TETRA TECH

King County

Final

King County Long-Term Waste Disposal Options Study

Prepared For:

King County Natural Resources and Parks, Solid Waste Division

King County RFP #KC000455

March 2025

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ACRONYMS

Acronym	Definition
BACT	Best Available Control Technology
BNSF	Burlington Northern and Santa Fe Railroad
BTU	British Thermal Unit
BTU/lb	British Thermal Unit per pound
C&D	Construction & Demolition Debris
CCA	Climate Commitment Act
CETA	Clean Energy Transformation Act
CHRL	Cedar Hills Regional Landfill
CO2	Carbon Dioxide
Comp Plan	2019 Comprehensive Solid Waste Management Plan
County	King County
CPI	Consumer Price Index
CRLF	Columbia Ridge Landfill
CTUh	Cancer Comparative Toxic Units for Human Toxicity
DOT	United States Department of Transportation
DST	Decision Support Tool
Ecology	Washington Department of Ecology
EG	Emission Guidelines
EIA	United States Energy Information Administration
EIS	Environmental Impact Statement
eq	Equivalency
ESJ	Environmental Social Justice
EV	Electric Vehicle
FLM	Federal Land Managers
FRA	United States Federal Railroad Administration
GHG	Greenhouse Gas
GJ/t	Gigajoules to Ton
GREET	GHGs, Regulated Emissions, and Energy Use in Transportation
GWP	Global Warming Potential

Acronym	Definition
H20	Water
ICI	Industrial, Commercial and Institutional
ILA	Interlocal Agreements
IMF	Intermodal Facility
IPCC	Intergovernmental Panel on Climate Change
kg	Kilograms
L	Liters
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LFG	Landfill Gas
LMWC	Large Municipal Waste Combustors
MACT	Maximum Achievable Control Technology
mil	Millimeter
MJ	Megajoules
MPH	Miles per Hour
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
MSWAC	Metropolitan Solid Waste Advisory Committee
MSW-DST	Municipal Solid Waste Decision Support Tool
MT	Metric Tons
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Pollutants
NOC	Notice of Construction
NOx	Nitrous Oxide
NR	Non-Renewable
NSPS	New Source Performance Standard
O&M	Operations and Maintenance
O3	Ozone
ODEQ	Oregon Department of Environmental Quality
PFAS	Per- and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid

Acronym	Definition
PM	Particulate Matter
PSCAA	Puget Sound Clean Air Agency
PSD	Prevention of Significant Deterioration
PSE	Puget Sound Energy
RDF	Refuse Derived Fuel
Re+	King County's zero waste of resources initiative
RFP	Request for Proposal
RNG	Renewable Natural Gas
SEPA	State Environmental Policy Act
SO2	Sulphur Dioxide
SWAC	Solid Waste Advisory Committee
SWD	Solid Waste Division
T&D	Transport and Disposal
TDF	Tire Derived Fuel
Tetra Tech Team	Tetra Tech, WIH Resource Group, Cascadia Consulting Group, ERG, and B-Town Consulting
tpd	Tons per Day
tpy	Tons per Year
TRACI	Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts
UP or UPRR	Union Pacific Railroad
US	United States
USEPA	United States Environmental Protection Agency
UTC	Washington Utilities and Transportation Commission
VOC	Volatile Organic Compounds
WEBR	Waste Export by Rail
WM	Waste Management
WSDOT	Washington State Department of Transportation
WtE	Waste-to-Energy

EXECUTIVE SUMMARY

King County (County) provides garbage transfer, disposal, and recycling for approximately 1.3 million residents and 660,000 employees that live and work in King County. The County solid waste system serves a large unincorporated area and 37 partner cities through Interlocal Agreements (ILA). Two of the 39 cities in the County – the cities of Seattle and Milton - are not part of the County system. In the County, collection of solid waste, recyclables and organics is provided primarily by private-sector collection companies with two cities, Enumclaw and Skykomish, providing their own solid waste collection services.

On November 14, 2019, King County's 2019 Comprehensive Solid Waste Management Plan (Comp Plan) which outlines solid waste management goals and strategies for a period of 20 years was approved by the Washington State Department of Ecology (Ecology). The Comp Plan set forth policies to maximize the life of the County's Cedar Hills Regional Landfill (CHRL) but did not specify how the County's Solid Waste Division (SWD) will manage the disposal of solid waste after the landfill closes. The CHRL is projected to reach capacity between 2037 and 2046 depending on waste disposal rates and projected diversion of waste from the landfill. The decision on how the County will manage waste after the CHRL closes will be an important part of an update to the Comp Plan which is anticipated to be adopted in 2028.

The purpose of this Long-term Solid Waste Disposal Options Study (Study) is to evaluate potential disposal options to replace the CHRL when it closes. For the Study, a comparative evaluation of five disposal options was performed which included (1) Waste Export by Rail (WEBR), (2) Mass Burn with residual waste export by rail (Mass Burn), (3) Gasification with residual waste export by rail (Gasification), (4) Pyrolysis with residual waste export by rail (Pyrolysis) and (5) Refuse Derived Fuel (RDF). Evaluations of multi-disposal options (for example, a combination of WEBR and Pyrolysis) were not considered in the Study.

The Study comparative evaluation is not a detailed, project level analysis of each disposal option nor is it intended to address State Environmental Policy Act (SEPA) requirements for any of the options. It is strictly a comparison of disposal options/technologies based on established evaluation criteria, without specifics on facility design, operations or location. The assumed Study period is 20 years starting in the year 2040 and ending in 2060. Criteria developed as part of the Comp Plan and refined since then were used to perform the comparative analysis of the five disposal options under three projected tonnage scenarios. This Study will inform County decision-makers, ILA partners, Metropolitan Solid Waste Advisory Committee (MSWAC) and Solid Waste Advisory Committee (SWAC) members, haulers, and other stakeholders of the comparative merits of the five alternative disposal options once SWD ceases to deliver waste to the CHRL. Future studies and analyses would be required for SEPA environmental impacts; rate setting/financial study including market analysis for electricity, metals and other end products; siting a new facility including environmental/social justice considerations; and air and other permits including health risk assessment.

Overview of Results

The Study evaluated five disposal options for three tonnage scenarios using six major criteria and thirty-two sub-criteria. For each major criteria evaluated by disposal option, results of the criteria analyses were compared for low, medium and high tonnage disposal scenarios. A high-level overview of the results, by disposal option, follows:

For the **Gasification and Pyrolysis** options, the analysis found:

- No facilities are currently in operation that meet King County's disposal capacity needs.
- Operating history is unproven at scale (most are pilot facilities) and for Municipal Solid Waste (MSW) feedstock.

For the **Refuse Derived Fuel** (RDF) disposal option, the analysis found:

- Performance is proven at a small scale for homogeneous feedstock. No plants are currently operating at the lowest projected Study tonnage scenario.
- RDF replaces coal resulting in low environmental impacts but higher human health impacts.
- There is not sufficient market capacity for projected quantities of MSW RDF (300,000 to 800,000 tons per year [tpy]) due to technical challenges with chloride content, permitting requirements and competition for preferred feedstock.
- Cost effective option at $109 - $153/per ton (2040$) if stable markets are available. If markets are not available, the option is not viable as a landfill disposal alternative.

After reviewing the results for the Gasification, Pyrolysis and RDF options, SWD and representatives of MSWAC and SWAC **recommended that these three options not be further considered** as long-term disposal options due to their inability to manage the estimated King County 2040 tonnages and/or waste material types.

For the **WEBR and Mass Burn** options, the analysis found that both have long-term proven performance and operating history for the broad range of MSW and tonnage projections for King County while maintaining high compatibility with the existing collection system. Therefore, the primary analysis of interest to King County were the WEBR and Mass Burn options due to their ability to best manage the County' estimated 2040 tonnage requirements.

The results of the comparative analysis of the WEBR (Section 3.0) and Mass Burn (Section 4.0) disposal options for each sub-criteria are referenced in Section 8.0 of the report, (and included for all disposal options in Appendix B – Comparative Evaluation Summary Matrices) with a summary of findings for the medium tonnage scenarios presented.

Comparison of Mass Burn and WEBR

The most important key finding for the Study is that Mass Burn and WEBR are the only two viable options of the five evaluated to consider in meeting King County's long-term disposal needs after the closure of the CHRL. A summary of key comparative evaluation findings for the Mass Burn and WEBR options are as follows:

WEBR

- WEBR costs are significantly lower than Mass Burn for the Study period (estimated $108.19/ton vs. $230.99/ton for the Medium tonnage scenario in 2040$) based on current contract pricing for rail transport and disposal (T&D). WEBR is a variable cost based on tonnage and rate for contract term duration.
- It is an established disposal option in Washington State with a proven track record of over 30 plus years.
- There is existing adequate rail (including Intermodal facilities) and landfill capacity for King County's three projected tonnage scenarios according to railroad representatives and landfill operators.
- To minimize their risk, railroads typically want contracts of 5 to 10 years. This affects pricing projections and exposes the County to higher disposal cost risk in the future as railroad pricing increases would likely be passed on to the waste companies contracted with the County for WEBR.
- Additional traffic and rail congestion as capacity is used on railroads will increase traffic delays for at-grade crossings and may impact capacity availability in the future. A future traffic study would determine impacts of at-grade crossings.

- In recent years, Snohomish and Skagit counties had to close transfer stations due to service interruptions by Burlington Northern and Santa Fe (BNSF) Railway. Existing contracts cover alternative disposal due to service interruptions, which should be considered for any future WEBR contract with King County.
- Life cycle environmental impacts are similar to or higher than Mass Burn for the Study environmental parameters evaluated except for human health - cancer potential which was determined to be lower for WEBR. However, more of the impacts are created outside King County because waste is exported. Other human health parameters were not able to be modeled for the Study.

Mass Burn

- Mass Burn costs are much higher than WEBR for the Study period (estimated $230.99/ton vs. $108.19/ton for the Medium tonnage scenario in 2040$), typically requiring energy markets and economies of scale to ensure financial feasibility. Mass Burn has a fixed cost component to the rate which effective cost per ton would be higher with lower than projected tonnages and lower after the capital cost debt service period.
- Mass Burn facilities reduce the volume of waste that ends up in landfills while also generating energy from the thermal conversion of MSW.
- Mass Burn is an established technology with a proven track record of 40 plus years for quantities and types of waste projected for King County.
- Siting and permitting is difficult, typically with a high level of public opposition due to air pollution concerns.
- Process produces air emissions that require proper treatment and management and intensive permitting. Mass Burn facilities are required to comply with federal Clean Air Act, State and local air pollution district requirements for meeting air emission standards.
- Residuals include ash waste (estimated 20% of total waste by weight) that requires treatment and disposal at an ash monofill by WEBR at a landfill outside of King County. All three WEBR landfills considered in the Study have ash monofills, assumed to be used for ash disposal in the Study options. Ash transport by WEBR is subject to the same renegotiation as waste transport by WEBR, noted above.
- Mass Burn facilities recently closed in Long Beach and Stanislaus, California due to changes in regulations reducing feedstock, an expired Power Purchase Agreement resulting in lower rates (for Long Beach) and higher costs to operate the facility.
- The Clean Energy Transformation Act (CETA) restricts electricity from Waste-to-Energy (WtE) facilities for grid sale to retail customers in Washington State after 2045. CETA does not define electricity from waste as a renewable resource. Electricity from a WtE facility can be used for parasitic loads, can be sold out of State and/or can be sold in-State to wholesale or district heating customers. Discounted revenue potential for interstate sale of electricity was assumed for the Study.
- Life cycle environmental impacts are similar to or less than WEBR for the environmental parameters evaluated in the Study except for human health – cancer potential which was determined to be higher for Mass Burn. More of the environmental impacts are created inside King County at the facility. Other human health parameters were not able to be modeled for the Study.

Next Steps

After the Study is finalized and results presented to cities in early 2025, the SEPA process in support of the Study will be initiated to provide additional programmatic environmental impact analyses on the WEBR and Mass Burn options to facilitate decision-making. It is anticipated that in Calendar Year 2026, King County will release for public comment its draft SEPA Environmental Impact Statement (EIS) with the final EIS expected to be completed by the end of Calendar Year 2026. A final decision will then be made on which option best meets the long-term disposal needs of the County. That decision will be added to King County's updated Comp Plan, which will then begin the Comp Plan adoption process currently anticipated to conclude in Calendar Year 2028. More details on the Comp Plan adoption process and opportunities for cities and other partners to weigh in is included in Section 9.2 of this Study report.

1.0 INTRODUCTION

The Washington State Department of Ecology (Ecology) approved King County's Comprehensive Solid Waste Management Plan (Comp Plan) on November 14, 2019. The Comp Plan set forth policies to maximize the life of King County's (County) Cedar Hills Regional Landfill (CHRL) but did not specify how the King County Solid Waste Division (SWD) will manage the disposal of solid waste after the landfill closes. The 920-acre CHRL is located in Maple Valley, Washington and is owned and operated by the County. The CHRL is projected to reach capacity between 2037 and 2046 depending on waste disposal rates and projected diversion of waste from the landfill. The decision on how the County will manage waste after the CHRL closes will be an important part of an update to the Comp Plan which is anticipated to be adopted in 2028.

The Tetra Tech Team consisting of Tetra Tech, WIH Resource Group, Cascadia Consulting Group, ERG, and B-Town Consulting (Tetra Tech Team) was retained by the County's SWD to perform a comparative evaluation of five long-term waste disposal options to pursue once the CHRL closes. The SWD also sought input on the Long-term Solid Waste Disposal Options Study (Study) evaluation from the County's solid waste advisory committees, Metropolitan Solid Waste Advisory Committee (MSWAC) and Solid Waste Advisory Committee (SWAC). Since this Study is a comparison of options to each other at the same point in time, an analysis of possible closure dates for the landfill is not considered in the evaluation and the assumed Study period is 20 years starting in the year 2040 and ending in 2060.

The five options to be considered in the Study include (1) Waste Export by Rail (WEBR), (2) Mass Burn with residual waste export by rail (Mass Burn), (3) Gasification with residual waste export by rail (Gasification), (4) Pyrolysis with residual waste export by rail (Pyrolysis) and (5) Refuse Derived Fuel (RDF). The Comp Plan included a list of potential disposal options to be considered in making the final decision of how waste would be disposed after the CHRL closes. SWD used that list to discuss with MSWAC and SWAC what options should be included for further study. The solid waste advisory committees agreed to include WEBR, Mass Burn, Gasification, and Pyrolysis.

In its solicitation for this Study, SWD asked respondent firms to suggest a fifth option for analysis and Tetra Tech selected RDF. Building another landfill in King County was not included in this Study because it was decided in the 2001 Comp Plan and reiterated in the 2019 Comp Plan (Chapter 6) that the County will "not consider the option of developing a replacement landfill either in King County or in another county," because, "conditions…such as land availability, environmental considerations, public acceptance, cost, and other issues would impede any effort to site a replacement landfill."

Criteria developed as part of the Comp Plan and refined since then were used to perform the comparative analysis of the five disposal options under three projected tonnage scenarios. This Study will inform County decision-makers, Interlocal Agreements (ILA) partners, solid waste advisory members, haulers, and other stakeholders of the viability and relative merits of the five alternative disposal options to replace waste disposal at the CHRL.

1.1 Background

King County's current solid waste management system has evolved from a relatively basic system of refuse collection and disposal to a much more complex network of collection, sorting, salvage, reuse, recycling, composting, and disposal managed by the County, area cities, private-sector collection and processing companies and community-based organizations. Initial improvements to solid waste facilities and operations have been further developed to incorporate waste prevention and recycling programs that strive to balance resource use and conservation with production and consumption.

The County's SWD is working toward waste reduction and climate goals through enhanced reuse and recycling and moving away from a disposal-based system through an effort branded Re+ [1]. Re+ is being executed as part of the County's Comp Plan (Chapter 4) which states that a major factor impacting long term disposal options is progress in achieving the County's goal of zero waste of resources by 2030. Re+ is a community-focused, systems-level approach to creating a more circular economy by prioritizing reuse and recycling to achieve waste reduction and climate goals. The level of success of Re+ will affect the rate of landfill disposal which in turn will affect CHRL's closure date and the composition of the waste disposed.

To capture various success rates of Re+, the long-term disposal options evaluated for this Study were assessed based on three disposal tonnage scenarios represented by high, medium, and low diversion rates that range from approximately 360,000 to 1,000,000 tons per year (tpy) by 2040. As further clarified below and in Section 2.2, the low tonnage/high diversion scenario represents a conservative estimate of waste disposal needs, while the medium tonnage/medium diversion scenario considers a more moderate projection and the high tonnage/low diversion scenario accounts for the highest projected disposal tonnage.

By evaluating the five disposal options based on established criteria and sub-criteria for the three potential tonnage scenarios, this report is intended to provide valuable information and findings on how the options compare to help guide King County decision-makers, ILA partners and solid waste advisory committees in shaping a sustainable waste management strategy for King County. As part of the Study planning process, input from the County's MSWAC and SWAC members was sought and incorporated.

1.2 Long-Term Waste Disposal Options Study Process

The Tetra Tech Team approach to the Study evaluation was to perform an exploratory evaluation and comparison of identified disposal options to meet the County's long-term solid waste disposal needs. Figure 1-1 presents the general process that was undertaken to perform the comparative evaluation of options.

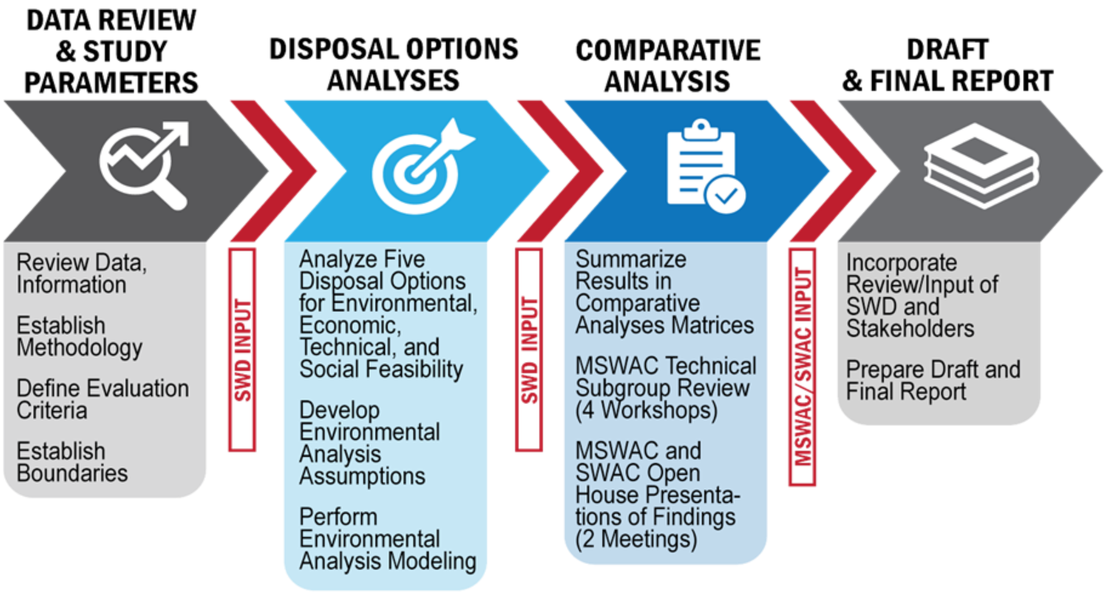


Figure 1-1: Long-Term Waste Disposal Options Evaluation Process

[1] Re+ (zero waste) - King County, Washington

The evaluation began with review of data, establishment of study methodology and boundaries, and definition of evaluation criteria (see Section 2.0). The analysis of the five disposal options is presented as part of Sections 3.0 through 7.0 of this report. The development of and SWD concurrence on the environmental analysis assumptions was integral to this phase of analyses. Comparative analyses summary matrices (see Section 8.0) for the medium tonnage scenario were prepared and reviewed by SWD and a MSWAC technical subgroup. Stakeholder presentations of the Study evaluation findings were conducted during Open House meetings to seek input. Input from SWD and stakeholders were incorporated into a Draft and Final Report with Study findings and a summary of the County's Next Steps included in Section 9.0 of this report. Additional details on the Study process follows.

Data Review and Study Parameters

An initial data and information review included a review of tonnage projections provided by SWD, projected waste characteristics for the low, medium and high tonnage scenarios, interviews with the railroads and facility operators and gathering of the latest information available for the five disposal options. Project memorandums were prepared to better define the evaluation criteria provided for the Study, establish study boundaries, provide assumptions for cost analysis and define environmental parameters, models and data sources to be used in the analysis. A discussion of the Study methodology and parameters are presented in the following section (see Section 2.0).

Disposal Options Analysis

The five disposal options were evaluated for the 32 Study sub-criteria under the low, medium and high tonnage scenarios as presented in the following sections of this report:

- Section 3.0 Waste Export By Rail
- Section 4.0 Mass Burn
- Section 5.0 Gasification
- Section 6.0 Pyrolysis
- Section 7.0 Refuse Derived Fuel

A summary of advantages and disadvantages for each disposal option is provided at the end of each section.

Comparative Analyses

The results of the disposal options analyses were summarized in comparative analyses matrices for review and input by SWD, MSWAC technical subgroup members and SWAC representatives and is presented in Section 8.0 Options Comparative Evaluation.

Draft and Final Report

The Draft and Final report for the Study includes discussion of the analysis performed for each disposal option, the comparative analysis findings and next steps in the process that the County will undertake to decide which long-term disposal option best suits their disposal needs (see Section 9.0).

1.3 Study Overview of Results

The Study evaluated five disposal options for three tonnage scenarios and 32 sub-criteria which are described in detail for each disposal option in Sections 3.0 through 7.0 of the Study. For each major criteria evaluated by disposal option, results of the criteria analyses are compared for the low, medium and high tonnage disposal scenarios. Table 1-1 presents high level results of the comparative analysis of the five Study options for the medium tonnage scenario with additional context provided throughout the report.

