283
25. Recovered Non-Ferrous Revenues ($000's)	$13,259	$13,657	$14,067	$14,489	$14,923	$15,371	$15,832
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$35,989	$37,069	$38,181	$39,326	$40,506	$41,721	$42,973
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	76,392	67,327	58,211	49,043	39,822	30,549	21,223
31. Non-County Waste Tip Fee ($/ton)	$95.62	$98.49	$101.44	$104.48	$107.62	$110.85	$114.17
32. Non-County Waste Revenues ($000's)	$7,304	$6,631	$5,905	$5,124	$4,286	$3,386	$2,423
33. **Subtotal County Revenues**	$101,358	$102,635	$103,906	$105,168	$106,420	$107,660	$108,887
Revenues per ton ($/ton)	$60.82	$61.58	$62.34	$63.10	$63.85	$64.60	$65.33
County Expenses							
34. Base O&M Fee ($000s/yr)	$115,184	$118,639	$122,199	$125,865	$129,641	$133,530	$137,536
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$10.85	$11.18	$11.51	$11.86	$12.21	$12.58	$12.96
39. Pebble Lime Usage Cost ($000s)	$18,085	$18,628	$19,187	$19,762	$20,355	$20,966	$21,595
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$0.94	$0.97	$1.00	$1.03	$1.06	$1.09	$1.12
41. Ammonium Hydroxide Usage Cost ($000)	$1,566	$1,613	$1,661	$1,711	$1,762	$1,815	$1,870
42. Carbon Unit Price ($/ton)	$0.99	$1.02	$1.05	$1.08	$1.11	$1.14	$1.18
43. Carbon Usage Costs ($000s)	$1,644	$1,694	$1,745	$1,797	$1,851	$1,906	$1,964
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$2,913	$3,018	$3,126	$3,238	$3,354	$3,475	$3,599
46. Non Processible Waste WEBR Disposal including Haul Cos	$251.26	$258.80	$266.56	$274.56	$282.80	$291.28	$300.02
47. Non Processible Waste WEBR Disposal including Haul Cos	$14,492	$15,012	$15,551	$16,109	$16,686	$17,285	$17,905
48. Ash Disposal Fee ($/ton)	207.56	213.79	220.20	226.81	233.61	240.62	247.84
49. Ash Disposal Expenses ($000's)	$26,267	$27,055	$27,866	$28,702	$29,563	$30,450	$31,364
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$4.46	$4.59	$4.73	$4.87	$5.02	$5.17	$5.32
52. Utilities Pass Through ($000's)	$7,427	$7,650	$7,879	$8,116	$8,359	$8,610	$8,868
53. Haul Cost to WTE Facility ($/ton)	$50.51	$52.02	$53.59	$55.19	$56.85	$58.55	$60.31
54. Haul Cost to WTE Facility ($000's)	$80,324	$83,205	$86,189	$89,281	$92,484	$95,801	$99,238
55. Bypass Waste Disposal ($000's)	$1,038	$1,069	$1,101	$1,134	$1,168	$1,203	$1,239
56. **Subtotal Expenses ($000's)**	$251,535	$259,552	$267,827	$276,368	$285,183	$294,282	$303,673
Expenses per ton ($/ton)	$150.92	$155.73	$160.70	$165.82	$171.11	$176.57	$182.20
FACILITY EXPENSES LESS REVENUES ($000's)	$150,176	$156,917	$163,921	$171,200	$178,764	$186,622	$194,786
NET O&M COST PER TON OF WASTE	$90.11	$94.15	$98.35	$102.72	$107.26	$111.97	$116.87
Amortized Annual Initial Capital Cost ($000's)	$0	$0	$0	$0	$0	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356	$0
Amortized Expansion Cost Per Ton of Waste	$40.07	$40.07	$40.07	$40.07	$40.07	$40.07	$0.00
Total Amortized Capital Cost ($000's)	$13,356	$13,356	$13,356	$13,356	$13,356	$13,356	$0
Net Facility Cost ($000's)	$163,533	$170,273	$177,278	$184,557	$192,120	$199,978	$194,786
Net Facility Cost Per Ton of Waste ($/ton)	$98.12	$102.16	$106.37	$110.73	$115.27	$119.99	$116.87
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$50.51	$52.02	$53.59	$55.19	$56.85	$58.55	$60.31
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$200.75	$206.78	$212.98	$219.37	$225.95	$232.73	$239.71
Disposal By Rail less Hauling to IMF ($/ton)	$200.75	$206.78	$212.98	$219.37	$225.95	$232.73	$239.71
Disposal By Rail ($/ton)	$251.26	$258.80	$266.56	$274.56	$282.80	$291.28	$300.02
Disposal Tonnage Required	1,590,275	1,599,339	1,608,456	1,617,624	1,626,844	1,636,117	1,645,443
Disposal By Rail ($000's)	$399,577	$413,910	$428,757	$444,137	$460,069	$476,572	$493,667
Difference between WTE and Rail Disposal (cost per ton)	($153.14)	($156.64)	($160.20)	($163.83)	($167.53)	($171.30)	($183.15)
Difference between WTE and Rail Disposal ($000's)	($236,044)	($243,637)	($251,480)	($259,581)	($267,949)	($276,594)	($298,881)

Waste to Energy Option - O&M Cost Estimate	2069	2070	2071	2072	2073	2074	2075
ECONOMIC EVALUATION	42	43	44	45	46	47	48
Waste Processing							
1. Processible Waste Delivered	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
2. Processible Waste Processed (tons)	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667	1,666,667
3. Bypass Waste (tons)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Nonprocessible Waste (tons)	60,019	60,362	60,706	61,052	61,400	61,750	62,102
5. Ash Generation (tons)	471,667	471,667	471,667	471,667	471,667	471,667	471,667
6. Ferrous Recovered (tons)	69,335	69,335	69,335	69,335	69,335	69,335	69,335
7. Non-Ferrous Recovered (tons)	6,934	6,934	6,934	6,934	6,934	6,934	6,934
8. Aggregate Recovered (tons)	268,850	268,850	268,850	268,850	268,850	268,850	268,850
9. Ash Disposal (tons)	126,548	126,548	126,548	126,548	126,548	126,548	126,548
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%	7.59%
Energy Revenues							
11. Gross Electrical Rate (kWh/ton)	675	675	675	675	675	675	675
12. Net Electrical Rate (kWh/ton)	600	600	600	600	600	600	600
13. Net Electrical Generation (mwh/yr)	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
14. Capacity Factor Achieved	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0	$0	$0	$0	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0644	$0.0654	$0.0664	$0.0674	$0.0684	$0.0694	$0.0705
18. Electrical Energy Revenues ($000s)	$64,443	$65,410	$66,391	$67,387	$68,397	$69,423	$70,465
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0	$0	$0	$0	$0	$0
21. Total Energy Revenues ($000s)	$64,443	$65,410	$66,391	$67,387	$68,397	$69,423	$70,465
22. Operator Energy Revenue Share ($000s)	$0	$0	$0	$0	$0	$0	$0
Other Material Revenues							
23. Recovered Ferrous Market Price ($/ton)	$403.19	$415.28	$427.74	$440.57	$453.79	$467.41	$481.43
24. Recovered Ferrous Revenues ($000's)	$27,955	$28,794	$29,657	$30,547	$31,464	$32,408	$33,380
25. Recovered Non-Ferrous Market Price ($/ton)	$2,352	$2,422	$2,495	$2,570	$2,647	$2,727	$2,808
25. Recovered Non-Ferrous Revenues ($000's)	$16,307	$16,796	$17,300	$17,819	$18,354	$18,904	$19,472
26. Recovered Aggregate Market Price ($/ton)	$0	$0	$0	$0	$0	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0	$0	$0	$0	$0	$0
28. Total Other Material Revenues ($000's)	$44,262	$45,590	$46,958	$48,366	$49,817	$51,312	$52,851
29. Operator Material Revenue Share ($000s)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Other Revenues							
30. Non-County Waste Accepted (tons)	11,844	2,412	0	0	0	0	0
31. Non-County Waste Tip Fee ($/ton)	$117.60	$121.12	$124.76	$128.50	$132.36	$136.33	$140.42
32. Non-County Waste Revenues ($000's)	$1,393	$292	$0	$0	$0	$0	$0
33. **Subtotal County Revenues**	$110,098	$111,292	$113,348	$115,753	$118,215	$120,735	$123,316
Revenues per ton ($/ton)	$66.06	$66.78	$68.01	$69.45	$70.93	$72.44	$73.99
County Expenses							
34. Base O&M Fee ($000s/yr)	$141,662	$145,912	$150,289	$154,798	$159,441	$164,225	$169,151
35. Excess O&M Fee ($/ton)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37. Consumable Costs							
38. Pebble Lime Unit Cost ($/ton waste)	$13.35	$13.75	$14.16	$14.58	$15.02	$15.47	$15.94
39. Pebble Lime Usage Cost ($000s)	$22,243	$22,910	$23,597	$24,305	$25,034	$25,785	$26,559
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$1.16	$1.19	$1.23	$1.26	$1.30	$1.34	$1.38
41. Ammonium Hydroxide Usage Cost ($000)	$1,926	$1,984	$2,043	$2,104	$2,167	$2,233	$2,299
42. Carbon Unit Price ($/ton)	$1.21	$1.25	$1.29	$1.33	$1.37	$1.41	$1.45
43. Carbon Usage Costs ($000s)	$2,022	$2,083	$2,146	$2,210	$2,276	$2,345	$2,415
44. Nonprocessible Waste							
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$3,728	$3,862	$4,001	$4,144	$4,293	$4,447	$4,606
46. Non Processible Waste WEBR Disposal including Haul Cos	$309.02	$318.29	$327.84	$337.68	$347.81	$358.24	$368.99
47. Non Processible Waste WEBR Disposal including Haul Cos	$18,547	$19,213	$19,902	$20,616	$21,355	$22,121	$22,915
48. Ash Disposal Fee ($/ton)	255.27	262.93	270.82	278.95	287.31	295.93	304.81
49. Ash Disposal Expenses ($000's)	$32,305	$33,274	$34,272	$35,300	$36,359	$37,450	$38,573
50. Other Expenses ($000's)							
51. Utilities Pass Through ($/ton)	$5.48	$5.65	$5.81	$5.99	$6.17	$6.35	$6.54
52. Utilities Pass Through ($000's)	$9,134	$9,408	$9,691	$9,981	$10,281	$10,589	$10,907
53. Haul Cost to WTE Facility ($/ton)	$62.12	$63.98	$65.90	$67.88	$69.92	$72.01	$74.17
54. Haul Cost to WTE Facility ($000's)	$102,797	$106,485	$109,838	$113,134	$116,528	$120,023	$123,624
55. Bypass Waste Disposal ($000's)	$1,276	$1,315	$1,354	$1,395	$1,437	$1,480	$1,524
56. **Subtotal Expenses ($000's)**	$313,365	$323,370	$333,230	$343,227	$353,524	$364,129	$375,053
Expenses per ton ($/ton)	$188.02	$194.02	$199.94	$205.94	$212.11	$218.48	$225.03
FACILITY EXPENSES LESS REVENUES ($000's)	$203,267	$212,078	$219,881	$227,474	$235,309	$243,394	$251,737
NET O&M COST PER TON OF WASTE	$121.96	$127.25	$131.93	$136.48	$141.19	$146.04	$151.04
Amortized Annual Initial Capital Cost ($000's)	$0	$0	$0	$0	$0	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$0	$0	$0	$0	$0	$0	$0
Amortized Expansion Cost Per Ton of Waste	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Amortized Capital Cost ($000's)	$0	$0	$0	$0	$0	$0	$0
Net Facility Cost ($000's)	$203,267	$212,078	$219,881	$227,474	$235,309	$243,394	$251,737
Net Facility Cost Per Ton of Waste ($/ton)	$121.96	$127.25	$131.93	$136.48	$141.19	$146.04	$151.04
WEBR Year							
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$62.12	$63.98	$65.90	$67.88	$69.92	$72.01	$74.17
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$246.90	$254.31	$261.94	$269.80	$277.89	$286.23	$294.81
Disposal By Rail less Hauling to IMF ($/ton)	$246.90	$254.31	$261.94	$269.80	$277.89	$286.23	$294.81
Disposal By Rail ($/ton)	$309.02	$318.29	$327.84	$337.68	$347.81	$358.24	$368.99
Disposal Tonnage Required	1,654,822	1,664,255	1,673,741	1,683,281	1,692,876	1,702,525	1,712,230
Disposal By Rail ($000's)	$511,376	$529,719	$548,721	$568,404	$588,793	$609,914	$631,792
Difference between WTE and Rail Disposal (cost per ton)	($187.06)	($191.05)	($195.91)	($201.19)	($206.62)	($212.20)	($217.95)
Difference between WTE and Rail Disposal ($000's)	($308,108)	($317,641)	($328,839)	($340,930)	($353,484)	($366,520)	($380,055)

Waste to Energy Option - O&M Cost Estimate	2076	2077
ECONOMIC EVALUATION	49	50
Waste Processing		
1. Processible Waste Delivered	1,666,667	1,666,667
2. Processible Waste Processed (tons)	1,666,667	1,666,667
3. Bypass Waste (tons)	5,000	5,000
4. Nonprocessible Waste (tons)	62,102	62,102
5. Ash Generation (tons)	471,667	471,667
6. Ferrous Recovered (tons)	69,335	69,335
7. Non-Ferrous Recovered (tons)	6,934	6,934
8. Aggregate Recovered (tons)	268,850	268,850
9. Ash Disposal (tons)	126,548	126,548
10. Ash Disposal as a percentage of Waste Processed	7.59%	7.59%
Energy Revenues		
11. Gross Electrical Rate (kWh/ton)	675	675
12. Net Electrical Rate (kWh/ton)	600	600
13. Net Electrical Generation (mwh/yr)	1,000,000	1,000,000
14. Capacity Factor Achieved	N/A	N/A
15. Electrical Capacity Fee ($/MW/mo.)	$0	$0
16. Electrical Capacity Revenues ($000's)	$0	$0
17. Average Electrical Energy ($/kWh)	$0.0715	$0.0726
18. Electrical Energy Revenues ($000s)	$71,522	$72,595
19. Green Energy Credits ($/kWh)	$0.0000	$0.0000
20. Green Energy Revenues ($000s)	$0	$0
21. Total Energy Revenues ($000s)	$71,522	$72,595
22. Operator Energy Revenue Share ($000s)	$0	$0
Other Material Revenues		
23. Recovered Ferrous Market Price ($/ton)	$495.87	$510.75
24. Recovered Ferrous Revenues ($000's)	$34,381	$35,413
25. Recovered Non-Ferrous Market Price ($/ton)	$2,893	$2,979
25. Recovered Non-Ferrous Revenues ($000's)	$20,056	$20,657
26. Recovered Aggregate Market Price ($/ton)	$0	$0
27. Recovered Aggregate Revenues ($000's)	$0	$0
28. Total Other Material Revenues ($000's)	$54,437	$56,070
29. Operator Material Revenue Share ($000s)	N/A	N/A
Other Revenues		
30. Non-County Waste Accepted (tons)	0	0
31. Non-County Waste Tip Fee ($/ton)	$144.63	$148.97
32. Non-County Waste Revenues ($000's)	$0	$0
33. **Subtotal County Revenues**	$125,959	$128,665
Revenues per ton ($/ton)	$75.58	$77.20
County Expenses		
34. Base O&M Fee ($000s/yr)	$174,226	$179,453
35. Excess O&M Fee ($/ton)	N/A	N/A
36. Excess O&M Cost ($000's)	N/A	N/A
37. Consumable Costs		
38. Pebble Lime Unit Cost ($/ton waste)	$16.41	$16.91
39. Pebble Lime Usage Cost ($000s)	$27,356	$28,176
40. Ammonium Hydroxide Unit Cost ($/ton waste)	$1.42	$1.46
41. Ammonium Hydroxide Usage Cost ($000)	$2,368	$2,440
42. Carbon Unit Price ($/ton)	$1.49	$1.54
43. Carbon Usage Costs ($000s)	$2,487	$2,562
44. Nonprocessible Waste		
45. Nonprocessible Waste Haul Cost to WTE ($000's)	$4,745	$4,887
46. Non Processible Waste WEBR Disposal including Haul Cos	$380.06	$391.46
47. Non Processible Waste WEBR Disposal including Haul Cos	$23,602	$24,310
48. Ash Disposal Fee ($/ton)	313.96	323.37
49. Ash Disposal Expenses ($000's)	$39,731	$40,922
50. Other Expenses ($000's)		
51. Utilities Pass Through ($/ton)	$6.74	$6.94
52. Utilities Pass Through ($000's)	$11,234	$11,571
53. Haul Cost to WTE Facility ($/ton)	$76.40	$78.69
54. Haul Cost to WTE Facility ($000's)	$127,333	$131,153
55. Bypass Waste Disposal ($000's)	$1,570	$1,617
56. **Subtotal Expenses ($000's)**	$386,305	$397,894
Expenses per ton ($/ton)	$231.78	$238.74
FACILITY EXPENSES LESS REVENUES ($000's)	$260,346	$269,229
NET O&M COST PER TON OF WASTE	$156.21	$161.54
Amortized Annual Initial Capital Cost ($000's)	$0	$0
Amortized Initial Capital Cost Per Ton of Waste	$0.00	$0.00
Amortized Annual Expansion Cost ($000's)	$0	$0
Amortized Expansion Cost Per Ton of Waste	$0.00	$0.00
Total Amortized Capital Cost ($000's)	$0	$0
Net Facility Cost ($000's)	$260,346	$269,229
Net Facility Cost Per Ton of Waste ($/ton)	$156.21	$161.54
WEBR Year		
Disposal by Rail Capital Cost IMF ($/ton)	$0.00	$0.00
Disposal by Rail Haul to IMF Cost ($/ton)	$76.40	$78.69
Disposal By Rail less Capital and Hauling to IMF ($/ton)	$303.66	$312.77
Disposal By Rail less Hauling to IMF ($/ton)	$303.66	$312.77
Disposal By Rail ($/ton)	$380.06	$391.46
Disposal Tonnage Required	1,712,230	1,712,230
Disposal By Rail ($000's)	$650,746	$670,268
Difference between WTE and Rail Disposal (cost per ton)	($223.85)	($229.92)
Difference between WTE and Rail Disposal ($000's)	($390,400)	($401,039)

Initial Facility Capacity Options Modeled	3,000	TPD
	4,000	TPD
Expansion Capacity Modeled	1,000	TPD

EPC Construction Cost	
PBREF 2 B&W Bid Price	$667,981,128
Year of Bid Price	2010
PBREF 2 EPC Price (including COs)	$672,284,230
Year of Final EPC Price (COD)	2015
Average Annual Escalation	3.00%
Year PBREF 2 Construction Price Escalated To	2019
PBREF 2 Final EPC Escalated Price	$756,661,824
Assumed Labor Cost as Percentage of Construction Price	15%
Seattle Labor Cost Increase Compared to Miami (BLS)	50%
Additional Labor Cost for Project Location	$56,749,636.78
Assumed Equipment and Materials Cost as Percentage of Construction Price	50%
Sales Tax WPB in 2015	6%
Sales Tax King County	10.0%
Additional Cost for HIgher Sales Tax Rate	$15,133,236
PBREF 2 Final EPC Escalated Price Including Location Adjustment	$828,544,697
PBREF 2 Facility Capacity (TPD)	3000
PBREF 2 Facility Capacity (TPY)	1000000
PBREF 2 Final EPC Escalated Price per TPD	$276,181.57
Aesthetic Treatment Allowance (2010)	$12,000,000
Spare Parts Allowance (2010)	$10,000,000
Percentage of EPC Price Increase for Tonnage above 3000 tpd	75%
Percentage of EPC Price for 1000 TPD Expansion	40%
Additional Items Not Included in PBREF 2	
AMR Unit Cost ($/tpd ash processed)	$11,400
Carbon Sequestration of Flue Gas (GHG Regulations) ($/tpd)	$20,000
Land Acquisition Cost per Acre ($/Acre)	$900,000
Acres Needed for 3000 TPD Facility Site (Acres)	30
Acres Needed for 4000 TPD Facility Site (Acres)	43
Acres Needed for 5000 TPD Facility Site (Acres)	55
Estimated Land Acquisition Cost ($/TPD) for 3000 TPD (end 4000 TPD)	$12,750
Estimated Land Acquisition Cost ($/TPD) for 4000 TPD (end 5000 TPD)	$12,375
Estimated Land Acquisiton Cost ($/TPD) Average	$12,563

O&M Costs

PBREF 2 Base O&M Fee (2015)		$20,490,000
PBREF 2 Base O&M Fee (2019)		$23,061,676
Assumed Base O&M Fee for 3000 tpd Facility (2019)		$25,000,000
Assumed Base O&M Fee per TPD (2019)		$8,333.33
Percentage of Base O&M Fee Increase for Tonnage above 3000 tpd		50%
Percentage of Base O&M Fee for renegotiation of O&M term		100%
Natural Gas Usage at PBREF 2 (ccf/year)		703,000
Natural Gas Price ($/mcf)	$	6.61
Annual Natural Gas Cost ($/ton)		$0.465
Potable Water Usage (gallons/year)		92,500,000
Potable Water Price ($/ccf)	$	2.36
Annual Potable Water Cost ($/ton)		$0.292
Wastewater Disposal (gallons/year)		25,500,000
Wastewater Disposal Price ($/ccf)	$	14.48
Annual Wastewater Disposal Cost ($/ton)		$0.494
Total Utilties Pass Through Cost ($/ton)		$1.25
WEBR Cost Per Ton (includes capital, excludes haul to IMF)		$59.67
Haul Cost to IMF ($/ton)		$14.17
Intermodal Facility Land + Capital Cost ($/ton)		$3.35
WEBR Cost Per Ton (excludes capital and haul to IMF)		$56.32
Intermodal Facility Land + Capital Cost Payment Term (years)		10
Ash Disposal WEBR - Includes hauling to existing IMF ($/ton)		$58.23
Ash Disposal at Landfill ($/ton)		$17.00

Revenues

Electrical Energy Revenue - Average 2019 WA ($/kWh)	$	0.0353
Electrical Energy Revenue - HIgh 2019 WA ($/kWh)	$	0.0387
Electrical Energy Revenue - Low 2019 WA ($/kWh)	$	0.0317

PBREF 2 System:

Mass Burn
Ferrous and Non Ferrous Recovery from Ash
ACC
SCR
Carbon Injection

PBREF 2 EPC Contract

Design-Build-Operate

PBREF 2 O&M Contact

Base O&M Fee up to Throughput Guarantee
Excess O&M Fee for waste over Throughput Guarantee
Electrical revenue shared for electrical generation above Electrical Generation Guarantee
60% Operator Energy Rev Share Above Net kWh/T
Operator does not receive a share of metals revenues

King County

ARCADIS

King County Solid Waste Division
Waste to Energy Feasibility Study
Basis of Costs

Nonprocessible Waste %		3.50%								
Facility Capacity Modeled		Facility Capacity Modeled		1,333,333				-	only works for initial 3000 TPD	only works for initial 4000 tpd
	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Expansion Low Bound	Expansion High Bound
Year	**Low Bound**	**Low Bound**	**Low Bound**	**Low Bound**	**High Bound**	**High Bound**	**High Bound**	**High Bound**	**Low Bound**	**High Bound**
2018	888,513	31,098	857,415	475,918	888,513	31,098	857,415	475,918	0	0
2019	888,988	31,115	857,874	475,459	895,673	31,349	864,324	469,009	0	0
2020	898,180	31,436	866,744	466,590	936,563	32,780	903,783	429,550	0	0
2021	904,153	31,645	872,508	460,825	958,103	33,534	924,569	408,764	0	0
2022	910,126	31,854	878,272	455,061	994,511	34,808	959,703	373,630	0	0
2023	916,100	32,063	884,036	449,297	1,012,412	35,434	976,978	356,356	0	0
2024	922,073	32,273	889,800	443,533	1,049,871	36,745	1,013,126	320,207	0	0
2025	928,046	32,482	895,565	437,769	1,079,268	37,774	1,041,493	291,840	0	0
2026	933,450	32,671	900,779	432,554	1,117,042	39,096	1,077,946	255,388	0	0
2027	938,853	32,860	905,993	427,340	1,144,968	40,074	1,104,894	228,439	0	0
2028	944,256	33,049	911,207	422,126	1,183,897	41,436	1,142,461	190,873	0	0
2029	949,660	33,238	916,422	416,912	1,204,364	42,153	1,162,211	171,122	0	0
2030	955,063	33,427	921,636	411,697	1,225,184	42,881	1,182,303	151,030	0	0
2031	960,075	33,603	926,472	406,861	1,246,365	43,623	1,202,742	130,591	0	0
2032	965,087	33,778	931,309	402,025	1,267,912	44,377	1,223,535	109,799	0	0
2033	970,099	33,953	936,145	397,188	1,289,831	45,144	1,244,687	88,647	0	0
2034	975,110	34,129	940,982	392,352	1,312,129	45,925	1,266,204	67,129	0	0
2035	980,122	34,304	945,818	387,515	1,334,812	46,718	1,288,094	45,239	0	0
2036	985,373	34,488	950,885	382,448	1,357,888	47,526	1,310,362	22,971	0	0
2037	990,625	34,672	955,953	377,380	1,381,363	48,348	1,333,015	318	0	0
2038	995,876	34,856	961,020	372,313	1,405,243	49,184	1,356,060	0	0	0
2039	1,001,127	35,039	966,088	367,245	1,429,536	50,034	1,379,503	0	0	0
2040	1,006,379	35,223	971,155	362,178	1,454,250	50,899	1,403,351	0	695,511	263,316
2041	1,012,086	35,423	976,663	356,671	1,462,539	51,189	1,411,350	0	690,004	255,317
2042	1,017,825	35,624	982,201	351,132	1,470,875	51,481	1,419,395	0	684,466	247,272
2043	1,023,597	35,826	987,771	345,562	1,479,259	51,774	1,427,485	0	678,896	239,181
2044	1,029,402	36,029	993,373	339,961	1,487,691	52,069	1,435,622	0	673,294	231,045
2045	1,035,239	36,233	999,006	334,327	1,496,171	52,366	1,443,805	0	667,661	222,862
2046	1,041,110	36,439	1,004,671	328,662	1,504,699	52,664	1,452,035	0	661,996	214,632
2047	1,047,014	36,645	1,010,368	322,965	1,513,276	52,965	1,460,311	0	656,298	206,355
2048	1,052,951	36,853	1,016,098	317,235	1,521,902	53,267	1,468,635	0	650,569	198,032
2049	1,058,923	37,062	1,021,860	311,473	1,530,576	53,570	1,477,006	0	644,806	189,660
2050	1,064,928	37,272	1,027,655	305,678	1,539,301	53,876	1,485,425	0	639,012	181,241
2051	1,070,967	37,484	1,033,483	299,850	1,548,075	54,183	1,493,892	0	633,184	172,775

	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Expansion Low Bound	Expansion High Bound
2052	1,077,040	37,696	1,039,344	293,990	1,556,899	54,491	1,502,407	0	627,323	164,259
2053	1,083,148	37,910	1,045,238	288,096	1,565,773	54,802	1,510,971	0	621,429	155,696
2054	1,089,290	38,125	1,051,165	282,168	1,574,698	55,114	1,519,584	0	615,502	147,083
2055	1,095,467	38,341	1,057,126	276,207	1,583,674	55,429	1,528,245	0	609,541	138,421
2056	1,101,680	38,559	1,063,121	270,213	1,592,701	55,745	1,536,956	0	603,546	129,710
2057	1,107,927	38,777	1,069,150	264,184	1,601,779	56,062	1,545,717	0	597,517	120,950
2058	1,114,210	38,997	1,075,213	258,121	1,610,909	56,382	1,554,527	0	591,454	112,139
2059	1,120,529	39,218	1,081,310	252,023	1,620,091	56,703	1,563,388	0	585,357	103,278
2060	1,126,883	39,441	1,087,442	245,891	1,629,326	57,026	1,572,300	0	579,225	94,367
2061	1,133,273	39,665	1,093,609	239,725	1,638,613	57,351	1,581,262	0	573,058	85,405
2062	1,139,700	39,889	1,099,810	233,523	1,647,953	57,678	1,590,275	0	566,856	76,392
2063	1,146,163	40,116	1,106,047	227,286	1,657,347	58,007	1,599,339	0	560,619	67,327
2064	1,152,663	40,343	1,112,320	221,014	1,666,793	58,338	1,608,456	0	554,347	58,211
2065	1,159,199	40,572	1,118,627	214,706	1,676,294	58,670	1,617,624	0	548,039	49,043
2066	1,165,773	40,802	1,124,971	208,362	1,685,849	59,005	1,626,844	0	541,696	39,822
2067	1,172,384	41,033	1,131,351	201,983	1,695,458	59,341	1,636,117	0	535,316	30,549
2068	1,179,032	41,266	1,137,766	195,567	1,705,123	59,679	1,645,443	0	528,900	21,223
2069	1,185,719	41,500	1,144,218	189,115	1,714,842	60,019	1,654,822	0	522,448	11,844
2070	1,192,443	41,735	1,150,707	182,626	1,724,616	60,362	1,664,255	0	515,960	2,412
2071	1,199,205	41,972	1,157,233	176,101	1,734,447	60,706	1,673,741	0	509,434	-7,074
2072	1,206,005	42,210	1,163,795	169,538	1,744,333	61,052	1,683,281	0	502,872	-16,615
2073	1,212,844	42,450	1,170,395	162,938	1,754,276	61,400	1,692,876	0	496,272	-26,209
2074	1,219,722	42,690	1,177,032	156,301	1,764,275	61,750	1,702,525	0	489,635	-35,859
2075	1,226,639	42,932	1,183,707	149,627	1,774,331	62,102	1,712,230	0	482,960	-45,563

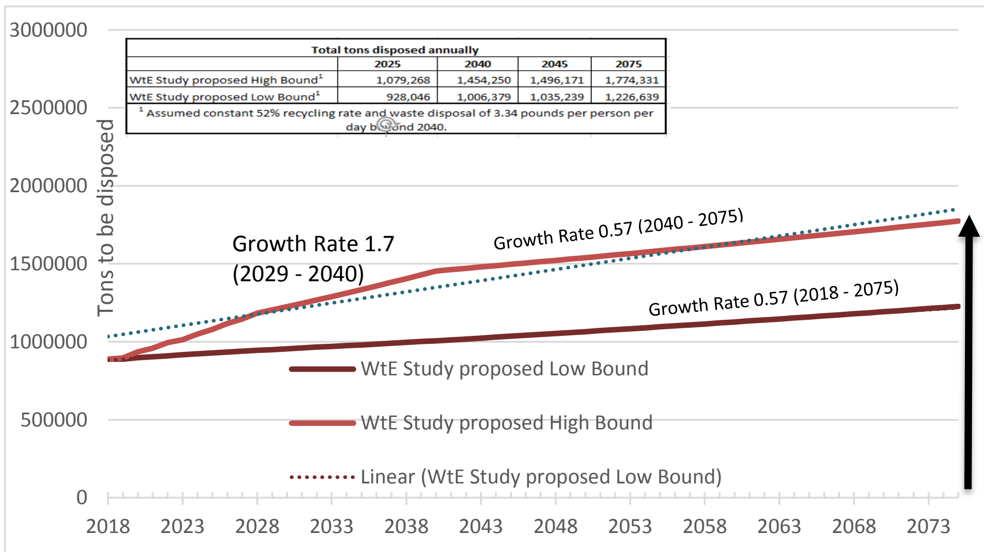
Notes:

yellow highlight indicates likely expansion tonnage and therefore expansion year used in model

green highlight indicates 30 year initial bond payoff date

blue highlight indicates possible delayed expansion tonnage and expansion year

Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Estimate Amount of Waste (tons)	Estimate Amount of Non-processible Waste (tons)	Estimate Amount of Processible Waste (tons)	Facility Capacity Available for Outside Waste	Expansion Low Bound	Expansion High Bound



Total tons disposed annually				
	2025	2040	2045	2075
WtE Study proposed High Bound[1]	1,079,268	1,454,250	1,496,171	1,774,331
WtE Study proposed Low Bound[1]	928,046	1,006,379	1,035,239	1,226,639

[1] Assumed constant 52% recycling rate and waste disposal of 3.34 pounds per person per day beyond 2040.