Table 1-1: Summary of Analysis Findings for All Disposal Options - Medium Tonnage

Criteria	Sub criteria	Waste Export by Rail (WEBR)	Mass Burn	Gasification	Pyrolysis	Refuse Derived Fuel (RDF)
Environmental (Net Total of Process and Transport Impacts and Offsets)[2]	Non-Renewable Energy Demand (MJ) - (Energy Production)	539,995,760	(685,760,535)[3]	Not Applicable (N/A)	N/A	(1,614,430,251)
	Water Consumption (L H_20) - (Water Quantity)	30,471,217	28,332,069	N/A	N/A	32,848,079
	Acidification Potential (kg SO_2 eq) - (Air Quality)	342,581	(47,865)	N/A	N/A	(1,444,091)
	Global Warming Potential (MT CO_2 eq) - (Climate Change)	55,588	18,395	N/A	N/A	(151,058)
	Smog Formation Potential (kg O_3 eq) - (Air Quality)	5,014,996	(2,010,928)	N/A	N/A	(10,664,550)
	Human Health Toxicity - Cancer Potential (CTUh[4]) - (Human Health)	7	10,519,046	N/A	N/A	10,487,991
	Resource Conservation	Converts landfill gas (LFG) to electricity or renewable natural gas (RNG).	Generates electricity and/or industrial/residential heating.	Creates synthetic gas (syngas) to be used for fuel, process into ammonia and methanol, or convert to RNG.	Creates syngas, marketable crude oils, solid carbon, non-condensable gases/char and other chemicals. Also converts waste plastic into hydrocarbons.	Creates fuel with increased heating value used in industrial operations such as electricity-generating plants and cement kilns.

[2] Positive environmental value represents impacts (poor result) and negative environmental value represents avoided impacts or offsets (good result).
[3] See Section 2.4.1.2 for context on assumptions for offsets due to out-of-state electricity sales.
[4] CTUh = Comparative Toxic Unit (human).

Criteria	Sub criteria	Waste Export by Rail (WEBR)	Mass Burn	Gasification	Pyrolysis	Refuse Derived Fuel (RDF)
	Compatibility with Waste Prevention & Recycling	No further opportunity for waste prevention or recycling.	Metals removed for recycling.	Metals removed for recycling.	Metals removed for recycling.	Metals removed for recycling.
	Total Capital Costs (2040$) Annualized Capital Costs (2040$)[5]	$3,378,549 (Total) $337,855 (Annualized)	$1,182,371,054 (Total) $86,707,211 (Annualized)	$2,302,201,254 (Total) $168,828,092 (Annualized)	$2,302,201,254 (Total) $168,828,092 (Annualized)	$399,335,422 (Total) $29,284,598 (Annualized)
Economic	Annual Operating & Disposal Costs (2040$)	Total Cost Transport and Disposal (T&D) + Equipment Depreciation: $72,155,415 T & D Only: $71,817,560[6] Equipment Depreciation Only: $337,855	$53,863,170 (Operations) $23,221,011 (Ash Disposal)	$67,029,723 (Operations) $27,865,213 (Ash Disposal)	$67,029,723 (Operations) $27,865,213 (Ash Disposal)	$59,847,967 (Operations) $14,363,512 (Municipal Solid Waste [MSW] Residuals Disposal)
	Revenue (2040$)	Electricity or RNG Sales from converted LFG included in Cost per Ton	Electricity Sales (annual): $7,336,453 Recycling Sales (annual): $2,393,919	Methanol Sales (annual): $71,926,584 Recycling Sales (annual): $4,189,358	Electricity Sales (annual): $5,869,162 Recycling Sales (annual): $4,189,358	RDF Sales (annual): $10,004,254 Recycling Sales (annual): $4,189,358
	Cost Per Ton, 2040$[7]	$108.19	$230.99	$281.29	$380.33	$133.90

[5] Annualized Capital Cost based on 10-year amortization for WEBR equipment and 30-year municipal bond financing at 4% for non-WEBR options.
[6] Rail T&D Cost based on recent legacy contract rates for higher tonnage contracts at $60/ton in 2023$adjusted to 2040$.Disposal cost approximately 30% of T&D cost based on recent procurement data for WEBR contracts.
[7] Cost Per Ton = Annualized Capital + Annual Operating & Disposal Costs – Annual Revenue / Total Tons.

Criteria	Sub criteria	Waste Export by Rail (WEBR)	Mass Burn	Gasification	Pyrolysis	Refuse Derived Fuel (RDF)
	Financial Risk	Financial risk with short term contracts for future rate increases when up for renewal (beyond projected inflation rate increase).[8] Significant regulatory changes may impact future rates. Study assumes use of existing IMF infrastructure. Containers and any IMF improvements included in rail T&D rate.	Financial risk with further discounted electricity sales rate potential due to Clean Energy Transformation Act (CETA) restrictions limiting in-State sales or for selling out-of-State; higher costs to comply with the Climate Commitment Act (CCA) cap-and-trade regulations and potential increased costs due to future regulatory requirements. Effective cost per ton increases if projected tonnages decrease (to pay off capital debt service) and should also decrease once capital debt service is paid off. Potential that rates from short term contracts for WEBR component of Mass Burn increase in the future. In case of emergency or catastrophic event, back-up disposal option would be	No proven operations at scale. Commodity sales limited due to clean, homogeneous feedstock requirements not conducive to MSW.	No proven operations at scale. Commodity sales limited due to clean, homogeneous feedstock requirements not conducive to MSW. Potential risk of no or nominal electricity sales.	Market potential limited for MSW due to permitting impediments and technical issues with chlorides restricting use for cement kilns which are target end users. Current markets lacking to take projected material volume (75% of total tonnage). If RDF cannot be sold, this would not be a viable technology option.

[8] Railroads indicated preferred contract terms of 5 to 10 years when interviewed. However, existing and recently executed WEBR contracts between municipalities and waste companies have been longer terms,10 years terms with 1-to-5-year renewal clauses between parties. Contracts between waste companies and respective railroads are not public information unlike the contracts between public entities and the respective waste companies.

Criteria	Sub criteria	Waste Export by Rail (WEBR)	Mass Burn	Gasification	Pyrolysis	Refuse Derived Fuel (RDF)
			WEBR or direct haul to a landfill			
	Proven Performance (Years of operations)	30+	40+	No operating plants at proposed processing capacity.	No operating plants at proposed processing capacities	No operating plants at proposed processing capacities
Operating History	Safety Record	Decades of industry safety-centered approach to investments and operations.	Long operating facilities with periodic updates have a good safety record.	No operating plants at proposed processing capacity.	No operating plants at proposed processing capacity.	No operating plants at proposed processing capacities
	Environmental Compliance	Rail Industry Climate Challenge implemented by the Federal Railroad Administration (FRA) to reach net-zero Greenhouse Gas (GHG) emissions by 2050.	Good environmental records and regulatory compliance with Maximum Available Control Technology (MACT) and Best Available Control Technology (BACT) standards.	No operating plants at proposed processing capacity.	No operating plants at proposed processing capacity.	No operating plants at proposed processing capacities
	Regulatory Compliance	The Burlington Northern and Santa Fe (BNSF) and the Union Pacific Railroad (UPRR) Company comply with local, state, and federal regulations.	Upgrades to emission control systems and safety mechanisms per regulatory requirements.	No operating plants at proposed processing capacity.	No operating plants at proposed processing capacity.	No operating plants at proposed processing capacities
	Operating Life of Facilities (Years)	Over 300 years (Combined life span of all three Northwest end destination regional landfills)	20-40 years	No known commercial operations	No known commercial operations	20-40 years based on smaller operating facilities
Logistics	Siting/Design/Permitting/ Construction Considerations	Does not require siting, design, or construction of new facility	Difficult siting and permitting. 7-10 years	Difficult siting and permitting. 7-10 years	Difficult siting and permitting. 7-10 years	Medium difficulty siting and permitting. 5-7 years

Criteria	Sub criteria	Waste Export by Rail (WEBR)	Mass Burn	Gasification	Pyrolysis	Refuse Derived Fuel (RDF)
Social	Compatibility w/Current Collection System	High	High	Low	Low	Medium
	Environmental & Social Justice/Equity	Impacts on communities near Intermodal Facility (IMF) and around rail line to be considered when rail program is selected. Increased congestion near IMF and longer wait times at railroad crossings to be analyzed when location of Mixed Waste Processing Facility and IMF are identified. Environmental impacts greater for frontline communities[9]. Economic impacts greater for low-income households.	Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. Environmental impacts greater for frontline communities. Economic impacts greater for low-income households.	Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. Environmental impacts greater for frontline communities. Economic impacts greater for low-income households.	Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. Environmental impacts greater for frontline communities. Economic impacts greater for low-income households.	Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. Environmental impacts greater for frontline communities. Economic impacts greater for low-income households.
	Local Traffic Impacts (truck trips/day)	144	180	186	186	288
	Local Job Creation (Number of jobs)	10	48	48	48	42

[9]. "Frontline communities" is a term used to describe communities who are the most vulnerable to and will be the most adversely affected by climate change and inequitable actions because of systemic and historical socioeconomic disparities, environmental injustice, or other forms of injustice ((Justice40 Initiative - Climate Program Office (noaa.gov)). In the Washington State HEAL Act and the CCA, frontline communities are labeled Vulnerable Populations and Overburdened Communities (*How We Define Frontline Communities in Policy Affects Their Lives - Front and Centered*).

Criteria	Sub criteria	Waste Export by Rail (WEBR)	Mass Burn	Gasification	Pyrolysis	Refuse Derived Fuel (RDF)
	Other Potential Neighborhood Impacts (Air, Odor, Noise, Groundwater)	Air - Low Impact Odor - Low Impact Noise - Medium Impact Groundwater - No Impact (at IMF)	Air - Medium Impact Odor - Low Impact Noise - Medium Impact Groundwater - No Impact	Air - Medium Impact Odor - Low Impact Noise - Medium Impact Groundwater - No Impact	Air - Medium Impact Odor - Low Impact Noise - Medium Impact Groundwater - No Impact	Air - Low Impact Odor - Low Impact Noise - Medium Impact Groundwater - No Impact
	Capacity/Minimum Waste Requirements	Technology capable of processing amount of waste from this tonnage scenario. Both serving railroads indicated that tonnage scenario volume could be accepted although traffic and congestion as capacity is used on railroads can be a factor in the future.	Technology capable of processing amount of waste from this tonnage scenario.	Technology still in development. Not capable of processing amount of waste from this tonnage scenario.	Technology still in development. Not capable of processing amount of waste from this tonnage scenario.	Technology capable of processing amount of waste from this tonnage scenario.
Capacity	Waste Type Composition & Acceptance	Non-hazardous waste	Non-hazardous waste	Homogeneous feedstock, no MSW processing (considered developing, not commercially proven).	Homogeneous feedstock, no MSW processing. Requires preprocessing to create uniform feedstock with little to no inert materials.	Non-hazardous waste
	Tonnage Flexibility	High Flexibility	Medium Flexibility Has ability to ramp up or down operations but not as flexible in addressing significant changes in tonnage as WEBR.	Low Flexibility No operating plants at proposed processing capacity.	Low Flexibility No operating plants at proposed processing capacity.	Low Flexibility Limited with lack of markets for projected tonnages.

Criteria	Sub criteria	Waste Export by Rail (WEBR)	Mass Burn	Gasification	Pyrolysis	Refuse Derived Fuel (RDF)
	Residual Waste Management	No residual waste generated.	Ash and rejected waste disposal required. Recycling of residual metals.	Residuals assumed to be disposed in ash monofill. Market for biochar end-product uncertain. Recycling of residual metals.	Residuals assumed to be disposed in ash monofill. Recycling of residual metals.	Non-combustibles and inert materials sent to recycling markets or disposal.

The results of the low and high tonnage scenarios are similar to the medium tonnage scenario for most of the criteria with the exception of the Economic, Environmental, and Social criteria whose results (or impacts) are higher for the high tonnage scenario and lower for the low tonnage scenario.

For the **Gasification and Pyrolysis** options, the analysis found the following:

- No facilities are currently in operation that meet King County's disposal capacity needs.
- Operating history is unproven at scale (most are pilot facilities) and for MSW feedstock.

For the **RDF** disposal option, the analysis found the following:

- Performance is proven at a small scale for homogeneous feedstock. No plants are currently operating at the lowest projected Study tonnage scenario.
- Replaces coal resulting in environmental benefits but has higher human health impacts.
- Cost effective option at $109 - $153/per ton (2040$) if stable markets are available. If markets are not available, the option is not viable (as landfill disposal would be the alternative).
- Markets for projected quantities of MSW RDF (300,000 to 800,000 tpy after processing) are limited due to technical challenges with chloride content, permitting requirements and competition for preferred feedstock.
- Risky long-term disposal option due to the lack of markets to take projected volume of material.

After reviewing the results for the Gasification, Pyrolysis and RDF options, SWD and representatives of MSWAC and SWAC **recommended that these three options not be considered further** as long-term disposal options due to their inability to manage the estimated King County 2040 tonnages and/or waste material types. The Study analysis and findings in support of that recommendation for Gasification, Pyrolysis and RDF are provided in Sections 5.0, 6.0 and 7.0, respectively, in this Study report.

For the **WEBR and Mass Burn** options, the analysis found that both options have long-term proven performance and operating history for the broad range of MSW and tonnage projections needed for King County as well as high compatibility with the existing collection system. The results of the comparative analysis of the WEBR and Mass Burn disposal options for each sub-criteria for the medium tonnage scenario are discussed in detail in Section 8.0 based on the analysis described in Section 3.0 (for WEBR) and 4.0 (for Mass Burn).

2.0 DISPOSAL OPTIONS EVALUATION METHODOLOGY

The Study addresses options for disposal of the remaining MSW stream after other efforts to capture and re-direct resources are exhausted upon closure of the CHRL. A comparison of WEBR, Mass Burn, Gasification, Pyrolysis, and RDF have been identified by King County for subsequent review and analysis. The Study does not address other technologies being considered by SWD as pre-long-term disposal options which are part of the Re+ effort to recover materials from MSW for beneficial use. Those pre-long-term options include anaerobic digestion, advanced material recovery and mixed waste processing.

2.1 Long-Term Disposal Options Selected for the Study

A brief description of the disposal options selected for the Study evaluation, with detailed descriptions in subsequent sections of the report, are presented below.

WEBR

A WEBR option would export compacted MSW in intermodal containers via railroad transport to an out-of-county landfill after the permitted disposal capacity at CHRL is reached. There are three primary regional landfills in the Northwest actively receiving waste by rail. All of them can receive King County's waste by rail from existing intermodal facilities (IMF) in King County with a combined landfill capacity sufficient to handle the county's waste in the long term. Figure 2-1[10] presents the UPRR – Argo Yard IMF located in Seattle, Washington.

Figure 2-1: Waste Export by Rail R) – UPRR Argo Yard IMF

[10] Fischer, J. (2021). *Union Pacific Railroad – Argo Yard* [Photograph]. Google.com

Mass Burn

Mass Burn (with residual waste export) is a type of Waste-to-Energy (WtE) technology that heats and burns MSW, producing heat that is used to create steam to generate electricity. The ash residual from the burning process is typically disposed of at a separate facility (an ash monofill). The burning process is also known as incineration. Mass Burn facilities reduce the volume of waste that ends up in landfills while also generating energy from the thermal conversion of MSW. There is one Mass Burn facility in Washington located in Spokane. The facility is owned and operated by the City of Spokane with the ability to process 800 tons of MSW per day (see Figure 2-2[11]).

For the purpose of clarification throughout this report, the Mass Burn option includes a WEBR component for the disposition of ash at a monofill registered landfill. The landfills assumed for the WEBR option in the Study have designated areas for ash monofills and the transport and disposal of that ash was considered in the Mass Burn option analyses.

Figure 2-2: Waste-to-Energy (Mass Burn) Facility – Spokane WtE Facility, Spokane Washington

Gasification

Gasification (with residual waste export) is a process of transforming MSW, using high heat, high pressure, and limited oxygen, into usable products – typically syngas that can be used as a fuel, industrial chemicals such as ammonia and methanol, fertilizer, and solid residuals that can be used as a fill material for construction, roadbeds,

[11] *Spokane, Washington's Waste to Energy Facility* [Photograph]. "Learn Where Your Garbage Goes", my.spokanecity.org.

etc. Figure 2-3[12] presents, the world's first commercial-sized waste-to-biofuels and circular chemicals facility located in Edmonton, Alberta, Canada (which is in the process of shutting down operations).

For the purpose of clarification throughout this report, the Gasification option includes a WEBR component for the disposition of ash at a monofill registered landfill. The landfills assumed for the WEBR option in the Study have designated areas for ash monofills and the transport and disposal of that ash was considered in the Gasification option analyses.

Figure 2-3: Gasification Facility – Edmonton, Alberta, Canada

Pyrolysis

Pyrolysis (with residual waste export) is a thermal depolymerization process that uses high heat, high pressure, and no oxygen to produce usable products such as oils, solid carbon, or char (used as a solid fuel, soil amendment, and for industrial processes), syngas, and other chemicals. Pyrolysis also converts plastic waste into a synthetic crude. It has the potential to divert plastics destined for the landfill, displace virgin fossil fuel production, and reduce GHG emissions. Hydrocarbons including crude oil produced by Pyrolysis can be marketed as feedstock for oil refineries, petrochemical processors, or consumed on site. Figure 2-4[13] presents a Pyrolysis system employed by a chemical recycling technology company (Agilyx) in Oregon, to convert various plastic resins into their original building blocks for reuse as a biofuel for refineries. That plant was recently shut down due to issues with the high cost of removing tar buildup in their equipment and their end-product being twice the cost of oil for their customers.

[12] Tetra Tech (2015). *Enerkem Gasification Facility in Edmonton, Canada* [Photograph].
[13] Tetra Tech (2015). *Interior of Agilyx pyrolysis facility* [Photograph].

For the purpose of clarification throughout this report, the Pyrolysis option includes a WEBR component for the disposition of ash at a monofill registered landfill. The landfills assumed for the WEBR option in the Study have designated areas for ash monofils and the transport and disposal of that ash was considered in the Pyrolysis option analyses.

Figure 2-4: Pyrolysis Facility - Agilyx

Refuse Derived Fuel (RDF)

A RDF facility processes the MSW stream by shredding and mixing the stream into a standardized size, removing inert materials[14] such as metals and non-combustibles, and dehydrating the remaining stream to increase the heating value of the remaining materials. RDF is used as a fuel in many industrial operations such as energy and cement plants. This offsets fossil fuel consumption and diverts waste from landfills. Some inert residuals will require disposal while the RDF would be sold be sold as a fuel for energy or cement plants that are permitted to use RDF as a fuel source. Figure 2-5[15] presents an initial step in the production of RDF which begins with material volume reduction.

[14] Defined in this report as "Waste that cannot disintegrate naturally, either biologically or chemically." Source: Inert Waste - an overview | ScienceDirect Topics

[15] Tetra Tech (2015). *Conveyor at Enerkem Gasification Facility in Edmonton, Canada* [Photograph].

Figure 2-5: Refuse Derived Fuel (RDF)

2.2 Tonnage Scenarios

The tonnage scenarios discussed below are based on forecasts developed by SWD. These take into account population growth over time, economic variables (such as projected employment rates), and impacts from diversion efforts. The composition of the waste (how much is metal vs paper vs plastic, etc.) is based on the 2019 Waste Characterization Study[16].The projected disposal tonnages in 2040 range from 367,000 (low tonnage) to 1,000,000 (high tonnage) and, for reference, the annual disposal tonnage at the CHRL was 839,000 tons in 2024.

One of the major diversion efforts to consider is Re+. As discussed in Section 1.1, Re+ sets forth policies to advance towards achieving zero waste of resources but does not yet outline a complete path to achieving zero waste. The current plan establishes actions to prevent and divert useful materials away from disposal and is focused mainly on food, paper, and plastics. Future updates will be needed to divert more of these key materials and address diversion of other waste streams like construction and demolition (C&D), metals, etc.

The medium and low tonnage scenarios assume reductions in tonnage across varying streams based on different assumptions for diversion. It should be noted that all disposal options assume that waste will be pre-processed at a Mixed Waste Processing Facility in support of Re+ and zero waste goals. A summary of the three diversion scenarios, which was assumed for the Study, is provided below and is summarized in Table 2-:

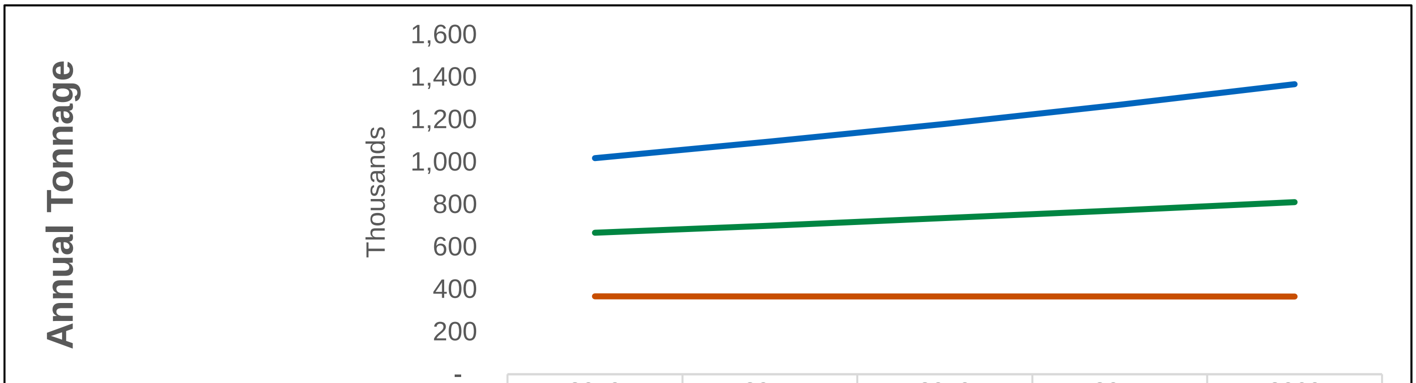
[16] 2019 King County Waste Characterization and Customer Survey Report - King County Waste Monitoring Program - King County Solid Waste Division

1. **High Tonnage/Low Diversion** (business as usual) – Assumes a “business as usual” case where Re+ currently has minimal impacts and approximately 1,000,000 tpy of waste would need to be managed by the year 2040 (when the CHRL is expected to reach capacity).
2. **Medium Tonnage/Medium Diversion** (Re+) – Assumes the programs and initiatives implemented under Re+ in the year 2030 have been implemented and approximately 667,000 tpy of waste would need to be managed by the year 2040 (when the CHRL is expected to reach capacity).
3. **Low Tonnage/High Diversion** (zero waste) – Assumes a “zero waste” scenario whereby Re+ has been fully implemented and approximately 367,000 tpy of waste is projected to be managed by the year 2040 (when the CHRL is expected to reach capacity). Disposal tonnage is expected to be much lower and the waste composition was estimated based on a dramatic reduction of divertible materials in the waste stream.

Table 2-1: Summary of Disposal Rates for the Three Waste Diversion Scenarios. (2040)

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Annual Disposal (tpy)	1,018,367	666,950	367,202

Projected tonnages for the Study period starting with the tonnages estimated for 2040 (presented in Table 2-1) through 2060 are presented in Figure 2-6 which is what the Study evaluations are based on for the low, medium and high tonnage scenarios.



	2040	2045	2050	2055	2060
High Tonnage/Low Diversion Business As Usual	1,018,367	1,096,133	1,179,837	1,269,933	1,366,909
Medium Tonnage/Medium Diversion RE+	666,950	700,369	735,463	772,315	811,014
Low Tonnage/High Diversion Zero Waste	367,202	366,967	366,733	366,499	366,266

Figure 2-6: Tonnage Projections for 2040 through 2060, All Scenarios

2.3 Waste Composition

SWD provided estimated waste composition of the waste stream for the three tonnage scenarios for 2040. The waste composition figures provided estimated annual quantities for each detailed material category and those quantities were combined to calculate the primary material category amounts shown in Figure 2-7. Although the percentage of primary material categories varies for each tonnage scenario as shown on Figure 2-7, the high-level comparative analysis performed for the Study found that the thermal characteristics or combustibility of the waste streams would be similar and had no material impact on the three waste diversion scenarios analyzed.

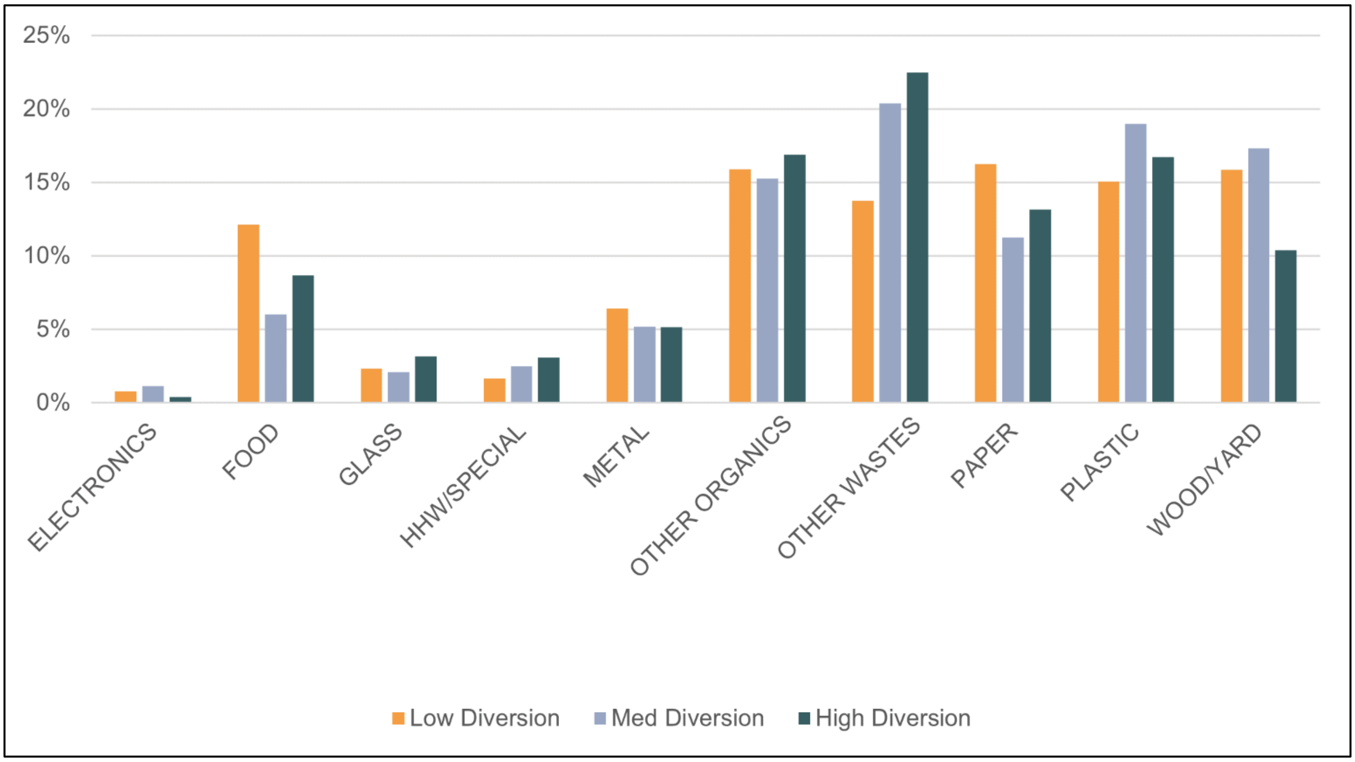


Figure 2-7:Comparison of Material Categories for Each Diversion Scenario

2.4 Evaluation Criteria

The long-term disposal options discussed in Section 2.1 were evaluated and assessed based on six primary evaluation criteria. The six primary criteria identified in the Comp Plan and provided by SWD for the Study includes Environmental, Economic, Operating History, Logistics, Social, and Capacity.

As part of the Study, the six primary criteria and thirty-two sub-criteria were further defined for evaluation of disposal options, as discussed below. It should be noted that some of the criteria were adjusted as the Study progressed, which is reflected in this section.

2.4.1 Environmental

The Environmental criteria focused on impacts to people and the environment globally. For comparative purposes of the Study, a Life Cycle Assessment (LCA) approach was used to compare potential impacts. While a future State Environmental Policy Act (SEPA) Environmental Impact Statement (EIS) analysis would further evaluate project level environmental impacts (per National Environmental Policy Act [NEPA] requirements), high level impact parameters were selected for this Study to represent modeled outputs widely used in LCA and scientific literature.

The environmental impact parameters initially included nine categories: Non-renewable and Total Energy Demand (for Energy Production), Water Consumption (for Water Quantity), Eutrophication (for Water Quality), Acidification and Smog Formation Potential (for Air Quality), Global Warming Potential (for Climate Change) and Cancer and Non-Cancer Potential (for Human Health)[17]. Reliable and comparable data for modeling Study impacts were not available for Total Energy Demand, Eutrophication, and Human Health Toxicity (Non-Cancer), therefore, impacts were not assessed for those three parameters. Human Health Toxicity (Non-Cancer) covers all health impacts except for cancer (such as heart disease, kidney failure, and reproductive disorders).

Two additional sub-criteria considered for the Environmental criteria analysis include Resource Conservation and Compatibility with Waste Prevention and Recycling. Resource conservation includes usable end products for the disposal options considered.

The goal for this criterion is to minimize environmental impacts or provide an environmental benefit.

2.4.1.1 Environmental Impact Factors

The environmental impact factors cover the six Study primary criteria based on existing impact assessment and inventory methods and tools that represent industry standards developed, commissioned, recommended, or used by the United States Environmental Protection Agency (USEPA). The Tetra Tech Team primarily used MSW-DST (Municipal Solid Waste Decision Support Tool), which is an industry-standard model commissioned by the USEPA.[18] MSW-DST requires more extensive data and effort than USEPA's Waste Reduction Model and includes a wider range of environmental impacts beyond global warming potential. MSW-DST uses underlying LCA databases that have also been developed, commissioned, recommended, or used by USEPA and which each represent a standard and generally accepted methodology / data source for their specific environmental impacts.

A key underlying data source is the USEPA's Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)[19]. GHG factors are based on global warming potential from the Intergovernmental Panel on Climate Change's (IPCC) 5th assessment report, using a 100-year time horizon. Human health toxicity impacts came from USEtox, another industry-standard model.[20] For impacts and disposal options without existing factors, the most suitable existing proxy was used, if it could be considered reliable. Another source to help calculate the environmental impact factors for some of the materials and pathways, primarily hazardous waste, came from Ecoinvent[21]. This source provides users with information on the environmental impacts of their products and services.

Where reasonably reliable factors could not be produced, the Tetra Tech Team identified the gaps and provided a qualitative professional assessment on whether these gaps prevented rational comparisons between disposal alternatives. As mentioned above, reliable data was not available for Total Energy Demand, Eutrophication potential, and Human Health Toxicity (non-cancer) potential, so they were not assessed. Eutrophication potential data was available for Mass Burn facilities and for landfills that manage leachate using wastewater treatment plants,

[17] Note: A CTUh for noncancer related toxicity, which covers all health impacts except for cancer (such as heart disease, kidney failure, and reproductive disorders), could not be reliably measured as part of this Study
[18] Municipal Solid Waste Decision Support Tool, available at https://mswdst.rti.org. Also see CPRG Tools and Technical Resources – Waste and Materials Management Sector | US EPA.
[19] Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI) | US EPA
[20] USEtox https://usetox.org/model
[21] Ecoinvent - Data with purpose.

however, LCA model data on leachate evaporation systems (which are used by the WEBR landfills considered in the Study) was not available for this Study's modeling purposes.

In addition to the discussion above, Environmental criteria factors were not evaluated for the Gasification and Pyrolysis disposal options. Because both disposal technologies are comparatively new, both had significant data gaps, such as missing impact factors for materials, or impact factors that were not comparable to those for landfill, Mass Burn or RDF.

The environmental impact categories, definitions, associated unit of measurement and LCA methodology are presented in Table 2-2 and are further described in Appendix A – Environmental Impact Factors and Assumptions.

Table 2-2: Environmental Impact Factors

Impact/Inventory Category and Definition	Unit	LCA Methodology
Non-Renewable Energy Demand (Energy Production). Measures the fossil and nuclear energy from point of extraction. Includes coal, natural gas and oil which exist in limited quantities in nature.	MJ	Cumulative energy inventory
Water Consumption (Water Quantity). Freshwater that is evaporated, diverted from its natural watershed, incorporated into products and waste or disposed into the sea. Most of water consumption impacts in the Study occur due to processing or energy offsets, particularly energy offsets related to the hydropower portion of grid electricity.	L H_2O	Cumulative water consumption inventory
Acidification Potential (Air Quality). Environmental damage caused by release of acid-forming compounds into atmosphere, primarily due to burning of fossil fuels and biomass.	kg SO_2 equivalents (eq)	TRACI v2.1
Global Warming Potential (Climate Change). Potential increase in Earth's temperature due to GHG emitted by human activities. Main GHG is carbon dioxide (CO_2) released primarily through burning of fossil fuels like coal, oil and natural gas. Another significant GHG is methane, which comes from breakdown of	MT CO_2 eq	IPCC (2013) GWP[22] 100a

[22] Global Warming Potential (GWP)

organic materials in environments without oxygen such as wetlands or landfills.		
Smog Formation Potential (Air Quality). Process by which certain chemicals in the atmosphere react with sunlight and heat to produce ozone, a major component of smog. Typically occurs when nitrogen oxides and Volatile Organic Compounds (VOC), which are released during the combustion of fuels like gasoline and diesel, interact under certain conditions. Ozone at ground level is harmful as it can cause respiratory problems and other health issues, as well as damage vegetation.	kg O_3 eq	TRACI v2.1
Human Health Toxicity—Cancer Potential. Potential dangers to people's health from release of toxic chemicals into the environment are significant. These chemicals can cause various health problems such as different cancers. Comparative toxicity units (CTU) characterize the probable increase in cancer related morbidity[23] (from inhalation or ingestion) for the total human population per unit mass of chemical emitted, assuming equivalent exposure. However, a LCA study can only measure hazard presence (type and quantity of chemicals emitted) and not exposure, so results should be interpreted as comparing the production of chemicals associated with cancer, not morbidity.	CTUh	USEtox™ 2.02

2.4.1.2 LCA Impacts and Offsets Description

To provide a comprehensive comparison of disposal options for environmental impacts and benefits, the LCA approach was used to evaluate process impacts of facilities, transport impacts and offsets due to avoided impacts as further described below:

[23] The term "morbidity" typically refers to having a specific illness or health condition. This is different from "mortality" which refers to the number of deaths that a specific illness or health condition caused. Source: Morbidity vs. Mortality Rate: What's the Difference?

Process Impacts

- **Direct impacts of operating the facility** such as water use, fuel combusted onsite, air emissions, wastewater discharges, and surface water discharges.
- Upstream impacts of external inputs needed to operate the facility:
  - Grid electricity production (including associated upstream impacts of fossil fuels used to generate electricity).
  - Fossil fuels extraction, transport, and refining.
  - Extraction and production of other material inputs and energy sources.

Transport Impacts

- Direct impacts of fossil fuel combusted by trains and train-to-landfill shuttles for transporting ash and MSW exported to the landfill or ash monofill for final disposal. Truck transport from transfer stations to a Mixed Waste Processing Facility and then to an IMF or a new processing facility was included in the analysis and was assumed to be the same distance for both options. Without knowing specific locations, assumptions were made that would impact the final results if said assumptions differed from the final location site.
- Upstream impacts of grid electricity production for operating electric vehicles (EVs) (including associated upstream impacts of fossil fuels used to generate electricity), including transporting waste to the IMF, Mass Burn and RDF facilities (options modeled), transporting ash from the Mass Burn facility to the IMF, transporting recovered metals from the Mass Burn facility to the smelter for recycling and transporting RDF to end markets.
- Upstream impacts of fossil fuels extraction, transport, and refining.
- Extraction and production of other transportation inputs and energy sources.

Offsets/Avoided Impacts

The modeling for this Study assumes that energy produced from Mass Burn can be sold to the grid, per Puget Sound Energy (PSE), but its use is restricted to out-of-state or in-state wholesale customers (can't be used for retail customers). If electricity sales occur out of the United States Energy Information Administration (EIA) region that was modeled for this Study, the impacts would likely vary. Using an average of the projected electricity sources, the electricity sold by a facility would ultimately displace other grid energy generators. The Study also assumes that RNG sold by a WEBR landfill facility will displace conventional natural gas. Therefore, we offset (count as benefits) impacts avoided by reducing the following product:

- Grid electricity production **including direct combustion and upstream impacts (e.g., extraction and refining)** of fossil fuels and reduced demand for hydropower used to generate electricity.
- Conventional natural gas production including upstream impacts (extraction and refining).
- That is, other generators will reduce energy production by the amount of electricity sold to the grid by the disposal option. This eliminates the need to extract, refine, and transport fossil fuel or other sources to create that energy.

The modeling excludes offsets of Water Consumption. The model was designed to use a single electricity grid mix, which was developed to most closely reflect the regional mix including a high proportion of hydropower. Hydropower, and therefore electricity use, is associated with water consumption due to evaporation from hydropower reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn or landfill gas conversion to electricity), reported results exclude Water Consumption associated with electricity offsets.

Total Net Impact

The environmental results for the Study are provided for **Total Net Impact** = Process + Transport – Offsets.

Construction Impacts

Construction impacts were not considered or included in the LCA as there isn't enough information available at this stage of assessment to provide input parameters for modeling of construction impacts (such as global warming potential). Further, the user's manual for USEPA's MSW-DST used for calculating Life Cycle Inventory (LCI) for GWP states the following:

"Construction related LCI effects are not included. A decision to exclude construction from the overall model was made during the system definition phase of this research. Estimates of the significance of construction have shown that for most waste management facilities, this assumption is appropriate. However, for landfills, the total energy consumption for construction were found to represent 25% and 2% of the total landfill LCI for scenarios without and with energy recovery, respectively. The parallel energy values for combustion without and with energy recovery were estimated to be 0.2 and 3.2%, respectively. To the extent that the model solution includes a traditional landfill, the overall LCI values will be low due to the exclusion of its construction."[24]

2.4.1.3 Modeling Tools and Data Sources

The following are the modeling tools and sources used in this Study for evaluating the environmental effects of process, transport and offsets:

Process Emissions

As mentioned above, MSW DST is a USEPA-commissioned, peer-reviewed tool that evaluates environmental impacts of specific waste management strategies or existing systems using LCA optimization framework. The tool has received both a formal peer review and extensive input from stakeholders representing a wide range of interests (see list at https://mswdst.rti.org). MSW-DST uses underlying LCA databases that have also been developed, commissioned, recommended, or used by USEPA and each represent a standard and generally accepted methodology / data source for their specific environmental impacts, such as:

- TRACI which is both an industry standard and USEPA-developed LCA tool. https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci
- IPCC is the industry-standard authority on climate change and USEtox is an industry-standard model https://usetox.org/model

Transport Impacts

GREET (GHGs, Regulated Emissions, and Energy Use in Transportation) - Argonne National Lab life cycle model was used to assess LCA transportation impacts.

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[24] Section 4, Page 4-5 of A Decisions Support Tool for Assessing the Cost and Environmental Performance of Integrated Municipal Solid Waste Management Strategies: USER MANUAL

Energy Grid

EIA was used to determine offsets for the regional energy grid. The EIA is the only source that provides data projected out to the dates needed for the Study. The EIA's most local projections are for the Pacific region, which includes Washington, Oregon, California, Alaska, and Hawaii. Projections excluding Alaska and Hawaii were not available. To provide some localization, because Washington has a high percentage of hydropower, the renewable vs. non-renewable split projected for the EIA Pacific region was re-allocated to align with the renewable split for Washington. The final percentages used in modeling are shown in Table 2-3.

Table 2-3: Energy Grid Mix

Type	Energy Source	Modeled Grid Mix	Major impacts
Non-renewable (NR) fossil combustion	Residual oil	1.75%	NR energy, acidification, global warming, smog
Non-renewable fossil combustion	Natural gas	13.61%	NR energy, acidification, global warming, smog
Non-renewable fossil combustion	Coal	0.48%	NR energy, acidification, global warming, smog
Non-renewable non-combustion	Nuclear power	2.43%	NR energy
Renewable other combustion	Biomass	1.21%	Acidification, smog [note: biogenic carbon not counted to align with IPCC standards]
Renewable non-combustion	Hydroelectric	72.65%	Water consumption (evaporation from reservoirs) for process and transport impacts only
Renewable non-combustion	Wind	7.42%	*Minimal impacts*
Renewable non-combustion	Solar	0.44%	*Minimal impacts*

Using these environmental impact factors, data sources and grid assumptions as well as process and transport assumptions for the disposal options and LCA modeling tools, life cycle environmental impacts and benefits were analyzed for WEBR, Mass Burn and RDF options as further described in this report.

2.4.2 Economic

The Economic criterion examines the estimated Capital and Operating Cost of the disposal options and potential Cost per Ton (2040-2060$) to implement. Economic criteria for each disposal option includes (1) Capital Cost (equipment, building, infrastructure, potential expansion where applicable and estimated land acquisition costs), (2) Operating Cost (labor, maintenance, materials, fuel, regular facility and equipment upgrades) including disposal costs, (3) Revenue, (4) Cost per Ton, and (5) Financial Risks. The Capital and Operating Costs were developed based on input from facility operators who indicated that the Operating Costs cover regular facility and equipment upgrades to avoid major replacement costs in the future. The Cost per Ton is calculated by adding the annualized Capital and Operating Costs then subtracting Revenue and dividing by tons for that year. The goal for this criterion is to minimize the cost impact of options.

An economic financial model was developed to compare options based on assumptions for bond financing (30-years at 4% interest rate), inflation (3.5% annual rate) and cost and revenue based on reference facilities and available data. The cost model includes estimated Capital and Operating Costs as well as Revenue, if applicable, for each disposal option for all three tonnage scenarios. The basis for the comparison of alternatives is the Cost per Ton (Annual Capital + Operating Cost – Revenue divided by tons) projected over the 20-year Study period from 2040 to 2060. Detailed assumptions and results of the economic cost models are provided in each disposal option section of this report.

2.4.3 Operating History

The Operating History criterion focuses on whether the disposal options are considered commercially and technically proven or utilized successfully in other known jurisdictions. The evaluation of Operating History for each disposal option considered how many years the option has been operating at the scale needed for King County, Safety records and Regulatory and Environmental Compliance. The goal for this criterion is for disposal options to have a proven Operating History at the scale needed for King County and to have proven Safety records and Operating History of Environmental and Regulatory Compliance.

2.4.4 Logistics

The Logistics criterion examines the logistics of implementing the disposal options including the operational life of the facility/program, the level of difficulty to site and permit the facility (as well as design and construct, if applicable) and the compatibility of each option to integrate with the County's current collection system (including transfer of waste from transfer stations and processing facilities). The goal for this criterion is to ensure that the option is logistically feasible as it relates to the likelihood of being implemented and being compatible with the current solid waste collection system.

2.4.5 Social

The Social criterion focuses on identifying potential disparate impacts to communities due to disposal options and associated facilities. The goal of this criterion is to minimize social impacts on or provide social benefits to communities based on disposal options that create jobs and have less impacts on the livability and character of a community due to truck traffic, and noise, air, odor and groundwater impacts. It should be noted that many Social impacts are related to a specific site and this Study does not assume a site location so a more detailed analysis of those Social impacts will occur as part of a future siting process.

2.4.6 Capacity

The Capacity criterion focuses on the disposal options' ability to process the total volume and fluctuating quantities of waste (i.e., flexibility in operating low and high volumes), residual waste management and changing characteristics of waste. The goal for this criterion is to assess whether there are limitations to the capacity of the disposal options and whether additional processes are required to process the waste and manage the residuals.

2.5 Solid Waste System Analysis Boundaries

To streamline the Study analysis, the following boundaries were established to ensure the results for the evaluation criteria were consistent and comparable across the Study parameters.

Figure 2-8 provides a visual representation of the boundaries that are being applied to the analysis. To ensure the results were comparable, a closure date of 2040 for the CHRL was chosen to provide a starting point for the options analysis with a 20-year (2040-2060) study period.