APPENDIX D

US EPA WARM Model Results and Documentation

Appendix D-1: WEBR and WTE Comparisons Excluding Credits for AMP and Ash Recycling

D-1 WEBR and WTE Comparisons Excluding Credits for AMP and Ash Recycling
Analysis Inputs

ersion 15

Waste Reduction Model (WARM) -- Inputs

Use this worksheet to describe the baseline and alternative waste management scenarios that you want to compare. The blue shaded areas indicate where you need to enter information.
Please enter data in short tons (1 short ton = 2,000 lbs.)

1. Describe the baseline generation and management for the waste materials listed below.
If the material is not generated in your community or you do not want to analyze it, leave it blank or enter 0. Make sure that the total quantity generated equals the total quantity managed

2. Describe the alternative management scenario for the waste materials generated in the baseline
Any decrease in generation should be entered in the Source Reduction column
Any increase in generation should be entered in the Source Reduction column as a negative value
Make sure that the total quantity generated equals the total quantity managed.

Material Type	Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
Paper	Corrugated Containers				NA	NA	0.00					NA	NA
	Magazines/Third-class Mail				NA	NA	0.00					NA	NA
	Newspaper				NA	NA	0.00					NA	NA
	Office Paper				NA	NA	0.00					NA	NA
	Phonebooks				NA	NA	0.00					NA	NA
	Textbooks				NA	NA	0.00					NA	NA
	Mixed Paper (general)				NA	NA	0.00					NA	NA
	Mixed Paper (primarily residential)				NA	NA	0.00					NA	NA
	Mixed Paper (primarily from offices)				NA	NA	0.00					NA	NA
Food Waste	Food Waste	NA					0.00		NA				
	Food Waste (non-meat)	NA					0.00		NA				
	Food Waste (meat only)	NA					0.00		NA				
	Beef	NA					0.00		NA				
	Poultry	NA					0.00		NA				
	Grains	NA					0.00		NA				
	Bread	NA					0.00		NA				
	Fruits and Vegetables	NA					0.00		NA				
	Dairy Products	NA					0.00		NA				
Yard Trimmings	Yard Trimmings	NA					0.00	NA	NA				
	Grass	NA					0.00	NA	NA				
	Leaves	NA					0.00	NA	NA				
	Branches	NA					0.00	NA	NA				
Mixed Plastics	HDPE				NA	NA	0.00					NA	NA
	LDPE	NA			NA	NA	0.00		NA			NA	NA
	PET				NA	NA	0.00					NA	NA
	LLDPE	NA			NA	NA	0.00		NA			NA	NA
	PP	NA			NA	NA	0.00		NA			NA	NA
	PS	NA			NA	NA	0.00		NA			NA	NA
	PVC	NA			NA	NA	0.00		NA			NA	NA
	Mixed Plastics				NA	NA	0.00					NA	NA
Bioplastics	PLA	NA				NA	0.00		NA				NA
Electronics	Desktop CPUs				NA	NA	0.00					NA	NA
	Portable Electronic Devices				NA	NA	0.00					NA	NA
	Flat-Panel Displays				NA	NA	0.00					NA	NA
	CRT Displays				NA	NA	0.00	NA				NA	NA
	Electronic Peripherals				NA	NA	0.00					NA	NA
	Hard-Copy Devices				NA	NA	0.00					NA	NA
	Mixed Electronics				NA	NA	0.00	NA				NA	NA
Metals	Aluminum Cans				NA	NA	0.00					NA	NA
	Aluminum Ingot				NA	NA	0.00					NA	NA
	Steel Cans				NA	NA	0.00					NA	NA
	Copper Wire				NA	NA	0.00					NA	NA
	Mixed Metals				NA	NA	0.00					NA	NA
Glass	Glass				NA	NA	0.00					NA	NA
Construction Materials	Asphalt Concrete			NA	NA	NA	0.00				NA	NA	NA
	Asphalt Shingles				NA	NA	0.00					NA	NA
	Carpet				NA	NA	0.00					NA	NA
	Clay Bricks	NA		NA	NA	NA	0.00		NA		NA	NA	NA
	Concrete			NA	NA	NA	0.00	NA			NA	NA	NA
	Dimensional Lumber				NA	NA	0.00					NA	NA
	Drywall			NA	NA	NA	0.00				NA	NA	NA
	Fiberglass Insulation	NA		NA	NA	NA	0.00		NA		NA	NA	NA
	Fly Ash			NA	NA	NA	0.00	NA			NA	NA	NA
	Medium-density Fiberboard				NA	NA	0.00					NA	NA
	Vinyl Flooring	NA			NA	NA	0.00		NA			NA	NA
	Wood Flooring	NA			NA	NA	0.00		NA			NA	NA
Tires	Tires				NA	NA	0.00					NA	NA
	Mixed Recyclables				NA	NA	0.00	NA				NA	NA

D-1 WEBR and WTE Comparisons Excluding Credits for AMP and Ash Recycling
Analysis Inputs

Mixed Materials	Mixed Organics	NA					0.00	NA	NA				
	Mixed MSW	NA	1.00		NA	NA	1.00	NA	NA		1.00	NA	NA

Please refer to the User's Guide if you need assistance completing this table.

3. **In order to account for the avoided electricity-related emissions in the landfilling and combustion pathways, EPA assigns the appropriate regional "marginal" electricity grid mix emission factor based on your location. Select state for which you are conducting this analysis.**

Please select state or select national average: Washington

Region Location: Pacific

4. **To estimate the benefits from source reduction, EPA usually assumes that the material that is source reduced would have been manufactured from the current mix of virgin and recycled inputs. However, you may choose to estimate the emission reductions from source reduction under the assumption that the material would have been manufactured from 100% virgin inputs in order to obtain an upper bound estimate of the benefits from source reduction. Select which assumption you want to use in the analysis. Note that for materials for which information on the share of recycled inputs used in production is unavailable or is not a common practice; EPA assumes that the current mix is comprised of 100% virgin inputs. Consequently, the source reduction benefits of both the "Current mix" and "100% virgin" inputs are the same.**

- (●) Current Mix
- ( ) 100% Virgin

5. **The emissions from landfilling depends on whether the landfill where your waste is disposed has a landfill gas (LFG) control system. If you do not know whether your landfill has LFG control, select "National Average" to calculate emissions based on the estimated proportions of landfills with LFG control in 2012 and proceed to question 7. If your landfill does not have a LFG system, select "No LFG Recovery" and proceed to question 8. If a LFG system is in place at your landfill, select "LFG Recovery" and click one of the options in 6a to indicate whether LFG is recovered for energy or flared.**

- ( ) National Average
- (●) LFG Recovery
- ( ) No LFG Recovery

6a. **If your landfill has gas recovery, does it recover the methane for energy or flare it?**

- (●) Recover for energy
- ( ) Flare

6b. **For landfills that recover gas, the landfill gas collection efficiency will vary throughout the life of the landfill. Based on a literature review of field measurements and expert discussion, a range of collection efficiencies was estimated for a series of different landfill scenarios. The "typical" landfill is judged to represent the average U.S. landfill, although it must be recognized that every landfill is unique and a typical landfill is an approximation of reality. The worst-case collection scenario represents a landfill that is in compliance with EPA's New Source Performance Standards (NSPS). The aggressive gas collection scenario includes landfills where the operator is aggressive in gas collection relative to a typical landfill. Bioreactor landfills, which are operated to accelerate decomposition, are assumed to collect gas aggressively. The California regulatory collection scenario allows users to estimate and view landfill management results based on California regulatory requirements.**

- (●) Typical operation - DEFAULT
- ( ) Worst-case collection
- ( ) Aggressive gas collection
- ( ) California regulatory collection

	Landfill gas collection efficiency (%) assumptions
Typical	*Years 0-1: 0%; Years 2-4: 50%; Years 5-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Worst-case	*Years 0-4: 0%; Years 5-9: 50%; Years 10-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Aggressive	*Year 0: 0%; Years 0.5-2: 50%; Years 3-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
California	*Year 0: 0%; Year 1: 50%; Years 2-7: 80%; Years 8 to 1 year before final cover: 85%; Final cover: 90%*

7. **Which of the following moisture conditions and associated bulk MSW decay rate (k) most accurately describes the average conditions at the landfill? The decay rates, also referred to as k values, describe the rate of change per year (yr-1) for the decomposition of organic waste in landfills. A higher average decay rate means that waste decomposes faster in the landfill.**

- ( ) National average - DEFAULT
- (●) Dry (k=0.02)
- ( ) Moderate (k = 0.04)
- ( ) Wet (k = 0.06)

	Moisture condition assumptions
Dry (k=0.02)	*Less than 20 inches of precipitation per year*
Moderate (k=0.04)	*Between 20 and 40 inches of precipitation per year*
Wet (k=0.06)	*Greater than 40 inches of precipitation per year*
Bioreactor (k=0.12)	*Water is added until the moisture content reaches 40 percent moisture on a wet weight basis*
National average	*Weighted average based on the share of waste received at each landfill type*

- ○ Bioreactor (k = 0.12)

8a. For anaerobic digestion of food waste materials (including beef, poultry, grains, bread, fruits and vegetables, and dairy products), please choose the appropriate type of anaerobic digestion process used.
Note that for grass, leaves, branches, yard trimmings and mixed organics, wet digestion is not applicable based on current technology and practices in the United States. Therefore, dry digestion is the only digestion type modeled in WARM for these materials.
Only one type of digestion process (wet or dry) can be modeled at a time in WARM.

- ○ Wet Digestion
- ● Dry Digestion

8b. WARM assumes that digestate resulting from anaerobic digestion processes will be applied to land. In many cases, the digestate is cured before land application.
When digestate is cured, the digestate is dewatered and any liquids are recovered and returned to the reactor (when using a wet digester). Next, the digestate is aerobically cured in turned windrows, then screened and applied to agricultural fields.
Select whether the digestate resulting from your anaerobic digester is cured before land application.

- ● Cured - DEFAULT
- ○ Not cured

9a. Emissions that occur during transport of materials to the management facility are included in this model. You may use default transport distances, indicated in the table below, or provide information on the transport distances for the various MSW management options.

- ○ Use Default Distances
- ● Provide Information

9b. If you have chosen to provide information, please fill in the table below. Distances should be from the curb to the landfill, combustor, or material recovery facility (MRF).
***Please note that if you chose to provide information, you must provide distances for both the baseline and the alternative scenarios.**

Management Option	Default Distance (Miles)	Distance (Miles)
Landfill	20	84
Combustion	20	20
Recycling	20	
Composting	20	
Anaerobic Digestion	20	

10. If you wish to personalize your results report, input your name & organization, and also specify the project period corresponding to the data you entered above.

Name	Arcadis Team
Organization	WEBR and WTE Comparisons, Excluding AMP and Ash Recycling Credits

Project Period	From		to	

Congratulations! You have finished all the inputs.
A summary of your results awaits you on the sheet(s) titled "Summary Report."
For more detailed analyses of results, see the sheet(s) titled "Analysis Results."

D-1 WEBR and WTE Comparisons Excluding Credits for AMP and Ash Recycling
Summary Report (MTCO2E)

GHG Emissions Analysis -- Summary Report

Version 15

GHG Emissions Waste Management Analysis for WEBR and WTE Comparisons, Excluding AMP and Ash Recycling Credits

Prepared by: Arcadis Team

Project Period for this Analysis: 01/00/00 to 01/00/0(

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): **0.12**

GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): **0.13**

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Mixed MSW	NA	1.00	-	NA	NA	0.12	Mixed MSW	NA	NA	-	1.00	NA	NA	0.13	0.01
						0								0	0.00
						0								0	0.00
						0								0	0.00
						0								0	0.00
						0								0	0.00
						0								0	0.00
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						0								0	0.00
						0								0	0.00

D-1 WEBR and WTE Comparisons Excluding Credits for AMP and Ash Recycling
Summary Report (MTCO2E)

						0								0		0.00

Total Change in GHG Emissions ($MTCO_2E$): 0.01

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…		
Adding annual emissions from	**0**	Passenger Vehicles
Consuming	**1**	Gallons of Gasoline
Consuming	**0**	Cylinders of Propane Used for Home Barbeques
	0.00000%	Annual CO_2 emissions from the U.S. transportation sector
	0.00000%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:
Documentation Chapters for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)
-- available on the Internet at https://www.epa.gov/warm/documentation-chapters-greenhouse-gas-emission-and-energy-factors-used-waste-reduction-model

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

Appendix D-2: AMP Recycling Credits

D-2 AMP Recycling Credits
Analysis Inputs

ersion 15

Waste Reduction Model (WARM) -- Inputs

Use this worksheet to describe the baseline and alternative waste management scenarios that you want to compare. The blue shaded areas indicate where you need to enter information.
Please enter data in short tons (1 short ton = 2,000 lbs.)

1. Describe the baseline generation and management for the waste materials listed below.
If the material is not generated in your community or you do not want to analyze it, leave it blank or enter 0. Make sure that the total quantity generated equals the total quantity managed

2. Describe the alternative management scenario for the waste materials generated in the baseline
Any decrease in generation should be entered in the Source Reduction column
Any increase in generation should be entered in the Source Reduction column as a negative value
Make sure that the total quantity generated equals the total quantity managed.

Material Type	Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
Paper	Corrugated Containers				NA	NA	0.00					NA	NA
	Magazines/Third-class Mail				NA	NA	0.00					NA	NA
	Newspaper				NA	NA	0.00					NA	NA
	Office Paper				NA	NA	0.00					NA	NA
	Phonebooks				NA	NA	0.00					NA	NA
	Textbooks				NA	NA	0.00					NA	NA
	Mixed Paper (general)				NA	NA	0.00					NA	NA
	Mixed Paper (primarily residential)				NA	NA	0.00					NA	NA
	Mixed Paper (primarily from offices)				NA	NA	0.00					NA	NA
Food Waste	Food Waste	NA					0.00		NA				
	Food Waste (non-meat)	NA					0.00		NA				
	Food Waste (meat only)	NA					0.00		NA				
	Beef	NA					0.00		NA				
	Poultry	NA					0.00		NA				
	Grains	NA					0.00		NA				
	Bread	NA					0.00		NA				
	Fruits and Vegetables	NA					0.00		NA				
	Dairy Products	NA					0.00		NA				
Yard Trimmings	Yard Trimmings	NA					0.00	NA	NA				
	Grass	NA					0.00	NA	NA				
	Leaves	NA					0.00	NA	NA				
	Branches	NA					0.00	NA	NA				
Mixed Plastics	HDPE				NA	NA	0.00					NA	NA
	LDPE	NA			NA	NA	0.00		NA			NA	NA
	PET				NA	NA	0.00					NA	NA
	LLDPE	NA			NA	NA	0.00		NA			NA	NA
	PP	NA			NA	NA	0.00		NA			NA	NA
	PS	NA			NA	NA	0.00		NA			NA	NA
	PVC	NA			NA	NA	0.00		NA			NA	NA
	Mixed Plastics				NA	NA	0.00					NA	NA
Bioplastics	PLA	NA				NA	0.00		NA				NA
Electronics	Desktop CPUs				NA	NA	0.00					NA	NA
	Portable Electronic Devices				NA	NA	0.00					NA	NA
	Flat-Panel Displays				NA	NA	0.00					NA	NA
	CRT Displays				NA	NA	0.00	NA				NA	NA
	Electronic Peripherals				NA	NA	0.00					NA	NA
	Hard-Copy Devices				NA	NA	0.00					NA	NA
	Mixed Electronics				NA	NA	0.00	NA				NA	NA
Metals	Aluminum Cans		0.01		NA	NA	0.01		0.01			NA	NA
	Aluminum Ingot				NA	NA	0.00					NA	NA
	Steel Cans		0.00		NA	NA	0.00		0.00			NA	NA
	Copper Wire				NA	NA	0.00					NA	NA
	Mixed Metals				NA	NA	0.00					NA	NA
Glass	Glass				NA	NA	0.00					NA	NA
Construction Materials	Asphalt Concrete			NA	NA	NA	0.00				NA	NA	NA
	Asphalt Shingles				NA	NA	0.00					NA	NA
	Carpet				NA	NA	0.00					NA	NA
	Clay Bricks	NA		NA	NA	NA	0.00		NA		NA	NA	NA
	Concrete			NA	NA	NA	0.00	NA			NA	NA	NA
	Dimensional Lumber				NA	NA	0.00					NA	NA
	Drywall			NA	NA	NA	0.00				NA	NA	NA
	Fiberglass Insulation	NA		NA	NA	NA	0.00		NA		NA	NA	NA
	Fly Ash			NA	NA	NA	0.00	NA			NA	NA	NA
	Medium-density Fiberboard				NA	NA	0.00					NA	NA
	Vinyl Flooring	NA			NA	NA	0.00		NA			NA	NA
	Wood Flooring	NA			NA	NA	0.00		NA			NA	NA
Tires	Tires				NA	NA	0.00					NA	NA
	Mixed Recyclables				NA	NA	0.00	NA				NA	NA

Mixed Materials	Mixed Organics	NA					0.00	NA	NA				
	Mixed MSW	NA			NA	NA	0.00	NA	NA			NA	NA

Please refer to the User's Guide if you need assistance completing this table.

3. In order to account for the avoided electricity-related emissions in the landfilling and combustion pathways, EPA assigns the appropriate regional "marginal" electricity grid mix emission factor based on your location. Select state for which you are conducting this analysis.

Please select state or select national average:	Washington
Region Location:	Pacific

4. To estimate the benefits from source reduction, EPA usually assumes that the material that is source reduced would have been manufactured from the current mix of virgin and recycled inputs. However, you may choose to estimate the emission reductions from source reduction under the assumption that the material would have been manufactured from 100% virgin inputs in order to obtain an upper bound estimate of the benefits from source reduction. Select which assumption you want to use in the analysis. Note that for materials for which information on the share of recycled inputs used in production is unavailable or is not a common practice; EPA assumes that the current mix is comprised of 100% virgin inputs. Consequently, the source reduction benefits of both the "Current mix" and "100% virgin" inputs are the same.

- (●) Current Mix
- ( ) 100% Virgin

5. The emissions from landfilling depends on whether the landfill where your waste is disposed has a landfill gas (LFG) control system. If you do not know whether your landfill has LFG control, select "National Average" to calculate emissions based on the estimated proportions of landfills with LFG control in 2012 and proceed to question 7. If your landfill does not have a LFG system, select "No LFG Recovery" and proceed to question 8. If a LFG system is in place at your landfill, select "LFG Recovery" and click one of the options in 6a to indicate whether LFG is recovered for energy or flared.

- ( ) National Average
- (●) LFG Recovery
- ( ) No LFG Recovery

6a. If your landfill has gas recovery, does it recover the methane for energy or flare it?

- (●) Recover for energy
- ( ) Flare

6b. For landfills that recover gas, the landfill gas collection efficiency will vary throughout the life of the landfill. Based on a literature review of field measurements and expert discussion, a range of collection efficiencies was estimated for a series of different landfill scenarios. The "typical" landfill is judged to represent the average U.S. landfill, although it must be recognized that every landfill is unique and a typical landfill is an approximation of reality. The worst-case collection scenario represents a landfill that is in compliance with EPA's New Source Performance Standards (NSPS). The aggressive gas collection scenario includes landfills where the operator is aggressive in gas collection relative to a typical landfill. Bioreactor landfills, which are operated to accelerate decomposition, are assumed to collect gas aggressively. The California regulatory collection scenario allows users to estimate and view landfill management results based on California regulatory requirements.

- (●) Typical operation - DEFAULT
- ( ) Worst-case collection
- ( ) Aggressive gas collection
- ( ) California regulatory collection

	Landfill gas collection efficiency (%) assumptions
Typical	*Years 0-1: 0%; Years 2-4: 50%; Years 5-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Worst-case	*Years 0-4: 0%; Years 5-9: 50%; Years 10-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Aggressive	*Year 0: 0%; Years 0.5-2: 50%; Years 3-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
California	*Year 0: 0%; Year 1: 50%; Years 2-7: 80%; Years 8 to 1 year before final cover: 85%; Final cover: 90%*

7. Which of the following moisture conditions and associated bulk MSW decay rate (k) most accurately describes the average conditions at the landfill? The decay rates, also referred to as k values, describe the rate of change per year (yr-1) for the decomposition of organic waste in landfills. A higher average decay rate means that waste decomposes faster in the landfill.

- ( ) National average - DEFAULT
- (●) Dry (k=0.02)
- ( ) Moderate (k = 0.04)
- ( ) Wet (k = 0.06)

	Moisture condition assumptions
Dry (k=0.02)	*Less than 20 inches of precipitation per year*
Moderate (k=0.04)	*Between 20 and 40 inches of precipitation per year*
Wet (k=0.06)	*Greater than 40 inches of precipitation per year*
Bioreactor (k=0.12)	*Water is added until the moisture content reaches 40 percent moisture on a wet weight basis*
National average	*Weighted average based on the share of waste received at each landfill type*

○ Bioreactor (k = 0.12)

8a. For anaerobic digestion of food waste materials (including beef, poultry, grains, bread, fruits and vegetables, and dairy products), please choose the appropriate type of anaerobic digestion process used.
Note that for grass, leaves, branches, yard trimmings and mixed organics, wet digestion is not applicable based on current technology and practices in the United States. Therefore, dry digestion is the only digestion type modeled in WARM for these materials.
Only one type of digestion process (wet or dry) can be modeled at a time in WARM.

○ Wet Digestion
● Dry Digestion

8b. WARM assumes that digestate resulting from anaerobic digestion processes will be applied to land. In many cases, the digestate is cured before land application.
When digestate is cured, the digestate is dewatered and any liquids are recovered and returned to the reactor (when using a wet digester). Next, the digestate is aerobically cured in turned windrows, then screened and applied to agricultural fields.
Select whether the digestate resulting from your anaerobic digester is cured before land application.

● Cured - DEFAULT
○ Not cured

9a. Emissions that occur during transport of materials to the management facility are included in this model. You may use default transport distances, indicated in the table below, or provide information on the transport distances for the various MSW management options.

● Use Default Distances
○ Provide Information

9b. If you have chosen to provide information, please fill in the table below. Distances should be from the curb to the landfill, combustor, or material recovery facility (MRF).
*Please note that if you chose to provide information, you must provide distances for both the baseline and the alternative scenarios.

Management Option	Default Distance (Miles)	Distance (Miles)
Landfill	20	
Combustion	20	
Recycling	20	
Composting	20	
Anaerobic Digestion	20	

10. If you wish to personalize your results report, input your name & organization, and also specify the project period corresponding to the data you entered above.

Name	Arcadis Team
Organization	AMP Recycling Credits

Project Period	From		to	

Congratulations! You have finished all the inputs.
A summary of your results awaits you on the sheet(s) titled "Summary Report."
For more detailed analyses of results, see the sheet(s) titled "Analysis Results."

D-2 AMP Recycling Credits
Summary Report (MTCO2E)

GHG Emissions Analysis -- Summary Report

Version 15

GHG Emissions Waste Management Analysis for AMP Recycling Credits

Prepared by: Arcadis Team

Project Period for this Analysis: 01/00/00 to 01/00/00

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): 0.00

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$
Aluminum Cans	-	0.01	-	NA	NA	0.00
Steel Cans	-	0.00	-	NA	NA	0.00
						0
						0
						0
						0
						0
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GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (0.11)

Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Aluminum Cans	-	0.01	-	-	NA	NA	(0.10)	(0.10)
Steel Cans	-	0.00	-	-	NA	NA	(0.01)	(0.01)
							0	0.00
							0	0.00
							0	0.00
							0	0.00
							0	0.00
							0	0.00
							0	0.00
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							0	0.00

D-2 AMP Recycling Credits
Summary Report (MTCO2E)

							0

								0

0.00

Total Change in GHG Emissions ($MTCO_2E$): (0.11)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…		
Removing annual emissions from	**0**	Passenger Vehicles
Conserving	**12**	Gallons of Gasoline
Conserving	**4**	Cylinders of Propane Used for Home Barbeques
	0.00000%	Annual CO_2 emissions from the U.S. transportation sector
	0.00000%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Documentation Chapters for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)

-- available on the Internet at https://www.epa.gov/warm/documentation-chapters-greenhouse-gas-emission-and-energy-factors-used-waste-reduction-model

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

Appendix D-3: Ash Recycling Credits

rsion 15

Waste Reduction Model (WARM) -- Inputs

Use this worksheet to describe the baseline and alternative waste management scenarios that you want to compare. The blue shaded areas indicate where you need to enter information.
Please enter data in short tons (1 short ton = 2,000 lbs.)

1. Describe the baseline generation and management for the waste materials listed below. If the material is not generated in your community or you do not want to analyze it, leave it blank or enter 0. Make sure that the total quantity generated equals the total quantity managed.

2. Describe the alternative management scenario for the waste materials generated in the baseline. Any decrease in generation should be entered in the Source Reduction column. Any increase in generation should be entered in the Source Reduction column as a negative val Make sure that the total quantity generated equals the total quantity managed.