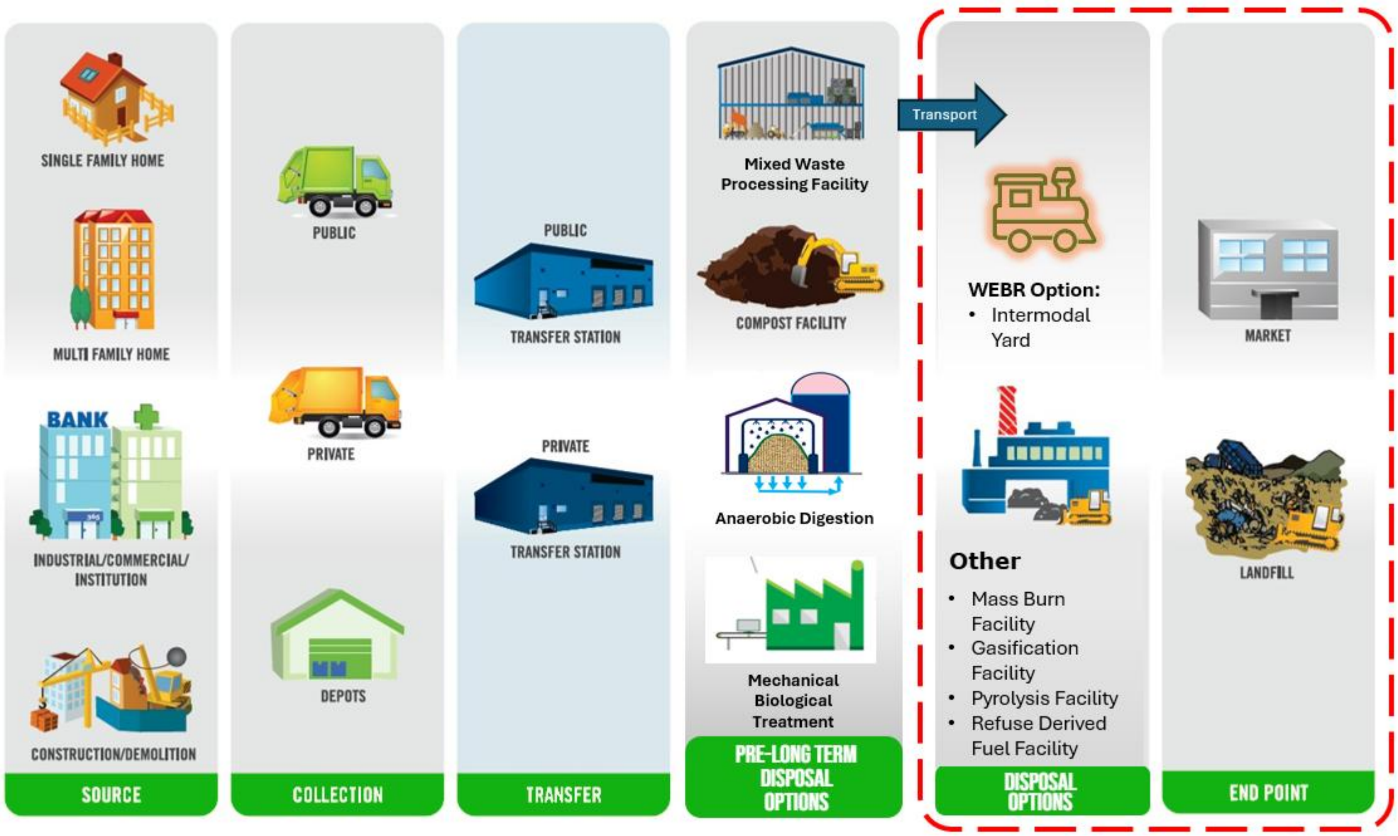

Figure 2-8: Identification of Study Boundaries for the Disposal Options Analysis

The Study boundaries start at the IMF yard for WEBR and at the other facility option locations, assuming that operations at the Mixed Waste Processing Facility or other pre-long term disposal option facilities and transport from those facilities to the Study facility are similar between all Study options. The exception is that the evaluation of the environmental transport impacts and traffic truck trips (under Social criteria) did consider the transport from the Mixed Waste Processing Facility to the Study facility. The boundaries also include transport to recycling markets and landfills for disposal of residuals.

3.0 WASTE EXPORT BY RAIL

3.1 Introduction

Section 3.0 of the Study explores the potential future use of a WEBR option to meet King County's future solid waste disposal needs. Research, industry interviews, analysis, and summaries of the WEBR option was led by Tetra Tech Team member WIH Resource Group.

A WEBR option would export compacted MSW in intermodal containers via railroad transportation Figure 3-1to an out-of-county landfill after the permitted disposal capacity at CHRL is reached (assumed to be 2040). WEBR is a proven disposal option used by neighboring jurisdictions, including the City of Seattle, Kitsap County, Thurston County, Skagit County, and Snohomish County.

There are three primary regional landfills in the Northwest actively receiving waste by rail. All can receive King County's waste by rail with a combined capacity sufficient to handle the County's waste in the long term under any of the three Study tonnage scenarios. It is key to point out, especially since King County manages its solid waste disposal internally, that a WEBR option would transfer a significant portion of the County's waste management activities into the private sector for railroad long haul and landfill disposal. This is in contrast to existing and historical County waste management practices. Therefore, the County would relinquish some direct control, risk and liability to the private sector while maintaining some oversight responsibility.

Figure 3-1: Double-Stack Rail Transport is the Standard Configuration for WEBR

3.1.1 Railroad Interviews

As part of the Study, members of the Tetra Tech Team interviewed the UPRR and the BNSF, the two Class 1 railroads that serve the major privately-owned landfills in Washington State 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 King County's solid waste, and to discuss their perception of the opportunities and constraints that King County faces in preparing for a potential WEBR program.

Before the interviews, each company was provided with a list of key questions and potential operating issues. 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 report.

The following summarizes the feedback from the railroads:

- Both railroads expressed an interest in handling King County's waste tonnage. Before deciding, each company would require more detailed information and would evaluate the overall economic and operational impacts of adding that tonnage.
- The railroads expect both railway freight and passenger traffic in the Seattle/Portland corridor to grow (see Section 3.8.1). 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 by 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 Consumer Price Index (CPI). 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. 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.

3.1.2 Background and Methodology

As a potential option for future waste disposal in King County, WEBR involves the transportation of pre-compacted MSW via 40' and 48' long intermodal shipping containers, each capable of accommodating an average payload between 25 and 31.5 US tons. As shown on Figure 3-1 the containers are "double stacked" on "Husky Stack" railroad "well cars" for maximizing the payload per railroad well car to reduce railroad transportation costs on either a per ton, intermodal container and/or railroad well car basis. For the purposes of the Study, the WEBR option evaluation assumes utilization of existing railroad tracks and intermodal infrastructure and capacity, and private sector-owned and operated waste disposal landfill infrastructure to provide efficient, cost effective and environmentally less impactful waste transport and disposal (T&D). This is due to capitalizing on the existing rail transportation and rail-served out-of-county private sector landfill infrastructure, other regional jurisdictions' experience dating back to the late 1980s, as well as both the BNSF and UPRR respective experiences in providing railroad transportation of waste.

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 located nearby). All three collect and beneficially reuse their LFG (methane). The WEBR-served and SWD-identified landfills (in alphabetical order) considered in this Study are listed in Table 3-1 and shown on Figure 3-2.

Table 3-1: Active Northwest WEBR Served Landfills (Alphabetically)

Landfill	Owner/Operator	Location	Serving Railroad
Columbia Ridge Landfill (CRLF) and Green Energy Plant	WM (Waste Management)	Arlington, OR	UPRR
Finley Buttes Landfill	Waste Connections	Boardman, OR	UPRR
Roosevelt Regional Landfill	Republic Services	Roosevelt, WA	BNSF Railway

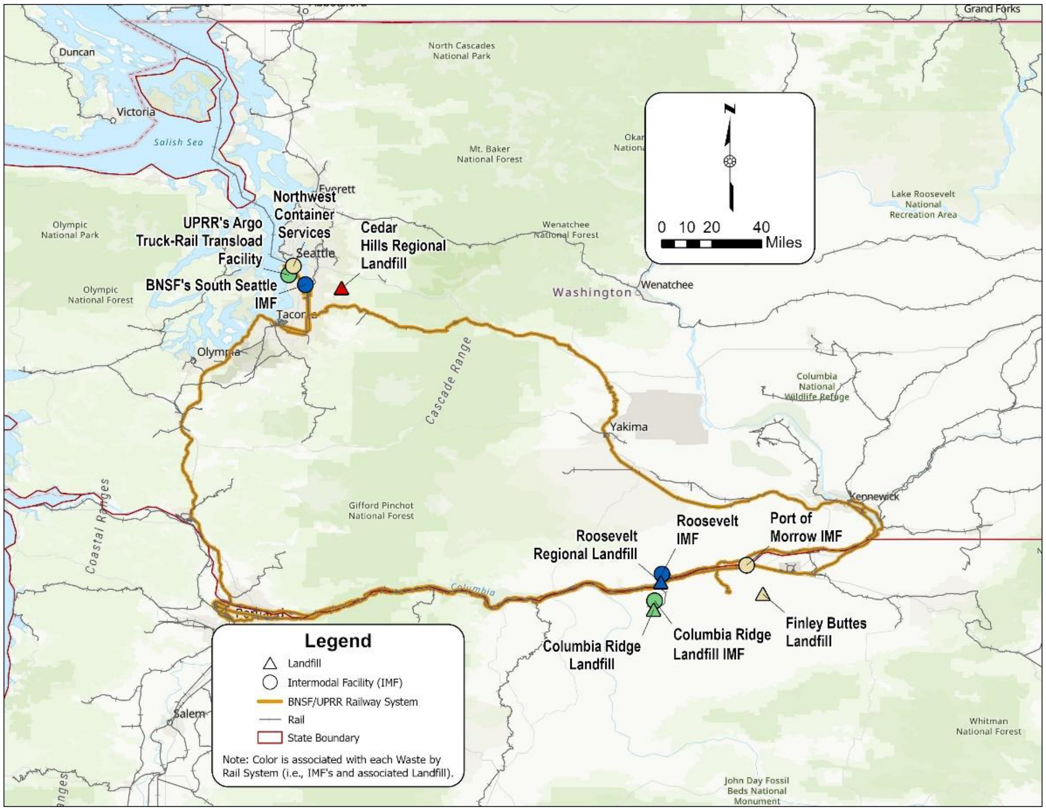

Figure 3-2: Active Northwest WEBR Served Landfills and IMFs

3.1.2.1 Other WEBR WA State Landfills

In addition to the three landfills in Table 3-1, the Tetra Tech Team evaluated several other potential landfills for consideration including WM Greater Wenatchee landfill located outside Wenatchee, WA, and WM's Adams County landfill near Washtucna, WA. However, at the time of the Study they either are not conveniently served by rail, not completed in terms of landfill cell construction (Adams), or they lack LFG collection and beneficial reuse systems required to meet King County's requirements. As a result of these factors, they have all been excluded from this Study.

Greater Wenatchee Landfill

This landfill could be a viable option for the County by 2040 with BNSF Railway service. It does have pest protocols for apple maggot restrictions and there is not an active rail siding at the landfill. An over-the-road trucking service could provide cost-effective backup services in the event of a railroad outage or capacity constraint via Interstate 90. Highway legal 32 to 34-ton payloads could be achieved with lightweight over-the-road equipment, assuming preloading compaction of waste in transfer trailers.

Adams County Landfill

WM is developing this facility as a permitted landfill. The timeline for completion is to be determined but will be operational in the next few years. There are no restrictions on out-of-county waste, and it will be a fully permitted and lined Subtitle D landfill. Rail service would be available but not onsite, so a transload and trucking of intermodal containers would be necessary at a local IMF. Both the UPRR and BNSF service this area.

3.2 WEBR Evaluation Parameters and Assumptions

This section addresses the key Study boundaries, assumptions, and parameters for the WEBR portion of the Study as agreed upon with SWD staff in Project Memorandum No. 3 – Study Evaluation Boundaries and summarized below:

- The gate of the future disposal option facility is assumed to be located within the County (i.e., no County waste will cross over into neighboring counties to IMF's located outside of King County). For the WEBR option, the gate represents the intermodal yard where waste would be delivered from transfer stations, or Mixed Waste Processing Facility.
- Compacted waste container payloads for the WEBR option are assumed to be in truck/intermodal containers and chassis to determine how many intermodal containers and chassis will be required.
- Capital Cost estimates on chassis were secured from manufacturers for the cost model. The cost for intermodal containers would be part of the rail T&D rate and borne by the railroad company (not a cost to the County).
- Landfill environmental criteria factors were determined for the three primary landfills (see Table 3-1).
- Estimated Capital and Operating Costs for the WEBR option do not include solid waste transfer station costs or costs associated with truck drayage of preloaded intermodal containers from a Mixed Waste Processing Facility to the IMF as those costs are assumed to be similar for each of the Study long-term disposal options. It should be noted that any additional transport costs for Mass Burn and other disposal options on the back end of the facility operation are added in the cost analysis for those particular options.
- Intermodal containers and super chassis are assumed to be used for transport to IMFs and estimated charges from rail service providers are based on available capacity and historic rates and annual rate increases to determine 2023$.
- A specific location for the IMF assumed for the waste export option is not identified, rather a general area for assessing transport distances is used.

3.3 Environmental Criteria

To perform modeling of environmental criteria, detailed assumptions and input parameters were developed for WEBR which included landfill characteristics, transport assumptions and locomotive assumptions. These assumptions are detailed in Appendix A - Environmental Impact Factors and Assumptions for County Consideration and Approval (January 23, 2024) which was concurred on by SWD.

3.3.1 Environmental Modeling Assumptions - Waste Export Landfill Characteristics

As part of interviews, research, and data requested from the three WEBR-served and King County-qualified landfills, the following information was collected and is summarized in Table 3-2 which includes each landfill's gas recovery and beneficial reuse of the methane captured and leachate management operations as reported by the landfill operators. The key landfill characteristics are as follows:

- LFG management processes, gas collection performance, and LFG characteristics/properties.
- Energy from LFG (amount, energy source it will replace).
- Leachate managed through a leachate collection and removal system which pumps leachate to ponds for evaporation or recirculation within the landfill pursuant to Ecology permits.

Table 3-2: Summary of WEBR Landfill Gas Management Characteristics

LFG Collection Efficiency	Columbia Ridge	Finley Buttes	Roosevelt Regional
LFG 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%	• 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%	• 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%
Moisture condition assumptions	Dry (k=0.02), Less than 20 inches of precipitation per year	Dry (k=0.02), Less than 20 inches of precipitation per year	Dry (k=0.02), Less than 20 inches of precipitation per year
Collected Landfill Methane			
Use(s) of the captured gas	Currently, LFG is sent to 12 Caterpillar Engines generating approximately 12.8MW of electrical energy that is sent to Seattle City Light. Columbia Ridge has permitted and is in the process of constructing a brand new state-of-the-art 12,000 cubic feet per minute RNG facility. This RNG facility will complement the existing LFG electrical energy system.	To create renewable energy, a vast majority of the landfills' methane gas is harvested through a perforated piping system of over 100 vertical and horizontal extraction wells and high-density polyethylene piping. Managed by Finley BioEnergy, the gas is routed to suitable energy recovery systems or combustion devices. The Combined Heat and Power system allows for the sale of 25 million kilowatts per year to the local utility, Pacific Corp, and over 45,000 Therms (heat)/month to Cascade Specialties, a local food processing plant.	Recovered for processing to RNG. Landfill cells are covered for gas capture in advance of the regulatory requirement of 5yrs of waste placement or 2yrs if at final grade.

The ratio of flared gas to the gas used for beneficial use	This varies but approximately 51% is sent to the LFG Flares currently. The new RNG plant will treat the balance of the LFG that is currently flared.	100% of the captured gas is used.	2022 data – 99% of the gas was processed for RNG, 1% flared
If the gas is used to generate electricity or put back into the grid, how is it purified?	All LFG to Energy engine power produced is fed directly into the grid. Electricity is not purified but is produced to meet grid standards.	The gas is used to run Caterpillar engines. It is filtered to use the gas to create electricity to supply the grid along with the heat from the engines used to dry onions next door at an onion plant.	Recovered for energy - RNG
Efficiency of the gas burned for electricity – How many kWh for each cubic foot of gas burned?	This is typically not measured and is highly dependent on LFG methane quality. However, the typical engine conversion efficiency is approximately 30% to 32%.	2.4 Kw	2022 data – 99% of the gas was processed for RNG, 1% flared

Summary of WEBR Leachate Management Practices

Interviews with operators of the Columbia Ridge and Roosevelt landfills were conducted to learn more about how they prevent and mitigate environmental impacts from leachate. The interviews indicated that both disposal facilities have effective leachate management treatment procedures that include implementation of advanced engineering controls, adherence to state and federal regulatory requirements, and continuous monitoring of the sites to ensure that liquids permeating through waste materials are properly collected, treated, and disposed of.

The Columbia Ridge Landfill (owned and operated by WM in Arlington, Oregon), uses a composite liner system that includes multiple layers to prevent leachate from seeping into the surrounding environment. A leachate collection system is installed above the liner to efficiently capture and remove leachate. The collected leachate is stored in engineered impoundments designed to meet or exceed regulatory standards. WM ensures that leachate is treated appropriately before disposal, adhering to the guidelines set forth by the Oregon Department of Environmental Quality (ODEQ)[25]. Continuous monitoring of leachate and groundwater conditions is conducted to ensure the effectiveness of the leachate management system. This includes regular sampling and analysis to detect any potential contamination, allowing for prompt corrective actions if necessary.

The Roosevelt Regional Landfill (owned and operated by Republic Services) in Roosevelt, Washington, is a lined facility with 430 acres constructed of the permitted 915 acres. The landfill utilized an 80 mil High Density Polyethylene liner with either 2' clay liner or with a Geocomposite Clay Liner to protect groundwater. Leachate is removed from the landfill via gravity to three dual lined ponds. From there the leachate is either put back into the landfill into one of the five existing reintroduction areas or moved to one of three purpose-built, dual lined evaporation ponds. Because the management of leachate is done at the landfill, "Forever Chemicals" (PFAS, PFOA, etc.) are fully retained onsite with no impact to the environment. The landfill operates under permits issued by Ecology[26],

[25] https://www.oregon.gov/deq/FilterDocs/SWGuidance06.pdf
[26] https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Solid-waste-permits

which mandates specific leachate management practices to protect water quality. These permits require the implementation of the best management practices and regular reporting to ensure compliance.

3.3.2 Environmental Modeling - Transport Assumptions

This subsection addresses the following transport assumptions and characteristics (see Table 3-3) for WEBR long-distance for all three tonnage scenarios.

1. Distances;
2. Vehicle types; and
3. Vehicle weights and payloads.

The intermodal container payload capacity is limited by a combination of the truck, chassis, and container tare weights, Washington State legal highway limits, and the railroad's Husky-stack double container well cars being rated for 84.5-ton payloads (which includes the container tare weight). As a result, an achievable payload of preload compacted waste could be about 32 tons, which may be difficult to achieve on a consistent basis.

Per SWD input, an assumed compacted waste payload ranging from 25 to 28 tons per intermodal container was requested. Furthermore, 28 tons per County transfer trailer, with about a 100 cubic yard capacity, was assumed. Under WEBR, the current equipment configuration would change from the current transfer trailers to intermodal containers on superchassis. Therefore, 28-ton average payloads were selected for the WEBR analysis.

Additional County input included:

- Although compaction ability will not likely be an issue, the County could bump up against the Washington State Department of Transportation bridge weight limit before it maxes out its compaction capability;
- SWD staff created a rough estimate of the compaction rate on the residuals resulting from the Juno mixed waste processing facility in Toledo, Oregon[27] (which exceeded 28 tons payload per trailer if a different mixed waste processing technology was used, the resulting residual mix/density would likely be different);
- It is anticipated that SWD will be using EV trucks by 2040. Since current EV trucks are heavier than diesel trucks, this could reduce the waste payload since the gross vehicle weight rating of the combined truck, superchassis, and loaded container is a fixed number;
- There are not any current labor agreement rules regarding load density; and
- The County would benefit cost-wise if it were able to achieve a payload of 30 or 31 tons in the future, but this was not the base assumption for WEBR in the Study.

The landfills currently use diesel or low-sulfur diesel Class 8 Off-road trucks (aka tractors) to shuttle (dray) intermodal containers from the nearby IMF to the landfill. During the bidding process, the County could specify a different type of tractor for emissions reduction or other reasons.

[27] Home - Juno | Georgia-Pacific (gpjuno.com)

Table 3-3: Summary of WEBR Transport Characteristics

Note: This information applies to all tonnage scenarios			
Transport Characteristic/Assumptions	**Columbia Ridge**	**Finley Buttes**	**Roosevelt Regional**
Distance: Estimated one way (in miles) from Seattle to Landfill(s)	325	352	330
Vehicle Type (Landfills): Class 8 Trucks - Off-Road Container Drayage Trucks from landfills' IMFs to the working face of the landfills for tipping containers.	Class 8 Trucks - Off Road – Diesel powered. Manufacturer varies but largely Peterbilt's.	Class 8 Trucks - Off Road – Diesel powered. Manufacturer varies but largely Peterbilt's.	Class 8 Trucks - Off Road – Diesel powered. Manufacturer varies but largely Peterbilt's.
Vehicle Type (King County): For container drayage to origin to IMFs.	Assumed to be Class 8 Kenworth T680E – EVs, based on information obtained from SWD staff.		
Vehicle/Container Payloads	For planning purposes for this Study, and in communications with SWD staff, 28 tons average payloads are to be used. All landfills cited can accommodate higher container payloads.		
Locomotive Engines	The BNSF and the UPRR use various locomotive manufacturers, primarily diesel-powered. Only in the past few years have hybrid locomotives been developed to use electric and hydrogen. Based on research summarized in following sections, it was assumed for the Study that locomotives would be powered by a combination of low sulfur diesel and 30% biodiesel blend fuel.		
Fuel Types & Amounts	Currently off-road and low-sulfur diesel. Amounts of fuel used varies by the respective landfills' IMF distance to the working face. Kwh equivalents would be used for any future vehicles running on batteries.		

Locomotive Engines

The following is a summary of the railroad industry's current stance (as of 2020, latest information available during analysis) on electric locomotives according to the Association of American Railroads[28]. The County would need to carefully consider attempting to require the railroads to provide electric-powered locomotives as part of a WEBR procurement for services.

[28] Freight Rail Data Center - AAR

Electric locomotives are not able to satisfy the extremely demanding requirements of heavy long-haul freight railroading and would cost far more than a new diesel locomotive costs today. Because U.S. Class I freight railroads alone have more than 24,000 locomotives in their fleets, the cost of replacing just half of the existing Class I locomotive fleet would be close to $100 billion. Finally, the demands of this catenary system may exceed the capacity of available electric grids in certain areas throughout the rail network. As a result, electrification would likely require building new power plants in areas where the existing electrical supply is inadequate and constructing countless transmission substations to deliver uninterrupted electricity supply.

Freight railroads' savings on future diesel fuel purchases would not sufficiently offset the costs of electrification either. Over the past 10 years, annual Class I railroad fuel expenses have averaged $8.7 billion. As such, it would take decades to fully recover the total investment made by freight railroads to electrify their networks, and that timespan fails to account for the likely extensive ongoing maintenance for such a system.[29] In addition, a University of Illinois at Urbana-Champaign Study concurred with this finding, concluding that electric locomotives would be unable to generate fuel and energy cost savings large enough to offset increases in annual non-capital costs and additionally noting that its finding did not factor in the likely large-scale diversion of freight from rail to truck due to electrification.[30]

Unlike America's trucks, barges, and airlines, America's freight railroads operate overwhelmingly on infrastructure that they own, build, maintain, and pay for themselves. If the total cost of installing and maintaining this catenary system was placed upon railroads, it would severely impair their ability to make needed long-term infrastructure investments to maintain and improve the productivity and sustainability of their systems, provide better service to their customers, and remain competitive within the freight transportation sector. Additionally, this cost burden would weaken railroads' ability to develop and implement innovative technologies that could improve their safety and efficiency.

Finally, even if the federal government completely covered the cost of the construction of this system, there are many other far more cost-effective and impactful ways to reduce US GHG emissions by 0.5%, which is the freight railroads' share of US GHG emissions.

Union Pacific Railroad Hybrid-Electric Locomotives

According to the 2023 Union Pacific Railroad Building America Report[31], while current advances in low- or zero-emission passenger rail vehicles are encouraging, additional research and development is required before the industry can adopt zero emissions locomotives at scale. The rate of adoption of new low- or zero-emission technologies by Class I railroads will depend on seven factors. These include (1) technological readiness determined through locomotive reliability testing; (2) safety considerations; (3) the rate of growth of alternative fuel sources or electricity; (4) readiness of the national infrastructure to deliver alternative fuels or electricity; (5) interoperability within the rail network; (6) workforce education on new locomotive technologies; and (7) the production capabilities of locomotive manufacturers.

The UPPR has partnered with ZTR to build six hybrid battery-electric locomotives for operational testing and revenue service. The locomotives are being constructed at UPPR's locomotive shop in North Little Rock, Arkansas,

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[29] AAR-Electrification-Fact-Sheet.pdf
[30] Transitioning to a Zero or Near-Zero Emission Line-Haul Freight Rail System in California: Operational and Economic Considerations -FINAL-2016-Spring-R2
[31] pdf_up_2023_build_america_rpt.pdf

and the first unit was expected to undergo extensive testing beginning in May 2024. The next of the remaining five hybrid locomotives is expected to be ready for testing in 2025. These would be the first of its kind locomotives within North America's freight rail industry and would function similarly to plugin hybrid cars, with the ability to operate in various modes. These locomotives will have multiple charging options for their batteries, including wayside charging and onboard self-charging capabilities.

Depending on the mode of operation, these hybrid switchers are expected to consume as much as 80% less fuel – reducing associated GHG and criteria pollutants. Additional benefits include reduced noise and lower maintenance expenses compared to diesel units.

Recent conversations (September 2024) with UPRR representatives indicated that the railroads do not have EV charging infrastructure along the mainlines and that these are not foreseeable any time soon. The representatives also stated that the locomotives currently being tested are not proven, nor is the technology available at this time to be able to attempt to utilize EV locomotives in mainline service. The UPRR could not provide a timeline as to if, or when, fully electric locomotives would be used in mainline service such as for trains hauling MSW from Seattle to WM's CRLF.

3.3.3 Environmental Criteria Analysis Results

Table 3-4 summarizes impacts by environmental factor for WEBR to landfill, and Table 3-5, Table 3-6 and Table 3-7 break down the results by Process, Transport and Offsets for the low, medium and high tonnage scenarios. Positive figures represent a harm or impact, while negative figures represent a benefit or savings by avoiding an environmental harm. The summary includes impacts from transporting waste by rail, landfill operations, and offsets or avoided impacts from replacing conventional natural gas with RNG or electricity derived from LFG. Offsets or avoided impacts are those that do not occur from other sources of electricity generation and natural gas because the LFG is replacing/offsetting them with the electricity/RNG that it generates. The impacts of generating electricity/RNG from LFG is accounted for in the Process impacts.

WEBR Environmental criteria impacts presented in Table 3-4, Table 3-5, Table 3-6, and Table 3-7 are influenced by diesel use in rail transport (contributes to Non-Renewable Energy Demand, Global Warming Potential and Smog Formation), landfill equipment used for onsite operations (contributes to Acidification Potential and Smog Formation) and escaped LFG before closure/capping (contributes to Global Warming Potential). WEBR has process and transport impacts for Water Consumption. Environmental benefits for Water Consumption associated with generated energy offsets were not considered in the Study findings because the majority of credit for grid electricity replacement would be due to avoiding upstream and process impacts of hydroelectric power, reducing evaporation in reservoirs (considered water consumption), which is considered a baseload power source in Washington so would not be replaced. It should be noted that the Study did not include a feasibility study to determine the electricity sales end user so if the end user is outside the EIA region modeled for the Study, the results will be different.

Human Health Toxicity - Cancer Potential is low for WEBR as landfills generally do not have as many direct emissions that contribute to Cancer Potential. Offsets or avoided impacts presented in Table 3-5, Table 3-6, and Table 3-7 are associated with natural gas production avoided with RNG converted from LFG or grid electricity avoided with LFG to electricity. Based on information for the three potential WEBR landfills, a 50/50 mix of LFG to electricity and LFG to RNG was assumed.

Table 3-4: Summary of Environmental Criteria for WEBR Disposal Option

Environmental Factor	Units	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Non-Renewable Energy Demand (Energy Production)	MJ	789,570,555	539,995,760	293,219,787
Water Consumption (Water Quantity)	L H_2O	47,468,701	30,471,217	16,238,251
Acidification Potential (Air Quality)	kg SO_2 eq	376,978	342,581	89,513
Global Warming Potential (Climate Change)	MT CO_2 eq	93,279	55,588	38,625
Smog Formation Potential (Air Quality)	kg O_3 eq	7,433,555	5,014,996	2,715,616
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	10	7	4

Table 3-5: Summary of WEBR Environmental Sub-criteria for High Tonnage/Low Diversion Scenario by Process, Transport and Offsets/Avoided Impacts

Environmental Factor	Units	Process (WEBR)	Transport	Offsets	Net Total
Non-Renewable Energy Demand (Energy Production)	MJ	761,244,670	110,863,429	(82,537,544)	789,570,555
Water Consumption (Water Quantity)	L H_2O	44,259,709	3,208,992	N/A[1]	47,468,701
Acidification Potential (Air Quality)	kg SO_2 eq	402,346	526	(25,894)	376,978
Global Warming Potential (Climate Change)	MT CO_2 eq	113,585	8,580	(28,885)	93,279
Smog Formation Potential (Air Quality)	kg O_3 eq	32,514	8,173,392	(772,351)	7,433,555
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	10	0	(0)	10

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Table 3-6 : Summary of WEBR Environmental Sub-criteria for Medium Tonnage/Medium Diversion Scenario by Process, Transfer and Offsets/Avoided Impacts

Environmental Factor	Units	Process (WEBR)	Transport	Offsets	Net Total
Non-Renewable Energy Demand (Energy Production)	MJ	506,768,197	72,606,823	(39,379,260)	539,995,760
Water Consumption (Water Quantity)	L H_2O	28,369,580	2,101,637	N/A[1]	30,471,217
Acidification Potential (Air Quality)	kg SO_2 eq	354,591	344	(12,354)	342,581
Global Warming Potential (Climate Change)	MT CO_2 eq	63,750	5,619	(13,782)	55,588
Smog Formation Potential (Air Quality)	kg O_3 eq	30,566	5,352,929	(368,499)	5,014,996
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	7	0	(0)	7

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Table 3-7: Summary of WEBR Environmental Sub-criteria for Low Tonnage/High Diversion Scenario by Process, Transfer and Offsets/Avoided Impacts

Environmental Factor	Units	Process (WEBR)	Transport	Offsets	Net Total
Non-Renewable Energy Demand (Energy Production)	MJ	278,674,811	39,975,003	(25,430,027)	293,219,787
Water Consumption (Water Quantity)	L H_2O	15,081,156	1,157,095	N/A[1]	16,238,251
Acidification Potential (Air Quality)	kg SO_2 eq	97,302	190	(7,978)	89,513
Global Warming Potential (Climate Change)	MT CO_2 eq	44,432	3,094	(8,900)	38,625
Smog Formation Potential (Air Quality)	kg O_3 eq	6,443	2,947,152	(237,979)	2,715,616
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	4	0	(0)	4

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Other sub-criteria considered includes Resource Conservation and Compatibility with Waste Prevention and Recycling.

3.3.4 Resource Conservation

LFG collected at landfills is converted into electricity or RNG.

3.3.5 Compatibility with Waste Prevention & Recycling

WEBR does not provide an opportunity for waste prevention or recycling.

Table 3-8: Other Environmental Considerations for WEBR Disposal Option

Environmental Factor	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Resource Conservation	LFG is converted to electricity or RNG.		
Compatibility with Waste Prevention and Recycling	Does not provide opportunity for waste prevention or recycling.		

3.4 Economic Criteria

This category examines the estimated Capital and Operating Cost for the WEBR disposal option. Information obtained for the economic modeling of the WEBR option included costs for purchasing equipment and rail T&D costs. Costs for truck transport from the Mixed Waste Processing Facility to the WEBR IMF were assumed to be similar to truck transport to the other disposal option facilities so were not considered in the Study. Cost projections were performed for 2040 through 2060, assuming 30-year bond financing, 4% interest and 3.5% inflation rate. Other assumptions are provided in the following sections.

3.4.1 Capital Costs

3.4.1.1 Equipment Costs – Trailer Chassis

This subsection provides details of the Capital Costs for the WEBR long-term disposal option which includes equipment required specifically for transporting rail containers on specialized chassis. An extended length, quad-axle, intermodal super-chassis combined with a 40 to 48-foot steel intermodal container can accommodate as high as 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-foot-long intermodal containers stacked two high.

Based on discussions with SWD staff, the Tetra Tech Team was requested to consider an average compacted waste payload per intermodal container range from 25 to 28 tons per load. Because the railroads have a higher payload capacity, the high end of the SWD range (28 tons per load) was used for the Study analysis. Table 3-9 presents the equipment cost for the trailer chassis required for each tonnage scenario.

Table 3-9: Estimated Equipment Cost for WEBR Alternative

Tonnage Scenario	Unit Cost	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion[3]
Trailer Chassis	$85,570	$2,738,255	$1,882,550	$1,026,846

[1] 32 trailer chassis to dray containers to the IMF.
[2] 22 trailer chassis to dray containers to the IMF.
[3] 12 trailer chassis to dray containers to the IMF.

It should be noted that for the cost modeling of WEBR equipment cost in the high tonnage scenario, only the differential cost between the additional walking trailers needed for the other disposal options and the WEBR equipment cost is considered.

3.4.1.2 Waste Compaction and On-site Transfer Operations

Figure 3-3: SSI 4500 Waste Compactors

The WEBR alternative requires a preload compactor (see Figure 3-3[32]) to fully utilize the limited volume capacity in standard 40 to 48-foot-long 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 as high as 32-ton payloads of compacted waste.

Daily waste volume controls the hours required to compact and transport waste into intermodal containers. Waste composition impacts the time to compact each load - the drier the waste, the longer it takes to compact and load into the intermodal containers. Compactor operations average 2.5 loads per hour or 25 loads per ten-hour shift.

Figure 3-4 Container Chassis

The minimum number of compactors required for the high-volume scenario is four. This calculation assumes a daily, ten-hour shift that could fill 100 containers. The midrange scenario would require three compactors, and the low tonnage scenario would only require two compactors. When the waste compactors are built in tandem, such as the SSI 4500 compactors in Figure 3-3[33], one compactor operator can manage both machines with a shared control panel. For the high-volume scenario, two compactor operators would be required. Compaction operations require one operator, plus a yard tractor operator and spotter to position and remove the containers from the compactor. Per input from SWD, existing compactors are assumed to be used so no purchase of compactors is included in the Study costing.

[32] Tetra Tech (2012). *Staggard compactor at a Transfer Station* [Photograph].
[33] *Marketing image for the 40' Lightweight Gooseneck 4-Axle Chassis sold by Cheetah Chassis Corporation* [Photograph]. Cheetah Chassis Corporation's website.

Time expended each day to compact loads is dependent on the daily count of containers available to fill. Ideally, SWD's Mixed Waste Processing Facility should have an area to stage two days of containers (approximately 200), container chassis and yard tractors.

3.4.2 Operating Costs (Rail Transport and Disposal Rate)

For the WEBR option, the Operations Cost as compared to other disposal options is the rate charged by the waste company for rail T&D - which is historically a bundled rate – less the depreciation cost of the equipment. For this Study, existing Washington WEBR program (legacy) contracts and recent Washington WEBR program contracts were reviewed to develop estimates for this Study's evaluation.

3.4.2.1 Existing Washington WEBR Contracts

For consideration of the "legacy" WEBR programs in place since the early 1990s, with the exception of Kitsap County which started in 2000, Table 3-10 below provides a summary of those legacy programs as a reference for legacy rail haul costs and associated waste volumes. Although these legacy contracts have been in place for decades, the rates are based on recent renewals or rate adjustments per contract provisions.

Table 3-10: Existing Washington WEBR Jurisdictions

	City of Seattle	Snohomish County	Kitsap County
WEBR Landfill	WM / Columbia Ridge	Republic/ Roosevelt	WM / Columbia Ridge
Current rail T&D rate	$46.75 per ton.	$57.25 per ton with credit for higher waste compaction payloads per container.	$56.89 per ton.
2022 Annual Waste Tons Railed and Disposed	355,010 tons, according to the "Rail Reporting" data set used to create invoices based on WM's RAIL dataset, looking only at loads from North Transfer Station and South Transfer Station.	712,861 tons.	220,000 tons.
Container Payload (Average)	26 tons (they intentionally self-limit).	N/A	30 tons.
Railroad Transport	UPRR	BNSF	UPRR
Contract Details	1990 and the contract expires on March 31, 2028.	Started in the early 1990s. The latest renewal was in 2017 and expires in 2027, with some optional extensions.	Started in 2001 and recently renewed with WM for an additional 10-year contract in 2023.

3.4.2.2 Recent Washington WEBR RFPs and Proposals

The Tetra Tech Team also conducted research and collected current market information on recently issued Request for Proposals (RFPs) and proposals from the private sector for WEBR programs in Washington State.

The purpose of providing this information is that Seattle and Snohomish Counties, and to some extent Kitsap County, are considered "legacy" WEBR programs in the Pacific Northwest, meaning that they have been active WEBR programs since the early 1990s, with Kitsap starting around 2001. In addition to the City of Seattle, Snohomish County, and Kitsap County WEBR programs, two other jurisdictions recently issued RFPs for WEBR program services. Table 3-11 below provides a summary of the respective proposer's service offerings and rates.

Although the contracts presented in Table 3-11 are reflective of current pricing, the annual waste tonnage (volume) is much lower for Skagit and Thurston Counties than that of King County, and their respective locations are not as close to the larger WEBR (UPRR and BNSF) IMF's in the Seattle area. It is expected that King County could see pricing similar to the legacy contracts presented in Table 3-10 since their rates have recently been updated and they have higher volumes similar to King County, especially at one million tpy for the high tonnage scenario.

Table 3-11: Recent Washington WEBR RFPs and Proposal[1]

	Proposer and Summary of Proposer's Offerings		Proposers' Rates Per Ton (Averaged)
Jurisdiction	CRLF (WM).	Roosevelt Regional Landfill.	
Skagit County:10-year Contract - CRLF / WM just won. 130,000 tons annually. Proposals were submitted in February 2023.	$89.00 per ton for T&D (bundled rates); $60.37/ton Receiving and Rail Transport + $28.63/ton Disposal (unbundled rates).	$88.50 per ton for T&D (bundled rates); $55.30/ton Receiving and Rail Transport + $33.20/ton Disposal (unbundled rates).	$88.75 per ton (T&D bundled).
Thurston County: 10-Year Contract – Roosevelt Regional / Republic awarded. 206,000 tons annually. Proposals were submitted in April 2021.	$81.05 per ton for T&D (bundled); $26.85/ton for operations and maintenance (O&M) & Processing + $34.71/ton for Transport + $19.49 for Landfill Disposal.	$70.48 per ton for T&D (bundled); $14.77/ton for O&M & Processing + $28.10/ton for Transport + $27.61 for Landfill Disposal.	$75.76 per ton (T&D bundled).

[1] Source: conversations with representatives Skagit and Thurston Counties, respectively.

Based on the above existing contracts and recent proposals for WEBR programs for similar tonnages, the following assumptions were developed for the Study:

Medium and High Tonnage – Assume $60/ton (2023$) based on existing contract for similar tonnage for Snohomish (712,861 tons) = $57.25 (2023$)

Low Tonnage – Assume $65/ton (2023$) rail T&D based on following recent proposals or contracts for similar tonnage:

- Thurston County (206,000 tpy) = $75.76 (avg cost 2021 proposal)
- Kitsap County (220,000) = $56.89 (2001 contract, recently renewed in 2023)[34]

It is also noted that costs for containers, IMF operations and improvements would be included in the contracted rail T & D rate.

3.4.3 Revenue

While direct haul of waste to a landfill disposal site would not provide direct revenue to the County, it should be noted that electricity or RNG sales from LFG were included in the Cost per Ton calculation.

3.4.4 Financial Risk

Given that any contracts signed with the railroads to transport waste by rail would be short-term in nature (5–10-year contract terms), the biggest risk to the County would be the potential for railroads to significantly increase rates after the initial contract period ends. Contracts with railroads should be designed so that the County is protected from incurring additional costs as a result of a catastrophic event, emergency or other service interruption. Lastly, the Study parameters assume the use of existing IMF infrastructure for the WEBR option pursuant to interviews with railroad representatives. Therefore, waste containers and any IMF improvements would be included in the rail T&D rate.

It should also be noted that any newly proposed railway legislation requirements in Washington State may have a future impact on T&D WEBR rates charged to the County. For example, House Bill 1862 establishes regulations regarding the total overall length of trains operating in Washington State, with the stated goal to enhance public safety and environmental protection, which would impact railroad logistics and associated costs. The effects on a future WEBR program cannot be determined at this time. However, King County should continuously track and monitor any new legislation requirements in the State that could potentially affect both short- and long-term contract rates.

3.4.5 Cost per Ton

The Cost per Ton for WEBR includes the Operating Cost (or rail T&D cost) plus the chassis equipment Capital Cost amortized over 10 years.

3.4.6 Economic Criteria Summary

Table 3-12 provides a summary of results in evaluating the economic considerations for the WEBR disposal option and all tonnage scenarios. To assess the economics of the WEBR option and determine a comparative Cost per Ton impact, the Economic sub-criterion evaluates the Capital (equipment) Cost and Operating (rail T&D) Cost per Ton, and Total Cost per Ton, assuming use of an existing IMF for each tonnage scenario. Cost assumptions and results are included in the Appendix B - Comparative Evaluation Summary Matrices for each of the disposal options.

[34] Contract is with Waste Management and is a combined Transfer/Transport and Disposal contract with Waste Management operating the County's Olympic View Transfer Station which may have some impact on T&D disposal rate structure.

Table 3-12: Summary of Economic Criteria for WEBR Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capital Costs (2040$)[1]	$3.7M	$3.4M	$1.8M
Capital Costs (annualized)[2]	$366,695	$337,855	$184,284
Operating Cost (annual)[3]	$110M	$72M	$43M
Ash Residuals Disposal (annual)	N/A	N/A	N/A
Annual Revenue (2040$) - Electricity	N/A	N/A	N/A
Annual Revenue (2040$) - Recycling	N/A	N/A	N/A
Total Annual Cost (2040$)[4]	$110M	$72M	$43M
Annual Cost/Ton (2023$)[5]	$60.20	$60.28	$65.28
Annual Cost/Ton (2040$)[5,6]	$108.04	$108.19	$117.16
Annual Cost/Ton (2050$)[5,6]	$152.32	$152.52	$165.24
Annual Cost/Ton (2060$)[5,6]	$214.78	$215.06	$233.08

[1]Includes chassis equipment costs.
[2]Annual cost based on 10-year amortization of equipment.
[3]Includes rail T&D cost ($60/ton for High and Medium Tonnage, $65/ton for Low Tonnage in 2023$).
[4]Includes Annualized Capital and Operating costs.
[5]Equals Total Annual Cost/Total Tonnage.
[6] Inflation assumed at 3.5% annual.

3.5 Operating History Criteria

The Operating History criteria is focused on whether a WEBR option is a proven technology for King County as well as its compliance with Safety and Environmental regulations. In an effort to make a reasonably accurate comparison of WEBR to the four alternative technology options identified, the responses from the various parties interviewed for the WEBR option have been consolidated in this section.

3.5.1 Proven Performance

3.5.1.1 Rail Transport

WEBR for Washington municipalities is well-established, having been utilized 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, traveling east along the Columbia River on the BNSF railroad tracks to the Roosevelt Regional Landfill. The remaining waste quantity continues south to Portland and then east on UPRR tracks to the CRLF.

3.5.1.2 Landfills

As discussed throughout this section, only three landfills in Washington and Oregon qualify for consideration as SWD-qualified, GHG-viable, and economically long-term disposal solutions. They are the CRLF and Green Energy Plant in Oregon, Finley Buttes Regional Landfill in Oregon and Roosevelt Regional Landfill in Washington State. These landfills have been in operation since the early 1990's. Table 3-13 provides a summary of the key attributes of the three landfills.

Table 3-13: Summary of WEBR Served Regional Landfills in Northwest

Landfill Information	Columbia Ridge	Finley Buttes	Roosevelt Regional
Landfill's Legal Name:	CRLF & Recycling Center.	Finley Buttes Regional Landfill.	Regional Disposal Company, Roosevelt Regional Landfill.
Physical address & Location	18177 Cedar Springs Lane. Arlington, OR 97812.	73221 Bombing Range Rd. Boardman, OR 97818.	500 Roosevelt Grade Rd, Roosevelt, WA 99356
Years in Operation	Since 1990	Since 1991	Since 1992
Origin IMF Locations	UPRR's Argo Truck-Rail Transload Facility, 402 South Dawson Street, Seattle, WA.	NW Container at 635 S. Edmunds – Seattle, WA 98108 or UPRR's Argo Truck-Rail Transload Facility 402 South Dawson Street, Seattle, WA.	BNSF's South Seattle IMF: 12400 51st Place South Seattle, WA 98178.
Receiving IMF Location	On Landfill Property.	Port of Morrow – Boardman, OR.	Roosevelt Intermodal Yard is located at 28 Railroad Ave., along Washington State Route 14, with the Columbia River bordering to the South. The IMF is five miles via a private haul road to the landfill.
Permitted Remaining Capacity	Approximately 120 years of permitted capacity left: it receives about 2.7 million tons of waste per year and has approximately 320 million tons of remaining permitted air space.[1]	131 million tons. 200 years of life remaining.[2]	120 million tons over 40 years.[3]
Miles from Seattle[4]	317	352	330
Serving Railroad	UPRR	UPRR	BNSF

[1] Competing For Your Trash: The Huge, Hidden Landfills Of The Columbia River Gorge | Northwest News Network (nwnewsnetwork.org)
[2] Roosevelt Regional Landfill | The Center for Land Use Interpretation (clui.org)
[3] Columbia Ridge Landfill Fact Sheet (wmnorthwest.com)
[4] Estimated and actual may vary.