Material Type	Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
Paper	Corrugated Containers				NA	NA	0.00					NA	NA
	Magazines/Third-class Mail				NA	NA	0.00					NA	NA
	Newspaper				NA	NA	0.00					NA	NA
	Office Paper				NA	NA	0.00					NA	NA
	Phonebooks				NA	NA	0.00					NA	NA
	Textbooks				NA	NA	0.00					NA	NA
	Mixed Paper (general)				NA	NA	0.00					NA	NA
	Mixed Paper (primarily residential)				NA	NA	0.00					NA	NA
	Mixed Paper (primarily from offices)				NA	NA	0.00					NA	NA
Food Waste	Food Waste	NA					0.00		NA				
	Food Waste (non-meat)	NA					0.00		NA				
	Food Waste (meat only)	NA					0.00		NA				
	Beef	NA					0.00		NA				
	Poultry	NA					0.00		NA				
	Grains	NA					0.00		NA				
	Bread	NA					0.00		NA				
	Fruits and Vegetables	NA					0.00		NA				
	Dairy Products	NA					0.00		NA				
Yard Trimmings	Yard Trimmings	NA					0.00	NA	NA				
	Grass	NA					0.00	NA	NA				
	Leaves	NA					0.00	NA	NA				
	Branches	NA					0.00	NA	NA				
Mixed Plastics	HDPE				NA	NA	0.00					NA	NA
	LDPE	NA			NA	NA	0.00		NA			NA	NA
	PET				NA	NA	0.00					NA	NA
	LLDPE	NA			NA	NA	0.00		NA			NA	NA
	PP	NA			NA	NA	0.00		NA			NA	NA
	PS	NA			NA	NA	0.00		NA			NA	NA
	PVC	NA			NA	NA	0.00		NA			NA	NA
	Mixed Plastics				NA	NA	0.00					NA	NA
Bioplastics	PLA	NA				NA	0.00		NA				NA
Electronics	Desktop CPUs				NA	NA	0.00					NA	NA
	Portable Electronic Devices				NA	NA	0.00					NA	NA
	Flat-Panel Displays				NA	NA	0.00					NA	NA
	CRT Displays				NA	NA	0.00	NA				NA	NA
	Electronic Peripherals				NA	NA	0.00					NA	NA
	Hard-Copy Devices				NA	NA	0.00					NA	NA
	Mixed Electronics				NA	NA	0.00	NA				NA	NA
Metals	Aluminum Cans				NA	NA	0.00					NA	NA
	Aluminum Ingot				NA	NA	0.00					NA	NA
	Steel Cans				NA	NA	0.00					NA	NA
	Copper Wire				NA	NA	0.00					NA	NA
	Mixed Metals				NA	NA	0.00					NA	NA
Glass	Glass				NA	NA	0.00					NA	NA
Construction	Asphalt Concrete			NA	NA	NA	0.00				NA	NA	NA
	Asphalt Shingles				NA	NA	0.00					NA	NA
	Carpet				NA	NA	0.00					NA	NA
	Clay Bricks	NA		NA	NA	NA	0.00		NA		NA	NA	NA
	Concrete			NA	NA	NA	0.00	NA			NA	NA	NA
	Dimensional Lumber				NA	NA	0.00					NA	NA

Materials	Drywall			NA	NA	NA	0.00				NA	NA	NA
	Fiberglass Insulation	NA		NA	NA	NA	0.00		NA		NA	NA	NA
	Fly Ash		0.08	NA	NA	NA	0.08	NA	0.08		NA	NA	NA
	Medium-density Fiberboard				NA	NA	0.00					NA	NA
	Vinyl Flooring	NA			NA	NA	0.00		NA			NA	NA
	Wood Flooring	NA			NA	NA	0.00		NA			NA	NA
Tires	Tires				NA	NA	0.00					NA	NA
Mixed Materials	Mixed Recyclables				NA	NA	0.00	NA				NA	NA
	Mixed Organics	NA					0.00	NA	NA				
	Mixed MSW	NA			NA	NA	0.00	NA	NA			NA	NA

Please refer to the User's Guide if you need assistance completing this table.

3. In order to account for the avoided electricity-related emissions in the landfilling and combustion pathways, EPA assigns the appropriate regional "marginal" electricity grid mix emission factor based on your location. Select state for which you are conducting this analysis.

Please select state or select national average: Washington

Region Location: Pacific

4. To estimate the benefits from source reduction, EPA usually assumes that the material that is source reduced would have been manufactured from the current mix of virgin and recycled inputs. However, you may choose to estimate the emission reductions from source reduction under the assumption that the material would have been manufactured from 100% virgin inputs in order to obtain an upper bound estimate of the benefits from source reduction. Select which assumption you want to use in the analysis. Note that for materials for which information on the share of recycled inputs used in production is unavailable or is not a common practice; EPA assumes that the current mix is comprised of 100% virgin inputs. Consequently, the source reduction benefits of both the "Current mix" and "100% virgin" inputs are the same.

- (●) Current Mix
- ( ) 100% Virgin

5. The emissions from landfilling depends on whether the landfill where your waste is disposed has a landfill gas (LFG) control system. If you do not know whether your landfill has LFG control, select "National Average" to calculate emissions based on the estimated proportions of landfills with LFG control in 2012 and proceed to question 7. If your landfill does not have a LFG system, select "No LFG Recovery" and proceed to question 8. If a LFG system is in place at your landfill, select "LFG Recovery" and click one of the options in 6a to indicate whether LFG is recovered for energy or flared.

- ( ) National Average
- (●) LFG Recovery
- ( ) No LFG Recovery

6a. If your landfill has gas recovery, does it recover the methane for energy or flare it?

- (●) Recover for energy
- ( ) Flare

6b. For landfills that recover gas, the landfill gas collection efficiency will vary throughout the life of the landfill. Based on a literature review of field measurements and expert discussion, a range of collection efficiencies was estimated for a series of different landfill scenarios. The "typical" landfill is judged to represent the average U.S. landfill, although it must be recognized that every landfill is unique and a typical landfill is an approximation of reality. The worst-case collection scenario represents a landfill that is in compliance with EPA's New Source Performance Standards (NSPS). The aggressive gas collection scenario includes landfills where the operator is aggressive in gas collection relative to a typical landfill. Bioreactor landfills, which are operated to accelerate decomposition, are assumed to collect gas aggressively. The California regulatory collection scenario allows users to estimate and view landfill management results based on California regulatory requirements.

- (●) Typical operation - DEFAULT
- ( ) Worst-case collection
- ( ) Aggressive gas collection

	Landfill gas collection efficiency (%) assumptions
Typical	*Years 0-1: 0%; Years 2-4: 50%; Years 5-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Worst-case	*Years 0-4: 0%; Years 5-9: 50%; Years 10-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Aggressive	*Year 0: 0%; Years 0.5-2: 50%; Years 3-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*

Aggressive gas collection

California regulatory collection

California *Year 0: 0%; Year 1: 50%; Years 2-7: 80%; Years 8 to 1 year before final cover: 85%; Final cover: 90%*

7. Which of the following moisture conditions and associated bulk MSW decay rate (k) most accurately describes the average conditions at the landfill?
The decay rates, also referred to as k values, describe the rate of change per year (yr-1) for the decomposition of organic waste in landfills. A higher average decay rate means that waste decomposes faster in the landfill.

- ○ National average - DEFAULT
- ◉ Dry (k=0.02)
- ○ Moderate (k = 0.04)
- ○ Wet (k = 0.06)
- ○ Bioreactor (k = 0.12)

	Moisture condition assumptions
Dry (k=0.02)	*Less than 20 inches of precipitation per year*
Moderate (k=0.04)	*Between 20 and 40 inches of precipitation per year*
Wet (k=0.06)	*Greater than 40 inches of precipitation per year*
Bioreactor (k=0.12)	*Water is added until the moisture content reaches 40 percent moisture on a wet weight basis*
National average	*Weighted average based on the share of waste received at each landfill type*

8a. For anaerobic digestion of food waste materials (including beef, poultry, grains, bread, fruits and vegetables, and dairy products), please choose the appropriate type of anaerobic digestion process used.
Note that for grass, leaves, branches, yard trimmings and mixed organics, wet digestion is not applicable based on current technology and practices in the United States. Therefore, dry digestion is the only digestion type modeled in WARM
Only one type of digestion process (wet or dry) can be modeled at a time in WARM.

- ○ Wet Digestion
- ◉ Dry Digestion

8b. WARM assumes that digestate resulting from anaerobic digestion processes will be applied to land. In many cases, the digestate is cured before land application.
When digestate is cured, the digestate is dewatered and any liquids are recovered and returned to the reactor (when using a wet digester). Next, the digestate is aerobically cured in turned windrows, then screened and applied to agricultura
Select whether the digestate resulting from your anaerobic digester is cured before land application.

- ◉ Cured - DEFAULT
- ○ Not cured

9a. Emissions that occur during transport of materials to the management facility are included in this model. You may use default transport distances, indicated in the table below, or provide information on the transport distances for the various MSW management options.

- ◉ Use Default Distances
- ○ Provide Information

9b. If you have chosen to provide information, please fill in the table below. Distances should be from the curb to the landfill, combustor, or material recovery facility (MRF).
***Please note that if you chose to provide information, you must provide distances for both the baseline and the alternative scenarios.**

Management Option	Default Distance (Miles)	Distance (Miles)
Landfill	20	
Combustion	20	
Recycling	20	
Composting	20	
Anaerobic Digestion	20	

10. If you wish to personalize your results report, input your name & organization, and also specify the project period corresponding to the data you entered above.

Name	Arcadis Team
Organization	Ash Recycling Credits

D-3 Ash Recycling Credits
Analysis Inputs

Project Period	From		to	

Congratulations! You have finished all the inputs.
A summary of your results awaits you on the sheet(s) titled "Summary Report."
For more detailed analyses of results, see the sheet(s) titled "Analysis Results."

D-3 Ash Recycling Credits
Summary Report (MTCO2E)

GHG Emissions Analysis -- Summary Report

Version 15

GHG Emissions Waste Management Analysis for Ash Recycling Credits

Prepared by: Arcadis Team

Project Period for this Analysis: 01/00/00 to 01/00/0(

Note: If you wish to save these results, rename this file (e.g., WARM-MN1) and save it. Then the "Analysis Inputs" sheet of the "WARM" file will be blank when you are ready to make another model run.

GHG Emissions from Baseline Waste Management ($MTCO_2E$): **0.00**

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$
Fly Ash	-	0.08	NA	NA	NA	0.00
						0
						0
						0
						0
						0
						0
						0
						0
						0
						0
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						0

GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): **(0.06)**

Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
Fly Ash	NA	0.08	-	NA	NA	NA	(0.06)	(0.07)
							0	0.00
							0	0.00
							0	0.00
							0	0.00
							0	0.00
							0	0.00
							0	0.00
							0	0.00
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							0	0.00
							0	0.00
							0	0.00

D-3 Ash Recycling Credits
Summary Report (MTCO2E)

							0

								0

0.00

Total Change in GHG Emissions ($MTCO_2E$): (0.07)

Note: a negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

This is equivalent to…		
Removing annual emissions from	**0**	Passenger Vehicles
Conserving	**7**	Gallons of Gasoline
Conserving	**3**	Cylinders of Propane Used for Home Barbeques
	0.00000%	Annual CO_2 emissions from the U.S. transportation sector
	0.00000%	Annual CO_2 emissions from the U.S. electricity sector

a) For explanation of methodology, see the EPA WARM Documentation:

Documentation Chapters for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)

-- available on the Internet at https://www.epa.gov/warm/documentation-chapters-greenhouse-gas-emission-and-energy-factors-used-waste-reduction-model

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

c) The GHG emissions results estimated in WARM indicate the full life-cycle benefits waste management alternatives. Due to the timing of the GHG emissions from the waste management pathways, (e.g., avoided landfilling and increased recycling), the actual GHG implications may accrue over the long-term. Therefore, one should not interpret the GHG emissions implications as occurring all in one year, but rather through time.

Appendix D-4: US EPA WARM Model Emission Factors and Assumptions

U.S. Environmental Protection Agency
Office of Resource Conservation and Recovery

Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM)

Management Practices Chapters

May 2019

Prepared by ICF
For the U.S. Environmental Protection Agency
Office of Resource Conservation and Recovery

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5 COMBUSTION

This document presents an overview of combustion as a waste management strategy in relation to the development of material-specific emission factors for EPA's Waste Reduction Model (WARM). Included are estimates of the net greenhouse gas (GHG) emissions from combustion of most of the materials considered in WARM and several categories of mixed waste.

5.1 A SUMMARY OF THE GHG IMPLICATIONS OF COMBUSTION

Combustion of municipal solid waste (MSW) results in emissions of CO_2 and N_2O. Note that CO_2 from combustion of biomass (such as paper products and yard trimmings) is not counted because it is biogenic (as explained in the WARM Background and Overview chapter). WARM estimates emissions from combustion of MSW in waste-to-energy (WTE) facilities. WARM does not consider any recovery of materials from the MSW stream that may occur before MSW is delivered to the combustor.

In the United States, about 80 WTE facilities process more than 30 million tons of MSW annually (ERC, 2014). WTE facilities can be divided into three categories: (1) mass burn, (2) modular, and (3) refuse-derived fuel (RDF). A mass burn facility generates electricity and/or steam from the combustion of mixed MSW. Most of the facilities (76 percent) employ mass burn technology. Modular WTE plants are generally smaller than mass burn plants, and are prefabricated off-site so that they can be assembled quickly where they are needed. Because of their similarity to mass burn facilities, modular facilities are treated as part of the mass burn category for the purposes of this analysis.

An RDF facility combusts MSW that has undergone varying degrees of processing, from simple removal of bulky and noncombustible items to more complex processes (such as shredding and material recovery) that result in a finely divided fuel. Processing MSW into RDF yields a more uniform fuel that has a higher heating value than that used by mass burn or modular WTE. MSW processing into RDF involves both manual and mechanical separation to remove materials such as glass and metals that have little or no fuel value. In the United States, approximately 14 facilities combust RDF (ERC, 2010).

This study analyzed the net GHG emissions from combustion of all individual and mixed waste streams in WARM at mass burn and RDF facilities, with the exception of asphalt concrete, drywall, and fiberglass insulation. These three materials were excluded because EPA determined that they are not typically combusted at end of life. Note that **WARM incorporates only the emission factors for mass burn facilities**, due to (1) the relatively small number of RDF facilities in the United States and (2) the fact that the RDF emission factors are based on data from only one RDF facility.

Net emissions consist of (1) emissions from the transportation of waste to a combustion facility, (2) emissions of non-biogenic CO_2, and (3) emissions of N_2O minus (4) avoided GHG emissions from the electric utility sector and (5) avoided GHG emissions due to the recovery and recycling of ferrous metals at the combustor. There is some evidence that as combustor ash ages, it absorbs CO_2 from the atmosphere. However, EPA did not count absorbed CO_2 because the quantity is estimated to be less than 0.02 $MTCO_2E$ per ton of MSW combusted.[26] The results of this analysis for the materials contained in WARM and the explanations for each of these results are discussed in section 5.3.[27]

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[26] Based on data provided by Dr. Jürgen Vehlow of the Institut für Technische Chemie in Karlsruhe, Germany, EPA estimated that the ash from one ton of MSW would absorb roughly 0.004 MTCE of CO_2.

[27] Note that Exhibit 5-1, Exhibit 5-2, and Exhibit 5-6 do not show mixed paper. Mixed paper is shown in the summary exhibit. The summary values for mixed paper are based on the proportions of the four paper types (newspaper, office paper, corrugated containers, and magazines/third-class mail) that make up the different "mixed paper" definitions.

5.2 CALCULATING THE GHG IMPACTS OF COMBUSTION

This study's general approach was to estimate (1) the gross emissions of CO_2 and N_2O from MSW combustion (including emissions from transportation of waste to the combustor and ash from the combustor to a landfill) and (2) the CO_2 emissions avoided because of displaced electric utility generation and decreased energy requirements for production processes using recycled inputs. A comprehensive evaluation would also consider the fate of carbon remaining in combustor ash. Depending on its chemical form, carbon may be aerobically degraded to CO_2, anaerobically degraded to CH_4, or remain in a relatively inert form and be stored. Unless the ash carbon is converted to CH_4 (which EPA considers unlikely), the effect on the net GHG emissions will be very small. To obtain an estimate of the *net* GHG emissions from MSW combustion, the GHG emissions avoided were subtracted from the direct GHG emissions. EPA estimated the net GHG emissions from waste combustion per ton of mixed MSW and per ton of each selected material in MSW. The remainder of this section describes how EPA developed these estimates.

5.2.1 Emissions of CO_2 from WTE Facilities

The carbon in MSW has two distinct origins: some of it is derived from sustainably harvested biomass (i.e., carbon in plant matter that was converted from CO_2 in the atmosphere through photosynthesis), and the remainder is from non-biomass sources, e.g., plastic and synthetic rubber derived from petroleum.

As explained in the WARM Background and Overview chapter, WARM considers only CO_2 that derives from fossil sources and does not consider biogenic CO_2 emissions. Therefore, only CO_2 emissions from the combustion of non-biomass components of MSW—plastic, textiles and rubber—were counted. These components make up a relatively small share of total MSW, so only a small portion of the total CO_2 emissions from combustion are considered in WARM.

To estimate the non-biogenic carbon content of the plastics, textiles, rubber and leather contained in one ton of mixed MSW, EPA first established assumptions for the non-biogenic share of carbon in these materials. For plastics in products in MSW, EPA assumed that all carbon is non-biogenic carbon, because biogenic plastics likely make up a small but unknown portion of products. For rubber and leather products in MSW, EPA assumed that the non-biogenic share of carbon contained in clothing and footwear is 25 percent; this assumption is based on expert judgment. The non-biogenic share of carbon in containers, packaging, and other durables is 100 percent; and the non-biogenic share of carbon in other nondurables is 75 percent (EPA, 2010). For textile products in MSW, EPA assumed that the non-biogenic share of carbon is 55 percent (DeZan, 2000). EPA then calculated the non-biogenic carbon content of each of these material groups. For plastics in products in MSW, EPA used the molecular formula of each resin type to assume that PET is 63 percent carbon; PVC is 38 percent carbon; polystyrene is 92 percent carbon; HDPE, LDPE, and polypropylene are 86 percent carbon; and a weighted average of all other resins is 66 percent carbon (by weight). Based on the amount of each plastic discarded in 2015 (EPA, 2018), EPA calculated a weighted carbon content of 78 percent for plastics in mixed MSW. For rubber and leather products, EPA used the weighted average carbon content of rubbers consumed in 2002 to estimate a carbon content of 85 percent (by weight) for rubber and leather products in mixed MSW. For textiles, EPA used the average carbon content of the four main synthetic fiber types to estimate a carbon content of 70 percent (by weight) for textiles in mixed MSW. Next, using data from BioCycle's *The State of Garbage in America* (Van Haaren et al., 2010), EPA assumed that seven percent of discards are combusted in the United States. Data from BioCycle is used instead of EPA's *Advancing Sustainable Materials Management: Facts and Figures* report (EPA, 2018a), because it is based off of direct reporting, and provides a more accurate representation of the amount of materials discarded at WTE facilities. Additionally, these data are also used in order to maintain consistency with the data source used in EPA's annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* report. Based on these assumptions, EPA estimated that there are 0.10 tons of non-biogenic carbon in the plastic, textiles, rubber and leather contained in one ton of mixed MSW (EPA, 2018a; Van Haaren et al., 2010).

The 10 percent non-biomass carbon content of mixed MSW was then converted to units of $MTCO_2E$ per short ton of mixed MSW combusted. The resulting value for mixed MSW is shown in Exhibit 5-1. Note that if EPA had used a best-case assumption for textiles (i.e., assuming that they have no petrochemical-based fibers), the resulting value for mixed MSW would have been slightly lower. The values for CO_2 emissions are shown in column (b) of Exhibit 5-1.

Exhibit 5-1: Gross GHG Emissions from MSW Combustion ($MTCO_2E$/Short Ton of Material Combusted)

(a) Material	(b) Combustion CO_2 Emissions from Non-Biomass per Short Ton Combusted	(c) Combustion N_2O Emissions per Short Ton Combusted	(d) Transportation CO_2 Emissions per Short Ton Combusted	(e) Gross GHG Emissions per Short Ton Combusted (e = b + c + d)
Aluminum Cans	–	–	0.01	0.01
Aluminum Ingot	–	–	0.01	0.01
Steel Cans	–	–	0.01	0.01
Copper Wire	–	–	0.01	0.01
Glass	–	–	0.01	0.01
HDPE	2.79	–	0.01	2.80
LDPE	2.79	–	0.01	2.80
PET	2.04	–	0.01	2.05
LLDPE	2.79	–	0.01	2.80
PP	2.79	–	0.01	2.80
PS	3.01	–	0.01	3.02
PVC	1.25	–	0.01	1.26
PLA	–	–	0.01	0.01
Corrugated Containers	–	0.04	0.01	0.05
Magazines/Third-Class Mail	–	0.04	0.01	0.05
Newspaper	–	0.04	0.01	0.05
Office Paper	–	0.04	0.01	0.05
Phone Books[a]	–	0.04	0.01	0.05
Textbooks[a]	–	0.04	0.01	0.05
Dimensional Lumber	–	0.04	0.01	0.05
Medium-Density Fiberboard	–	0.04	0.01	0.05
Food Waste	–	0.04	0.01	0.05
Food Waste (meat only)	–	0.04	0.01	0.05
Food Waste (non-meat)	–	0.04	0.01	0.05
Beef	–	0.04	0.01	0.05
Poultry	–	0.04	0.01	0.05
Grains	–	0.04	0.01	0.05
Bread	–	0.04	0.01	0.05
Fruits and Vegetables	–	0.04	0.01	0.05
Dairy Products	–	0.04	0.01	0.05
Yard Trimmings	–	0.04	0.01	0.05
Grass	–	0.04	0.01	0.05
Leaves	–	0.04	0.01	0.05
Branches	–	0.04	0.01	0.05
Mixed Paper (general)	–	0.04	0.01	0.05
Mixed Paper (primarily residential)	–	0.04	0.01	0.05

(a) Material	(b) Combustion CO_2 Emissions from Non-Biomass per Short Ton Combusted	(c) Combustion N_2O Emissions per Short Ton Combusted	(d) Transportation CO_2 Emissions per Short Ton Combusted	(e) Gross GHG Emissions per Short Ton Combusted (e = b + c + d)
Mixed Paper (primarily from offices)	–	0.04	0.01	0.05
Mixed Metals	–	–	0.01	0.01
Mixed Plastics	2.33	–	0.01	2.34
Mixed Recyclables	0.07	0.03	0.01	0.11
Mixed Organics	–	0.04	0.01	0.05
Mixed MSW	0.38	0.04	0.01	0.43
Carpet	1.67	–	0.01	1.68
Desktop CPUs	0.40	–	0.01	0.40
Portable Electronic Devices	0.88	–	0.01	0.89
Flat-panel Displays	0.73	–	0.01	0.74
CRT Displays	0.63	–	0.01	0.64
Electronic Peripheral	2.22	–	0.01	2.23
Hard-copy Devices	1.91	–	0.01	1.92
Mixed Electronics	0.86	–	0.01	0.87
Clay Bricks	NA	NA	NA	NA
Concrete	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA
Tires	2.20	–	0.01	2.21
Asphalt Concrete	NA	NA	NA	NA
Asphalt Shingles	0.65	0.04	0.01	0.70
Drywall	NA	NA	NA	NA
Fiberglass Insulation	NA	NA	NA	NA
Vinyl Flooring	0.28	–	0.01	0.29
Wood Flooring	–	0.04	0.05	0.08

– = Zero emissions.

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

[a] The values for phone books and textbooks are proxies, based on newspaper and office paper, respectively.

5.2.2 Emissions of N_2O from WTE Facilities

Studies compiled by the Intergovernmental Panel on Climate Change (IPCC) show that MSW combustion results in measurable emissions of N_2O, a GHG with a global warming potential (GWP) 298 times that of CO_2 (EPA, 2018a; IPCC, 2007; IPCC, 2006). The IPCC compiled reported ranges of N_2O emissions, per metric ton of waste combusted, from six classifications of MSW combustors. This study averaged the midpoints of each range and converted the units to $MTCO_2E$ of N_2O per ton of MSW. The resulting estimate is 0.04 $MTCO_2E$ of N_2O emissions per ton of mixed MSW combusted. Because the IPCC did not report N_2O values for combustion of individual components of MSW, EPA used the 0.04 value not only for mixed MSW, but also as a proxy for all components of MSW, except for aluminum cans, steel cans, glass, HDPE, LDPE, and PET. This exception was made because at the relatively low combustion temperatures found in MSW combustors, most of the nitrogen in N_2O emissions is derived from the waste, not from the combustion air. Because aluminum and steel cans, glass, and plastics do not contain nitrogen, EPA concluded that running these materials through an MSW combustor would not result in N_2O emissions.

5.2.3 Emissions of CO_2 from Transportation of Waste and Ash

WARM includes emissions associated with transporting of waste and the subsequent transportation of the residual waste ash to the landfill. Transportation energy emissions occur when fossil fuels are combusted to collect and transport material to the combustion facility and then to operate on-site equipment. Transportation of any individual material in MSW is assumed to use the same amount of energy as transportation of mixed MSW. To calculate the emissions, WARM relies on assumptions from FAL (1994) for the equipment emissions and NREL's US Life Cycle Inventory Database (USLCI) (NREL, 2015). The NREL emission factor assumes a diesel, short-haul truck.

5.2.4 Estimating Utility CO_2 Emissions Avoided

Most WTE plants in the United States produce electricity. Only a few cogenerate electricity and steam. In this analysis, EPA assumed that the energy recovered with MSW combustion would be in the form of electricity, with the exception of two materials that are not assumed to be combusted at WTE plants. For tires, the avoided utility CO_2 emissions per ton of tires combusted is based on the weighted average of three tire combustion pathways: combustion at cement kilns, power plants, and pulp and paper mills. For asphalt shingles, the avoided utility CO_2 emissions per ton of shingles combusted is equal to the amount of avoided refinery gas combusted at cement kilns where asphalt shingles are combusted. The avoided utility CO_2 emissions analysis is shown in Exhibit 5-2. EPA used three data elements to estimate the avoided electric utility CO_2 emissions associated with combustion of waste in a WTE plant: (1) the energy content of mixed MSW and of each separate waste material considered, (2) the combustion system efficiency in converting energy in MSW to delivered electricity, and (3) the electric utility CO_2 emissions avoided per kilowatt-hour (kWh) of electricity delivered by WTE plants.

Exhibit 5-2: Avoided Utility GHG Emissions from Combustion at WTE Facilities

(a) Material Combusted	(b) Energy Content (Million Btu Per Ton)	(c) Mass Burn Combustion System Efficiency (%)	(d) RDF Combus-tion System Efficiency (%)	(e) Emission Factor for Utility-Generated Electricity[a] ($MTCO_2E$/ Million Btu of Electricity Delivered)	(f) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities[a] ($MTCO_2E$) (f = b × c × e)	(g) Avoided Utility CO_2 per Ton Combusted at RDF Facilities ($MTCO_2E$) (g = b × d × e)
Aluminum Cans	-0.67[b]	17.8%	16.3%	0.21	-0.03	-0.02
Aluminum Ingot	-0.67	17.8%	16.3%	0.21	-0.03	-0.02
Steel Cans	-0.42[b]	17.8%	16.3%	0.21	-0.02	-0.01
Copper Wire	-0.55[c]	17.8%	16.3%	0.21	-0.02	-0.02
Glass	-0.47[b]	17.8%	16.3%	0.21	-0.02	-0.02
HDPE	39.97[d]	17.8%	16.3%	0.21	1.52	1.38
LDPE	39.75[d]	17.8%	16.3%	0.21	1.51	1.38
PET	21.20	17.8%	16.3%	0.21	0.80	0.73
LLDPE	39.89	17.8%	16.3%	0.21	1.51	1.38
PP	39.90	17.8%	16.3%	0.21	1.51	1.38
PS	36.00	17.8%	16.3%	0.21	1.37	1.25
PVC	15.75	17.8%	16.3%	0.21	0.60	0.55
PLA	16.74	17.8%	16.3%	0.21	0.64	0.58
Corrugated Containers	14.09[d]	17.8%	16.3%	0.21	0.53	0.49
Magazines/Third-Class Mail	10.52[d]	17.8%	16.3%	0.21	0.40	0.36
Newspaper	15.90[d]	17.8%	16.3%	0.21	0.60	0.55
Office Paper	13.60[d]	17.8%	16.3%	0.21	0.52	0.47
Phone Books	15.90[d]	17.8%	16.3%	0.21	0.60	0.55
Textbooks	13.60[d]	17.8%	16.3%	0.21	0.52	0.47

(a) Material Combusted	(b) Energy Content (Million Btu Per Ton)	(c) Mass Burn Combustion System Efficiency (%)	(d) RDF Combus-tion System Efficiency (%)	(e) Emission Factor for Utility-Generated Electricity[a] ($MTCO_2E$/ Million Btu of Electricity Delivered)	(f) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities[a] ($MTCO_2E$) (f = b × c × e)	(g) Avoided Utility CO_2 per Ton Combusted at RDF Facilities ($MTCO_2E$) (g = b × d × e)
Dimensional Lumber	16.60[f]	17.8%	16.3%	0.21	0.63	0.58
Medium-Density Fiberboard	16.60[f]	17.8%	16.3%	0.21	0.63	0.58
Food Waste	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Food Waste (meat only)	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Food Waste (non-meat)	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Beef	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Poultry	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Grains	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Bread	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Fruits and Vegetables	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Dairy Products	4.74[d]	17.8%	16.3%	0.21	0.18	0.16
Yard Trimmings	5.60[g]	17.8%	16.3%	0.21	0.21	0.19
Grass	5.60[g]	17.8%	16.3%	0.21	0.21	0.19
Leaves	5.60[g]	17.8%	16.3%	0.21	0.21	0.19
Branches	5.60[g]	17.8%	16.3%	0.21	0.21	0.19
Mixed Paper (general)	NA	17.8%	16.3%	0.21	0.54	NA
Mixed Paper (primarily residential)	NA	17.8%	16.3%	0.21	0.53	NA
Mixed Paper (primarily from offices)	NA	17.8%	16.3%	0.21	0.49	NA
Mixed Metals	NA	17.8%	16.3%	0.21	-0.02	NA
Mixed Plastics	NA	17.8%	16.3%	0.21	1.09	NA
Mixed Recyclables	NA	17.8%	16.3%	0.21	0.50	NA
Mixed Organics	NA	17.8%	16.3%	0.21	0.20	NA
Mixed MSW	10.00[h]	17.8%	16.3%	0.21	0.38	0.35
Carpet	15.20[i]	17.8%	16.3%	0.21	0.58	0.53
Desktop CPUs	3.07	17.8%	16.3%	0.21	0.12	0.11
Portable Electronic Devices	3.07	17.8%	16.3%	0.21	0.12	0.11
Flat-panel Displays	3.07	17.8%	16.3%	0.21	0.12	0.11
CRT Displays	3.07	17.8%	16.3%	0.21	0.12	0.11
Electronic Peripherals	3.07	17.8%	16.3%	0.21	0.12	0.11
Hard-copy Devices	3.07	17.8%	16.3%	0.21	0.12	0.11
Mixed Electronics	3.07	17.8%	16.3%	0.21	0.12	0.11
Clay Bricks	NA	NA	NA	NA	NA	NA
Concrete	NA	NA	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA	NA	NA
Tires	27.78[j]	NA	NA	NA	1.57	1.57

(a) Material Combusted	(b) Energy Content (Million Btu Per Ton)	(c) Mass Burn Combustion System Efficiency (%)	(d) RDF Combus-tion System Efficiency (%)	(e) Emission Factor for Utility-Generated Electricity[a] ($MTCO_2E$/ Million Btu of Electricity Delivered)	(f) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities[a] ($MTCO_2E$) (f = b × c × e)	(g) Avoided Utility CO_2 per Ton Combusted at RDF Facilities ($MTCO_2E$) (g = b × d × e)
Asphalt Concrete	NA	NA	NA	NA	NA	NA
Asphalt Shingles	8.80	NA[k]	NA[k]	NA[k]	1.05[l]	1.05[l]
Drywall	NA	NA	NA	NA	NA	NA
Fiberglass Insulation	NA	NA	NA	NA	NA	NA
Vinyl Flooring	15.75	17.8%	16.3%	0.21	0.60	0.55
Wood Flooring	17.99[m]	21.5%[n]	16.3%	0.21	0.82	0.62

NA = Not applicable.
Note that totals may not add due to rounding, and more digits may be displayed than are significant.
[a] The values in this column are based on national average emissions from utility-generated electricity. The Excel version of WARM also allows users to choose region-specific utility-generated factors, which are contained in Exhibit 5-4.
[b] EPA developed these estimates based on data on the specific heat of aluminum, steel, and glass and calculated the energy required to raise the temperature of aluminum, steel, and glass from ambient temperature to the temperature found in a combustor (about 750° Celsius), based on Incropera and DeWitt (1990).
[c] Average of aluminum and steel.
[d] Source: EPA (1995). “Magazines” used as proxy for magazines/third-class mail; “mixed paper” used as a proxy for the value for office paper and textbooks; “newspapers” used as a proxy for phone books.
[e] Source: Gaines and Stodolsky (1993).
[f] EPA used the higher end of the MMBtu factor for basswood from the USDA-FS. Basswood is a relatively soft wood, so its high-end MMBtu content should be similar to an average factor for all wood types (Fons et al., 1962).
[g] Proctor and Redfern, Ltd. and ORTECH International (1993).
[h] Source: IWSA and American Ref-Fuel (personal communication, October 28, 1997). Mixed MSW represents the entire waste stream as disposed of.
[i] Source: Realff, M. (2010).
[j] Tires used as tire-derived fuel substitute for coal in cement kilns and electric utilities; used as a substitute for natural gas in pulp and paper facilities. Therefore, columns (d) through (h) are a weighted average of multiple tire combustion pathways, and are not calculated in the same manner as the other materials and products in the table.
[k] The avoided utility GHG emissions are assumed to equal avoided cement kiln refinery gas combustion, so this factor is not used.
[l] Assumes avoided cement kiln refinery gas combustion.
[m] Bergman and Bowe (2008), Table 3, p. 454. Note that this is in agreement with values already in WARM for lumber and medium-density fiberboard.
[n] Based on average heat rate of U.S. dedicated biomass electricity plants.