3.5.2 Safety, Environmental and Regulatory Compliance

Railroad regulatory compliance and oversight is overseen at both the Federal and State levels. At the Federal level, the FRA[35] creates and enforces rail safety regulations, administers rail funding, and researches rail improvement strategies and technologies. At the State level, the Washington Utilities and Transportation Commission (UTC) provides oversight of the railroad in both compliance and safety within the State of Washington[36]. In general, and as of this writing, both the BNSF and UPRR railroads comply with local, state, and federal regulations.

3.5.2.1 Safety Record

FRA's Office of Railroad Safety promotes and regulates safety throughout the Nation's railroad industry. The office executes its regulatory and inspection responsibilities through a diverse staff of railroad safety experts. The staff includes nearly 400 Federal safety inspectors who specialize in technical disciplines (i.e., grade crossing, hazardous materials, motive power and equipment, operating practices, signal and train control and track) focusing on compliance and enforcement.

With a focus on infrastructure equipment improvements, technology-enhanced inspections, and expansive employee training, the last decade has been the safest ever for rail[37]. Analysis of 2023 FRA data per million train miles indicates:

- For all railroads, the derailment rates have dropped 30% since 2000.
- Per carload, the hazardous materials (hazmat) accident rate is at its lowest ever and down 75% since 2000 based on preliminary data.
- Class I railroads' mainline accident rate is down 42% since 2000 but increased slightly compared to 2022.
- Class I railroads decreased yard accident rate per million-yard switching miles by 11%, reversing last year's increase.

Railroads are expanding their use of advanced technologies to monitor the health of cars, locomotives, and track in real-time, while also investing significantly in maintenance and upgrades. These advanced technologies help railroads keep tabs on equipment while in use, enabling proactive steps to fix issues early. Work continues to implement concrete, voluntary safety commitments made in 2023 to enhance railroads' ability to detect certain equipment defects and act before they result in an accident. More than 95% of all rail-related injuries and fatalities are attributable to trespassers and grade-crossing users.

The Washington State UTC's Railroad Safety Program[38] serves the public and railroad employees by implementing engineering, education, and compliance programs that reduce deaths, injuries, and property damage on or around railroads. The UTC compiles and publishes annual statistics on railroad-related incidents within the state, encompassing data on crossing collisions, injuries, and fatalities, as well as trespasser fatalities. In 2023 there were 51 crossing collisions, 20 crossing injuries, 2 crossing fatalities and 24 trespass fatalities in Washington state.

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[35] https://railroads.dot.gov/
[36] https://www.utc.wa.gov/regulated-industries/transportation/regulated-transportation-industries/railroads
[37] https://www.aar.org/issue/freight-rail-safety-record/
[38] https://www.utc.wa.gov/public-safety/rail-safety/about-rail-safety-program

Additional data specific to King County was requested from the UTC. In 2024, for non-Link Light Rail[39] incidents, there were 8 crossing collisions, 1 crossing injury, 0 crossing fatalities, 4 trespass fatalities and 24 derailments[40]. Separately, for Link Light Rail, there were 21 crossing collisions, 1 crossing injury, 0 crossing fatalities, and 0 trespass fatalities. The UTC does not, however, track Light Link Rail derailments. It is noted that rail derailment is typically more significant than a truck spillage incident where usually only one truck is involved, spilling significantly less waste than a train carrying 80 to 100 intermodal containers depending on the specifics of the spill. The Washington State UTC does not provide detailed specifics on number of containers spilled during railroad accidents or derailments.

3.5.2.2 Environmental and Regulatory Compliance

The FRA is an agency in the United States Department of Transportation (DOT) with a staff of about 850 people. The agency was created by the DOT Act of 1966. The purpose of the FRA is to promulgate and enforce rail safety regulations, administer railroad assistance programs, conduct research and development in support of improved railroad safety and national rail transportation policy, provide for the rehabilitation of Northeast Corridor rail passenger service, and consolidate government support of rail transportation activities. The FRA provides its FRA Guidance Portal[41] which is intended to help regulated entities and the public understand existing requirements under the law or agency policies.

FRA's environmental staff are responsible for managing the environmental review process for projects that receive financial assistance from FRA. This process includes ensuring compliance with the NEPA and other relevant federal environmental laws, reviewing and approving environmental documents, and issuing decision documents.

On April 22, 2022, the FRA announced the Rail Industry Climate Challenge for owners and operators along national rail network and manufacturers of rail equipment to reach net-zero GHG emissions by 2050. This is not a law and it is up to the railroads to comply. It is difficult to predict the exact percentage that the locomotive fuel blend will be when CHRL closes in 2040 (e.g., 30%-40% or higher, etc.) but for the Environmental criteria analysis, an estimate of 30% biodiesel blend fuel was conservatively assumed based on existing UPRR-stated forecasts for the foreseeable future.

In Washington State, the FRA website provides a searchable database of railroad industry reports. The Washington State Rail Safety Oversight Program Standard[42] sets clear expectations and obligations for the Washington State Department of Transportation (WSDOT) State Safety Oversight Program and the rail transit agencies it oversees. The Program Standard contains requirements for rail transit agencies in Washington state, including accident notification, corrective action plans, and oversight of internal safety reviews. The Program Standard also clarifies how the State Safety Oversight team works with rail transit agencies to accomplish activities such as investigations and federally mandated triennial audits.

Other regulatory changes or policies that impact railroad operations should be monitored for any impact on a future WEBR program, for example the Climate Commitment Act (see Section 4.1.1.2).

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39 Link Light Rail is a rapid transit system in the Seattle metropolitan area that uses light rail trains to move people around. Link Light Rail uses the same railroad tracks as the UPRR and BNSF.

40 A derailment is defined as any time the wheels of a train car leave the track. For example, if the wheels of a train car hop off the track during a switching operation in a railyard, leaving the car upright, that is considered a derailment.

41 https://railroads.dot.gov/guidance

42 https://wsdot.wa.gov/engineering-standards/all-manuals-and-standards/manuals/rail-safety-oversight-program-standard

3.5.3 Operating History Criteria Summary

Table 3-14 provides a summary of results in evaluating the Operating History for each Study tonnage scenario. The subcriterion considered for Operating History includes an assessment of Proven Performance, Safety Record, Environmental and Regulatory Compliance for each Study tonnage scenario.

Table 3-14: Summary of Operating History Criteria for WEBR Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Proven Performance	• WEBR in practice in Washington 30 plus years and at tonnages needed.		
Safety Record	• Good. Industry's safety-centered approach to investments and operations delivers overall improvements that have made the last decade the safest ever for rail. • Analysis of 2023 FRA data per million train miles indicates that for all railroads, the derailment rates have dropped 30% since 2000; per carload, the hazardous materials (hazmat) accident rate is at its lowest ever and down 75% since 2000 based on preliminary data and Class I railroads' mainline accident rate is down 42% since 2000 but increased slightly compared to 2022. • Safety data specific to King County was requested from the UTC. In 2024, for non-Link Light Rail[1] incidents, there were 8 crossing collisions, 1 crossing injury, 0 crossing fatalities, 4 trespass fatalities and 24 derailments. • Rail derailment is typically more significant than a truck spillage incident where usually only one truck is involved, spilling significantly less waste than a train carrying 80 to 100 intermodal containers depending on the specifics of the spill. The Washington State UTC does not provide detailed specifics on number of containers spilled during railroad accidents or derailments.		
Environmental and Regulatory Compliance Record	• Both BNSF and UPRR railroads comply with local, state, and federal regulations. • On April 22, 2022, FRA announced the Rail Industry Climate Challenge for owners and operators along national rail network and manufacturers of rail equipment to reach net-zero GHG emissions by 2050. • Although not a requirement, for the Study Environmental criteria analysis, an estimate of 30% biodiesel blend fuel was conservatively assumed based on existing UPRR-stated forecasts for the foreseeable future. • Regulatory changes such as more (or less) stringent emissions limits from diesel locomotives; other GHG measures can affect the amount of available rail capacity by 2040.		

3.6 Logistics Criteria

The following are the key components for Logistics and system compatibility of a WEBR option for King County and includes evaluation of sub-criteria for Operating Life of Facility, Siting/Design/Permitting/Construction considerations and timelines for implementation, and Compatibility with the Existing Collection System.

3.6.1 Operating Life of Facilities

The Operating Life of Facilities considered for WEBR includes the IMF and end destination landfills. Existing IMFs owned by the railroads are expected to be in operation as long as the railroads are in existence. Based on feedback from the three landfills and their current and projected waste disposal volumes, they have a combined life of over 300 years as shown in Table 3-13.

3.6.2 Siting/Design/Permitting/Construction Considerations

3.6.2.1 Intermodal Facility (IMF) within King County

One of the most critical components for a WEBR option is locating an IMF within King County for loading and unloading the intermodal containers onto rail cars for transport to selected landfill(s) for disposal. 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. Ideally, if a WEBR option for long-term disposal were to be selected by the County, preferably the County would find a "reciprocally served" (i.e., dual access by both railroads) site within its borders. This would help maintain competition among both the railroads and the landfills. As part of this Study and research with the two railroads, a site of this nature is not currently available.

As part of this Study, the siting, design, and construction of a new IMF is not being considered under the direction of the SWD and the Tetra Tech Team's independent research and industry analysis concluded that the existing privately owned and operated IMFs within King County are sufficient to process the County's waste at any of the forecasted tonnage levels. The reliance on private sector IMFs eliminates the need for SWD to allocate capital for new IMF infrastructure, presenting a significant advantage for the WEBR system. Furthermore, the private sector landfills own and operate their own IMFs, making additional siting or construction of IMFs at landfill locations redundant.

The following Table 3-15 provides an overview of the available and foreseeable IMF alternatives for King County.

Table 3-15: King County IMF Alternatives

Option	Ownership/Location	Description and Characteristics
1	BNSF South Seattle IMF 12400 51st Pl S., Tukwila, WA 98178	The BNSF Railway owns an IMF that transfers intermodal containers from trucks to railroad and vice versa. This facility is located within the City of Tukwila city limits in the Allentown community. The IMF is adjacent to Interstate 5 (I-5) and just south of King County International Airport, also known as Boeing Field. BNSF calls this facility the South Seattle IMF.
2	UPRR Seattle Intermodal Terminal (aka Argo Yard) 4700 Denver Ave., So. Seattle, WA 98134	The Argo Yard is an intermodal rail shipping facility owned and operated by UPRR. Argo Yard is located at Fourth Avenue South and Dawson Street in Seattle. UPRR has a separate entrance for exclusive use by waste transfer vehicles. Currently, the UPRR operates a sufficient number of intermodal lift trucks (“top picks”) and provides sufficient storage space in the yard for loaded and empty containers to ensure service of transfer vehicles within the required 20-minute average cycle times.
3	King County’s Harbor Island Site (Formerly Fisher Mills)	King County purchased the former Fisher Flour Mills on Harbor Island in Seattle. In 2021, the King County SWD investigated the feasibility of siting a Transmodal Containerized Waste Shipping Facility at the site located at 3235 15th Avenue South. The project site is zoned Industrial (UI - IG1 U/85), and the Duwamish riverbank sections of the project site are in the City of Seattle’s Shoreline District. The existing site contains tilt-up concrete warehouse spaces, an occupied brick office/admin building, a collection of mothballed factory/admin buildings, and an array of concrete silos, some other spaces and areas of which are tenanted. In response to requests to the UPRR about railroad serviceability and access, in an email dated 3/11/2024, UPRR representatives offered the following response: The UPRR does service Harbor Island currently 3 times a week. Depending on the weekly proposed volume, and UPRR services at the time, they can give King County official approval upon receipt of an AccessUP request for service. The County would need to let the UPRR know when it is close so the UPRR can run the approvals through and provide the County with a Service Notification and respective track agreements for the County’s Harbor Island IMF. Use of this County-owned property as an IMF is not considered in this Study.

3.6.2.2 Development of RFP for a WEBR

While not part of this Study, if the County were to pursue a WEBR option for its long-term disposal, it is anticipated that the County would need to issue a Request for Proposal (RFP) for services that would be subject to an implementation timeline. In discussions with the two railroads and the three private sector landfill companies, all suggested a 3 to 4-year timeline from issuance of an RFP by the County in order for proposers to develop comprehensive responses, work with the respective railroads, and procure the necessary equipment and labor to accommodate the County’s waste volumes (which would be accounted for in the contract rate).

3.6.2.3 Procurement of Equipment

A wide range of equipment is necessary for a successful WEBR program and Table 3-16 summarizes the minimum needed equipment and their respective manufacturing lead times which longest lead time is 18 months to be considered for implementation timelines.

Table 3-16: 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 meet the 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.

3.6.3 Compatibility with Current Collection System

Utilizing existing private sector-owned and operated facilities such as the BNSF or UPRR IMFs in south Seattle as part of a WEBR option for King County is completely compatible with the County and its 37 member jurisdictions’ current collection systems.

3.6.4 Logistics Criteria Summary

Table 3-17 provides a summary of results in evaluating the Logistics criteria for each Study tonnage scenario. The Logistics criterion includes an assessment of sub-criteria such as the Operating Life of Facilities (in years), Siting, Permitting, Design, and Construction requirements and Compatibility with Current Collection System for each WEBR disposal option tonnage scenario.

Table 3-17: Summary of Logistics Criteria for WEBR Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Operating Life of Facility (years)	Based on current and projected waste disposal volumes, the 3 landfills have a combined life span of 300 + years.		
Siting/Permitting/Design/ Construction Requirements (years)	The WEBR option for this Study does not include siting, permitting, designing, and constructing a County owned IMF. The implementation timeline for this option includes an RFP for WEBR services (3 to 4 years) and 18-month lead time for equipment procurement.		
Compatibility with Existing Collection System	• High compatibility. • Utilizing existing, private sector-owned and operated facilities such as the BNSF or UPRR IMFs is compatible with the County's collection and processing system.		

3.7 Social Criteria

This subsection qualitatively identifies Environmental and Social Justice/Equity considerations and known localized impacts, such as Local Traffic and Other Potential Neighborhood impacts, that may affect the livability or character of the community where the IMF is located since currently the County transports its waste to the CHRL and that would change current traffic patterns. The Social criterion also considers social benefits such as Local Job Creation.

3.7.1 Environmental and Social Justice/Equity (ESJ)

For the WEBR option, ESJ potential impacts will be comparably less than for the other disposal options that require siting and permitting new facilities as the WEBR option assumes the use of existing facilities for the Mixed Waste Processing Facility, IMF, rail system and end destination landfills. There will be new transportation impacts between the Mixed Waste Processing Facility and the IMF which impacts would be similar to existing transport impacts from transfer stations to the CHRL. Additional rail use is also assumed to be similar to existing rail impacts.

3.7.2 Local Traffic Impacts

Truck Trips

Implementation of a WEBR option will impact traffic on regional transportation networks' roads and the railroads. Current MSW-related truck traffic flows are to/from County transfer stations to the CHRL. Under a WEBR option, those trucks would be re-directed to the IMFs. As part of this Study, and at the direction of the County, a specific site for a Mixed Waste Processing Facility, nor a specific receiving IMF, have not been selected. As a result, a localized analysis of traffic impacts at the IMF is not feasible. Traffic impacts will be shifted from the vicinity of the CHRL 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 CHRL.

To estimate truck trip impacts for the WEBR option at the IMF, the container hauls were calculated based on the total estimated peak tons and a 28-ton per container payload. The average monthly MSW disposed at the CHRL from 2021-22 was 72,745 tons (874,840 total tons for 2021 and 871,028 tons for 2022). The peak months of waste disposal during this period were 79,199 tons in 2021 and 79,391 tons in 2022. Both of these amounts are 9% higher than the two-year monthly average. Therefore, the WEBR baseline capacity assumption is 9% higher than a 12-month average (((79,199 + 79,391)/2) / 72,745) which is applied to the estimated daily container hauls. In Table 3-18, Estimated Daily Container Hauls from existing transfer stations to an IMF includes the number of daily container trips for the three Study tonnage volume scenarios.

Table 3-18: Estimated Daily Container Hauls

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Monthly Average (Annual Tons /12)	84,864	55,579	30,600
Plus Peak Month Tons (% of total tons)	109%	109%	109%
Monthly Tons (Average x Peak %)	92,506	60,584	33,356
Daily Tons (Monthly Tons / (365/12)	3,041	1,992	1,097
Tons per Container	28	28	28
Peak Estimated Daily Container Hauls (one way)	109	72	40

Railroad At-Grade Crossings

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 to run 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, railroads are attempting to minimize and eliminate highway-railroad at-grade crossings. This could further affect regional traffic impacts.

To help determine the potential regional traffic impacts due to additional railway traffic related to the WEBR option, the average speed of a train and the number of cars passing an at-grade crossing was estimated. An at-grade crossing is defined as a location where a railroad track intersects with a roadway, pedestrian path, or another rail line at the same level or elevation (See Figure 3-5[43] example of a train at an at-grade railroad crossing intersection). Railroads and local authorities monitor at-grade crossings for safety, efficiency,

Figure 3-5: Train at an At-Grade Crossing

[43] Frost, A (2019). *Safety crew inspecting at-grade rail crossing on a highway* [Photograph]. "US Transportation Secretary launches safety initiative for highway-rail crossings" from Traffic Technology Today's website.

and traffic flow, sometimes upgrading or converting them to overpasses or underpasses if traffic volume or accident rates are high.

The Tetra Tech Team reached out to representatives within the UPRR to better understand the potential impacts within King County. While UPPR could not provide an average railcar transport speed for local at-grade crossings in the King County area, mainline average train speeds are tracked and reported. The UPPR's trains reached an average speed of approximately 23 miles per hour[44] (MPH). This speed is based on their entire US rail network, so actual speeds will vary within King County, and most likely will be slower.

For purposes of calculating the ranges of a train passing at-grade crossings within King County, Longer Husky Stack well cars were assumed. While the actual length of the well cars can vary based on the railcar's design, purpose, and the rail company's specifications, the Husky Stack well cars used in Seattle's Waste by Rail program are between 60 and 70 feet in length (double stacked), so the assumption of a 65-foot-long well car was used in estimates to determine the length of time for a railcar, and for an entire train, to pass through an at-grade crossing. In order to calculate the time it takes for a single 65-foot railroad well car to pass a typical at-grade crossing at different speeds, the following formula was used:

$$Time\ (in\ seconds) = \frac{Length\ of\ the\ car\ (in\ feet)}{Speed\ (in\ feet\ per\ second)}$$

Using the summary estimates from the calculations and assumptions above, the medium tonnage scenario of 666,000 tpy was used for the elapsed passing times as detailed in Table 3-19 below. These estimates provide a summary of the assumptions, calculations, and the estimated range of at-grade crossing transit times based on varying train speeds with a range of between 2 and 15 minutes depending on the factors noted.

[44] The UPRR Key Performance Metrics can be found at https://investor.unionpacific.com/key-performance-metrics

Table 3-19 Railroad Crossing Potential Impacts, Variables, Assumptions and Estimates[1-5]

Constant Variables	
Annual Waste Tons	666,000
Container Payloads (In Tons)	28
No. of Containers Annually	23,785,71
No. of Days per Week (312 Days per Year)	6
No. of Containers per Day	76
No. of Double-Stack Well Cars Daily	38
Length of Well Car (In Feet)	65
Length of Cars in Train (In Feet)	2,478

Dependent Variables

Average Speed (MPH)	Transit Time per Railcar (In Seconds)	Total Elapsed Time Passing At-Grade Crossings for an Entire Train of Cars (In Minutes)
2	22.8	14.48
5	8.87	5.64
10	4.43	2.81
15	2.95	1.87

[1] The estimated range of at-grade crossing times is impacted by the average speed of a train and the number of cars passing an at-grade crossing.
[2] There are a lot of variables and caveats, and even some unknowns that cannot be discovered until an in-depth Study is conducted observing trains passing through various at-grade crossings within King County to gain a better idea of the real speeds and other factors.
[3] Ideally, a Study would need to be conducted to confirm estimates.
[4] Train speeds vary at different times, locations, and local other factors such as rail line traffic congestion, number of at-grade crossings within a given distance of railroad tracks, and residential homes and businesses adjacent or near the rail lines.
[5] Travel speeds and timing may change in the future depending on congestion, etc.

To gather information on more accurate local traffic impacts once an IMF location is determined, it is recommended that a comprehensive Traffic Study be conducted from the proposed SWD Mixed Waste Processing Facility to each of the IMFs by a qualified traffic consulting firm.

3.7.3 Local Job Creation

The estimated number and types of jobs created in King County for a WEBR option is based largely on the need for additional labor to load and unload the intermodal containers on and off the railroad cars at the IMF, assuming existing local labor is already managing the SWD waste volume at the Mixed Waste Processing Facility. The change in operation would be for the County's trucking fleet, which currently utilizes trucks and tipper-type trailers, to dray preload compacted waste for transport from the County's transfer stations to the CHRL daily. With Re+ and the use of a Mixed Waste Processing Facility in the future, the County trucks would transport the waste after it's processed and compacted into intermodal containers and take it to a central IMF so no new local job creation would result in terms of truck transportation.

The following categories were developed for consideration in comparing the Study disposal options based on skill/training and compensation level. Potential skill categories are:

- **Minimal skill.** Requires no prior skill and minimal on-the-job training. 0 Jobs.
- **Technical skill.** Requires an Associate's degree, technical certificate, or similar level of on-the-job technical training.
    - 6, 8 and 10 Skilled Laborers (respectively for tonnage scenarios).
    - Working at the IMF including container top pick operators, container twist lock handlers, railroad crews, scale house attendants, and other jobs as may be required by the County.
    - 1 Administrative support personnel for Manager
- **Advanced skill.** Requires Bachelor, Masters, or other advanced degree or equivalent level of on-the-job training and years of experience.
    - 1 Manager to serve as the WEBR Program Manager or Supervisor for SWD.