5.2.4.1 Energy Content

The energy content of each of the combustible materials in WARM is contained in column (b) of Exhibit 5-2. For the energy content of mixed MSW, EPA used a value of 10.0 million Btu (MMBtu) per short ton of mixed MSW combusted, which is a value commonly used in the WTE industry (IWSA and American Ref-Fuel, 1997). This estimate is within the range of values (9.0 to 13.0 MMBtu per ton) reported by FAL (1994) and is slightly higher than the 9.6 MMBtu per ton value reported in EPA’s *MSW Fact Book* (EPA, 1995). For the energy content of RDF, a value of 11.4 MMBtu per ton of RDF combusted was used (Harrington, 1997). This estimate is within the range of values (9.6 to 12.8 MMBtu per ton) reported by the DOE’s National Renewable Energy Laboratory (NREL, 1992). For the energy content of specific materials in MSW, EPA consulted three sources: (1) EPA’s *MSW Fact Book* (1995), a compilation of data from primary sources, (2) a report by Environment Canada (Procter and Redfern, Ltd. and ORTECH International, 1993), and (3) a report by Argonne National Laboratories (Gaines and Stodolsky, 1993). EPA assumed that the energy contents reported in the first two of these sources were for materials with moisture contents typically found for the materials in MSW (the sources imply this but do not explicitly state it). The Argonne study reports energy content on a dry weight basis.

5.2.4.2 Combustion System Efficiency

To estimate the combustion system efficiency of mass burn plants, EPA used a net value of 550 kWh generated by mass burn plants per ton of mixed MSW combusted (Zannes, 1997).

To estimate the combustion system efficiency of RDF plants, EPA evaluated three sources: (1) data supplied by an RDF processing facility located in Newport, MN (Harrington, 1997); (2) the Integrated Waste Services Association report, *The 2000 Waste-to-Energy Directory: Year 2000* (IWSA, 2000); and (3) the National Renewable Energy Laboratory (NREL, 1992). EPA used the Newport Processing Facility's reported net value of 572 kWh generated per ton of RDF for two reasons. First, this value is within the range of values reported by the other sources. Second, the Newport Processing Facility provides a complete set of data for evaluating the overall system efficiency of an RDF plant. The net energy value reported accounts for the estimated energy required to process MSW into RDF and the estimated energy consumed by the RDF combustion facility. The dataset includes estimates on the composition and amount of MSW delivered to the processing facility, as well as estimates for the heat value of RDF, the amount of energy required to process MSW into RDF, and the amount of energy used to operate the RDF facility.

Next, EPA considered losses in transmission and distribution of electricity specific to WTE combustion facilities. The U.S. average transmission and distribution ("line") loss rate is about nine percent, although for some facilities or cities, this rate may be lower. According to IWSA and American Ref-Fuel (1997), this rate could be as low as four percent. IWSA supports a five percent line loss rate, and for purposes of this analysis, we assume this value. Using the five percent loss rate, EPA estimated that 523 kWh are delivered per ton of waste combusted at mass burn facilities, and 544 kWh are delivered per ton of waste input at RDF facilities.

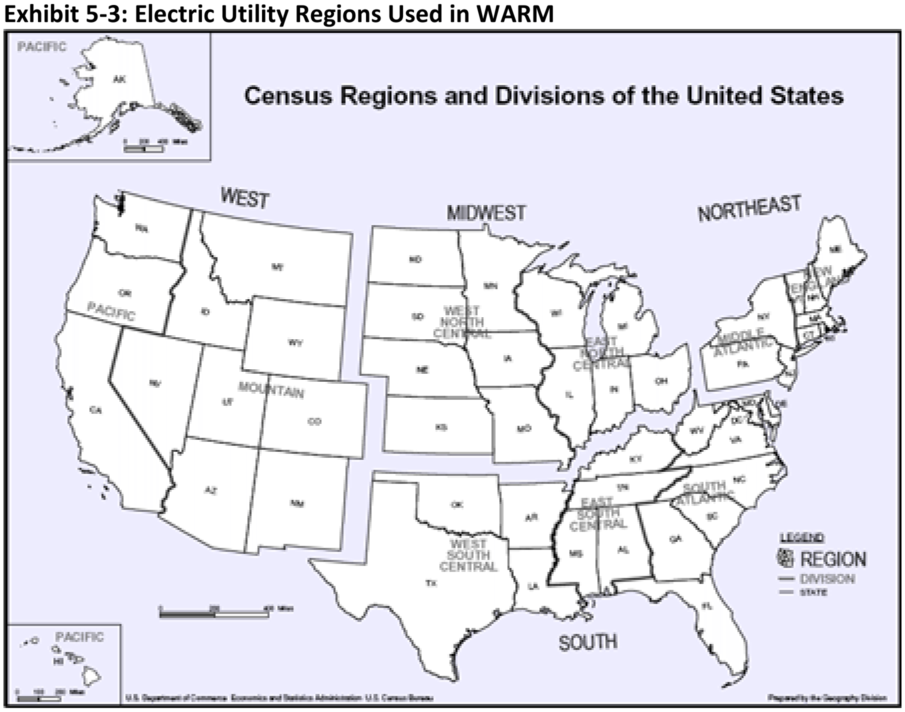
EPA then used the value for the delivered kWh per ton of waste combusted to derive the implicit combustion system efficiency (i.e., the percentage of energy in the waste that is ultimately delivered in the form of electricity). To determine this efficiency, we estimate the MMBtu of MSW needed to deliver one kWh of electricity. EPA divided the MMBtu per ton of waste by the delivered kWh per ton of waste to obtain the MMBtu of waste per delivered kWh. The result is 0.0191 MMBtu per kWh for mass burn and 0.0210 MMBtu per kWh for RDF. The physical constant for the energy in one kWh (0.0034 MMBtu) is then divided by the MMBtu of MSW and RDF needed to deliver one kWh, to estimate the total system efficiency at 17.8 percent for mass burn and 16.3 percent for RDF (see Exhibit 5-2, columns (d) and (e)). Note that the total system efficiency is the efficiency of translating the energy content of the fuel into the energy content of delivered electricity. The estimated system efficiencies of 17.8 and 16.3 percent reflect losses in (1) converting energy in the fuel into steam, (2) converting energy in steam into electricity, and (3) delivering electricity.

5.2.4.3 Electric Utility Carbon Emissions Avoided

To estimate the avoided utility GHG emissions from waste combustion, EPA used "non-baseload" emission factors from EPA's Emissions and Generation Resource Integrated Database (eGRID). EPA made the decision to use non-baseload factors rather than a national average of only fossil-fuel plants[28] because the non-baseload emission rates provide a more accurate estimate of the marginal emissions rate. The non-baseload rates scale emissions from generating units based on their capacity factor. Plants that run at more than 80 percent capacity are considered “baseload” generation and not included in the “non-baseload” emission factor; a share of generation from plants that run between 80 percent and 20 percent capacity is included in the emission factor based on a “linear relationship,” and all plants with capacity factors below 20 percent are included (E.H. Pechan & Associates, 2006).

In order to capture the regional differences in the emissions rate due to the variation in sources of electricity generation, WARM first uses state-level eGRID non-baseload emission factors and aggregates them into weighted average regional emission factors based on fossil-fuel-only state electricity generation. The geographic regions are based on U.S. Census Bureau-designated areas. Exhibit 5-3 contains a map, prepared by the U.S. Census Bureau, of the nine regions. Exhibit 5-4 shows the national average eGRID emission factor and the factors for each of the nine geographic regions. In addition to the calculated regional non-baseload emission factors, EPA also utilized eGRID’s national non-baseload emission factor to represent the national average non-baseload avoided utility emission factor. The resulting non-baseload regional and national average estimates for utility carbon emissions avoided for each material at mass burn facilities are shown in Exhibit 5-5. Columns (g) and (h), respectively, of Exhibit 5-2 show the national average estimates for mass burn and RDF facilities.

Exhibit 5-3: Electric Utility Regions Used in WARM



Source: U.S. Census Bureau (2009).

[28] While coal accounts for 33 percent of U.S. primary energy consumption—and 56 percent of fossil-fuel consumption—in the electricity sector, these plants may serve as baseload power with marginal changes in electricity supply met by natural gas plants in some areas (EIA, 2018). Natural gas plants have a much lower emissions rate than the coal-dominated national average of fossil-fuel plants.

Exhibit 5-4: Avoided Utility Emission Factors by Region

Region	Emission Factors for Utility-Generated Electricity[a] (MTCO$_2$E/Million Btu of Electricity Delivered)
National Average	0.221
Pacific	0.151
Mountain	0.230
West-North Central	0.294
West-South Central	0.193
East-North Central	0.265
East-South Central	0.237
New England	0.156
Middle Atlantic	0.203
South Atlantic	0.231

[a] Includes transmission and distributions losses, which are assumed to be 5.8% (EIA, 2018).

Exhibit 5-5: Avoided Utility GHG Emissions at Mass Burn Facilities by Region (MTCO$_2$E/Short Ton of Material Combusted)

Material Combusted	National Average	Pacific	Mount-ain	West-North Central	West-South Central	East-North Central	East-South Central	New England	Middle Atlantic	South Atlantic
Aluminum Cans	-0.03	-0.02	-0.03	-0.03	-0.02	-0.03	-0.03	-0.02	-0.02	-0.02
Aluminum Ingot	-0.03	-0.02	-0.03	-0.03	-0.02	-0.03	-0.03	-0.02	-0.02	-0.02
Steel Cans	-0.02	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02
Copper Wire	-0.02	-0.01	-0.02	-0.03	-0.02	-0.03	-0.02	-0.01	-0.02	-0.02
Glass	-0.02	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	-0.02
HDPE	1.52	1.02	1.66	21.94	1.42	1.94	1.57	1.01	1.38	1.47
LDPE	1.51	1.02	1.65	1.93	1.41	1.93	1.56	1.00	1.38	1.46
PET	0.80	0.54	0.88	1.03	0.75	1.03	0.83	0.53	0.73	0.78
LLDPE	1.51	1.02	1.66	1.93	1.41	1.94	1.57	1.00	1.38	1.47
PP	1.51	1.02	1.66	1.93	1.41	1.94	1.57	1.00	1.38	1.47
PS	1.37	0.92	1.50	1.74	1.27	1.75	1.41	0.91	1.25	1.432
PVC	0.60	0.40	0.66	0.76	0.56	0.77	0.62	0.40	0.54	0.58
PLA	0.64	0.43	0.70	0.81	0.59	0.81	0.66	0.42	0.58	0.61
Corrugated Containers	0.53	0.36	0.59	0.68	0.50	0.68	0.55	0.35	0.49	0.52
Magazines/Third-Class Mail	0.40	0.27	0.44	0.51	0.37	0.51	0.41	0.26	0.36	0.39
Newspaper	0.60	0.41	0.66	0.77	0.56	0.77	0.62	0.40	0.55	0.58
Office Paper	0.52	0.35	0.57	0.66	0.48	0.66	0.53	0.34	0.47	0.50
Phone Books	0.60	0.41	0.66	0.77	0.56	0.77	0.62	0.40	0.55	0.58
Textbooks	0.52	0.35	0.57	0.66	0.48	0.66	0.53	0.34	0.47	0.50
Dimensional Lumber	0.63	0.42	0.69	0.80	0.59	0.81	0.65	0.42	0.57	0.61
Medium-Density Fiberboard	0.63	0.42	0.69	0.80	0.59	0.81	0.65	0.42	0.57	0.61
Food Waste	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17
Food Waste (meat only)	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17
Food Waste (non-meat)	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17
Beef	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17
Poultry	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17
Grains	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17
Bread	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.217
Fruits and Vegetables	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17

Material Combusted	National Average	Pacific	Mount-ain	West-North Central	West-South Central	East-North Central	East-South Central	New England	Middle Atlantic	South Atlantic
Dairy Products	0.18	0.12	0.20	0.23	0.17	0.23	0.19	0.12	0.16	0.17
Yard Trimmings	0.21	0.14	0.23	0.27	0.20	0.27	0.22	0.14	0.19	0.21
Mixed MSW	0.38	0.26	0.42	0.48	0.35	0.49	0.39	0.25	0.35	0.37
Carpet	0.58	0.39	0.63	0.74	0.54	0.74	0.60	0.38	0.53	0.56
Desktop CPUs	0.12	0.08	0.13	0.15	0.11	0.15	0.12	0.08	0.11	0.11
Portable Electronic Devices	0.12	0.08	0.13	0.15	0.11	0.15	0.12	0.08	0.11	0.11
Flat-panel Displays	0.12	0.08	0.13	0.15	0.11	0.15	0.12	0.08	0.11	0.11
CRT Displays	0.12	0.08	0.13	0.15	0.11	0.15	0.12	0.08	0.11	0.11
Electronic Peripherals	0.12	0.08	0.13	0.15	0.11	0.15	0.12	0.08	0.11	0.11
Hard-copy Devices	0.12	0.08	0.13	0.15	0.11	0.15	0.12	0.08	0.11	0.11
Mixed Electronics	0.12	0.08	0.13	0.15	0.11	0.15	0.12	0.08	0.11	0.11
Tires[a]	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
Asphalt Shingles[b]	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Vinyl Flooring	0.60	0.40	0.66	0.76	0.56	0.77	0.62	0.40	0.54	0.58
Wood Flooring	0.82	0.56	0.90	1.05	0.77	1.06	0.85	0.55	0.75	0.80

Note that the "National Average" column is also represented in column (g) of Exhibit 5-2.
[a] Assumes weighted average avoided utility GHG emissions for multiple tire combustion pathways.
[b] Assumes avoided cement kiln refinery gas combustion.

5.2.5 Avoided CO_2 Emissions Due to Steel Recycling

WARM estimates the avoided CO_2 emissions from increased steel recycling made possible by steel recovery from WTE plants for steel cans, mixed MSW, electronics, and tires. Most MSW combusted with energy recovery in the United States is combusted at WTE plants that recover ferrous metals (e.g., iron and steel).[29] Note that EPA does not credit increased recycling of nonferrous materials due to a lack of data on the proportions of those materials being recovered. Therefore, the result tends to overestimate net GHG emissions from combustion.

For mixed MSW, EPA estimated the amount of steel recovered per ton of mixed MSW combusted, based on (1) the amount of MSW combusted in the United States, and (2) the amount of steel recovered, post-combustion. Ferrous metals are recovered at approximately 98 percent of WTE facilities in the United States (Bahor, 2010) and at five RDF processing facilities that do not generate power on-site. These facilities recovered a total of nearly 706,000 short tons per year of ferrous metals in 2004 (IWSA, 2004). By dividing 706,000 short tons (total U.S. steel recovery at combustors) by total U.S. combustion of MSW, which is 28.5 million tons (Van Haaren al., 2010), EPA estimated that 0.02 short tons of steel are recovered per short ton of mixed MSW combusted (as a national average).

For steel cans, EPA first estimated the national average proportion of steel cans entering WTE plants that would be recovered. As noted above, approximately 98 percent of MSW destined for combustion goes to facilities with a ferrous recovery system. At these plants, approximately 90 percent

[29] EPA did not consider any recovery of materials from the MSW stream that might occur before MSW is delivered to the combustor. EPA considered such prior recovery to be unrelated to the combustion operation—unlike the recovery of steel from combustor ash, an activity that is an integral part of the operation of many combustors.

of steel is recovered (Bahor, 2010). EPA multiplied these percentages to estimate the weight of steel cans recovered per ton of MSW combusted—about 0.88 tons recovered per ton combusted.

Finally, to estimate the avoided CO_2 emissions due to increased recycling of steel, EPA multiplied (1) the weight of steel recovered by (2) the avoided CO_2 emissions per ton of steel recovered. The estimated avoided CO_2 emissions results are in column (d) of Exhibit 5-6. For more information on the GHG benefits of recycling, see the Recycling and Metals chapters.

Exhibit 5-6: Avoided GHG Emissions Due to Increased Steel Recovery from MSW at WTE Facilities

(a) Material Combusted	(b) Short Tons of Steel Recovered per Short Ton of Waste Combusted (Short Tons)	(c) Avoided CO_2 Emissions per Short Ton of Steel Recovered ($MTCO_2E$/Short Ton)	(d) Avoided CO_2 Emissions per Short Ton of Waste Combusted ($MTCO_2E$/Short Ton)[a]
Aluminum Cans	–	–	–
Aluminum Ingot	–	–	–
Steel Cans	0.88	1.83	-1.62
Copper Wire	–	–	–
Glass	–	–	–
HDPE	–	–	–
LDPE	–	–	–
PET	–	–	–
LLDPE	–	–	–
PP	–	–	–
PS	–	–	–
PVC	–	–	–
PLA	–	–	–
Corrugated Containers	–	–	–
Magazines/Third-Class Mail	–	–	–
Newspaper	–	–	–
Office Paper	–	–	–
Phone Books	–	–	–
Textbooks	–	–	–
Dimensional Lumber	–	–	–
Medium-Density Fiberboard	–	–	–
Food Waste	–	–	–
Food Waste (meat only)	–	–	–
Food Waste (non-meat)	–	–	–
Beef	–	–	–
Poultry	–	–	–
Grains	–	–	–
Bread	–	–	–
Fruits and Vegetables	–	–	–
Dairy Products	–	–	–
Yard Trimmings	–	–	–
Mixed Paper (general)	–	–	–
Mixed Paper (primarily residential)	–	–	–
Mixed Paper (primarily from offices)	–	–	–
Mixed Metals	–	–	-1.04
Mixed Plastics	–	–	–
Mixed Recyclables	–	–	-0.04
Mixed Organics	–	–	–
Mixed MSW	0.02	1.83	-0.04
Carpet	–	–	–

(a) Material Combusted	(b) Short Tons of Steel Recovered per Short Ton of Waste Combusted (Short Tons)	(c) Avoided CO_2 Emissions per Short Ton of Steel Recovered ($MTCO_2E$/Short Ton)	(d) Avoided CO_2 Emissions per Short Ton of Waste Combusted ($MTCO_2E$/Short Ton)[a]
Desktop CPUs	0.52	1.83	0.95
Portable Electronic Devices	0.06	1.83	0.12
Flat-panel Displays	0.33	1.83	0.60
CRT Displays	0.04	1.83	0.08
Electronic Peripherals	0.02	1.83	0.03
Hard-copy Devices	0.33	1.83	0.60
Mixed Electronics	0.20	1.83	0.37
Clay Bricks	–	–	–
Concrete	–	–	–
Fly Ash	–	–	–
Tires	0.06	1.80	-0.10
Asphalt Concrete	–	–	–
Asphalt Shingles	–	–	–
Drywall	–	–	–
Fiberglass Insulation	–	–	–
Vinyl Flooring	–	–	–
Wood Flooring	–	–	–

– = Zero emissions.

Note that totals may not sum due to independent rounding, and more digits may be displayed than are significant.

[a] The value in column (d) is a national average and is weighted to reflect 90 percent recovery at the 98 percent of facilities that recover ferrous metals.

[b] Assumes that only 68 percent of facilities that use TDF recover ferrous metals.

5.3 RESULTS

The national average results of this analysis are shown in

Exhibit 5-7. The results from the last column of Exhibit 5-1, the last two columns of Exhibit 5-2, and the last column of Exhibit 5-6 are shown in columns (b) through (e) in

Exhibit 5-7. The net GHG emissions from combustion of each material at mass burn and RDF facilities are shown in columns (f) and (g), respectively. These net values represent the gross GHG emissions (column (b)), minus the avoided GHG emissions (columns (c), (d), and (e)). As stated earlier, these estimates of net GHG emissions are expressed for combustion in absolute terms, and are not values relative to another waste management option, although they must be used comparatively, as all WARM emission factors must be. They are expressed in terms of short tons of waste input (i.e., tons of waste prior to processing).

Exhibit 5-7: Net National Average GHG Emissions from Combustion at WTE Facilities

(a) Material Combusted	(b) Gross GHG Emissions per Ton Combusted ($MTCO_2E$/ Short Ton)	(c) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities ($MTCO_2E$ / Short Ton)[a]	(d) Avoided CO_2 Emissions per Ton Combusted Due to Steel Recovery ($MTCO_2E$ / Short Ton)	(e = b – c – d) Net GHG Emissions from Combustion at Mass Burn Facilities ($MTCO_2E$ / Short Ton)
Aluminum Cans	0.01	-0.03	–	0.03
Aluminum Ingot	0.01	-0.03	–	0.03
Steel Cans	0.01	-0.02	1.62	-1.59
Copper Wire	0.01	-0.02	–	0.03
Glass	0.01	-0.02	–	0.03
HDPE	2.80	1.58	–	1.29

LDPE	2.80	1.57	–	1.29
PET	2.05	0.84	–	1.24
LLDPE	2.80	1.51	–	1.29
PP	2.80	1.51	–	1.29
PS	3.02	1.37	–	1.66
PVC	1.26	0.60	–	0.66
PLA	0.01	0.64	–	-0.63
Corrugated Containers	0.05	0.53	–	-0.49
Magazines/Third-Class Mail	0.05	0.40	–	-0.35
Newspaper	0.05	0.60	–	-0.56
Office Paper	0.05	0.52	–	-0.47
Phone Books	0.05	0.60	–	-0.56
Textbooks	0.05	0.52	–	-0.47
Dimensional Lumber	0.05	0.63	–	-0.58
Medium-Density Fiberboard	0.05	0.63	–	-0.58
Food Waste	0.05	0.18	–	-0.13
Food Waste (meat only)	0.05	0.18	–	-0.13
Food Waste (non-meat)	0.05	0.18	–	-0.13
Beef	0.05	0.18	–	-0.13
Poultry	0.05	0.18	–	-0.13
Grains	0.05	0.18	–	-0.13
Bread	0.05	0.18	–	-0.13
Fruits and Vegetables	0.05	0.18	–	-0.13
Dairy Products	0.05	0.18	–	-0.13
Yard Trimmings	0.05	0.21	–	-0.17
Grass	0.05	0.21	–	-0.17
Leaves	0.05	0.21	–	-0.17
Branches	0.05	0.21	–	-0.17
Mixed Paper (general)[b]	0.05	0.54	–	-0.49
Mixed Paper (primarily residential)[b]	0.05	0.53	–	-0.49
Mixed Paper (primarily from offices)[b]	0.05	0.29	–	-0.45
Mixed Metals	0.01	-0.02	1.05	-1.02
Mixed Plastics	2.34	1.09	–	1.26
Mixed Recyclables	0.11	0.50	0.04	-0.42
Mixed Organics	0.05	0.20	–	-0.15
Mixed MSW	0.43	0.38	0.04	-0.01
Carpet	1.68	0.58	–	1.10
Desktop CPUs	0.40	-0.12	0.95	-0.66
Portable Electronic Device	0.88	-0.12	0.12	0.65
Flat-panel Displays	0.73	-0.12	0.60	0.03

CRT Displays	0.63	-0.12	0.08	0.45
Electronic Peripherals	2.22	-0.12	0.03	2.08
Hard-copy Devices	1.91	-0.12	0.60	1.20
Mixed Electronics	0.86	-0.12	0.37	0.39
Clay Bricks	NA	NA	NA	NA
Concrete	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA
Tires[c]	2.21	1.57	0.13	0.50
Asphalt Concrete	NA	NA	NA	NA
Asphalt Shingles	0.70	1.05[m]	–	-0.35
Drywall	NA	NA	–	NA
Fiberglass Insulation	NA	NA	–	NA
Vinyl Flooring	0.29	0.60	–	-0.31
Wood Flooring	0.09	0.82	–	-0.74

Note that totals may not sum due to independent rounding, and more digits may be displayed than are significant.
[a] The values in this column represent the national average avoided utility GHG emissions. WARM also allows users to use region-specific avoided utility emissions, which are contained in Exhibit 5-5.
[b] The summary values for mixed paper are based on the proportions of the four paper types (corrugated containers, magazines/third-class mail, newspaper, and office paper) that constitute the different "mixed paper" definitions.
[c] Tires used as TDF substitute for coal in cement kilns and utility boilers and as a substitute for natural gas, coal, and biomass in pulp and paper facilities.

In the Excel version of WARM, the user can select the state where the waste is being disposed of to determine the combustion emissions based on regional avoided utility emission factors. This functionality is not available in the online version of WARM, which only allows for national average emissions calculations.

Net GHG emissions are estimated to be negative for all biogenic sources of carbon (paper and wood products, organics) because CO_2 emissions from these sources are not counted, as discussed earlier.

As shown in

Exhibit 5-7, combustion of plastics results in substantial net GHG emissions. This result is primarily because of the high content of non-biomass carbon in plastics. Also, when combustion of plastics results in electricity generation, the utility carbon emissions avoided (due to displaced utility fossil fuel combustion) are much lower than the carbon emissions from the combustion of plastics. This result is largely due to the lower system efficiency of WTE plants compared with electric utility plants. Recovery of ferrous metals at combustors results in negative net GHG emissions for steel cans, due to the increased steel recycling made possible by ferrous metal recovery at WTE plants. Combustion of mixed MSW results in slightly negative GHG emissions because of the high proportion of biogenic carbon and steel.

5.4 LIMITATIONS

The certainty of the analysis presented in this chapter is limited by the reliability of the various data elements used. The most significant limitations are as follows:

- Combustion system efficiency of WTE plants may be improving. If efficiency improves, more utility CO_2 will be displaced per ton of waste combusted (assuming no change in utility emissions per kWh), and the net GHG emissions from combustion of MSW will decrease.
- Data for the RDF analysis were provided by the Minnesota Office of Environmental Assistance and were obtained from a single RDF processing facility and a separate RDF combustion facility. Research indicates that each RDF processing and combustion facility is different. For example, some RDF combustion facilities may generate steam for sale off-site, which can affect overall system efficiency. In addition, the amount of energy required to process MSW into RDF and the amount of energy used to operate RDF combustion facilities can be difficult to quantify and can vary among facilities on daily, seasonal and annual bases. This is one of the reasons that RDF factors are not included in WARM.
- The reported ranges for N_2O emissions were broad. In some cases, the high end of the range was 10 times the low end of the range. Research has indicated that N_2O emissions vary with the type of waste burned. Thus, the average value used for mixed MSW and for all MSW components should be interpreted as approximate values.
- For mixed MSW, the study assumed that all carbon in textiles is from synthetic fibers derived from petrochemicals (whereas, in fact, some textiles are made from cotton, wool and other natural fibers). Because EPA assumed that all carbon in textiles is non-biogenic, all of the CO_2 emissions from combustion of textiles as GHG emissions were counted. This assumption will slightly overstate the net GHG emissions from combustion of mixed MSW, but the magnitude of the error is small because textiles represent only a small fraction of the MSW stream. Similarly, the MSW category of "rubber and leather" contains some biogenic carbon from leather and natural rubber. By not considering this small amount of biogenic carbon, the analysis slightly overstates the GHG emissions from MSW combustion.
- Because the makeup of a given community's mixed MSW may vary from the national average, the energy content also may vary from the national average energy content used in this analysis. For example, MSW from communities with a higher- or lower-than-average recycling rate may have a different energy content, and MSW with more than the average proportion of dry leaves and branches will have a higher energy content.
- In this analysis, EPA used the national average recovery rate for steel. Where waste is sent to a WTE plant with steel recovery, the net GHG emissions for steel cans will be slightly lower (i.e., more negative). Where waste is sent to a WTE plant without steel recovery, the net GHG emissions for steel cans will be the same as for aluminum cans (i.e., close to zero). EPA did not credit increased recycling of nonferrous materials, because of a lack of information on the proportions of those materials. This assumption tends to result in overstated net GHG emissions from combustion.
- This analysis uses the "non-baseload" emission factors for electricity as the proxy for fuel displaced at the margin when WTE plants displace utility electricity. These non-baseload emission factors vary depending on the state where the waste is assumed to be combusted. If some other fuel or mix of fuels is displaced at the margin (e.g., a more coal-heavy fuel mix), the avoided utility CO_2 would be different.

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6 LANDFILLING

This chapter presents an overview of landfilling as a waste management strategy in relation to the development of material-specific emission factors for EPA's Waste Reduction Model (WARM). Estimates of the net greenhouse gas (GHG) emissions from landfilling most of the materials considered in WARM and several categories of mixed waste streams (e.g., mixed paper, mixed recyclables, and mixed municipal solid waste (MSW)) are included in the chapter.

6.1 A SUMMARY OF THE GHG IMPLICATIONS OF LANDFILLING

When food waste, yard trimmings, paper, and wood are landfilled, anaerobic bacteria degrade the materials, producing methane (CH_4) and carbon dioxide (CO_2). CH_4 is counted as an anthropogenic GHG because, even if it is derived from sustainably harvested biogenic sources, degradation would not result in CH_4 emissions if not for deposition in landfills. The CO_2 produced after landfilling is not counted as a GHG because it is considered part of the natural carbon cycle of growth and decomposition; for more information, see the text box on biogenic carbon in the WARM Background and Overview chapter. The other materials in WARM either do not contain carbon or do not biodegrade measurably in anaerobic conditions, and therefore do not generate any CH_4.

In addition to carbon emissions, some of the carbon in these materials (i.e., food waste, yard trimmings, paper, and wood) is stored in the landfill because these materials are not completely decomposed by anaerobic bacteria. Because this carbon storage would not normally occur under natural conditions (virtually all of the biodegradable material would degrade to CO_2, completing the photosynthesis/respiration cycle), this is counted as an anthropogenic sink. However, carbon in plastics and rubber that remains in the landfill is not counted as stored carbon because it is of fossil origin. Fossil carbon (e.g., petroleum, coal) is already considered "stored" in its natural state; converting it to plastic or rubber and putting it in a landfill only moves the carbon from one storage site to another.

EPA developed separate estimates of emissions from (1) landfills without gas recovery systems, (2) those that flare CH_4, (3) those that combust CH_4 for energy recovery, and (4) the national average mix of these three categories. The national average emission estimate accounts for the extent to which CH_4 will not be managed at some landfills, flared at some landfills, and combusted onsite for energy recovery at others.[30] The assumed mix of the three landfill categories that make up the national average for all material types are presented in Exhibit 6-1. These estimates are based on the amount of CH_4 generated by U.S. landfills, as reported in Subpart HH and TT from EPA's Greenhouse Gas Reporting Program (EPA 2018a), and the type of collection system from EPA's Landfill Methane Outreach Program (LMOP) (EPA 2018b).

[30] Although gas from some landfills is piped to an offsite power plant and combusted there, for the purposes of WARM, the simplifying assumption was that all gas for energy recovery was combusted onsite. This assumption was made due to the lack of information about the frequency of offsite power generation, piping distances, and losses from pipelines.

Exhibit 6-1: Percentage of CH_4 Generated from Each Type of Landfill

Landfill Type	Percentage of CH_4 from Landfills without LFG Recovery	Percentage of CH_4 from Landfills with LFG Recovery and Flaring only	CH_4 from Landfills with LFG Recovery and Electricity Generation (%)[31]
Industrial Landfill	98%	2%	–
Municipal Landfill	8%	26%	66%
Total	**13%**	**24%**	**63%**

– = Zero Emissions.

6.2 CALCULATING THE GHG IMPACTS OF LANDFILLING

The landfilling emission factors are made up of the following components:

1. CH_4 emissions from anaerobic decomposition of biogenic carbon compounds;
2. Transportation CO_2 emissions from landfilling equipment;
3. Biogenic carbon stored in the landfill; and
4. CO_2 emissions avoided through landfill gas-to-energy projects.

As mentioned above, WARM does not calculate CH_4 emissions, stored carbon, or CO_2 avoided for materials containing only fossil carbon (e.g., plastics, rubber). These materials have net landfilling emissions that are very low because they include only the transportation-related emissions from landfilling equipment. Some materials (e.g., newspaper, dimensional lumber) result in net storage (i.e., carbon storage exceeds CH_4 plus transportation energy emissions) at all landfills, regardless of whether gas recovery is present, while others (e.g., food waste) result in net emissions regardless of landfill gas collection and recovery practices. Whether the remaining materials result in net storage or net emissions depends on the landfill gas recovery scenario.

6.2.1 Carbon Stocks and Flows in Landfills

Exhibit 6-2 shows the carbon flows within a landfill system. Carbon entering the landfill can have one of several fates: exit as CH_4, exit as CO_2, exit as volatile organic compounds (VOCs), exit dissolved in leachate, or remain stored in the landfill.[32]

After entering landfills, a portion of the biodegradable material decomposes and eventually is transformed into landfill gas and/or leachate. Aerobic bacteria initially decompose the waste until the available oxygen is consumed. This stage usually lasts less than a week and is followed by the anaerobic acid state, in which carboxylic acids accumulate, the pH decreases, and some cellulose and hemicellulose decomposition occurs. Finally, during the methanogenic state, bacteria further decompose the biodegradable material into CH_4 and CO_2.

The rate of decomposition in landfills is affected by a number of factors, including: (1) waste composition; (2) factors influencing microbial growth (moisture, available nutrients, pH, temperature); and (3) whether the operation of the landfill retards or enhances waste decomposition. Most studies have shown that the amount of moisture in the waste, which can vary widely within a single landfill, is a

[31] The LMOP database indicates landfills that have active landfill-gas-to-energy (LFGTE) systems. However, it does not report the percentage of LFG recovered at these facilities for energy generation versus the percentage of LFG recovered for flaring. In WARM, all LFG generation at landfills with LFGTE systems is assumed to be recovered for energy. Therefore, this approach likely underestimates the total percentage of LFG generation that is flared in the U.S. by not accounting for LFG flaring at landfills with LFGTE systems.

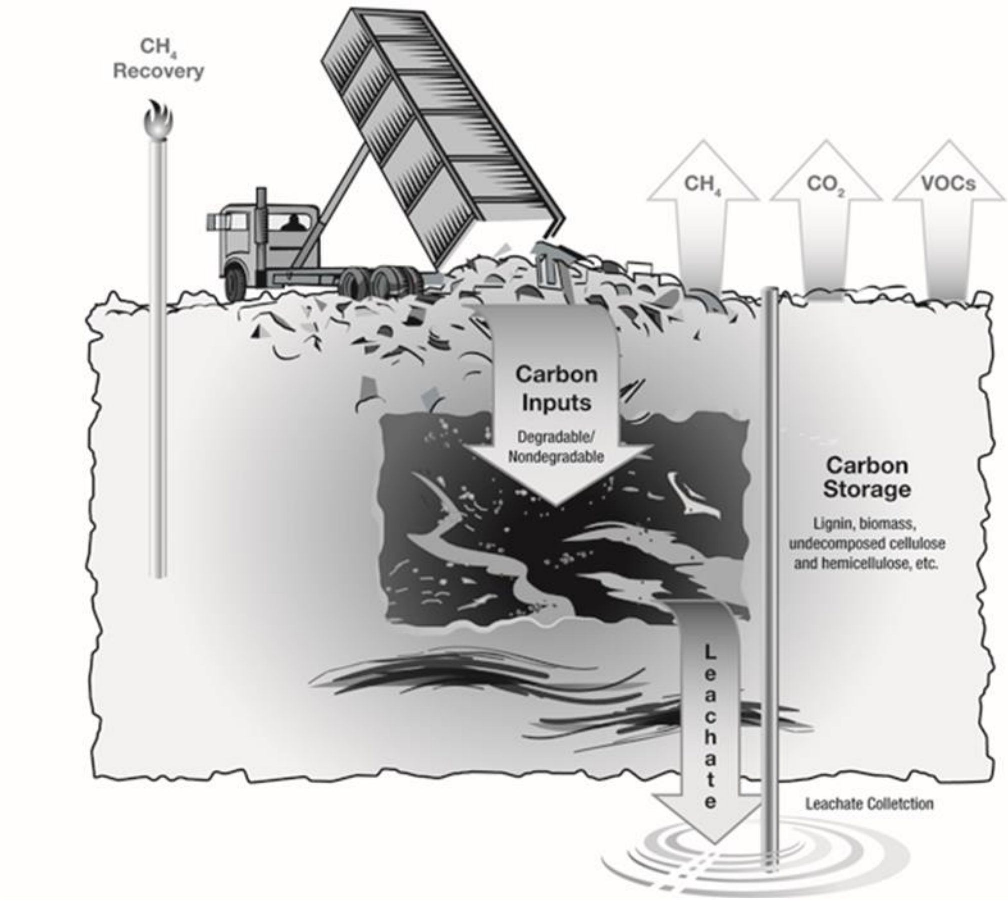
[32] The exhibit and much of the ensuing discussion are taken directly from Freed et al. (2004).

critical factor in the rate of decomposition (Barlaz et al., 1990). Due to this fact, the emission factors presented in WARM are per wet ton of waste.

Among the research conducted on the various components of the landfill carbon system, much to date has focused on the transformation of landfill carbon into CH_4. This interest has been spurred by a number of factors, including EPA's 1996 rule requiring large landfills to control landfill gas emissions (40 Code of Federal Regulations Part 60, Subparts Cc and WWW), the importance of CH_4 emissions in GHG inventories, and the market for CH_4 as an energy source. CH_4 production occurs in the methanogenic stage of decomposition, as methanogenic bacteria break down the fermentation products from earlier decomposition processes. Since CH_4 emissions result from waste decomposition, the quantity and duration of the emissions is dependent on the same factors that influence waste degradability (e.g., waste composition, moisture). The CH_4 portion of each material type's emission factor is discussed further in section 6.2.2.

Carbon dioxide is produced in the initial aerobic stage and in the anaerobic acid stage of decomposition. However, relatively little research has been conducted to quantify CO_2 emissions during these stages. Emissions during the aerobic stage are generally assumed to be a small proportion of total organic carbon inputs, and a screening-level analysis indicates that less than one percent of carbon is likely to be emitted through this pathway (Freed et al., 2004). Once the methanogenic stage of decomposition begins, landfill gas *as generated* is composed of approximately 50 percent CH_4 and 50 percent CO_2 (Bingemer and Crutzen, 1987). However, landfill gas *as collected* generally has a higher CH_4 concentration than CO_2 concentration (sometimes as much as a 60 percent: 40 percent ratio), because some of the CO_2 is dissolved in the leachate as part of the carbonate system ($CO_2 \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- \leftrightarrow CO_3^{2-}$).

Exhibit 6-2: Landfill Carbon Mass Balance



Source: Freed et al. (2004).

To date, very little research has been conducted on the role of VOC emissions in the landfill carbon mass balance. Given the thousands of compounds entering the landfill environment, tracking the biochemistry by which these compounds ultimately are converted to VOC is a complex undertaking. Existing research indicates that ethane, limonene, *n*-decane, *p*-dichlorobenzene, and toluene may be among the most abundant landfill VOCs (Eklund et al., 1998). Hartog (2003) reported non-CH_4 volatile organic compound concentrations in landfill gas at a bioreactor site in Iowa, averaging 1,700 parts per million (ppm) carbon by volume in 2001 and 925 ppm carbon by volume in 2002. If the VOC concentrations in landfill gas are generally of the order of magnitude of 1,000 ppm, VOCs would have a small role in the overall carbon balance, as concentrations of CH_4 and CO_2 will both be hundreds of times larger.

Leachate is produced as water percolates through landfills. Factors affecting leachate formation include the quantity of water entering the landfill, waste composition, and the degree of decomposition. Because it may contain materials capable of contaminating groundwater, leachate (and the carbon it contains) is typically collected and treated before being released to the environment, where it eventually degrades into CO_2. However, leachate is increasingly being recycled into the landfill as a means of inexpensive disposal and to promote decomposition, increasing the mass of biodegradable materials collected by the system and consequently enhancing aqueous degradation (Chan et al., 2002; Warith et al., 1999). Although a significant body of literature exists on landfill leachate formation, little research is available on the carbon implications of this process. Based on a screening analysis, Freed et al. (2004) found that loss as leachate may occur for less than one percent of total carbon inputs to landfills.

In mass balance terms, carbon storage can be characterized as the carbon that remains after accounting for the carbon exiting the system as landfill gas or dissolved in leachate. On a dry weight basis, municipal refuse contains 30–50 percent cellulose, 7–12 percent hemicellulose and 15–28 percent lignin (Hilger and Barlaz, 2001). Although the degradation of cellulose and hemicellulose in landfills is well documented, lignin does not degrade to a significant extent under anaerobic conditions (Colberg, 1988). Landfills in effect store some of carbon from the cellulose and hemicellulose and all of the carbon from the lignin that is buried initially. The amount of storage will vary with environmental conditions in the landfill; pH and moisture content have been identified as the two most important variables controlling decomposition (Barlaz et al., 1990). These variables and their effects on each material type's emission factor are discussed further below.

6.2.2 Estimating Emissions from Landfills

As discussed in section 6.2.1, when biodegradable materials such as wood products, food wastes, and yard trimmings are placed into a landfill, a fraction of the carbon within these materials degrades into CH_4 emissions. The quantity and timing of CH_4 emissions released from the landfill depends upon three factors: (1) how much of the original material decays into CH_4, (2) how readily the material decays under different landfill moisture conditions, and (3) landfill gas collection practices. This section describes how these three factors are addressed in WARM.

6.2.2.1 Methane Generation and Landfill Carbon Storage

The first step is to determine the amount of carbon contained in degradable materials that is emitted from the landfill as CH_4, and the amount that remains in long-term storage within the landfill. Although a large body of research exists on CH_4 generation from mixed solid wastes, only a few investigators—most notably Dr. Morton Barlaz and colleagues at North Carolina State University—have measured the behavior of specific waste wood, paper, food waste, and yard trimming components. The results of their experiments yield data on the inputs—specifically the initial carbon contents, CH_4 generation, and carbon stored—that are required for calculating material-specific emission factors for WARM.

Barlaz (1998) developed a series of laboratory experiments designed to measure biodegradation of these materials in a simulated landfill environment, in conditions designed to promote decomposition (i.e., by providing ample moisture and nutrients). Each waste component (e.g., grass, branches, leaves, paper) was dried; analyzed for cellulose, hemicellulose, and lignin content; weighed; placed in two-liter plastic containers (i.e., reactors); and allowed to decompose anaerobically under moist conditions (Eleazer et al., 1997). At the end of the experiment, the contents of the reactors were dried, weighed, and analyzed for cellulose, hemicellulose, lignin, and (in the case of food waste only) protein content. The carbon in these residual components is assumed to represent carbon that would remain undegraded over the long term in landfills: that is, it would be stored.

Based on these components, Dr. Barlaz estimated the initial biogenic carbon content of each waste material as a percent of dry matter. For some materials, the carbon content estimates have been updated to reflect more recent studies or to better reflect changes in material composition in recent years. Exhibit 6-3 shows the initial carbon contents of the wastes analyzed by Barlaz (1998) and Wang et al. (2011).

Exhibit 6-3: Initial Biogenic Carbon Content of Materials Tested in Barlaz (1998) and Wang et al. (2011)

Material	Initial Biogenic Carbon Content, % of Dry Matter	Source
Corrugated Containers	47%	Barlaz (1998)
Newspaper	49%	Barlaz (1998)
Office Paper	32%	Barlaz (1998)[a]
Coated Paper	34%	Barlaz (1998)
Food Waste	50%	Barlaz (1998)
Grass	45%	Barlaz (1998)
Leaves	46%	Barlaz (1998)
Branches	49%	Barlaz (1998)
Mixed MSW	42%	Barlaz (1998)
Gypsum Board	5%	Barlaz (1998)
Dimensional Lumber	49%	Wang et al. (2011)
Medium-density Fiberboard	44%	Wang et al. (2011)
Wood Flooring[b]	46%	Wang et al. (2011)

[a] Based on 2014 discussions with Dr. Morton Barlaz, the carbon content of office paper has been updated to account for an average calcium carbonate ($CaCO_3$) content of 20 percent in office paper in recent years.
[b] Based on an average of carbon content values for red oak and plywood in Wang et al. (2011).

The principal stocks and flows in the landfill carbon balance are:

- Initial carbon content (Initial C);
- Carbon output as CH_4 (CH_4^C);
- Carbon output as CO_2 (CO_2^C); and
- Residual carbon (i.e., landfill carbon storage, LF^C).

The initial carbon content, along with the other results from the Barlaz (1998), Wang et al. (2013), Wang et al. (2011), and Levis et al. (2013) experiments are used to estimate each material type's emission factor in WARM. The Barlaz (1998), Wang et al. (2013), Wang et al. (2011), and Levis et al. (2013) experiments did not capture CO_2 emissions in the carbon balance; however, in a simple system where the only carbon fates are CH_4, CO_2 and carbon storage, the carbon balance can be described as

$$CH_4^C + CO_2^C + LF^C = \text{Initial C}$$

If the only decomposition is anaerobic, then $CH_4^C = CO_2^C$.[33] Thus, the carbon balance can be expressed as

$$= \text{Initial C} 2 \times CH_4^C + LF^C = \text{Initial C}$$

Exhibit 6-4 shows the measured experimental values, in terms of the percentage of initial carbon for each of the materials analyzed, the implied landfill gas yield, and the sum of outputs as a percentage of initial carbon (Barlaz, 1998; Wang et al., 2013; Wang et al., 2011; Levis et al., 2013). As the sum of the outputs shows, the balance between carbon outputs and carbon inputs generally was not perfect. This imbalance is attributable to measurement uncertainty in the analytic techniques.

[33] The emissions ratio of CH_4 to CO_2 is 1:1 for carbohydrates (e.g., cellulose, hemicellulose). For proteins, the ratio is 1.65 CH_4 per 1.55 CO_2; for protein, it is $C_{3.2}H_5ON_{0.86}$ (Barlaz et al., 1989). Given the predominance of carbohydrates, for all practical purposes, the overall ratio is 1:1.

Exhibit 6-4: Experimental Values for CH_4 Yield and Carbon Storage[a]

(a) Material	(b) Measured CH_4 Yield as a % of Initial Carbon	(c) Implied Yield of Landfill Gas (CH_4+CO_2) as a Proportion of Initial Carbon (c = 2 × b)	(d) Measured Proportion of Initial Carbon Stored	(e) Output as % of Initial Carbon (e = c + d)
Corrugated Containers	17%	35%	55%	90%
Newspaper	8%	16%	85%	100%
Office Paper	29%	58%	12%	70%
Coated Paper	13%	26%	79%	100%
Food Waste	32%	63%	16%	79%
Grass	23%	46%	53%	99%
Leaves	8%	15%	85%	100%
Branches	12%	23%	77%	100%
Mixed MSW	16%	32%	19%	50%
Gypsum Board	0%	0%	55%	55%
Dimensional Lumber	1%	3%	88%	91%
Medium-density Fiberboard	1%	1%	84%	85%
Wood Flooring	2%	5%	99%	100%

[a] The CH_4, CO_2, and carbon stored from these experiments represents only the biogenic carbon in each material type.

To calculate the WARM emission factors, adjustments were made to the measured values so that exactly 100 percent of the initial carbon would be accounted for. After consultation with Dr. Barlaz, the following approach was adopted to account for exactly 100 percent of the initial carbon:

- For most materials where the total carbon output is less than the total carbon input (e.g., corrugated containers, office paper, food waste, grass, leaves), the "missing" carbon was assumed to be emitted as equal quantities of CH_4^C and CO_2^C. In these cases (corrugated containers, office paper, food waste, grass, leaves), the CH_4^C was increased with respect to the measured values as follows:

$$\frac{\text{Initial C-LF}^C}{2} = CH_4^C$$

This calculation assumes that $CO_2^C = CH_4^C$. In essence, the adjustment approach was to increase landfill gas production, as suggested by Dr. Barlaz.

- For coated paper, newspaper, and wood flooring, where carbon outputs were greater than initial carbon, the measurements of initial carbon content and CH_4 mass were assumed to be accurate. Here, the adjustment approach was to decrease carbon storage. Thus, landfill carbon storage was calculated as the residual of initial carbon content minus (2 × CH_4^C).

  The resulting adjusted CH_4 yields and carbon storage are presented in Exhibit 6-5.

- For branches, dimensional lumber, medium-density fiberboard, and mixed MSW, the measured CH_4 yield as a percentage of initial carbon was considered to be the most realistic estimate for methane yield, based on consultation with Dr. Barlaz. Therefore, no adjustment was made for these materials.
  - For gypsum board, the sulfate in wallboard is estimated to reduce methane generation, as bacteria use sulfate preferentially to the pathway that results in methane, as suggested by

Dr. Barlaz. As such, methane yield from gypsum board is likely to be negligible and is therefore adjusted to 0% in WARM.

Exhibit 6-5: Adjusted CH_4 Yield and Carbon Storage by Material Type

Material	Adjusted Yield of CH_4 as Proportion of Initial Carbon	Adjusted Carbon Storage as Proportion of Initial Carbon
Corrugated Containers[a]	22%	55%
Newspaper[b]	8%	84%
Office Paper[a]	44%	12%
Coated Paper[b]	13%	74%
Food Waste[a]	42%	16%
Grass[a]	23%	53%
Leaves[a]	8%	85%
Branches[c]	12%	77%
Mixed MSW[c]	16%	19%
Gypsum Board[d]	0%	55%
Dimensional Lumber[c]	1%	88%
Medium-density Fiberboard[c]	1%	84%
Wood Flooring[b]	2%	95%

[a] CH_4 yield is adjusted to account for measurement uncertainty in the analytic techniques to measure these quantities. For corrugated containers, office paper, food waste, grass, and leaves, the yield of CH_4 was increased such that the proportion of initial carbon emitted as landfill gas (i.e., $2 \times CH_4$) plus the proportion that remains stored in the landfill is equal to 100% of the initial carbon.

[b] For coated paper, newspaper, and wood flooring, the proportion of initial carbon that is stored in the landfill is decreased such that the proportion of initial carbon emitted as landfill gas (i.e., $2 \times CH_4$) plus the proportion that remains stored in the landfill is equal to 100% of the initial carbon.

[c] For branches, dimensional lumber, medium-density fiberboard, and mixed MSW, the measured CH_4 yield as a percentage of initial carbon and measured proportion of initial carbon stored shown in columns b and d, respectively of Exhibit 6-4 was considered to be the most realistic estimate for methane yield. Therefore, these values were not adjusted.

[d] For gypsum board, the sulfate in wallboard is estimated to reduce methane generation; thus, the methane yield from gypsum board is likely to be negligible and is therefore adjusted to 0%.

Dr. Barlaz's experiment did not test all of the biodegradable material types in WARM. EPA identified proxies for the remaining material types for which there were no experimental data. Magazines and third-class mail placed in a landfill were assumed to contain a mix of coated paper and office paper and were therefore assumed to behave like an average of those two materials. Similarly, phone books and textbooks were assumed to behave in the same way as newspaper and office paper, respectively. Results from two studies by Wang et al. were used for dimensional lumber, medium-density fiberboard, and wood flooring (2011; 2013). For wood flooring, the ratio of dry-to-wet weight was adjusted to more accurately represent the moisture content of wood lumber (Staley and Barlaz, 2009). Drywall was assumed to have characteristics similar to gypsum board. Exhibit 6-6 shows the landfill CH_4 emission factors and the final carbon storage factors for all applicable material types.

Exhibit 6-6: CH_4 Yield for Solid Waste Components

Material	Initial Biogenic Carbon Content	Adjusted Yield of CH_4 as Proportion Of Initial Carbon	Final (Adjusted) CH_4 Generation, $MTCO_2E$/Dry Metric Ton[a]	Final (Adjusted) CH_4 Generation ($MTCO_2E$ /Wet Short Ton)[b]
Corrugated Containers	47%	22%	3.48	2.62
Magazines/Third-Class Mail	36%	12%	1.43	1.19
Newspaper	49%	8%	1.33	1.05
Office Paper	32%	44%	4.71	3.89
Phonebooks	49%	8%	1.33	1.05
Textbooks	32%	44%	4.71	3.89
Dimensional Lumber	49%	1%	0.24	0.17
Medium-Density Fiberboard	44%	1%	0.08	0.06
Food Waste	49%	40%	6.63	1.62
Yard Trimmings				
Grass	45%	23%	3.48	0.57
Leaves	46%	8%	1.17	0.65
Branches	49%	12%	1.90	1.45
Mixed MSW	42%	16%	2.23	1.62
Drywall	5%	0%	0	0
Wood Flooring	43%	2%	0.27	0.18

[a] Final adjusted CH_4 generation per dry metric ton is the product of the initial carbon content and the final percent carbon emitted as CH_4 multiplied by the molecular ratio of carbon to CH_4 (12/16).
[b] CH_4 generation is converted from per dry metric ton to per wet short ton by multiplying the CH_4 generation on a dry metric ton basis by (1 – the material's moisture content) and by converting from metric tons to short tons of material.

6.2.2.2 Component-Specific Decay Rates

The second factor in estimating material-specific landfill emissions is the rate at which a material decays under anaerobic conditions in the landfill. The decay rate is an important factor that influences the landfill collection efficiency described further in the next section. Although the final adjusted CH_4 yield shown in Exhibit 6-6 will eventually occur no matter what the decay rate, the rate at which the material decays influences how much of the CH_4 yield will eventually be captured for landfills with collection systems.

Recent studies by De la Cruz and Barlaz (2010) found that different materials degrade at different rates relative to bulk MSW rates of decay. For example, one short ton of a relatively inert wood material—such as lumber—will degrade slowly and produce a smaller amount of methane than food waste, which readily decays over a much shorter timeframe. Materials will also degrade faster under wetter landfill conditions. Consequently, the rate at which CH_4 emissions are generated from decaying material in a landfill depends upon: (1) the type of material placed in the landfill, and (2) the moisture conditions of the landfill.

De la Cruz and Barlaz (2010) measured component-specific decay rates in laboratory experiments that were then scaled to field-level, component-specific decay rates based on mixed MSW field-scale decay rates published in EPA (1998) guidance.

To scale the laboratory-scale, component-specific decay rate measurements to field-scale values, De la Cruz and Barlaz (2010) assumed that the weighted average decay rate for a waste mixture of the same composition as MSW would be equal to the bulk MSW decay rate. They also related a lab-scale decay rate for mixed MSW to the field-scale decay rate using a scaling factor. Using these two relationships, the authors were able to estimate field-scale decay rates for different materials based on the laboratory data. The following equations were used to estimate the component-specific decay rates:

Equation 1

$$f \times \sum_{i=1}^{n} k_{lab,i} \times (wt.fraction)_i = decay\ rate$$

Equation 2

$$k_{field,i} = f \times k_{lab,i}$$

where,

f = a correction factor to force the left side of the equation to equal the overall MSW decay rate
$k_{lab,i}$ = the component-specific decay rate calculated from lab experiments
$k_{field,i}$ = the component-specific decay rate determined for the field
i = the i^{th} waste component

Based on the results from De la Cruz and Barlaz (2010), the Excel version of WARM allows users to select different component-specific decay rates based on different assumed moisture contents of the landfill to estimate the rate at which CH_4 is emitted for each material type (or "component"). The five MSW decay rates used are:

1. k = 0.02/year ("Dry"), corresponding to landfills receiving fewer than 20 inches of annual precipitation: based values reported in EPA (2010)
2. k = 0.04/year ("Moderate"), corresponding to landfills receiving between 20 and 40 inches of annual precipitation: based values reported in EPA (2010)
3. k = 0.06/year ("Wet"), corresponding to landfills receiving greater than 40 inches of annual precipitation: based values reported in EPA (2010)
4. k = 0.12/year ("Bioreactor"), corresponding to landfills operating as bioreactors where water is added until the moisture content reaches 40 percent moisture on a wet-weight basis: based on expert judgment using values reported in Barlaz et al. (2010) and Tolaymat et al. (2010)
5. k = 0.052/year ("National Average"), corresponding to a weighted average based on the share of waste received at each landfill type: based on expert judgment using values reported in EPA (2010)

The final waste component-specific decay rates as a function of landfill moisture conditions are provided in Exhibit 6-7.