These estimates do not include any jobs related to the Mixed Waste Processing Facility for pre-sorting and compaction of the County's waste as those jobs are similar between all options. These are estimates for new jobs created at the IMF in King County and do not include new jobs created at out of County landfills. Additional jobs created at the landfill are estimated at 7, 10 and 11 Skilled Laborers (respectively for tonnage scenarios).

3.7.4 Other Potential Neighborhood Impacts

Concerning Other Potential Neighborhood Impacts at the existing BNSF and UPRR IMFs based on a qualitative comparison between options, they are already located in industrial areas of the County and the incremental impacts of the additional truck traffic from the County's waste being trucked into the facilities would most likely increase potential odors, noise, vectors, and vibrations. In addition, highway use and road wear would increase within the neighboring areas. Again, a recommendation for the County is to retain a qualified traffic consulting firm to determine the exact impacts and identify possible ways to mitigate and minimize the impacts on local neighbors.

Air – Low Impact.

Air impacts are primarily emissions from truck and some rail transport. Air emissions from rail transport and landfill operations out-of-County are not considered in Other Potential Neighborhood Impacts for King County but are considered in the Environmental criteria analysis.

Odor – Low Impact.

The primary source of odor is loading containers at a Mixed Waste Processing Facility which would be similar to existing operations and unloading at the IMF which would be in an industrial area.

Noise – Medium Impact.

Incremental impacts of the additional truck traffic from the county's waste being trucked into the facilities would likely increase noise and vibration issues. In addition, highway use and road wear would increase within the neighboring areas. Location in industrial zone would minimize impacts on residential receptors.

Groundwater – No Impact (at IMF).

There is no impact to groundwater for the IMF loading operations. The potential for groundwater impacts with landfilling operations is considered in the Environmental criteria analysis.

3.7.5 Social Criteria Summary

Table 3-20 provides a summary of the results in evaluating the Social criteria for each tonnage scenario. The sub-criteria considered in this evaluation includes ESJ considerations, Local Traffic Impacts (truck trips), number of Local Jobs Created and Other Potential Neighborhood Impacts.

Table 3-20: Summary of Social Criteria for WEBR Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
ESJ/Equity	• Impacts on communities near IMF and around rail line to be considered when rail program is selected. Increased congestion near IMF and longer wait times at railroad crossings to be analyzed in project level SEPA analysis when location of Mixed Waste Processing Facility and IMF are identified. • Environmental impacts will be greater for frontline communities. • Economic impacts greater for low-income households because cost increases represent a higher share of their income than for other households.		
Local Traffic Impacts (Number of Truck Trips/Day)[1]	218	144	80
Local Job Creation[2]	12 Jobs Created Minimal Skill: 0 Jobs Technical Skill: 11 Jobs Advanced Skill: 1 Job	10 Jobs Created Minimal Skill: 0 Jobs Technical Skill: 9 Jobs Advanced Skill: 1 Job	8 Jobs Created Minimal Skill: 0 Jobs Technical Skill: 7 Jobs Advanced Skill: 1 Job
Other Potential Neighborhood Impacts (Air, Odor, Noise, Groundwater).	• Air – Low Impact • Odor – Low Impact • Noise – Medium Impact • Groundwater – No Impact (at IMF)		

[1] Roundtrips from Mixed Waste Processing Facility to IMF, assumes 9% increase for peak tonnage days.
[2] Description of minimal, technical and advanced skills included in Section 3.7.3 above. Additional jobs created at the out-of-County landfills estimated at 7, 9 and 11 Skilled Laborers (respectively for tonnage scenarios).

3.8 Capacity Criteria

This category of analysis is focused on the ability of a WEBR option to handle different types of waste and volumes (i.e., flexibility in operating low and high volumes) and residue disposal requirements. Another key sub-criteria consideration is capacity and availability of the WEBR option to support the projected tonnages for King County.

3.8.1 Capacity/Minimum Waste Requirements

For the WEBR option analysis, both long-term landfill disposal and railroad track and locomotive capacities must be considered. As mentioned above under Section 3.6.1 - Operating Life of Facilities, the combined landfill capacities for the three landfills considered for WEBR is over 300 years.

For analysis of rail capacity, the two serving railroads were interviewed and presented with the three waste tonnage volumes scenarios approved by SWD staff and both railroads stated that the low, medium, and high ranges do not pose a problem in terms of railroad transportation capacity. Both railroads did state that the high-range scenario of 1 million tons annually would need to be planned for in terms of local railroad logistics and they prefer at least a 3 to 5-year timeframe in advance of commencing services. In a recent interview with WM, they are currently seeking large volumes of tons for export and recently purchased additional containers and chassis to meet their capacity.

In addition to contacting the railroads and landfill operators, the Tetra Tech Team conducted research on rail capacity in Washington. Since the mid-2000s, numerous studies of the capacity of Washington's railroads have been performed, many on behalf of the WSDOT. These studies have looked at factors such as the inherent physical capacity of the track system; the location of traffic induced, construction and other types of transportation bottlenecks; growth in demand for shipment by rail as well as by truck or barge; the effects of climate change[45]; proposed capital improvement projects; and related public and private investment. The most recent Study relative to this Study's WEBR disposal option is the Washington State Rail Plan (2019-2040).[46]

The 2020 Washington State Rail Plan 2019 - 2040 described 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 planning observations found within the 2020 Plan include:

- The rail system in Washington consists of both freight and passenger rail elements, with the freight rail system containing a network of expansive main lines, branch lines, yards and terminals.
- Freight railroads are commonly categorized by their operating revenue, a classification system used by the federal Surface Transportation Board. The three classes of railroads are:
    - Class 1 (Annual Operating Revenue in excess of $489.9 million). BNSF Railway Company and UPPR are the only Class I railroads operating within Washington and operate the majority of freight rail lines.
    - Class 2 (Annual Operating Revenue between $39.2 million and $489.9 million) – none operating in Washington State.
    - Class 3 (Annual Operating Revenue below $39.2 million). These rail carriers (commonly called short line railroads) connect communities to the national rail system.

[45] WSDOT. 2011.
[46] Washington State Rail Plan 2019- 2040, https://wsdot.wa.gov/sites/default/files/2021-10/2019-2040-State-Rail-Plan.pdf

- In Washington State rail carriers not only move the freight, they commonly also own, maintain and control the physical infrastructure.
- It is the responsibility of each railroad to make decisions about capital investments and maintenance spending.
- Freight rail volumes declined between 2009 and 2013; rebounded in 2014; and increased gradually over the next three years (with an annual average of 120 million tons).
- In 2017, there were 42.8 million tons of cereal grains and other agricultural products shipped by rail, accounting for 35% of total rail shipments. Coal was the second largest commodity moved by rail, accounting for 10% of total rail volume.
- The rail plan established three scenarios to forecast possible future growth models for the freight rail system: low growth, moderate growth, and high growth as shown in Table 3-21**.**

Table 3-21: Freight Rail Demand Forecast Scenarios

Category	Low Growth Scenario	Moderate Growth Scenario	High Growth Scenario
Driven by:	A significant decline in export volumes and the resulting cumulative effects	Growth in industries requiring long-haul movement of heavy commodities	Robust growth in export volumes
Tariff Assumptions:	Tariffs imposed by the U.S. and other nations have a substantial, lasting effect on international trade and suppress export activity	No long-term effects from tariff and trade tensions	Tariffs imposed by the U.S. and other nations have little to no effect on international trade volumes and/or are removed with minimal or no lingering effects
Additional Assumptions:	Assumes high potential negative effects on agricultural imports/ exports and international containerized trade, and declined energy exports	Based on Federal Highway Administration's Freight Analysis Framework[1]growth rates and long-term macroeconomic forecasts derived from REMI model	Assumes high potential growth in energy exports caused by proposed bulk shipment facilities for coal and oil, and robust potential growth in international containerized trade and agricultural imports and exports

[1] Freight Analysis Framework - FHWA Freight Management and Operations

- In 2016, Washington's freight rail system moved 122 million tons of products. The low growth scenario projects a decline in rail tons to 110 million tons (0.4% annual decline). Under the moderate forecast, freight rail traffic is projected to grow annually by 2.4% to 216 million tons by 2040. The high growth scenario projects major growth to 321 million tons by 2040, an annual growth rate of 4.1%.
- Nationwide, rail coal volumes have declined in recent years, primarily due to domestic power plants converting to natural gas or other alternatives, but coal remains a crucial commodity for U.S. freight railroads. With the decline in coal for domestic consumption, coal export is expected as the main type of coal shipment by rail handled through Washington in the future.
- The freight volume forecasts indicate that some Class I rail corridors in Washington could see volumes that exceed current capacity. Unless rail system infrastructure is enhanced, this future growth could overwhelm

rail system capacity due to shortcomings, such as passenger/freight conflicts, height limitations on rail tunnels and bridges, inadequate siding lengths or bridge capacity.

- In reality, the Class I railroads (BNSF and UPRR) and other infrastructure owners will likely address key capacity issues as they emerge. Therefore, the 2040 capacity assessment is included here to illustrate the magnitude of future rail traffic anticipated for the rail system in Washington. It underscores the need for continued planning and action to address capacity and mobility concerns throughout the system.
- Rail is a relatively fuel efficient and therefore cleaner way to move freight. In 2015, particulate matter (PM) emission was estimated to be 0.008 grams per ton-revenue mile for rail, and 0.023 grams for trucks, indicating that rail emission rate for PM is 65% lower than trucks.

In 2017, WSDOT purchased eight new Siemens Charger locomotives to power Amtrak Cascades passenger trains. These diesel-electric locomotives meet USEPA's strictest Tier 4 emission standards and reduce PM and Nitrous Oxide (NOx) emissions by more than 80% over the locomotives they replaced.

WEBR: Solid Waste Transfer and Waste Management Plan (SWD 2006)[47]. In addition to the State studies noted above, the County performed its own analysis of WEBR in 2006. Notable points that may still apply today include:

- The County should decide about WEBR no more than 5 years before waste export is implemented.
- SWD evaluated a phased approach to WEBR, and 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".
- SWD evaluated a publicly owned and operated IMF as well as publicly owned but privately operated IMF.
    - The benefits of a privately owned and operated IMF include:
        - The County would avoid the 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.
        - If the 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 very likely enable a single, vertically integrated company to handle all aspects of waste export and disposal, which could discourage future competition in the region.

An important takeaway from the recent Study 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

[47] Solid Waste Transfer and Waste Export System Plan - King County Solid Waste Division

once. As stated above, the County considered this over a decade ago (SWD 2006). An updated potential scenario is described below:

The County would begin by exporting 100,000-200,000 tons/year three years before full transition to WEBR (approximately 12 to 24% of tonnage going to CHRL), 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 12-24% of the annual airspace, thereby extending the life of CHRL by under two years even with an aggressive phase-in.
- 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 CHRL, plus the cost of partial waste export, would likely exceed the value of nominally increasing the life of the CHRL.

3.8.1.1 Rail Capacity Findings

The numerous 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 for 15 years in the future (2040). Four major types of change can affect the amount of available rail capacity in 2040:

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

Even at a million tpy, the County's solid waste would represent a small fraction of the 122 to 321 million tons of cargo anticipated to be rail-hauled in Washington in 2040, depending on the scenario volume.

As of the writing of this report, and according to representatives of the two railroads, there appears to be enough rail capacity to ship an additional 1 million+ tpy of the County's waste to either of the three private landfills that currently serve city and county governments in Washington and Oregon.

Absent a major catastrophe such as a landslide or earthquake that wipes out a significant portion of the Seattle-Portland track, there will continue to be some rail capacity. If in 2040 there is not enough capacity to carry an additional 1 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 the length of the contract, stability and/or growth in tonnage of a commodity being shipped and other factors from outside the region, etc.

If the County solicits bids for WEBR, its RFPs 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.

3.8.1.2 Recent Railroad Service Constraints

In early January 2022, Snohomish County solid waste transfer stations began experiencing a lack of needed containers via rail from BNSF, and during the following five months, garbage was piling up at their facilities.

In April, 2022, the Snohomish County Council approved an emergency contract with WM to aid Snohomish County Solid Waste in the removal of excess refuse at local transfer stations. The $2 million short-term waste transportation and disposal agreement gave county solid waste workers the ability to transport more garbage to out-of-county facilities through the end of October 2022.

Refuse had been at sustainable levels throughout the summer of 2023 but began to build up again due to railway staffing issues along with intermodal container shortages. The lack of a daily required number of intermodal containers to haul garbage impacted Snohomish County causing garbage piles and heightened risk of fires at county transfer stations[48].

Any future WEBR contract for King County should include provisions for the waste company providing WEBR service to provide alternate disposal options in the case of rail service interruptions or other emergency/catastrophic event impacting rail service.

3.8.2 Waste Type Composition and Acceptance

All non-hazardous MSW, including C&D waste, is accepted at all three WEBR landfills for disposal as presented in Table 3-22. The exceptions to this would be WtE ash which requires an ash monofill to be disposed of at the three receiving WEBR landfills.

[48] https://www.snohomishcountywa.gov/DocumentCenter/View/102822/Snohomish-County-Preparing-for-Possible-Temporary-Solid-Waste-Facility-Closures-as-Rail-Transportation-Issues-Persist?bidId=

Table 3-22: Acceptable Waste Types

Columbia Ridge	Finley Buttes	Roosevelt Regional
Accepted Waste		
• Abrasive blast media • Agricultural wastes • Animal carcasses • Asbestos-containing material (friable and non-friable) • Auto shredder residue • Biosolids • C&D debris Comprehensive Environmental Response, Compensation, and Liability Act of 1980 wastes • Dredged wet sediments • Filter cake • Incinerator ash • Industrial and special wastes • Medical waste (treated) • Treated wood	• MSW[1] • C&D[1] • Special Wastes (including liquids[1]	• MSW • C&D Debris • Wood Wastes • Petroleum Contaminated Soils • Incinerator Ash (in a permitted, ash monofill)
Unaccepted Waste		
• Appliances • Loose Sharps • Batteries • Tires • Discarded Vehicles • Used Oil • Hazardous Wastes (but does accept incinerator ash)	Does not accept hazardous waste or dangerous waste (but does accept incinerator ash).	Does not accept hazardous waste or dangerous waste (but does accept incinerator ash).
[1] Accepted with proper approval.		

The primary consideration for a successful, efficient, and especially cost-effective WEBR program, it to ensure that the MSW will be pre-load compacted before being loaded into the intermodal containers for T&D. The key factor here is that the lower compaction of the County's waste increases transportation costs.

3.8.3 Tonnage Flexibility

Considering future waste volume disposal capacities and the ability to handle and dispose of King County's proposed three scenario tonnage volumes, all three WEBR landfills stated they would be able to accommodate the County's waste given current waste volume projections, foreseeable landfill cell expansion plans, and future waste disposal capacities based on the current projected life of the three respective landfills.

Under the Flexibility criteria, consideration was given to disposal option ability to handle disruptions in operations due to emergencies or catastrophic events. For WEBR, the County should provide for a backup facility if rail transport is interrupted and truck transport to a landfill is required. In recent years, Snohomish and Skagit counties have had to close their transfer stations due to interruptions in rail haul service by BNSF (see Section 3.8.1.2).

Existing rail contracts include provisions for waste companies to provide alternative disposal options if WEBR service is interrupted. Future potential contract between County and their waste company should include similar provisions.

3.8.4 Residual Waste Management

With a WEBR disposal option, there would be no residual waste generated.

3.8.5 Capacity Criteria Summary

Table 3-23 provides a summary of the results in evaluating the capacity and flexibility for each WEBR tonnage scenario. This criterion evaluated above considers Capacity/Minimum Waste Required, Waste Type Composition and Acceptance, Waste Volume/Flexibility, and Residual Waste Management such as disposal or further processing.

Table 3-23: Summary of Capacity Criteria for WEBR Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capacity/Minimum Waste Required	• Technology is capable of processing amount of waste from this tonnage scenario including projected amount of 366,266 tpy by 2060. • Both serving railroads indicated that tonnage scenario volumes could be accepted although traffic and congestion as capacity is used on railroads can be a factor in the future. • Four major types of change can affect the amount of available rail capacity in 2040: Global Economic, Political, Climate or Regulatory Changes.		
Waste Type Composition and Acceptance	• High waste acceptance. • All non-hazardous MSW accepted at 3 landfill disposal facilities. • No requirements for the waste composition presorting or elimination of certain wastes, except the following: White Goods, Sharps, Batteries, Tires, Vehicles, Used Oil.		
Tonnage Flexibility	• High Flexibility. • Both serving railroads indicated that all 3 waste tonnage scenario volumes could be accepted. However, high range scenario would need 3-5 years of pre-planning. • Back-up alternative to WEBR should be identified and included in contract for emergencies or catastrophic events.		
Residual Waste Management (Disposal or Further Processing)	• No residual wastes generated.		

3.9 WEBR Evaluation Summary

Many communities (including several in and neighboring King County) 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 have older engines that emit more air pollutants such as PM and 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. Rail haul typically requires a truck haul (for drayage) of intermodal containers from the Mixed Waste Processing Facility or transfer station to the exporting IMF, as well as from the receiving IMF to the landfill working face to be “tipped” on a trailer tipper for disposal.

The advantages and disadvantages associated with implementing a WEBR option for the county’s long-term disposal solution are provided below.

Summary of Advantages

- Established disposal option for six other municipalities in Washington State at cost-effective rates at higher tonnages.
- Lower cost option. WEBR is a variable cost based on tonnage and rate for contract term duration.
- New IMF construction would not be needed – can utilize existing facilities.
- Current adequate rail and landfill capacity for King County’s three projected tonnage scenarios according to railroad representatives and landfill operators.
- 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 or service interruption, the waste companies should make alternative disposal landfills available.

Summary of Disadvantages

- To minimize their risk, railroads typically want contracts of 5 to 10 years. This affects future pricing projections and exposes the County to higher disposal cost risk in the future as railroad pricing increases would likely be passed on to the waste companies contracted with the County for WEBR. It would be the responsibility of the waste company contracted by the County to renegotiate directly with the railroad companies and to work with the County on any impacts to WEBR contract terms and conditions.
- Additional traffic and rail congestion as capacity is used on railroads will increase traffic delays for at-grade crossings and may impact capacity availability in the future. A future traffic study would determine impacts of at-grade crossings.
- In recent years, Snohomish and Skagit counties have had to temporarily close transfer stations due to service interruptions by BNSF Railway. Existing contracts cover alternative disposal due to service interruptions, which should be considered for any future WEBR contract with King County.
- While a USEPA rule has been proposed, no current Federal or USEPA mandates on emissions standards of alternative fuel usage exist. Thus, significant reductions in PM and NOx have not been required as early as they were for trucks (since 2007).
- Life cycle environmental impacts were determined for all environmental parameters evaluated except for Water Consumption (which was determined to be an environmental benefit). Most of the impacts are created outside King County because waste is exported. Human Health – Cancer Potential was low for WEBR.

4.0 MASS BURN

4.1 Introduction

Mass Burn is a well-established MSW disposal option more commonly found in Europe and Asia with over 70 plants in the US (further discussed in Section 4.4 – Operating History Criteria). It is a type of WtE technology that heats and burns MSW, producing heat that is used to create steam that is usually used to generate electricity. The ash residual from the burning process needs to be disposed of at a separate facility (i.e., ash monofill) via a WEBR type option. Any contract that King County enters into for ash transfer would be with the waste company service provider who would themselves contract directly with the railroad, similar to the WEBR option described in Section 3.0 of this report.

Mass Burn facilities reduce the volume of waste that ends up in landfills and generate energy from the thermal conversion of MSW to energy. In this type of facility, waste is generally burned as received with minimal pre-processing (some screening may be required for bulky items or large inert materials, but most is assumed to be removed at the Mixed Waste Processing Facility). Mass Burn also has a wide allowance of waste energy value as the primary limitation is at the upper end of the energy threshold. Most waste values range between 10.5 to 14 Gigajoules/ton (GJ/t)[49] but Mass Burn units can combust waste that has an energy value as low as 7 GJ/t. Because of this, Mass Burn facilities can typically process waste with a wide variety of energy values. Mass Burn facilities typically create energy in the form of high-pressure steam that can be used directly for industrial processes, district heating, and/or to generate electricity. Since the location of the potential facility has not been determined for the Study, the potential heating customers are unknown and any net electricity generated is assumed to be sold onto the grid.

MSW is either received on a tip floor or unloaded into a bunker. Grapple cranes can be used to mix the loads and feed the waste into a feed hopper or loaders can be used to feed the hopper. Some facilities use pre-processing equipment such as a shredder to reduce the size of the large bulky items and remove inert items and/or hazardous substances. For King County, most large bulky items and hazardous waste is to be removed at the Mixed Waste Processing Facility. From the feed hopper, the waste is fed into the combustion chamber where the heat in the combustion chamber and fuel from the waste stream and air which is injected into the chamber, come together to sustain the combustion process, producing a considerable amount of thermal energy. The produced thermal energy is used to heat water pipes to produce steam or hot water. The waste in most Mass Burn facilities is reduced by more than 90% by volume and 75% by weight[50]. For this Study, 20% ash residual and 5% recovered metals are assumed by weight (tons) for the process.

Mass Burn results in bottom ash which is composed of post-combustion solid waste including ash and non-combustible residuals (e.g., metal, rock, and concrete), and fly ash which is PM and compounds produced by the combustion process and captured in the air pollution control equipment (i.e. flue gas cleaning process). Bottom ash is heavier and collects at the bottom of the combustion chamber. The ash is typically cooled by dipping it in a quench tank. The ash is then passed by magnets and eddy current technologies to recover recyclable metals. It should be noted that all three WEBR landfills have specially permitted ash monofills and are capable of receiving and disposing of Mass Burn residual ash at their landfills. During Study interviews, both CRLF and Roosevelt reported

[49] Study of Waste to Energy Approaches for Processing Residual Municipal Solid Waste in Canada, Dated April 4, 2023, prepared by Morrison Hershfield for Environment and Climate Change Canada.
[50] Municipal Waste Combustors | Mass.gov

that they could handle and manage the residual ash from King County's three proposed tonnage scenarios that would be generated from a Mass Burn option. Finley Buttes Landfill currently accepts ash residue from the Spokane Mass Burn facility. The cost of disposal for Mass Burn ash includes the cost of transportation and end tipping fees as per the WEBR option.

It should be noted that for purposes of this Study, both bottom ash and fly ash are assumed to be disposed at a specially permitted ash monofill via WEBR, although if permitted by regulation it can be used as a construction aggregate substitute. Figure 4-1[51] provides an illustration of a Mass Burn combustion process.