Exhibit 6-7: Component-Specific Decay Rates (yr^{-1}) by Landfill Moisture Scenario

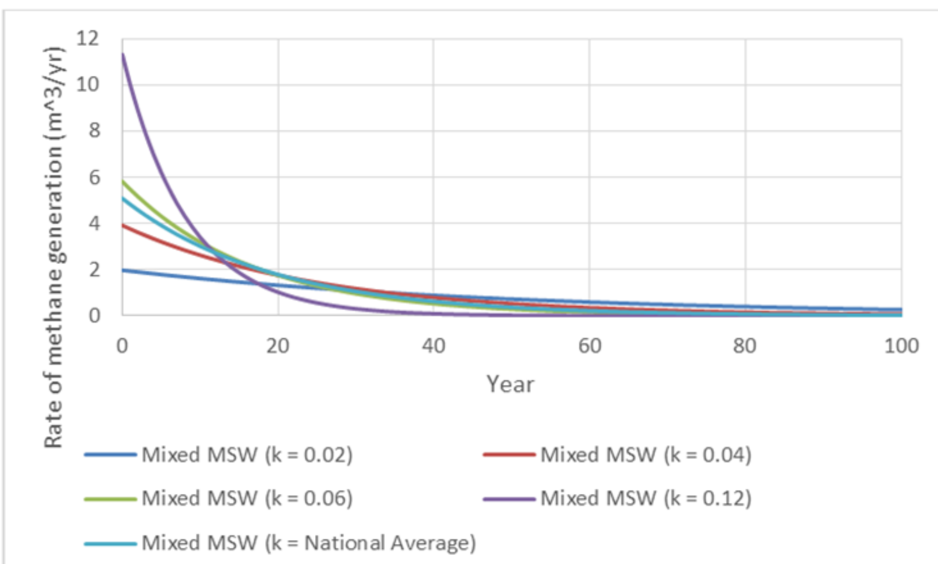
	Landfill Moisture Conditions				
Material	Dry	Moderate	Wet	Bioreactor	National Average
Corrugated Containers	0.01	0.02	0.03	0.06	0.03
Magazines/Third-Class Mail	0.06	0.12	0.18	0.37	0.16
Newspaper	0.02	0.03	0.05	0.10	0.04
Office Paper	0.01	0.03	0.04	0.09	0.04
Phone Books	0.02	0.03	0.05	0.10	0.04
Textbooks	0.01	0.03	0.04	0.09	0.04
Dimensional Lumber	0.04	0.08	0.12	0.25	0.11
Medium-Density Fiberboard	0.03	0.06	0.10	0.19	0.08
Food Waste	0.07	0.14	0.22	0.43	0.19
Yard Trimmings	0.10	0.20	0.29	0.59	0.26
Grass	0.15	0.30	0.45	0.89	0.39

Material	Landfill Moisture Conditions				
	Dry	Moderate	Wet	Bioreactor	National Average
Leaves	0.09	0.17	0.26	0.51	0.22
Branches	0.01	0.02	0.02	0.05	0.02
Mixed MSW	0.02	0.04	0.06	0.12	0.05
Drywall[a]	–	–	–	–	–
Wood Flooring[a]	–	–	–	–	–

– = Zero Emissions.
[a]Decay rates were not estimated since WARM assumes that the construction and demolition landfills where these materials are disposed of do not collect landfill gas.

The profile of methane emissions as materials decay in landfills over time is commonly approximated using a first-order decay methodology summarized in De la Cruz and Barlaz (2010). The CH_4 generation potential of landfilled waste decreases gradually throughout time and can be estimated using first order decomposition mathematics. The profile of methane emissions from landfills over time for mixed MSW is shown in Exhibit 6-8 as a graphic representation of the methane emissions approximated using a first-order decay equation. As Exhibit 6-8 shows, materials will degrade faster under wetter conditions in landfills (i.e., landfills whose conditions imply higher decay rates for materials).

Exhibit 6-8. Rate of Methane Generation for Mixed MSW as a Function of Decay Rate



Although in each landfill moisture scenario, the total final CH_4 yield for solid waste components (Exhibit 6-6) will eventually be emitted over time, the rate at which methane is emitted greatly depends on the decay rate. Finally, since different materials have very different methane emission profiles in landfills, the effectiveness and timing of the installation of landfill gas collection systems can greatly influence methane emissions, as discussed in the next section.

6.2.2.3 Landfill Gas Collection

WARM estimates the amount of methane that is collected by landfill gas collection equipment. In practice, the landfill gas collection system efficiency does not remain constant over the duration of gas production. Rather, the gas collection system at any particular landfill is typically expanded over time. Usually, only a small percentage (or none) of the gas produced soon after waste burial is collected, while almost all of the gas produced is collected once a final cover is installed. To provide a better estimate of gas collection system efficiency, EPA used a Monte Carlo analysis to estimate the fraction of produced gas that is vented directly, flared and utilized for energy recovery while considering annual waste disposal and landfill operating life (Levis and Barlaz, 2014).[34]

The gas collection efficiencies that WARM uses are evaluated from the perspective of a short ton of a specific material placed in the landfill at year zero. The efficiencies are calculated based on one of five moisture conditions (dry, moderate, wet, bioreactor, and national average conditions, described in section 6.2.2.2) and one of four landfill gas collection practices over a 100-year time period, which is approximately the amount of time required for 95 percent of the potential landfill gas to be produced under the "Dry" (k = 0.02/yr) landfill scenario. The final average efficiency is equal to the total CH_4 collected over 100 years divided by the total CH_4 produced over 100 years.

The combination of four different landfill gas collection scenarios and five different landfill moisture conditions means there are 20 possible landfill gas collection efficiencies possible for each material in WARM. The landfill collection efficiency scenarios are described below and the assumptions for each are shown in Exhibit 6-9:

1. Typical collection – phased-in collection with an improved cover; judged to represent the average U.S. landfill, although every landfill is unique and a typical landfill is an approximation of reality.
2. Worst-case collection – the minimum collection requirements under EPA's New Source Performance Standards.
3. Aggressive collection – landfills where the operator is aggressive in gas collection relative to a typical landfill; bioreactor landfills are assumed to collect gas aggressively.
4. California regulatory scenario[35] – equivalent to landfill management practices based on California regulatory requirements.

Exhibit 6-9: WARM Gas Collection Scenario Assumptions and Efficiencies Compared to EPA AP-42 (1998) with Landfill Gas Recovery for Energy

Scenario	Gas Collection Scenario Description	Gas Collection Scenario	Landfill Gas Collection Efficiency (%) for Mixed MSW[a]				
			MSW Decay Rate (yr^{-1})				
			0.02	0.04	0.06	0.12	National Average
AP-42	EPA default gas collection assumption (EPA 1998 AP-42) (not modeled in WARM)	All years: 75%	75.0	75.0	75.0	75.0	75.0
1	"Typical collection", judged to represent the average U.S. landfill	Years 0–1: 0% Years 2-4: 50% Years 5–14: 75% Years 15 to 1 year before final cover: 82.5% Final cover: 90%	68.2	65.0	64.1	60.6	64.8

[34] This improved analysis of landfill gas collection was incorporated in June 2014 into WARM Version 13.
[35] This additional landfill gas collection scenario was incorporated in June 2014 into WARM Version 13 to allow WARM users to estimate and view landfill management results based on California regulatory requirements.

Scenario	Gas Collection Scenario Description	Gas Collection Scenario	Landfill Gas Collection Efficiency (%) for Mixed MSW[a]				
			MSW Decay Rate (yr^{-1})				
			0.02	0.04	0.06	0.12	National Average
2	"Worst-case collection" under EPA New Source Performance Standards (NSPS)	Years 0-4: 0% Years 5-9: 50% Years 10–14: 75% Years 15 to 1 year before final cover: 82.5% Final cover: 90%	66.2	61.3	59.2	50.6	60.3
3	"Aggressive gas collection," typical bioreactor operation	Year 0: 0% Years 0.5-2: 50% Years 3–14: 75% Years 15 to 1 year before final cover: 82.5% Final Cover: 90%	68.6	65.8	66.3	63.9	66.4
4	"California regulatory scenario", landfill management based on California regulatory requirements	Year 0: 0% Year 1: 50% Years 2-7: 80% Years 8 to 1 year before final cover: 85% Final cover: 90%	83.6	79.5	77.4	72.9	78.8

[a] The values in this table are for landfills that recover gas for energy. In reality, a small share of gas recovered is eventually flared. The values provided in this table include both the gas recovered for energy and the small portion recovered for flaring.

The landfill gas collection efficiencies by material type for each of the four landfill collection efficiency scenarios and each of the five moisture conditions are provided in Exhibit 6-10. In addition to the gas collected, EPA also took into account the percentage of gas that is flared, oxidized, and emitted for landfills that recover gas for energy, as described in Levis and Barlaz (2014). Some of the uncollected methane is oxidized to CO_2 as it passes through the landfill cover; Levis and Barlaz (2014) adapted EPA recommendations for methane oxidation (71 FR 230, 2013) to develop the following oxidation rates at various stages of landfill gas collection:

- Without gas collection or final cover: 10 percent
- With gas collection before final cover: 20 percent
- After final cover installation: 35 percent

In the EPA recommendations, the fraction of uncollected methane that is oxidized varies with the methane flux (mass per area per time) and ranges from 10 percent to 35 percent (71 FR 230, 2013). Measurement or estimation of the methane flux is possible on a site-specific basis but requires assumptions on landfill geometry and waste density to estimate flux for a generic landfill as is represented by WARM. As such, the methane oxidation values published by EPA were used as guidance for the values listed above. Landfills with a final cover and a gas collection system in place will have a relatively low flux through the cover, which justifies the upper end of the range (35 percent) given by EPA. Similarly, landfills without a gas collection system in place will have a relatively high flux, suggesting that an oxidation rate of 10 percent is most appropriate. Landfills with a gas collection system in place but prior to final cover placement were assigned an oxidation rate of 20 percent. Based on preliminary calculations for a variety of landfill geometries and waste densities, Levis and Barlaz (2014) determined that the methane flux would justify an oxidation rate of 25 percent most but not all of the time. As such, an oxidation rate of 20 percent was adopted in WARM for landfills with gas collection before final cover (Levis and Barlaz, 2014).

For landfill gas that is not collected for energy use, EPA took into account the percentage of landfill CH_4 that is flared (when recovery for flaring is assumed), oxidized near the surface of the landfill, and emitted. Based on analysis by Levis and Barlaz, EPA estimated the percentage of the landfill CH_4 generated that are either flared, chemically oxidized or converted by bacteria to CO_2, and emitted for each material type for each of the four landfill collection efficiency scenarios and each of the five moisture conditions (Levis and Barlaz, 2014).

Exhibit 6-10: Waste Component-Specific Collection Efficiencies by Landfill Moisture Condition with Landfill Gas Recovery for Energy

	Typical Landfill Scenario					Worst-Case Landfill Scenario					Aggressive Collection Landfill Scenario					California Regulations Collection Scenario				
Material	Dry	Moderate	Wet	Bioreactor	National Avg.	Dry	Moderate	Wet	Bioreactor	National Avg.	Dry	Moderate	Wet	Bioreactor	National Avg.	Dry	Moderate	Wet	Bioreactor	National Avg.
Corrugated Containers	61%	55%	54%	55%	56%	60%	54%	53%	50%	54%	61%	56%	56%	58%	57%	66%	59%	60%	62%	61%
Magazines/ Third-Class Mail	59%	55%	52%	45%	54%	55%	46%	40%	26%	43%	61%	58%	57%	51%	57%	67%	63%	61%	54%	62%
Newspaper	62%	59%	59%	57%	59%	61%	56%	55%	49%	56%	62%	59%	61%	60%	61%	67%	64%	65%	65%	65%
Office Paper	62%	58%	58%	57%	59%	61%	56%	55%	50%	56%	62%	59%	60%	60%	60%	67%	63%	64%	65%	64%
Phone Books	62%	59%	59%	57%	59%	61%	56%	55%	49%	56%	62%	59%	61%	60%	61%	67%	64%	65%	65%	65%
Textbooks	62%	58%	58%	57%	59%	61%	56%	55%	50%	56%	62%	59%	60%	60%	60%	67%	63%	64%	65%	64%
Dimensional Lumber	62%	59%	57%	50%	58%	59%	52%	48%	35%	50%	63%	61%	60%	55%	60%	68%	66%	65%	60%	65%
Medium-Density Fiberboard	62%	60%	59%	53%	59%	60%	55%	51%	40%	53%	63%	62%	62%	58%	62%	68%	66%	67%	62%	67%
Food Waste	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Food Waste (meat only)	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Food Waste (non-meat)	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Beef	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Poultry	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Grains	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Bread	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Fruits and Vegetables	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Dairy Products	58%	53%	50%	42%	52%	53%	43%	36%	22%	40%	59%	56%	55%	49%	55%	65%	61%	59%	51%	60%
Yard Trimmings	54%	47%	44%	39%	47%	47%	37%	31%	21%	35%	55%	51%	49%	44%	50%	61%	55%	52%	45%	54%
Grass	49%	43%	39%	33%	41%	39%	27%	20%	9%	25%	51%	47%	45%	39%	46%	57%	51%	48%	38%	50%
Leaves	56%	51%	47%	40%	49%	50%	40%	33%	19%	37%	58%	54%	52%	46%	53%	64%	59%	57%	48%	58%
Branches	61%	53%	51%	52%	54%	60%	52%	51%	49%	53%	61%	54%	53%	54%	55%	65%	57%	57%	58%	59%
Mixed MSW	62%	60%	60%	57%	60%	61%	56%	55%	47%	56%	63%	61%	62%	60%	62%	67%	65%	67%	65%	66%

Material	Typical Landfill Scenario					Worst-Case Landfill Scenario					Aggressive Collection Landfill Scenario					California Regulations Collection Scenario				
	Dry	Moderate	Wet	Bioreactor	National Avg.	Dry	Moderate	Wet	Bioreactor	National Avg.	Dry	Moderate	Wet	Bioreactor	National Avg.	Dry	Moderate	Wet	Bioreactor	National Avg.
Gypsum[a]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Wood Flooring[a]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

– = Zero Emissions.

[a]WARM assumes that construction and demolition landfills do not collect landfill gas.

6.2.3 Emissions from Transportation to Landfills and Landfill Operation

WARM includes emissions associated with transportation and landfilling the material. Transportation energy emissions occur when fossil fuels are combusted to collect and transport material to the landfill facility and then to operate landfill operational equipment. To calculate the emissions, WARM relies on assumptions from FAL (1994) for the equipment emissions and NREL's US Life Cycle Inventory Database (USLCI) (NREL, 2015). The NREL emission factor assumes a diesel, short-haul truck. Exhibit 6-11 provides the transportation emission factor calculation.

Exhibit 6-11: Transportation CO_2 Emissions Assumptions and Calculation

Equipment	Total ($MTCO_2E$/Short Ton)
Collection Vehicles	0.00
Landfill Equipment	0.02
Total	**0.02**

6.2.4 Estimating Landfill Carbon Storage

The other anthropogenic fate of carbon in landfills is storage. As described in section 6.2.1, a portion of the carbon in biodegradable materials (i.e., food waste, yard trimmings, paper, and wood) that is not completely decomposed by anaerobic bacteria remains stored in the landfill. This carbon storage would not normally occur under natural conditions, so it is counted as an anthropogenic sink (IPCC, 2006; Bogner et al., 2007).

The discussion in section 6.2.2 on initial carbon contents and CH_4 generation includes the measured carbon stored from the Barlaz (1998), Wang et al. (2013), Wang et al. (2011), and Levis et al. (2013) experiments. For the most part, the amount of stored carbon measured as the output during these experiments is considered the final ratio of carbon stored to total initial dry weight of each material type. For newspaper, wood flooring, and coated paper—which is used to estimate landfill characteristics for magazines and third-class mail—the amount of carbon stored is reduced because carbon outputs were *greater than* initial carbon.

To estimate the final carbon storage factor, the proportion of initial carbon stored found in Exhibit 6-5 is multiplied by the initial carbon contents in Exhibit 6-3 to obtain the ratio of carbon storage to dry weight for each material type found in Exhibit 6-12. These estimates are then converted from dry weight to wet weight and from grams to metric tons of CO_2 per wet short ton of material. The last column of Exhibit 6-12 provides the final carbon storage factors for the biodegradable solid waste components modeled in WARM.

Exhibit 6-12: Carbon Storage for Solid Waste Components

Material	Ratio of Carbon Storage to Dry Weight (gram C/dry gram)	Ratio of Dry Weight to Wet Weight	Ratio of Carbon Storage to Wet Weight (gram C/wet gram)	Amount of Carbon Stored ($MTCO_2E$ per Wet Short Ton)
Corrugated Containers	0.26	0.83	0.22	0.72
Magazines/Third-Class Mail	0.28	0.92	0.25	0.85
Newspaper	0.41	0.87	0.36	1.19
Office Paper	0.04	0.91	0.04	0.12
Phonebooks	0.41	0.87	0.36	1.19
Textbooks	0.04	0.91	0.04	0.12
Dimensional Lumber	0.44	0.75	0.33	1.09
Medium-Density Fiberboard	0.37	0.75	0.28	0.92
Food Waste	0.10	0.27	0.03	0.09
Yard Trimmings	0.31	0.45	0.16	0.54
Grass	0.24	0.18	0.04	0.14
Leaves	0.39	0.62	0.24	0.79
Branches	0.38	0.84	0.32	1.06
Mixed MSW	0.08	0.80	0.06	0.21
Drywall	0.03	0.94	0.02	0.08
Wood Flooring	0.42	0.75	0.31	1.04

6.2.5 Electric Utility GHG Emissions Avoided

The CH_4 component of landfill gas that is collected from landfills can be combusted to produce heat and electricity, and recovery of heat and electricity from landfill gas offsets the combustion of other fossil fuel inputs. WARM models the recovery of landfill gas for electricity generation and assumes that this electricity offsets non-baseload electricity generation in the power sector.

WARM applies non-baseload electricity emission rates to calculate the emissions offset from landfill gas energy recovery because the model assumes that incremental increases in landfill energy recovery will affect non-baseload power plants (i.e., power plants that are "demand-following" and adjust to marginal changes in the supply and demand of electricity). EPA calculated non-baseload emission rates as the average emissions rate from power plants that combust fuel and have capacity factors less than 0.8 (EPA, 2015a).

EPA estimated the avoided GHG emissions per $MTCO_2E$ of CH_4 combusted using several physical constants and data from EPA's Landfill Methane Outreach Program and eGRID (EPA, 2013; EPA, 2018c). The mix of fuels used to produce electricity varies regionally in the United States; consequently, EPA applied a different CO_2-intensity for electricity generation depending upon where the electricity is offset. The Excel version of WARM includes CO_2-intensity emission factors for non-baseload electricity generated in nine different U.S. regions as well as a U.S.-average CO_2-intensity (EPA, 2015a). The formula used to calculate the quantity of electricity generation emissions avoided per $MTCO_2E$ of CH_4 combusted is as follows:

$$\frac{BTU_{CH4}}{H_{LFGTE}} \times a \times E_{Grid} = R$$

Where:

Btu_{CH4} = Energy content of CH_4 per $MTCO_2E$ CH_4 combusted; assumed to be 1,012 Btu per cubic foot of CH_4 (EPA, 2013), converted into Btu per $MTCO_2E$ CH_4 assuming 20 grams per cubic foot of CH_4 at standard temperature and pressure and a global warming potential of CH_4 of 21

H_{LFGTE} = Heat rate of landfill gas to energy conversion; assumed to be 11,700 Btu per kWh generated (EPA, 2013)

a = Net capacity factor of electricity generation; assumed to be 85 percent (EPA, 2013)

E_{grid} = Non-baseload CO_2-equivalent GHG emissions intensity of electricity produced at the regional or national electricity grid; values assumed for each region and U.S. average are shown in Exhibit 6-14

R = Ratio of GHG emissions avoided from electricity generation per $MTCO_2E$ of CH_4 combusted for landfill gas to energy recovery

Exhibit 6-13 shows variables in the GHG emissions offset for the national average fuel mix. The final ratio is the product of columns (a) through (h). Exhibit 6-14 shows the amount of carbon avoided per kilowatt-hour of generated electricity and the final ratio of $MTCO_2E$ avoided of utility carbon per $MTCO_2E$ of CH_4 combusted (column (g) and resulting column (i)).

Exhibit 6-13: Calculation to Estimate Utility GHGs Avoided Through Combustion of Landfill CH_4 for Electricity Based on National Average Electricity Grid Mix

(a) Metric Tons CH_4/$MTCO_2E$ CH_4 Combusted	(b) Grams CH_4/Metric Ton CH_4	(c) Cubic Ft. CH_4/ Gram CH_4	(d) Btu/Cubic Ft. CH_4	(e) kWh Electricity Generated/ Btu	(f) Electricity Generation Efficiency	(g) Kg Utility CO_2 Avoided/ kWh Generated Electricity	(h) Metric Tons Avoided Utility CO_2/Kg Utility CO_2	(i) Ratio of $MTCO_2E$ Avoided Utility CO_2 per $MTCO_2E$ CH_4 Combusted
0.04	1,000,000	0.05	1,012	0.00009	0.85	0.73	0.001	0.11

Exhibit 6-14: Ratio of $MTCO_2E$ Avoided Utility Carbon per $MTCO_2E$ CH_4 Combusted by Region

Region	Kg Utility CO_2 Avoided/kWh Generated Electricity	Ratio of $MTCO_2E$ Avoided Utility C per $MTCO_2E$ CH_4
Pacific	0.52	0.08
Mountain	0.78	0.12
West-North Central	1.00	0.15
West-South Central	0.66	0.10
East-North Central	0.90	0.13
East-South Central	0.81	0.12
New England	0.53	0.08
Mid Atlantic	0.69	0.10
South Atlantic	0.79	0.12
National Average	0.75	0.11

If regional avoided utility emission factors are not employed, WARM calculates U.S.-average avoided utility emission factors based on the percent of CH_4 generated at landfills in the nation with landfill gas recovery and electricity production found in Exhibit 6-1, and assuming U.S.-average, non-baseload electricity GHG emission intensity. Exhibit 6-15 shows this calculation for each material type for the national average fuel mix.

Exhibit 6-15: Overall Avoided Utility CO_2 Emissions per Short Ton of Waste Material (National Average Grid Mix)

(a)	(b)	Methane from Landfills With LFG Recovery and Electricity Generation					(h)
Material	CH_4 Generation ($MTCO_2E$/ Wet Short Ton) (Exhibit 6-6)	(c) Percentage of CH_4 Recovered (Exhibit 6-10)	(d) Utility GHG Emissions Avoided per $MTCO_2E$ CH_4 Combusted ($MTCO_2E$) (Exhibit 6-14)	(e) Percentage of CH_4 Recovered for Electricity Generation Not Utilized Due to LFG System "Down Time"	(f) Utility GHG Emissions Avoided ($MTCO_2E$/Wet Short Ton) (f = b × c × d × (1-e))	(g) Percentage of CH_4 From Landfills With LFG Recovery and Electricity Generation (Exhibit 6-1)	Net Avoided CO_2 Emissions from Energy Recovery ($MTCO_2E$/ Wet Short Ton) (h = f × g)
Corrugated Containers	2.62	56%	-0.11	3%	-0.15	63%	-0.10
Magazines/ Third-Class Mail	1.19	54%	-0.11	3%	-0.07	63%	-0.04
Newspaper	1.05	59%	-0.11	3%	-0.06	63%	-0.04
Office Paper	3.89	59%	-0.11	3%	-0.24	63%	-0.15
Phonebooks	1.05	59%	-0.11	3%	-0.06	63%	-0.04
Textbooks	3.89	59%	-0.11	3%	-0.24	63%	-0.15
Dimensional Lumber	0.17	58%	-0.11	3%	-0.05	63%	-0.01
Medium-Density Fiberboard	0.06	59%	-0.11	3%	0.00	63%	0.00
Food Waste	1.62	52%	-0.11	3%	-0.09	63%	-0.05
Yard Trimmings	0.81	47%	-0.11	3%	-0.04	63%	-0.02
Grass	0.57	41%	-0.11	3%	-0.02	63%	-0.02
Leaves	0.65	49%	-0.11	3%	-0.03	63%	-0.02
Branches	1.45	54%	-0.11	3%	-0.08	63%	-0.05
Mixed MSW	1.62	60%	-0.11	3%	-0.10	63%	-0.06
Drywall[a]	0.00	–	-0.11	3%	–	–	–
Wood Flooring[a]	0.18	–	-0.11	3%	–	–	–

– = Zero Emissions.
[a] WARM assumes that construction and demolition landfills do not collect landfill gas.

6.2.6 Net GHG Emissions from Landfilling

CH_4 emissions, transportation CO_2 emissions, carbon storage, and avoided utility GHG emissions are then summed to estimate the net GHG emissions from landfilling each material type. Exhibit 6-16 shows the net emission factors for landfilling each material based on typical landfill gas collection practices, average landfill moisture conditions (i.e., for landfills receiving between 20 and 40 inches of precipitation annually), and U.S.-average non-baseload electricity grid mix.

Exhibit 6-16: Net GHG Emissions from Landfilling ($MTCO_2E$/Short Ton)

Material	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Landfill	Landfill CH_4	Avoided CO_2 Emissions from Energy Recovery	Landfill Carbon Sequestration	Net Emissions (Post-Consumer)
Aluminum Cans	–	0.02	–	–	–	0.02

Material	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Landfill	Landfill CH_4	Avoided CO_2 Emissions from Energy Recovery	Landfill Carbon Sequestration	Net Emissions (Post-Consumer)
Aluminum Ingot	–	0.02	–	–	–	0.02
Steel Cans	–	0.02	–	–	–	0.02
Copper Wire	–	0.02	–	–	–	0.02
Glass	–	0.02	–	–	–	0.02
HDPE	–	0.02	–	–	–	0.02
LDPE	–	0.02	–	–	–	0.02
PET	–	0.02	–	–	–	0.02
LLDPE	–	0.02	–	–	–	0.02
PP	–	0.02	–	–	–	0.02
PS	–	0.02	–	–	–	0.02
PVC	–	0.02	–	–	–	0.02
PLA	–	0.02	–	–	-1.66	-1.64
Corrugated Containers	–	0.02	1.05	-0.10	-0.72	0.26
Magazines/Third-Class Mail	–	0.02	0.48	-0.04	-0.85	-0.39
Newspaper	–	0.02	0.40	-0.04	-1.19	-0.82
Office Paper	–	0.02	1.50	-0.15	-0.12	1.25
Phonebooks	–	0.02	0.40	-0.04	-1.19	-0.82
Textbooks	–	0.02	1.50	-0.15	-0.12	1.25
Dimensional Lumber	–	0.02	0.06	-0.01	-1.09	-1.01
Medium-density Fiberboard	–	0.02	0.02	0.00	-0.92	-0.88
Food Waste	–	0.02	0.66	-0.05	-0.09	0.54
Food Waste (meat only)	–	0.02	0.66	-0.05	-0.09	0.54
Food Waste (non-meat)	–	0.02	0.66	-0.05	-0.09	0.54
Beef	–	0.02	0.66	-0.05	-0.09	0.54
Poultry	–	0.02	0.66	-0.05	-0.09	0.54
Grains	–	0.02	0.66	-0.05	-0.09	0.54
Bread	–	0.02	0.66	-0.05	-0.09	0.54
Fruits and Vegetables	–	0.02	0.66	-0.05	-0.09	0.54
Dairy Products	–	0.02	0.66	-0.05	-0.09	0.54
Yard Trimmings	–	0.02	0.36	-0.02	-0.54	-0.18
Grass	–	0.02	0.27	-0.02	-0.14	0.13
Leaves	–	0.02	0.28	-0.02	-0.79	-0.52
Branches	–	0.02	0.60	-0.05	-1.06	-0.50
Mixed Paper (general)	–	0.02	0.93	-0.09	-0.72	0.14
Mixed Paper (primarily residential)	–	0.02	0.90	-0.09	-0.76	0.08
Mixed Paper (primarily from offices)	–	0.02	0.88	-0.08	-0.64	0.18
Mixed Metals	–	0.02	–	–	–	0.02
Mixed Plastics	–	0.02	–	–	–	0.02
Mixed Recyclables	–	0.02	0.79	-0.07	-0.65	0.09
Mixed Organics	–	0.02	0.53	-0.04	-0.30	0.21
Mixed MSW	–	0.02	0.61	-0.06	-0.21	0.36
Carpet	–	0.02	–	–	–	0.02
Desktop CPUs	–	0.02	–	–	–	0.02
Portable Electronic Devices	–	0.02	–	–	–	0.02

Material	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Landfill	Landfill CH_4	Avoided CO_2 Emissions from Energy Recovery	Landfill Carbon Sequestration	Net Emissions (Post-Consumer)
Flat-panel Displays	–	0.02	–	–	–	0.02
CRT Displays	–	0.02	–	–	–	0.02
Electronic Peripherals	–	0.02	–	–	–	0.02
Hard-copy Devices	–	0.02	–	–	–	0.02
Mixed Electronics	–	0.02	–	–	–	0.02
Clay Bricks	–	0.02	–	–	–	0.02
Concrete	–	0.02	–	–	–	0.02
Fly Ash	–	0.02	–	–	–	0.02
Tires	–	0.02	–	–	–	0.02
Asphalt Concrete	–	0.02	–	–	–	0.02
Asphalt Shingles	–	0.02	–	–	–	0.02
Drywall	–	0.02	–	–	-0.08	-0.06
Fiberglass Insulation	–	0.02	–	–	–	0.02
Vinyl Flooring	–	0.02	–	–	–	0.02
Wood Flooring[a]	–	0.02	0.16	0.00	-1.04	-0.86

– = Zero Emissions.

[a] WARM assumes that construction and demolition landfills do not collect landfill gas

In WARM, emissions from landfills are dependent on the user selection of one of four different landfill scenarios (i.e., "Landfills: National Average," "Landfills Without LFG Recovery," "Landfills With LFG Recovery and Flaring," and "Landfills With LFG Recovery and Electric Generation") as described in section 1. The net landfilling emission factors for landfilling each material based on the default options in WARM (i.e., typical landfill gas collection practices, average landfill moisture conditions, and U.S.-average non-baseload electricity grid mix) are shown in Exhibit 6-17.

Exhibit 6-17: Landfilling Net Emission Factors in WARM Using Default Options ($MTCO_2E$/Ton)

Material	Landfills: National Average (Exhibit 6-16)	Landfills without LFG Recovery	Landfills with LFG Recovery and Flaring	Landfills with LFG Recovery and Electricity Generation
Aluminum Cans	0.02	0.02	0.02	0.02
Aluminum Ingot	0.02	0.02	0.02	0.02
Steel Cans	0.02	0.02	0.02	0.02
Copper Wire	0.02	0.02	0.02	0.02
Glass	0.02	0.02	0.02	0.02
HDPE	0.02	0.02	0.02	0.02
LDPE	0.02	0.02	0.02	0.02
PET	0.02	0.02	0.02	0.02
LLDPE	0.02	0.02	0.02	0.02
PP	0.02	0.02	0.02	0.02
PS	0.02	0.02	0.02	0.02
PVC	0.02	0.02	0.02	0.02
PLA	-1.64	-1.64	-1.64	-1.64
Corrugated Containers	0.26	1.66	0.47	0.06
Magazines/Third-Class Mail	-0.39	0.25	-0.39	-0.49
Newspaper	-0.82	-0.23	-0.74	-0.90
Office Paper	1.25	3.40	1.54	0.95
Phonebooks	-0.82	-0.23	-0.74	-0.90
Textbooks	1.25	3.40	1.54	0.95

Material	Landfills: National Average (Exhibit 6-16)	Landfills without LFG Recovery	Landfills with LFG Recovery and Flaring	Landfills with LFG Recovery and Electricity Generation
Dimensional Lumber	-1.01	-0.89	-0.98	-1.00
Medium-density Fiberboard	-0.88	-0.99	-1.02	-1.03
Food Waste	0.54	1.39	0.54	0.42
Food Waste (meat only)	0.54	1.39	0.54	0.42
Food Waste (non-meat)	0.54	1.39	0.54	0.42
Beef	0.54	1.39	0.54	0.42
Poultry	0.54	1.39	0.54	0.42
Grains	0.54	1.39	0.54	0.42
Bread	0.54	1.39	0.54	0.42
Fruits and Vegetables	0.54	1.39	0.54	0.42
Dairy Products	0.54	1.39	0.54	0.42
Yard Trimmings	-0.18	0.21	-0.18	-0.24
Grass	0.13	0.39	0.11	0.09
Leaves	-0.52	-0.18	-0.52	-0.56
Branches	-0.50	0.26	-0.38	-0.61
Mixed Paper (general)	0.14	1.44	0.32	-0.04
Mixed Paper (primarily residential)	0.08	1.33	0.25	-0.09
Mixed Paper (primarily from offices)	0.18	1.42	0.31	0.00
Mixed Metals	0.02	0.02	0.02	0.02
Mixed Plastics	0.02	0.02	0.02	0.02
Mixed Recyclables	0.09	1.19	0.25	-0.06
Mixed Organics	0.21	0.84	0.20	0.11
Mixed MSW	0.36	1.27	0.46	0.23
Carpet	0.02	0.02	0.02	0.02
Desktop CPUs	0.02	0.02	0.02	0.02
Portable Electronic Devices	0.02	0.02	0.02	0.02
Flat-panel Displays	0.02	0.02	0.02	0.02
CRT Displays	0.02	0.02	0.02	0.02
Electronic Peripherals	0.02	0.02	0.02	0.02
Hard-copy Devices	0.02	0.02	0.02	0.02
Mixed Electronics				
Clay Bricks	0.02	0.02	0.02	0.02
Concrete	0.02	0.02	0.02	0.02
Fly Ash	0.02	0.02	0.02	0.02
Tires	0.02	0.02	0.02	0.02
Asphalt Concrete	0.02	0.02	0.02	0.02
Asphalt Shingles	0.02	0.02	0.02	0.02
Drywall	-0.06	-0.06	-0.06	-0.06
Fiberglass Insulation	0.02	0.02	0.02	0.02
Vinyl Flooring	0.02	0.02	0.02	0.02
Wood Flooring	-0.86	-0.86	-0.86	-0.86

6.3 LIMITATIONS

The landfilling analysis has several limitations, outlined below.

- The net GHG emissions from landfilling each material are quite sensitive to the LFG recovery rate. Because of the high global warming potential of CH_4, small changes in the LFG recovery rate (for the national average landfill) could have a large effect on the net GHG impacts of landfilling each material and the ranking of landfilling relative to other MSW management options.

- The distribution of waste in place is not a perfect proxy for the distribution of ongoing waste generation destined for landfill.
- Ongoing shifts in the use of landfill cover and liner systems are likely to influence the rate of CH_4 generation and collection. As more landfills install effective covers and implement controls to keep water and other liquids out, conditions will be less favorable for degradation of biodegradable wastes. Over the long term, these improvements may result in a decrease in CH_4 generation and an increase in carbon storage. Moreover, Dr. Barlaz believes that the CH_4 yields from his laboratory experiments are likely to be higher than CH_4 yields in a landfill, because the laboratory experiments were designed to generate the maximum amount of CH_4 possible. If the CH_4 yields from the laboratory experiments were higher than yields in a landfill, the net GHG emissions from landfilling biodegradable materials would be lower than estimated here.
- EPA assumed that once wastes are disposed in a landfill, they are never removed. In other words, it was assumed that landfills are never “mined.” A number of communities have mined their landfills—removing and combusting the waste—in order to create more space for continued disposal of waste in the landfill. To the extent that landfills are mined in the future, it is incorrect to assume that carbon stored in a landfill will remain stored. For example, if landfilled wastes are later combusted, the carbon that was stored in the landfill will be oxidized to CO_2 in the combustor.
- The estimate of avoided utility GHG emissions per unit of CH_4 combusted assumes that all landfill gas-to-energy projects produce electricity. In reality, some projects are “direct gas” projects, in which CH_4 is piped directly to the end user for use as fuel. In these cases, the CH_4 typically replaces natural gas as a fuel source. Because natural gas use is less GHG-intensive than average electricity production, direct gas projects will tend to offset fewer GHG emissions than electricity projects will—a fact not reflected in the analysis.
- For landfilling of yard trimmings (and other organic materials), EPA assumed that all carbon storage in a landfill environment is incremental to the storage that occurs in a non-landfill environment. In other words, it was assumed that in a baseline where yard trimmings are returned to the soil (i.e., in a non-landfill environment), all of the carbon is decomposed relatively rapidly (i.e., within several years) to CO_2, and there is no long-term carbon storage. To the extent that long-term carbon storage occurs in the baseline, the estimates of carbon storage reported here are overstated, and the net postconsumer GHG emissions are understated.
- Another limitation is the assumptions used in developing “corrected” CH_4 yields for biodegradable materials in MSW. Because of the high GWP of CH_4, a small difference between estimated and actual CH_4 generation values would have a large effect on the GHG impacts of landfilling and the ranking of landfilling relative to other MSW management options.

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APPENDIX E

Transport and Rail-haul Costs

Transport and Rail-haul Costs

Rail-haul Costs

Tonnage Projection 2045	1,035,239
Tonnage Low	1,175,875
Tonnage High	1,496,171

Equipment	Cost	Source
KW T 880	$ 215,000	WIH research
53' 4x4 Western Trailer	$ 105,000	WIH research
Intermodal Chassis	$ 65,000	WIH research
Intermodal Container	$ 15,000	WIH research

WA Sales Tax	8.9%
Fed Excise Tax	12.0%

	Pounds	Tons
Max Allowable Road Weight	104,000	52.0
PB 579 Chassis Wt.	17,346	8.7
Western Transfer Trailer	14,700	7.4
Max SW Payload	71,954	36.0
Max Allowable Road Weight	104,000	52.0
PB 579 Chassis Wt.	17,346	8.7
Cheetah Intermodal Chassis	12,250	6.1
PNW Intermodal Container	9,620	4.8
Max SW Payload	64,784	32.4

Tip Fees		
Columbia Ridge	$ 17.00	Metro bid
RDC	$ 17.15	Metro bid
Wenatchee	$ 20.00	Estimate

Transport and Rail-haul Costs
Rail-haul Costs

Rail Haul Fees		
Everett to RDC by rail	$ 49.47	Snohomish Cty bid
Everett to CRL by rail	$ 52.52	Snohomish Cty bid
Everett to CRL by rail	$ 53.67	Snohomish Cty bid - required WM to build a separate intermodal yard
Everett to WRL by rail	$ 50.48	Snohomish Cty bid - required WM to build a separate intermodal yard
Seattle to CRL by rail	$ 42.98	Snohomish Cty bid
Rail Transport	$ 25.99	1993 Skagit County Contract with Regional Disposal Company (Rabanco)
Landfill Disposal	$ 18.75	1993 Skagit County Contract with Regional Disposal Company (Rabanco)
Total 1993 Rate	$ 44.74	
Mt. Vernon to RDC by rail	$ 52.93	Skagit County Contract with Republic
Min Weight per Container	26.00	Skagit County Contract with Republic
Seattle to CRL by Rail	$ 41.49	Hans Van Duessen — We currently pay $41.49 (effective 4/1/19) and average 25.7 tons per trailer (primarily closed 40 ft.).
Landfill Cost	$ 17.00	
Rail Haul Cost	$ 24.49	Intermodal Facility, container handling, and transport to CRLF
WM-UP Discount	$ 11.00	
Seattle rail haul cost	$ 35.49	
Av Wt. per Container	25.70	25.7 tons per trailer (primarily closed 40 ft.) is the Seattle average weight
Container Transport Cost	$ 912.09	
Current Market per Acre	$ 900,000	$35M transfer station in Tampa, 30,000 SF tipping floor, 1200 TPD
Minimum Acreage	20	$12M for reskin and redo TS floor at Tampa
Total Land Cost	$ 18,000,000	assumes intermodal containers provided by contracted company
Facility Build Cost	$ 5,000,000	rough estimate for IMF and 1 mile of rail spur
Total Cost	$ 23,000,000	
IMF Capital Cost	4.0%	updated to 4% to match WTE financing
Bond Life in Years	10	likely only 10 year disposal agreement, assume private financing
Annual Bond Cost	$ 2,835,692	
2019 Tonnage	846,745	
Cost per Ton	$ 3.35	

Transport and Rail-haul Costs
Rail-haul Costs

	Seattle Cost per container	Seattle Cost per Ton	
Rail Haul Cost	$ 912.09	$ 35.49	Seattle's rail cost per container is $912.09, and the average weight per container is 25.7 tons.
Disposal Cost	$ 510.00	$ 17.00	WM's estimated disposal fee per ton is $17. This is from a bid in 2018 for disposal services at Columbia Ridge Landfill, where Seattle's waste is currently
Total Cost	$ 1,422.09	$ 52.49	
Transfer to Rail Yard/ IMF (King	325.03	10.83	
IMF capital Cost/Fee	100.47	3.35	
King County Total (30 tons per	1,847.59		

Cost per Ton	Seattle	30 tons per cor	King County		
Average Payload	25.70	30.00	23.20		King County's average payload from the transfer stations is 23.2 ton
Rail Haul Cost	$ 35.49	$ 30.40	$ 39.32		Rail haul cost per ton for a 23.2 payload is $39.23 ($912.09 / 23.2 tons)
Intermodal Facility		$ 3.35	$ 3.35		Estimated Intermodal Facility Cost if King County built its own facility or if rail company adds cost for capital to charge
Disposal Cost	$ 17.00	$ 17.00	$ 17.00		WM's estimated disposal fee - Republic would match this amount to get the business
Cost per Ton	$ 52.49	$ 50.75	$ 59.67		
Haul Cost per Ton (TS to IMF)		$ 10.83	$ 10.83	14.17	Current County hauling cost (not used in WTE model)
Total Cost per Ton (including Hauling)		$ 61.59	$ 70.50	$ 73.84	

Cost per Ton	Skagit
Average Container Payload	28.00
Disposal Cost at RDC	$ 19.00
Rail Haul Cost (BNSF)	$ 34.95
Cost per Ton	$ 53.95

Transport and Rail-haul Costs
Truck Transport Cost

Labor Costs	Transfer
Driver Wage per hr.	$ 28.00
OT per hr.	$ 42.00
Regular Hr. Ratio	75%
OT Hr. Ratio	25%
Labor Burden	60%
Driver Coverage Ratio	30%
Weekly Hrs.	55
Weekly Pay	$ 1,750
Payroll Burden	$ 1,050
Labor Cost per hr.	$ 50.91
Driver Cost per Hr.	$ 66.18
Truck Cost	$ 259,935
Truck Ratio	50%
Truck Life in years	10
Annual Truck Hours	1,600
Truck Cost per Hour	$ 24.37

	Tipper Trailer	Intermodal
Transfer Trailer Cost	$ 126,945	$ 78,585
Trailer Ratio	100%	1
Trailer Life in years	10	10
Trailer Annual Hrs.	1,600	1600
Cost per Hour	$ 7.93	$ 4.91

Insurance per Truck	$ 3,500
License per Truck	$ 1,200
Ins & Lic per Trk hr.	$ 2.94
Fuel Cost per Gallon	$ 2.60
Fuel Burn Rate per Hr.	4
Fuel Cost per Hr.	$ 10.40
Truck R&M per Hr.	$ 8.00
Trailer R&M per Hr.	$ 3.00
Mgmt. / Admin per Hr.	$ 4.00
Total Cost	$ 15.00
WTE Trans Cost per Hr.	$ 127.00
Rail Trans Cost per Hr.	$ 124.00

	Current	WTE	Rail
Transport Hours	101,184	68,603	79,711
Transport Cost	$ 12,850,421	$ 8,712,623	$ 9,884,185
Annual Trips	36,500	24,362	28,358
Cost per Trip	$ 352	$ 358	$ 349
Annual Tons	846,745	846,745	846,745
Cost per Ton	$ 15.18	$ 10.29	$ 11.67
Annual Cost Savings $ ▲		$ (4,137,798)	$ (2,966,236)
Savings per Ton ▲		$ 4.89	$ 3.50
Cost per Haul			

Transport and Rail-haul Costs
Truck Transport Cost

Description	**Current**	**WTE**	**Rail**
Annual SW Tons	846,745	846,745	846,745
Daily Trips (360 days)	102	67	79
Estimated Truck Hours	101,184	68,603	79,711
Weekly Hours	1,946	1,319	1,533
FTEs per Day	39	27	31
Labor Cost per Hour	$ 50.91	$ 50.91	$ 50.91
Driver Coverage Ratio	30%	30%	30%
Estimated Payroll Hours	131,540	89,184	103,625
Total Labor Cost	$ 6,696,569	$ 4,540,293	$ 5,275,430
Truck Ratio	50%	50%	50%
Required Trucks	59	41	47
Truck Cost	$ 259,935	$ 259,935	$ 259,935
Truck Life in years	10	10	10
Annual Truck Cost	$ 1,533,617	$ 1,065,734	$ 1,221,695
Trailer Ratio	100%	100%	100%
Required Trailers	78	54	62
Transfer Trailer Cost	$ 126,945	$ 126,945	$ 78,585
Trailer Life in years	10	10	10
Annual Trailer Cost	$ 990,171	$ 685,503	$ 487,227
Annual Fuel Cost	$ 1,052,318	$ 713,475	$ 828,996
Truck & Trailer R&M Cost	$ 1,113,029	$ 754,637	$ 876,823
License Cost	$ 70,800	$ 49,200	$ 56,400
Insurance Cost	$ 136,500	$ 94,500	$ 108,500
Mgmt. / Admin Cost	$ 404,738	$ 274,413	$ 318,845
Total Transport Cost	$ 11,997,740	$ 8,177,755	$ 9,173,915
Cost per Ton	$ 14.17	$ 9.66	$ 10.83
Cost per Truck Hour	$ 118.57	$ 119.20	$ 115.09
Annual Cost Savings $ ▲		$ (3,819,986)	$ (2,823,825)
Savings per Ton ▲		$ (4.51)	$ (3.33)
Av. Cost per Haul	$ 326.74	$ 339.04	$ 322.57

Haul Cost per Hour	**Current**	**WTE**	**Rail**
Labor Cost per Hr.	$ 66.18	$ 66.18	$ 66.18
Truck & Trailer per Hr.	$ 24.94	$ 25.53	$ 21.44
Fuel Cost per Hr.	$ 10.40	$ 10.40	$ 10.40
Repair & Maint. Cost per Hr.	$ 11.00	$ 11.00	$ 11.00
License / Insurance per Hr.	$ 2.05	$ 1.42	$ 1.63
Mgmt. / Admin per Hr.	$ 4.00	$ 4.00	$ 4.00
Total Cost per Truck Hr.	$ 118.57	$ 118.53	$ 114.65

Haul Cost per Ton	**Current**	**WTE**	**Rail**
Labor	$ 7.91	$ 5.36	$ 6.23
Truck & Trailer	$ 2.98	$ 2.07	$ 2.02
Fuel	$ 1.24	$ 0.84	$ 0.98
Haul Costs	$ 2.04	$ 1.39	$ 1.61
Total Cost	$ 14.17	$ 9.66	$ 10.83

APPENDIX F

Railroad and Landfill Interviews

RAILROAD AND LANDFILL INTERVIEWS

Railroad Company Interview Questions

1. What are the current track capacity and constraints for the local track in the King County area and the mainline between Seattle and Portland? In other words, can the existing local rail lines in Seattle and the mainline between Seattle and Portland handle an additional unit train per day to accommodate the County's waste volumes in intermodal double stack?
2. What is a planning level cost per container, in well car (double stack) or per ton from Seattle / ARGO area to Columbia Ridge (WM's landfill) for an estimated 1.2 MM tons annually of compacted containerized waste in unit trains? Assume 30-ton payloads. Perhaps the rates being charged WM for the waste from the City of Seattle as an example?
3. What is the maximum length contract the railroad is willing to sign for King County's waste volumes? 3, 5 or 10 years?
4. Since the current project study has an estimated planning start date of 2045, what should be used, or assumed, as an annual rate escalator (%) to develop, project and estimate the rail transportation rates for the County's estimated 1.2 MM tons of waste to be shipped via rail to the landfill?
5. What other issues or concerns should we consider as part of the WEBR project's body of work for inclusion?
6. What is the current applicable fuel surcharge?
7. Can the UPRR handle a unit train per day from the UP's ARGO intermodal ramp?
8. What other properties are available to lease or buy to develop a suitable intermodal facility in the greater Seattle area and within King County – Kent, Renton, South Seattle, Fife, Auburn, etc.?
9. Of the following previously identified properties (sites) – from a 2004 intermodal siting study for the County by URS Corp. – Which are UPRR served and can you let me know which, if any, are still available for leasing or purchase by the County:
   a. Boeing Site – Auburn, WA
   b. Adesa Site – Auburn, WA
   c. Green River Site – King County
   d. Barnier Site – Kent, WA
   e. Manheim Site – Kent, WA
   f. United Grocers Site – Tukwila, WA
   g. Kenworth / NW Container Site – Tukwila, WA
   h. Harbor Island Site – Seattle, WA

BNSF Railway (BNSF) Responses

The following provides a summary of BNSF's responses to the interview questions.

1. Current track capacity and constraints:

- The railroad industry should say "Yes, there is capacity in the 'Seattle Subdivision'."

- Is there additional capacity? Capacity is defined not only by the line haul capacity on the mainline, but individual BNSF's terminal capacity at their "Interbay" Ramp (located between Queen Anne and Magnolia). Thinks they could have capacity.
- There is expected growth with both freight and passenger traffic in the Seattle / Portland corridor. Getting off and on the mainline and out of the Interbay site location is absolutely key to being able to determine the BNSF's ability to serve the site.

2. **Planning level cost per container:**
   - Very low-level assurances on rate levels and related annual rate increases as the future is unpredictable.
   - The BNSF is going to look at the KC waste volume in terms of the overall economics to determine their interests in the business opportunity.
   - Determining the parameters of their service design will be impacted by the overall economics of the opportunity for the BNSF.
   - BNSF wants to reiterate they have a high level of interest and would need more information to provide a detailed rate quote.
   - At this time, the BNSF Representative could not provide a planning level rate as its dependent on the terminal facility to be used – its location, local track access, equipment needed (and who supplies it – container top picks, well cars, etc.) and frequency of service.
   - Rates are based and determined largely on supply and demand on the railroad's track capacity, both locally at their terminals and on the mainline.
3. **Maximum contract length:**
   - BNSF is probably not unique and struggles with some of the long-term legacy agreements that are in place, such as Snohomish County and the City of Seattle.
   - These contracts are viewed by internal BNSF stakeholders as "what not to do ever again". They would look at a multi-year agreement – and if the economics were good enough for the BNSF, then they could enter into a 10-year agreement.
   - The agreed upon annual rate escalator would determine how long of an agreement the BNSF would enter into.
   - The indices used would be truly be based on rail economics and not a regional CPI escalator, based largely on how the BNSF's costs change annually. Perhaps an all-inclusive index, less fuel.
   - Fuel surcharge index would be independent of the annual rate escalator. Refer to https://www.aar.org/rail-cost-indexes/ specifically the All-Inclusive Index Less Fuel (AII-LF).
4. **Estimated annual CPI for 2045 start date:**

Unable to commit to what the CPI or annual rate escalator of fuel surcharge will be in 2045.

5. **Other issues or concerns to consider:**
   - Intermodal Facility – location, layout is critical - ease of rail access in and out of the facility by the BNSF. Encourages KC to engage the RR's to participate from the origin when doing facility siting and facility track layout

- Equipment – who owns and operates them? Top picks, containers, railroad well cars, trucks, chassis, etc.
- Intermodal containers – size, specifications & ownership
- Well cars – who owns or leases them or supplies them?
- Seattle Subdivision local track capacity
- Mainline track capacity
- Direct or indirect access of the facility by the BNSF verses having to go through a shortline or the UPRR on an interline exchange of the rail well cars
- What is the destination landfill? Same concerns about the origin exist for the destination as well. i.e. impacts to servicing the site – ease of getting in and out of the receiving facility.
- King County should consider the potential for early waste exportation of some percentage of their annual volume and implement a phased in approach, ramping up the volumes every year thereafter. Perhaps start with 100,000 – 200,000 TPY until the program is exporting all KC's volumes over several years.

6. Current applicable fuel surcharge:

See: https://www.aar.org/wp-content/uploads/2019/05/MRF201904indexes.pdf

Higher valued commodities are charged higher transportation rates verse lower valued commodities rail transportation rates. As a result, the BNSF now largely utilizes the percentage of revenue index now.

7. Ability to handle a unit train per day from the BNSF's local intermodal ramps:

Auburn, Interbay (located between Queen Anne and Magnolia) and Tukwila BNSF facilities are their local IMFs. Tukwila is already a constrained facility today. Tukwila is the BNSF's primary freight ramp for all regional customers in the Seattle Subdivision and probably doesn't have any real capacity for KC's waste volumes. This would be subject to further BNSF internal stakeholder discussions. Also, the "NIMBY" stakeholders need to be considered for any intermodal facility siting. It will be difficult to site a facility that does not impact some NIMBY group. Open to further discussion and recommend working with waste company selected for disposal to perhaps site an industry provided IMF.

8. Properties within KC available to lease or buy to develop an IMF:

Would need to talk to the BNSF's Reeve Geary – NW Region Economic Development Group - about any private customer facilities available for consideration.

9. Capacity:

BNSF: Capacity is defined not only by the line haul capacity on the mainline, but by terminal capacity at their "Interbay" Ramp (located between Queen Anne and Magnolia). There is capacity in the "Seattle Subdivision" (the track from Portland to Seattle) and there could be adequate capacity in the future.

There is expected growth with both freight and passenger traffic in the Seattle / Portland corridor. Getting off and on the mainline and out of the Interbay site location is absolutely key to determining the BNSF's ability to serve the site.

Union Pacific Railroad (UP) Responses

The following provides a summary of UP's responses to the interview questions.

1. **Current track capacity and constraints:**
   - The UP is very interested in this business and would be happy to have the volumes and will make it work to accommodate the County's needs.
   - To adequately evaluate the overall opportunity, the UP would need to conduct an operational review internally just prior to implementation of a King County WEBR program.
2. **Planning level cost per container:**

The rate will be priced on the current markets basically charging the highest rate that they can get at the time based on current market and traffic volumes on the UPRR's system.

3. **Maximum contract length:**

Willing to entertain whatever contract term – less of a hurdle internally providing a 5 year and less term agreement. 5+ year contract term would require senior level executive or CEO involvement to approve a longer-term agreement but the UPRR open to it at this time.

4. **Estimated annual CPI for 2045 start date:**

The annual rate increase is based on a comprehensive rate index from the AAR website – (AII-LF) All-inclusive less fuel or RCAP Rail cost adjustment factor less the fuel component. Industry Indexes: https://www.aar.org/rail-cost-indexes/

5. **Other issues or concerns to consider:**

With the new timeline of 2045, for the closure of the County's landfill, it's hard for the UPRR to predict track capacity or rate levels.

6. **Current applicable fuel surcharge:**

Mileage based fuel surcharge – see general description below and the link below for the current fuel surcharge index: https://www.up.com/customers/surcharge/mileage/index.htm

7. **Ability to handle a unit train per day from the UPRR's local ARGO intermodal ramp in Seattle:**

Given the long timeline now, it's difficult to predict, however the UPRR, barring any environmental constraints, will work to make capacity for KC's waste volumes. At this time, they do not see capacity as an issue.

8. **Properties within KC available to lease or buy to develop an IMF:**

The UPRR Networking & Industrial Group contact is Melissa Meier for intermodal facility siting studies and new (greenfield) or existing properties. After further vetting with the UPRR Economic Development team in King County, the UPRR staff stated that there are not any industrial sites with 50+ acres adjacent to UP track. The only site they really had is in Auburn and it was only 7-10 acres. They were sorry they couldn't find anything in addition to the sites listed below from the 2004 KC siting Study.

Landfill Company Interview Questions

Landfill Interview Questions

1. Available intermodal receiving facilities located within King County?
2. What is a planning level cost for a WEBR program from King County to your landfill on a rate per ton or per container?

3. What is the estimated legal over-the-road intermodal container payload, assuming preload compaction at each of the County's transfer stations?
4. Would you provide the necessary intermodal containers as part of the bundled T&D (transfer and disposal) rate per ton?
5. Planning level estimate for waste disposal tip fee for the County's annual waste volumes
6. Any other thoughts?

Republic Services (RS) Responses

The following provides a summary of Republic Services' responses to the interview questions.

1. **Available intermodal receiving facilities located within King County?**

   Due to the variability on locations, volumes, hours the best estimate RS can come up with is $5-$8 per ton in operating costs. IMF research with the BNSF for use of existing facility and research of other available rail served commercial real estate would be conducted for a new site.

2. **What is a planning level cost for a WEBR program from King County to Roosevelt landfill on a rate per ton or per container?**

   $800-$1,300 per container

3. **What is the estimated legal over-the-road intermodal container payload, assuming preload compaction at each of the County's transfer stations?**

   Depending on chassis configuration, 32 tons of MSW payload per closed top container.

4. **Would RS provide the needed intermodal containers as part of the bundled T&D (transfer and disposal) rate per ton?**

   Yes, RS's T&D pricing will include supplying MSW intermodal containers.

5. **Planning level for waste disposal tip fee for the County's annual waste volumes**

   For budgetary/exploratory T&D (transfer and disposal) pricing, use $23-$30 per ton.

6. **Other thoughts:**

   For comparison, RS's current rate with Snohomish County is $50.56 in total for transport and disposal from RS's private IMF in Everett served by the BNSF Railway.

Waste Management (WM)

The following provides a summary of Waste Management's responses to the interview questions.

1. **Are there available intermodal receiving facilities located within King County?**

   - Waste Management (WM) has identified multiple rail sites in King County that could serve as viable intermodal receiving facilities. The condition of these sites ranges from greenfield (currently undeveloped) to turnkey.
   - If the County wanted to establish its own intermodal receiving facility and had identified a desirable parcel, WM would assist the County in working with a railroad engineering firm and the respective railroad to go through the processes needed to establish rail service.
   - Equipment and operational costs are dependent on several variables, including whether manifest or unit train service is utilized. WM has strong partnerships with both UPRR and BNSF and

would thoroughly vet all service options to provide King County with the best possible solution to fit their needs.

- WM can provide King County with a safe, environmentally friendly and cost-effective WasteByRail® solution. We welcome the opportunity to discuss this further and learn more about King County's plans.

2. **What is the planning level cost estimate of a WEBR program from King County to CRLF on a rate per ton or per container?**

   WM is open to offering pricing per load or per ton, whichever method is preferred by King County. See answer to question 5 below for pricing guidance.

3. **What is the estimated legal over the road intermodal container payloads - assuming preload compaction at each of the County's transfer stations?**

   A 30-ton payload should be attainable, and road legal, with the appropriate tractor, chassis and container configuration.

4. **Would WM provide the needed intermodal containers as part of the bundled T&D (transfer and disposal) rate per ton?**
   - Yes, typically, WM's T&D pricing includes supplying intermodal containers.
   - Chassis, tractors and drayage services will vary by contract, but WM has vast experience under all scenarios and will tailor the services offered based on the County's preference.

5. **What is a planning level waste disposal tip fee for the County's annual waste volumes?**
   - For budgetary/exploratory T&D pricing, WM asked to reference the Snohomish County and Metro Regional Government RFP responses submitted by WM in recent years
   - Both proposals included comprehensive WasteByRail® solutions, including the development and operation of new intermodal receiving facilities, with an average T&D price ranging from approximately $45 to $55 per ton.

6. **Other thoughts:**
   - WM has nearly 30-years of WasteByRail® experience in the Pacific Northwest. With rail accessible disposal options in Washington and Oregon, we look forward to further discussing our unique, industry leading solutions.
   - WM can provide container drayage transportation services as part of their comprehensive offering. An approximate rate, for budgetary purposes only, in today's market would be $125-150 per hour.
   - WM offered a thank you for the opportunity to provide input on King County's preliminary exploration of disposal alternatives. We value our partnership with King County and look forward to bringing innovative solutions to the community.

APPENDIX G

WEBR Case Studies from Other Regional Jurisdictions

WEBR CASE STUDIES FROM OTHER REGIONAL JURISDICTIONS

City of Seattle

The City of Seattle contracts with Washington Waste Systems, a subsidiary of Waste Management Inc., for the transport and disposal of the City's solid waste. The waste is transported by the Union Pacific Railroad to the Columbia Ridge Landfill and Recycling Center (CRLF) about 320 miles away in Gilliam County, Oregon. The City requires that solid waste be transported on a dedicated train, also referred to as a “unit train”, as opposed to a “merchant” or “manifest” train that carries cargo from multiple railroad customers to different locations. This requirement ensures that the solid waste train cars will all remain together and reduces the chance that a rail car could become separated from the group and end up in another location.

The UPRR sends 5-6-unit trains per week to CRLF. About 63% of the solid waste tonnage shipped through Union Pacific’s Argo Yard comes from the City of Seattle’s two transfer stations and other private sector transfer stations, while the remaining 37% comes from cities and counties north of Seattle.

Seattle’s contracted combined rate for rail transport and disposal with WM is $41.49 per ton.[1] The estimated landfill cost per ton is $17 and includes the cost of the intermodal container, with the balance covering the container loading and rail transportation costs. Loading and transporting the 40-foot intermodal containers occurs at the Union Pacific Railroad’s Argo rail yard on Dawson Street in Seattle. The rail haul cost of $24.49 is approximately $11 per ton less than the actual cost of service due to a long-term price settlement between WM and the Union Pacific Railroad dating back to the early 2000s. The discount is in effect until the contract’s end in March 2024. Without the rail settlement discount, the real cost of loading and transport from Seattle to Arlington, Oregon on the Union Pacific system would be approximately $35.49 per ton.

Seattle averages 25.7 tons[2] of compacted solid waste per container; therefore, the average rail haul cost per container is $912.09 (25.7 tons x $35.49).

Snohomish County

With the County’s Cathcart Landfill slated to be full in March 1992, the County decided in June 1990 to contract with Regional Disposal Company (RDC), now a subsidiary of Republic Services, to export its solid waste by rail for disposal to the Roosevelt Regional Landfill, now owned by Republic Services, located in Roosevelt, WA in Klickitat County.

Solid waste collected at the County’s transfer stations is compacted into intermodal shipping containers with an average payload of 29 tons. The full intermodal containers are then trucked to the Regional Disposal Company (RDC) Rail Loading Facility in Everett, previously leased from the port of Everett. After purchasing the IMF from the Port in 2012, Snohomish County assumed the Port’s lease to Republic Services. The intermodal containers are loaded onto a BNSF train for the 360-mile, 12-hour trip. The containers are removed from the train in Roosevelt and loaded onto trucks with superchassis for the

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[1] Hans VanDusen, City of Seattle Contracts Manager; and City of Seattle’s contract with Waste Management.
[2] Hans VanDusen, City of Seattle Contracts Manager; and City of Seattle’s contract with Waste Management.

heavier-payload containers, then trucked 6 miles up the hill to the landfill, where they are unloaded via a large trailer tipper. The empty containers are then trucked back to the rail yard in Roosevelt and staged for the return trip.

As of May 1, 2019, Snohomish's contracted cost for rail transport and disposal is $50.56 per ton.[3] No fuel surcharges are assessed. The exact "unbundled" rate breakdown for the rail transport and landfill disposal components was not revealed to the project team but is estimated to be about $17.15 per ton for disposal and $33.41 per ton for intermodal container handling and rail haul.

[3] Matt Zybas, Director Solid Waste Division, Snohomish County Public Works.

APPENDIX H

Transportation Cost Calculations

TRANSPORTATION COST CALCULATIONS

Transportation Cost Assumptions

This Transportation Cost Analysis compares the expected transportation cost components of WTE vs. WEBR disposal alternatives. For simplicity, the analysis assumes that both the WTE plant and the WEBR IMF are located the same distance from the transfer stations as CHRL. While the total tonnage from the transfer stations is the same, the transport equipment and payloads for WTE and WEBR are different.

The analysis uses 2019 prices. It does not include any of the costs to load or move trailers on-site at the County's eight transfer facilities, but only the costs of round-trip hauling waste from the gate of each transfer station to the WTE or WEBR IMF or Cedar Hills Landfill.

Two travel times were calculated for each facility: a low time and high time (based on regional traffic impacts and delays). Using Google Maps, the low time assumes regular traffic flows whereas the high time assumes regular traffic congestion within the King County region.

Reported transfer trips from each facility to the landfill in 2018 were multiplied by the estimated haul (travel) times. For this calculation, the model assumes that 25% of the transfer hauls encounter regular traffic and 75% of the hauls encounter higher traffic congestion.

Table 4-7 details the tons, hauls, estimated time in minutes expended at each transfer station, and the average pay load from each station to CHRL.

Table 4-7. Transfer Station 2018 Operational Data

Transfer Station	Google Maps		Estimated Time			Average Time per Roundtrip	Tons	Current Annual Trips	Current Hours	Current Daily Trips (360 days)	Av. Payload (tons)
	Miles	Minutes	Low Time (one way)	High Time (one way)	Hook Up and Unload						
Bow Lake	17	25	45	65	30	2.5	267,725	9,692	24,230	27.0	27.6
Algona	20	25	35	45	30	1.9	153,349	7,810	14,969	22.0	19.6
Houghton	23	31	65	95	30	3.4	143,790	7,164	24,477	20.0	20.1
Factoria	16	26	65	95	30	3.4	139,685	5,180	17,698	14.0	27.0
Renton	11	20	35	45	30	1.9	61,229	3,206	6,145	9.0	19.1
Shoreline	35	44	80	130	30	4.4	50,689	2,057	9,085	6.0	24.6
Enumclaw	21	33	45	70	30	2.6	22,325	1,000	2,625	3.0	22.3
Vashon (via Ferry)	36	1:30	120	140	30	5.0	7,953	391	1,955	1.0	20.3
Totals							846,745	36,500	101,184	102	23.2

The County's short-term plan is to equip seven of the eight facilities with a preload compactor to minimize the number of loads. Using the expected average weight for each disposal option (35 tons for WTE or 30 tons for WEBR, less an adjustment for uncompacted waste from Vashon), Table 4-8 below compares the number of annual trips required to transport waste to the landfill.

Table 4-8. Comparison of Transfer Trips for Each Disposal Alternative

Transfer Station	Tons	Current Annual Trips	Current Daily Trips (360 days)	WTE Annual Trips	WTE Daily Trips	Rail Annual Trips	Rail Daily Trips
Bow Lake	267,725	9,692	27.0	7,649	21	8,924	25
Algona	153,349	7,810	22.0	4,381	12	5,112	14
Houghton	143,790	7,164	20.0	4,108	11	4,793	13
Factoria	139,685	5,180	14.0	3,991	11	4,656	13
Renton	61,229	3,206	9.0	1,749	5	2,041	6
Shoreline	50,689	2,057	6.0	1,448	4	1,690	5
Enumclaw	22,325	1,000	3.0	638	2	744	2
Vashon (via Ferry)	7,953	391	1.0	398	1	398	1
Totals	846,745	36,500	102	24,362	67	28,358	79
Decrease from Current				-50%		-22%	

While the distance from some of the transfer stations to the future WTE or WEBR facility will increase, some will decrease, and the net difference will be close to zero. This approach assumes that wherever the WTE or WEBR IMF is located, the travel time and distance will be the same as to CHRL. Current truck travel distance is approximately 20 miles on average between the County's transfer stations and CHRL.

Transportation costs for each alternative are compared to the current system, so the differences are easily understood. The average time per trip from Table 4-7 and the number of trips from the transfer stations to Cedar Hills Landfill (Table 4-8) are the basis for the costs. Because the actual site for either facility is not presently known, the landfill location is used as the point to compare the WTE and WEBR alternatives' costs.

Table 4-10 on the following page details the assumptions utilized to calculate the differences between the current system and the two alternatives. Table 4-11 below summaries the transport costs calculated from Table 4-10 above by the haul cost per hour and the cost by ton.

Table 4-9. Detailed Assumptions and Cost Calculations for Each Transport Alternative

Description	Current	WTE	Rail
Annual SW Tons	846,745	846,745	846,745
Daily Trips (360 days)	102	67	79
Estimated Truck Hours	101,184	68,603	79,711
Weekly Hours	1,946	1,319	1,533
FTEs per Day	39	27	31
Labor Cost per Hour	$ 50.91	$ 50.91	$ 50.91
Driver Coverage Ratio	30%	30%	30%
Estimated Payroll Hours	131,540	89,184	103,625
Total Labor Cost	$ 6,696,569	$ 4,540,293	$ 5,275,430
Truck Ratio	50%	50%	50%
Required Trucks	59	41	47
Truck Cost	$ 259,935	$ 259,935	$ 259,935
Truck Life in years	10	10	10
Annual Truck Cost	$ 1,533,617	$ 1,065,734	$ 1,221,695
Trailer Ratio	100%	100%	100%
Required Trailers	78	54	62
Transfer Trailer Cost	$ 126,945	$ 126,945	$ 78,585
Trailer Life in years	10	10	10
Annual Trailer Cost	$ 990,171	$ 685,503	$ 487,227
Annual Fuel Cost	$ 1,052,318	$ 713,475	$ 828,996
Truck & Trailer R&M Cost	$ 1,113,029	$ 754,637	$ 876,823
License Cost	$ 70,800	$ 49,200	$ 56,400
Insurance Cost	$ 136,500	$ 94,500	$ 108,500
Mgmt. / Admin Cost	$ 404,738	$ 274,413	$ 318,845
Total Transport Cost	$ 11,997,740	$ 8,177,755	$ 9,173,915

Description	Current	WTE	Rail
Cost per Ton	$ 14.17	$ 9.66	$ 10.83
Cost per Truck Hour	$ 118.57	$ 118.53	$ 114.65
Annual Cost Savings $ ▲		$ (3,819,986)	$ (2,823,825)
Savings per Ton ▲		$ (4.51)	$ (3.33)
Av. Cost per Haul	$ 326.74	$ 339.04	$ 322.57

Table 4-10. Transport Cost per Hour and per Ton

Haul Cost per Hour	Current	WTE	Rail
Labor Cost per Hr.	$ 66.18	$ 66.18	$ 66.18
Truck & Trailer per Hr.	$ 24.94	$ 25.53	$ 21.44
Fuel Cost per Hr.	$ 10.40	$ 10.40	$ 10.40
Repair & Maint. Cost per Hr.	$ 11.00	$ 11.00	$ 11.00
License / Insurance per Hr.	$ 2.05	$ 1.42	$ 1.63
Mgmt. / Admin per Hr.	$ 4.00	$ 4.00	$ 4.00
Total Cost per Truck Hr.	$ 118.57	$ 118.53	$ 114.65
Haul Cost per Ton	**Current**	**WTE**	**Rail**
Labor	$ 7.91	$ 5.36	$ 6.23
Truck & Trailer	$ 2.98	$ 2.07	$ 2.02
Fuel	$ 1.24	$ 0.84	$ 0.98
Haul Costs	$ 2.04	$ 1.39	$ 1.61
Total Cost	$ 14.17	$ 9.66	$ 10.83

Cost Impact on Customer of Changes in Disposal Fee

Cart and container weights are from three sources:

Collection service bids from Recology and Waste Management submitted to the City of Federal Way. This is the low weight source.

City of Portland annual vessel weight study completed by Portland State University from 2006 to 2008 when the City of Portland collected solid waste on a weekly basis. This is the high weigh source for roll carts.

High Weight containers are from various solid waste rate review / rate study engagements completed by Bell & Associates. This is the high weight source for containers.

The table below details the range of weights for the most common waste receptacles used in King County for storage and disposal of solid waste.

Cart Volume	Low Weight	High Weight
20 gal cart	10.50	13.85
35 gal cart	18.14	25.93
65 gal cart	33.80	45.20
95 gal cart	49.20	63.12
Container Volume	Low Weight	High Weight
1 yd. container weekly	97.77	120.00
1.5 yd. container weekly	146.65	180.00
2 yd. container weekly	195.53	240.00
3 yd. container weekly	293.30	360.00
4 yd. container weekly	391.06	480.00
6 yd. container weekly	586.59	720.00
8 yd. container weekly	782.12	960.00

The calculation of the rate impact utilizes three sources to provide a low and high range of costs that King County customers may experience with a change in the cost of disposal. The rate calculation below is for the low weight 35-gallon rolling cart:

Cart Weight per Set-out x 4.33[1] pick-ups per month (18.14 x 4.33 = 78.55 pounds)

Pounds Collected per month divided into 2,000 pounds per ton 78.55 / 2,000 = .039275

[1] 52 weeks per year divided by 12 months per year is 4.33

Weight in Tons multiplied by $10 change in cost 039275 x $10 = $0.39275

Cost divided by 10% Operating Margin (if applicable) $0.39275 / (1 – 10%) = $0.44

The same method is employed for a 3-yard commercial container with an increase of $10 in the disposal fee

Container Weight per Set-out x 4.33 pick-ups per month (293.3 x 4.33 = 1,270 pounds)

Pounds Collected per month divided into 2,000 pounds per ton 1,270 / 2,000 = .63

Weight in Tons multiplied by $10 change in cost 63 x $10 = $6.35

Cost divided by 10% Operating Margin (if applicable) $6.35 / (1 – 10%) = $7.06

The table below details the rate impacts for a range of costs and containers. The calculated costs include a 10% operating margin on the disposal increases. If switching to WEBR (from Cedar Hills) increases the total disposal cost-per-ton by $10, the customer with a 95-gallon waste cart will see an increase of about $1.18 to $1.52 per month.

Cart / Container Volume	Low Weight	$1 increase	$5 increase	$10 increase
20 gal cart	10.50	$0.03	$0.13	$0.25
35 gal cart	18.14	$0.04	$0.22	$0.44
65 gal cart	33.80	$0.08	$0.41	$0.81
95 gal cart	49.20	$0.12	$0.59	$1.18
1 yd. container weekly	97.77	$0.24	$1.18	$2.35
1.5 yd. container weekly	146.65	$0.35	$1.76	$3.53
2 yd. container weekly	195.53	$0.47	$2.35	$4.70
3 yd. container weekly	293.30	$0.71	$3.53	$7.06
4 yd. container weekly	391.06	$0.94	$4.70	$9.41
6 yd. container weekly	586.59	$1.41	$7.06	$14.11
8 yd. container weekly	782.12	$1.88	$9.41	$18.81

Cart / Container Volume	High Weight	$1 increase	$5 increase	$10 increase
20 gal cart	13.85	$0.03	$0.17	$0.33
35 gal cart	25.93	$0.06	$0.31	$0.62
65 gal cart	45.20	$0.11	$0.54	$1.09
95 gal cart	63.12	$0.15	$0.76	$1.52
1 yd. container weekly	120.00	$0.29	$1.44	$2.89
1.5 yd. container weekly	180.00	$0.43	$2.17	$4.33
2 yd. container weekly	240.00	$0.58	$2.89	$5.77
3 yd. container weekly	360.00	$0.87	$4.33	$8.66
4 yd. container weekly	480.00	$1.15	$5.77	$11.55
6 yd. container weekly	720.00	$1.73	$8.66	$17.32
8 yd. container weekly	960.00	$2.31	$11.55	$23.09

APPENDIX I

Ramboll Peer Review Memo

RAMBOLL

ENERGY

MEMO

Project name King County Waste to Energy
Project no.
Client Arcadis
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To Joseph Krupa
From Jørgen Haukohl

Date September 17, 2019

1 Background for the Memo

Ramboll has been asked by Arcadis to conduct a peer review of the draft WTE feasibility study dated September 2019 prepared for King County by Arcadis. The study compares the following two options

- Waste – To – Energy
- Waste export by Rail for landfilling

This memo covers mainly the WTE option.

Ramboll
Hannemanns Allé 53
DK-2300 Copenhagen S
Denmark

T +45 5161 1000
F +45 5161 1001
https://ramboll.com/energy

The comments are based on Ramboll's experience on modern WTE plants, mainly developed in Europe during the last 20 years. During this period a high activity level on building new facilities and upgrade and renovation of existing facilities has taken place, while only few has been built in United States during the same period. The high-profile Palm Beach Florida plant is one of the few exceptions.

Ramboll will concentrate primarily on issues related to our expertise from modern plant primarily as developed in Europe.

2 Ramboll's background

Ramboll has been working on waste to energy projects since more than 50 years and has been in the forefront as consultant engineer's in development of many important facilities, including the new iconic Copenhagen plant.

During the last 20 years there has been great developments in new technologies with the dual goal of optimizing energy efficiency and improving environmental performance. This has secured that the facilities are of high standard and are well accepted in the community. A good example of this is that the facilities can be integrated in the cities and provide both heat for district heating in addition to the production of electricity.

This dual energy production is typical in Scandinavia and in Germany. The Hamburg facility serves as a good example of a modern plant and the above-mentioned energy optimization. This facility has also been in the forefront of bottom ash utilization which has provided increased revenue and an even better understanding of the resource efficiency of modern plants. Metal recovery, especially recovery of precious metals like silver, copper and lead are part of the developments. Examples of these developments takes place at several facilities in Switzerland and in Denmark.

Several new modern WTE facilities are also being built in United Kingdom. The driving force is to move away from landfilling of waste, which is becoming less and less accepted in the society. Ramboll is involved in several of these projects. A typical project set-up is based on a Design-Build-Operation concept. In Scandinavia and Germany are the facilities normally operated by the public waste management company.

Ramboll's experience also entails WTE projects outside Europe, mainly in the Middle East and South East Asia. Ramboll also worked together with Arcadis on the Palm Beach facility.

3 Documents received

Ramboll's review is based on the draft report on the WTE facility for King County dated September 11th 2019 and a presentation of a financial model covering up to 50 years lifetime of the facility. The model is based on two alternative forecasts for waste generation.

Ramboll's comments refer to the individual sections in the report. The reference will be given to the individual sections without copying the text

4 Ramboll's comments

The report presents a good overview of the project and the two alternative methods, WTE or WEBR, with the main focus on the WTE solution.

The very long project lifetime period of 50 years is longer than normally used in project evaluations. Our experience is that the mechanical equipment (grate and combustion system, boiler, turbine and air pollution control equipment) must be gradually replaced or upgraded after 25-30 years. For the APC system this has often been necessary due to strengthen emission requirements. Beyond the initial period of 25/30 year, it is therefore important that the maintenance cost estimate includes sufficient capital for reinvestments.

Response:
The Arcadis Team agrees that 50 years is a long planning period. However, the County is responsible for the long term solid waste management for their partner cities and this was a requirement for the Study. Additional funds were allocated for future retrofit / maintenance at the time of the boiler expansion in both scenarios. The O&M cost also includes an increase as compared to the basis of design to account for additional contractor maintenance to maintain equipment over the planning period.

The conclusions in the Executive summery are generally commented below in the main report with the following exceptions.

Page iii Waste-to-Energy Methodology

The turbine-generator (T-G) concept is not clear in relation to the future expansion of the facility. Section 3.3.2.9 page 3-9 gives the correct description that the T-G must be sized to the steam production in each stage of the development of the facility (100% capacity in relation to boiler steam production). This gives the optimal power generation efficiency.

Response:
The Arcadis Team agrees, and it was anticipated that an additional turbine will be installed during the expansion of the facility to account for this concern.

Page vii Greenhouse Gas Impact
Greenhouse gas estimations are very detailed and done according to the USEPA WARM model. We note that the landfill gas (LFG) capture efficiency of 80 % is very optimistic.

Response:
The Arcadis Team agrees; however, the Report will remain unchanged to provide some conservatism in comparison to WTE option.

Page ix WTE Conclusions
Carbon capture technology is in an initial stage of development, with many alternative solutions under development. Solutions looks very expensive and debate is ongoing between sequestration and use of the CO2 gas. In some European countries it is the requirement that only solutions based on utilization of the gas should be allowed.

Response:
The Arcadis Team appreciates the European perspective on carbon sequestration. Significant additional costs have been added into the financial model for the construction of potential future carbon sequestration equipment.

Page 3-2 section 3.1 Facility General Description
The layout, see figure 3-1, is based on the Palm Beach design. The boiler house is very compact because of the vertical boiler design with an "optimized" superheater design. This means that the boiler building is very short, see later in section 3.3.2.4.

The remaining lay-out looks good including, tipping floor, bunker and APC building

Response:
The Report included the most recent U.S. based waste-to-energy facility as a basis for the capital cost, facility layout, boiler sizing, and resulting electrical generation efficiency. If there are design changes, such as reverting from a vertical boiler to horizontal boiler design, this could impact the electrical generation efficiency as noted; however, those changes would increase longevity of the facility and reduce operations and maintenance costs while potentially increasing capital costs.

Page 3-5 Section 3.3.2 Building and Structures
The layout is developed in two versions. Option 1 (4,000 tpd) and option 2 (5,000 tpd), both capacities after the expansion of the facility. Option 2 appears to be well prepared for the expansion and only requires space for the longer boiler building. Option 1 is not prepared for expansion of the turbine-generator building and the ACC. This should be explained further.

Response:
The Arcadis Team disagrees, we included expansion capability by upsizing the original building basis size. It is expected that in both scenarios the additional capacity will require a new turbine added in addition to the original turbine installation. Spacing for this is included for both options.

In both options the entrance and exit of the Tipping Building are located in opposite directions. To reduce any smell from the building it is preferable that entrance and exit is to the same direction (lower part of the drawing).

Response:
This is not a typical process in the US and limits the capability of using the tipping floor. In addition, the designs incorporate fast-acting curtain roll-up doors to mitigate odor concerns and pull draft for boiler combustion from the tipping / refuse building to further mitigate odor concerns.

Page 3-8 Section 3.3.2.4 Boiler Building
The boiler building should be prepared for a modern grate boiler design using a horizontal superheater/economizer layout. Optimizing the boiler design to high energy efficiency and long-life time is not described in the report. Trade-off between steam parameters, lifetime and power generation should be studied further. Based on our initial estimate the building should be larger. The size of each boiler bay should be enlarged to minimum 150-feet L x 100-feet W.

Response:
The Report included the most recent U.S. based waste-to-energy facility as a basis for the capital cost, facility layout, boiler sizing, and resulting electrical generation efficiency. If there are design changes, such as reverting from a vertical boiler to horizontal boiler design, this could impact the electrical generation efficiency as noted; however, those changes would increase longevity of the facility and reduce operations and maintenance costs while potentially increasing capital costs.

Page 3-9 Section 3.3.2.7 Ash Management Building
The size looks good. The interior should preferable be prepared for not only sorting out of ferrous and non-ferrous metal, but also fine metals like silver, copper and lead.

Response:
Agreed and sizing for recovery of finer metals is included with the addition of the advanced metals processing equipment.

Page 3-14 Section 3.4.4 Procurement
The procurement process should be further developed not only following the standard procedure, RFEI-RFQ-RFP.

The WTE market in United States has changed since the boom in new projects in the 1980's and early 90's. There were during that period a hand-full of international companies active in the US-market, capable in both doing design procurement and construction (EPC) followed by operation of the facilities (O&M). The available companies were European technology providers like Martin, Von Roll, Steinmuller and ABB. These companies teamed up with US construction companies and operators.

In the meantime, this company structure has changed. A few operating companies dominates the marked. The contractors is now active in other parts of the world. Production of the main structures is often fabricated in low cost countries. New operating companies have emerged in other parts of the World who may be interested in US-market.

It is suggested that a procurement process is developed to prepare potential companies for the new project. Invitation to informal information meetings can be considered.

Response:
Ramboll's procurement observations are noted. The information is provided for the County as decisions are made to move forward with WTE procurement.

Page3-23 Section 3.6 Permitting Requirements

This section is naturally based on the US-regulation system. Most modern plants in the world are designed the fulfil the European regulation system. It may therefore be relevant to compare the European system and eventually to consider the best of new ideas.

The current European regulation is based on the EU Directive 2010/75/EU published 24 November 2010 by the Parliament. IED Annex VI. A new development of the regulation is the "BREF" which is a supplemental system which both contains technical requirements and strengthens emission requirements. A separate email will give a short presentation of the "New BREF". The BREF requirement will be mandatory for all new permits given after the official publication from the Parliament which is expected in October 2019. For all existing plants it will be mandatory after 4 years. Examples of new requirements are continuous measurements of Mercury (Hg) and long-term sampling of Dioxin. Many of the daily average limit values are reduced, probably most importantly, the NOx values.

Response:
Ramboll's permitting requirements observations are appreciated. CEMS was included in the reference facility for mercury. US facilities already include annual sampling for dioxin. The US reference facility already included the most sophisticated emission control equipment for NOx reduction (selective catalytic reduction (SCR) technology). With the technology at the reference facility, we expect that it will already exceed the European regulations.

Page 3-27 Section 3.7.1.1 Capital Cost
The capital cost looks correct based on our experience from international projects.

Response:
Noted.

Page 3-28 Section 3.7.1.2
As mentioned above we recommend that the annual O&M cost includes planned update of the main technical equipment depending on expected life-time of the components. We understand that this is included in the budget.

RESPONSE:
Yes, this included in the budget.

Page 3-29 Section 3.7.1.3

In the financial model net sales of electricity is based on generation of 600 kWh/ton threating waste with a HHV 5,000 BTU per pound. This a high value of average annual electricity production for sale. Should probably be 5 % lower.

RESPONSE:
The Report included the most recent U.S. based waste-to-energy facility as a basis for the capital cost, facility layout, boiler sizing, and resulting electrical generation efficiency. If there are design changes, such as reverting from a vertical boiler to horizontal boiler design, this could impact the electrical generation efficiency as noted; however, those changes would increase longevity of the facility and reduce operations and maintenance costs while potentially increasing capital costs. Furthermore, a 5% reduction in the net kwh/ton would result in electrical generation efficiency of 570 net kwh/ton, which results in a total cost reduction of $100M over 50 years or $1.50 per ton of waste generated. The Arcadis Team does not believe a change in the published values of the report is necessary at this time.

Page 3-43 Section 3.10.2 Metal and Ash By-products
Based on our experience from Europe and the Middle East it is our experience that the amount of Ash (28 5) is high as is the total metal content. We assume that these figures are based on waste sorting analyses. The stated net income from sorting of metal should be estimated and included, based on that CAPEX and OPEX.

RESPONSE:
The figures are based on waste sorting analysis in the County. It is our experience that European regulations provide for slightly higher recycling rates when compared to the US. This metal availability in the waste stream recovery is typical when compared to other US municipalities with high recycling rates such as King County. Those net income values are already included in the financial model.

Page 3-48 Section 3.16 Greenhouse Gas Impacts
This section is very elaborate and gives a good overview the situation. CO2 emission and trade-off consideration are important. The best is to follow accepted US standards. Based on our experience N2O is only a minor contributor to the entire WTE emissions. As mentioned above a comparison to landfilling of waste should be based on both short-term and long-term estimates. A main contributor from even well engineered landfills is high emission methane, mainly until it is fully covered. Also, methane from operations gas motors should be counted.

RESPONSE:
Noted.

Arcadis U.S., Inc.
1100 Olive Way
Suite 800
Seattle, Washington 98101
Tel 206 325 5254
Fax 206 325 8218
www.arcadis.com