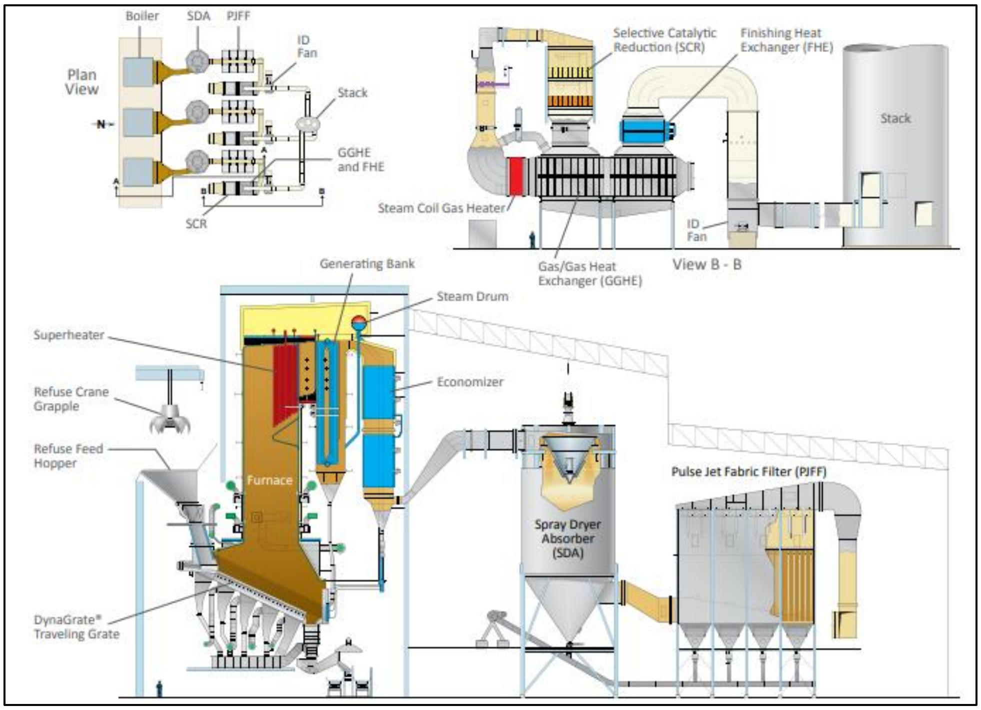

Figure 4-1: Typical Mass Burn Layout (SWA's Renewable Energy Facility 2)

4.1.1 Policy Impacts on Waste-to-Energy Technology

There are two recently enacted Acts passed in Washington State that impact WtE facilities (Mass Burn, Gasification or Pyrolysis), the CETA and the CCA, as summarized below.

4.1.1.1 Clean Energy Transformation Act (CETA)

The CETA was signed into law on May 7, 2019, and requires the State's electric utilities to fully transition to clean, renewable and non-emitting resources by 2045. The goal of this act is to reduce fossil fuel use to generate electricity, allowing for carbon free resources such as wind and solar.

[51] Facilities • Solid Waste Authority of Palm Beach County, FL • CivicEngage (swa.org)

Key considerations for the Study regarding CETA include the following:

- CETA requires Washington's electric utilities to:
  1. Eliminate coal-generated power by December 31, 2025;
  2. Make all retail sales of electricity GHG neutral by January 1, 2030; and
  3. Utilize 100% renewable or zero-carbon resources by 2045.
- Consumer-owned electric utilities selling to retail customers must transition to clean, renewable, non-emitting resources.
- CETA allows use of power from Spokane WtE facility until 2045.
- CETA does not define electricity from waste as a renewable resource. Renewable resource in CETA is defined to include water; wind; solar; geothermal; RNG; renewable hydrogen; wave, ocean, or tidal power; biodiesel fuel that is not derived from crops raised on land cleared from old growth or first growth forests; or biomass energy (which does not include MSW). Thermal energy is not mentioned in the act.
- CETA does not explicitly prohibit Mass Burn after 2045, but it does not allow sale of electricity to the grid for use by retail customers in Washington State. Electricity from a WtE facility can be used for parasitic loads, can be sold out of State and/or can be sold in-State to wholesale or district heating customers.

4.1.1.2 Climate Commitment Act (CCA)

The CCA was passed on April 23, 2021, and its purpose is to cap and reduce GHG emissions from Washington's largest emitting sources and industries. This act works alongside other policies to help achieve a commitment to reduce GHG emissions in the State by 95% by 2050.[52]

Key considerations for the Study with regard to the CCA include the following:

- Aims to reduce GHG via cap-and-invest program with funds for GHG reduction projects.
- Covers WtE facilities that emit more than 25,000 tons CO_2 equivalent. Facilities that exceed this limit will need to buy credits (i.e. added costs).
- CCA compliance could make WtE more costly.
- Washington Initiative 2117, Prohibit Carbon Tax Credit Trading and Repeal Carbon Cap-and-Invest Program Measure was on the ballot for November 2024 which would have repealed the CCA if passed. On November 5, 2024, voters in Washington rejected ballot initiative 2117.

The Tetra Tech Team contacted both the UPPR as well as the BNSF to better understand how they plan on addressing and complying with the emissions thresholds set by the CCA and if there would be added financial costs that would likely need to be passed down to King County under a WEBR program.

- According to the UPPR, they do not currently operate in any facility in Washington State that meets or exceeds the 25,000 metric tons of CO2 equivalent threshold. However, when determining rates for a given solution, they would consider a number of factors, including competitive alternatives, overall market conditions, and internal costs. To the extent that any regulation impacts their cost of doing business, the UPPR would incorporate that impact into the rate strategy, but that it would not necessarily be the single determining factor.

[52] Climate Commitment Act (CCA) – Washington State Department of Commerce

- According to the BNSF, they will be a covered entity under the CCA beginning in 2031, and plan to comply with the program as required. At the time of the report, the BNSF is not anticipating a change in rate due to the CCA.

4.1.1.3 Study Implications of the CETA and CCA (Acts)

The two Acts do not prohibit the sale of electricity from WtE facilities, but CETA does restrict selling electricity from the grid to retail customers in the state. The primary intent of the two Acts is to move away from fossil fuel based electric utilities and allow electricity generation from renewable resources such as wind and solar. These Acts should be monitored for challenges or changes in the future that may allow for electricity from a WtE facility to be defined as renewable for use in the State since they replace fossil fuel-based power plants.

Currently, other options for use of electricity generated from a Mass Burn facility include use for parasitic loads, interstate electricity sales and in-State sales to wholesale customers or for district heating (system for distributing heat generated in a centralized location through a system of insulated pipes for residential and commercial heating requirements such as space heating and water heating). For purposes of this Study, an assumption of discounted interstate electricity sales (accounting for potential interconnect and/or transmission costs) was used for Mass Burn. The potential for in-State wholesale sales or district heating is difficult to assess at this time without the location of a Mass Burn facility being identified.

4.2 Environmental Criteria

Environmental concerns associated with Mass Burn processes include emissions that could impact air quality that could potentially affect the health of people, animals, and plants. Air pollution control equipment is employed to remove contaminants from the emissions. A human health risk assessment would likely be required as part of environmental impact reporting and/or air quality permitting for any proposed Mass Burn plant. While water pollution from a Mass Burn facility is theoretically possible, the opportunities for leakage of polluted water from a modern plant are small.

There will be other environmental impacts such as air emissions from transporting MSW and bulk reagents to the facility. The residual ash, which is 20 percent of the feedstock by weight for Mass Burn, will need to be transported via a WEBR option to an ash monofill, which is available at the three WEBR landfill options. The assumptions used for the environmental modeling components for Mass Burn include transport of the ash via a WEBR option to one of the WEBR designated landfills for final disposal. Rejected waste such as oversized or non-combustible items will also require transport to a disposal point. Recyclables such as recovered metals will need to be hauled away for off-site recycling.

Metals can be recovered and recycled from the cooled bottom ash. Some jurisdictions have been able to utilize bottom ash as a construction aggregate substitute if allowed under local regulation. There might be sufficient demand for the ash if it is significantly less expensive than conventional materials. However, in general, both bottom ash and fly ash will require disposal in a specially permitted ash monofill.

4.2.1 Environmental Modeling Assumptions

Assumptions used for the modeling of environmental impacts presented in Section 4.2.2 for Mass Burn are detailed in Appendix A - Environmental Impact Factors and Assumptions for County Consideration and Approval (January 23, 2024) which was concurred on by SWD. A summary of key assumptions follows:

- For the purpose of estimating eventual energy generation and usage, it is estimated that waste has a range from 4,000 to 5,200 British Thermal Units (BTU)/lb. The difference in tonnages of the various materials is captured in this variance. This is important as Mass Burn facilities are typically thermally limited, therefore the design for a facility has to account for the thermal cap based on the variation of waste input.
- Given that at this time a location for a Mass Burn plant has not been identified, it is difficult to assess whether the plant could supply thermal energy to neighbors (via steam or District Heating whereby hot water is pushed through a series of pipes). Therefore, it was assumed that the thermal energy to generate electricity is a conservative industry average of 550 KWh/ton of waste for net export (accounts for internal consumption).
- For the purpose of estimating energy loss, it is assumed that the conversion of combustion to steam/hot water will be 60%. Similarly, for the conversion of steam to electrical energy it is assumed to also be 60%.

4.2.2 Environmental Criteria Analysis Results

Table 4-1 summarizes the net total impacts by environmental factor for Mass Burn while Table 4-2, Table 4-3, and Table 4-4 break down the results by Process, Transport, and Offsets. Positive figures represent an environmental harm, while negative figures represent an environmental benefit by avoiding an environmental harm. The results include impacts from facility operations, impacts of exporting ash and inerts by rail to landfill, and impacts of transporting metals to recycling as well as offsets (avoided impacts) from electricity generated from Mass Burn replacing grid electricity. Mass Burn environmental impact results presented in Table 4-1, Table 4-2, Table 4-3, and Table 4-4 are influenced by process impacts from facility operations that generate energy products through combustion of putrescible solid waste as well as plastics, exportation of ash and inerts by rail to landfill (partly by diesel) and impacts of transporting metals to recycling by electric truck that all contribute to Non-Renewable Energy Demand, Water Consumption, Acidification Potential, Global Warming Potential and Smog Formation (due to NOx and CO emissions) impacts.

Human Health Toxicity - Cancer Potential is high for Mass Burn as measured in the LCA as a hazard present (type and quantity of chemicals emitted, not exposed) derived primarily from combustion of plastics and to a much smaller extent metals. As noted in Section 2.4.1, noncancer related toxicity, which covers all health impacts except for cancer (such as heart disease, kidney failure, and reproductive disorders), could not be reliably measured as part of this Study. Combusting plastics releases toxins such as furans, dioxins and other substances which are known to cause cancer. The Cancer toxicity measurement units used are a way to standardize the potential cancer-related impacts of many different toxic chemicals based on their characteristics into a single measure per mass of the chemical. The Cancer Potential parameter multiplies the unit impacts by the total mass of chemicals released into the environment to estimate the potential increase in cancer-related morbidity in the total human population, assuming equivalent exposure.

However, a LCA study can only measure hazard presence (type and quantity of chemicals emitted) and not exposure, so results should be interpreted as comparing the production of chemicals associated with cancer, not morbidity. The Cancer Potential results are not about causation or actual cases of cancer. The LCA model cannot assess human exposure to the chemicals released, only the amount of chemicals released and their toxicity. It is also noted that emission concentrations in the MSW-DST tool used for modeling results were calculated using a combination of facility-specific data, including both “new” and “old” facilities as well as the 1995 Standards of Performance for New Municipal Waste Combustors.

The electricity offsets for Mass Burn (presented in Table 4-2, Table 4-3, and Table 4-4) are high for Non-Renewable Energy Demand due to the energy it generates replacing grid electricity production including upstream impacts (e.g., extraction and refining) of fossil fuels used to generate that replaced electricity. To a lesser degree, offsets also contribute to a net total environmental benefit for Acidification and Smog Formation Potential. Environmental benefits for Water Consumption associated with generated energy offsets were not considered in the Study findings because the majority of credit for grid electricity replacement would be due to avoiding upstream and process impacts of hydroelectric power, reducing evaporation in reservoirs (considered water consumption), which is considered a baseload power source in Washington so would not be replaced. It should be noted that the Study did not include a feasibility study to determine the electricity sales end user so if the end user is outside the EIA region modeled for the Study, the results will be different.

In summary, Mass Burn has environmental impacts on Water Consumption, Global Warming Potential and Human Health impacts for Cancer Potential and environmental benefits for Non-Renewable Energy Demand, Acidification Potential and Smog Formation.

Table 4-1: Summary of Environmental Criteria for Mass Burn Disposal Option

Environmental Factor	Units	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Non-Renewable Energy Demand (Energy Production)	MJ	(991,968,585)	(685,760,535)	(244,170,177)
Water Consumption (Water Quantity)	L H_2O	43,964,165	28,332,069	15,704,027
Acidification Potential (Air Quality)	kg SO_2 eq	(75,390)	(47,865)	(5,977)
Global Warming Potential (Climate Change)	MT CO_2 eq	19,122	18,395	19,691
Smog Formation Potential (Air Quality)	kg O_3 eq	(2,965,091)	(2,010,928)	(697,190)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	13,160,933	10,519,046	3,814,632

Table 4-2: Summary of Mass Burn Environmental Sub-criteria for High Tonnage/Low Diversion Scenario by Process, Transport and Offsets/Avoided Impacts

Environmental Factor	Units	Process (Mass Burn)	Transport	Offsets	Net Total
Non-Renewable Energy Demand (Energy Production)	MJ	840,931,582	21,764,515	(1,854,664,682)	(991,968,585)
Water Consumption (Water Quantity)	L H_2O	41,462,950	2,501,215	N/A[1]	43,964,165
Acidification Potential (Air Quality)	kg SO_2 eq	145,981	113	(221,484)	(75,390)
Global Warming Potential (Climate Change)	MT CO_2 eq	126,394	1,682	(108,954)	19,122
Smog Formation Potential (Air Quality)	kg O_3 eq	544,371	1,693,444	(5,202,906)	(2,965,091)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	13,160,933	0	(0)	13,160,933

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Table 4-3: Summary of Mass Burn Environmental Sub-criteria for Medium Tonnage/Medium Diversion Scenario by Process, Transport and Offsets/Avoided Impacts

Environmental Factor	Units	Process (Mass Burn)	Transport	Offsets	Net Total
Non-Renewable Energy Demand (Energy Production)	MJ	595,243,864	14,266,028	(1,295,270,427)	(685,760,535)
Water Consumption (Water Quantity)	L H_2O	26,707,074	1,624,995	N/A[1]	28,332,069
Acidification Potential (Air Quality)	kg SO_2 eq	107,459	74	(155,397)	(47,865)
Global Warming Potential (Climate Change)	MT CO_2 eq	93,736	1,103	(76,444)	18,395
Smog Formation Potential (Air Quality)	kg O_3 eq	530,228	1,109,299	(3,650,455)	(2,010,928)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	10,519,047	0	(0)	10,519,046

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Table 4-4: Summary of Mass Burn Environmental Sub-criteria for Low Tonnage/High Diversion Scenario by Process, Transport and Offsets/Avoided Impacts

Environmental Factor	Units	Process (Mass Burn)	Transport	Offsets	Net Total
Non-Renewable Energy Demand (Energy Production)	MJ	363,227,312	8,147,997	(615,545,487)	(244,170,177)
Water Consumption (Water Quantity)	L H_2O	14,800,811	903,216	N/A[1]	15,704,027
Acidification Potential (Air Quality)	kg SO_2 eq	68,511	42	(74,530)	(5,977)
Global Warming Potential (Climate Change)	MT CO_2 eq	55,724	630	(36,663)	19,691
Smog Formation Potential (Air Quality)	kg O_3 eq	421,240	632,360	(1,750,789)	(697,190)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	3,814,632	0	(0)	3,814,632

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Other sub-criteria considered for the Environmental sub-criteria includes Resource Conservation and Compatibility with Waste Prevention and Recycling.

4.2.3 Resource Conservation

The Mass Burn process creates heat that can be used to generate electricity and/or industrial and residential heating components. The facility would generate power/electricity which could be used to run the facility, locally for district heating or for sale to the electrical grid. Mass Burn facilities also reduce the amount of land needed to dispose of waste.

4.2.4 Compatibility with Waste Prevention & Recycling

A Mass Burn facility has recycling capability with metal recovery[53] from the ash for sale to recyclers. Knowing this could impact recycling behaviors from the general public if they are aware that recyclables would be converted to usable products which may lower consumer recycling rates. However, if recycling and other waste prevention measures are a lower cost than Mass Burn, that should incentivize increased recycling and waste prevention. In communities with Mass Burn facilities being used as the primary source of disposal, these communities typically

[53] Metals recovery is assumed to be about 5% of the incoming feedstock based on waste composition estimates provided for the three Study tonnage scenarios.

have higher recycling rates in place[54],[55]. The ash has also been used as a construction aggregate substitute if allowed by local regulations although assumed to be disposed of for this Study.

See Table 4-5 for a summary of these other environmental considerations for Mass Burn. The sale of energy, ash and metal would be a boost to the local economy and would help offset facility operation costs.

Table 4-5: Other Environmental Considerations for Mass Burn Disposal Option

Environmental Factor	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Resource Conservation	Creates heat that can be used to generate electricity and/or industrial/residential heating.		
Compatibility with Waste Prevention and Recycling	Metals (50,918 tons/year) removed after processing. Ash has also been used as construction aggregate substitute if allowed under local regulations.	Metals (33,348 tons/year) removed after processing for recycling. Ash has also been used as construction aggregate substitute if allowed under local regulations.	Metals (18,360 tons/year) removed after processing for recycling. Ash has also been used as construction aggregate substitute if allowed under local regulations.

4.3 Economic Criteria

4.3.1 Capital Costs

Capital Costs for Mass Burn facilities were estimated using cost factors based on processing capacity. Two Mass Burn facilities were used as reference facilities which were recently constructed (within the past decade), the Durham York Energy Center (2018) and the West Palm Beach WtE facility (2015).

- The Durham York, Ontario, Canada facility has a design capacity of 175,000 tpy and a reported capital cost in 2018 of $220M. This results in a capital cost factor of $1,260 per ton in 2018 dollars.
- The West Palm Beach, Florida facility, when opened in 2015, was the first incinerator to be built in the US in almost 20 years at that time. It has a design capacity of 1,000,000 tpy and a reported capital cost in 2015 of $672M. This results in a capital cost factor of $672 per ton in 2015 dollars.

When taking into account CPI increases for both facilities, in 2023 dollars, the capital cost factor for Durham is calculated to be approximately $1,500 per ton, and West Palm Beach cost factor is calculated to be approximately $860 per ton. As shown through these two examples, the capital cost per ton is known to decrease as the processing tonnage increases due to the economy of scale. The range of a Mass Burn facility that would meet King County's needs is between approximately 360,000 to 1,000,000 tpy, which means that the cost should be less than $1,500/ton which was a much lower tonnage facility and closer to $860/ton for the higher tonnage facility. Typically,

54 Scientific Truth about Waste-To-Energy Report
55 Microsoft Word - 090529 Berenyi recycling update.doc

capital cost per ton is between $800 and $1,500 per ton of incoming feedstock based on the Tetra Tech Team's data sources of Mass Burn facilities. For facilities that King County is considering, the facilities are large enough that economies of scale can be achieved (therefore, non-linear relationship as tonnage increases) and the unit costs should be between $800 and $1,000 per ton of material received. An average unit cost of $1,000/ton was assumed for the low and medium tonnage scenarios and $900/ton assumed for the high tonnage scenario in the cost analysis.

Although a specific location for a facility has not been identified and land costs are highly dependent on location, estimates were developed for potential land acquisition costs based on $40/square foot or $1,742,400/acre (provided by SWD from the County's real estate group) and assumptions of 35 acres for the high tonnage facility, 25 acres for the medium tonnage facility and 20 acres for the low tonnage facility. The acreage requirements for the facilities by tonnage projection vary depending on access, infrastructure and buffer requirements with the high tonnage ranging from 25 to 35 acres, the medium tonnage ranging from 15 to 25 acres and the low tonnage ranging from 10 to 20 acres. The high end of the acreage requirements was assumed in calculating potential property acquisition costs.

The estimated total Capital Costs, including equipment, buildings, infrastructure, and estimated land acquisition costs ($1,742,400/acre), were then calculated to 2040 dollars using an annual inflation rate of 3.5 percent for the three tonnage scenarios. It is noted that additional walking floor trailers are projected to be needed for the high tonnage scenario than what the current CHRL current fleet uses which costs are not included for Mass Burn as the cost differential for the additional trailer equipment needed for WEBR is higher and is accounted for in the WEBR costs for comparison purposes.

4.3.2 Operating Costs

Operating Costs for the Study include labor, maintenance, materials and regular facility and equipment upgrades. Operating Costs are based on reported figures from existing operating facilities who indicated that the operating costs cover regular facility and equipment upgrades to avoid major replacement costs in the future. The Durham York Energy Center was reported to have an operating cost of $12M in 2020 for its 175,000 tpy facility, which approximately equates to a cost of $75/ton in 2023 dollars. Base annual operation and maintenance costs for the West Palm Beach WtE facility in 2019 was $23.06M.

This cost was based on a 3,000 tpd facility that is operating at 50% capacity, and includes costs for air pollution controls, utilities, and ash disposal costs. The operating cost for the West Palm Beach WtE facility was calculated to be $42 per ton for a 550,000 tpy facility. As in Capital Costs, for facilities that King County is considering the facilities are large enough that economies of scale can be achieved (therefore, non-linear relationship as tonnage increases). This is due to proportionally less labor and processing requirements relative to increased processing capacity.

Taking into consideration inflation, the operating costs were estimated to be $55 per ton for the low tonnage option, $45 per ton for the medium tonnage option and $40 per ton for the high tonnage option. Ash T&D costs were estimated based on current ash disposal rates for the Spokane WtE facility adjusted for available WEBR transport costs at $97/ton (in 2023$). Disposal of residual MSW is anticipated to be insignificant as the materials received at the facility will have been processed at the Mixed Waste Processing Facility.

4.3.3 Revenue

Revenue from Mass Burn facilities is typically generated through electricity sales, which is a major contributor to offsetting the cost of Mass Burn plants. For this Study, it is assumed that there will be potential for revenue from interstate electricity sales to the grid. The potential electricity sale rate assumed for the Study is based on $.04/kWh (within range of rates for Spokane WtE facility who sells to Avista Utilities with customers in Washington, Oregon and Idaho) discounted to $.02/kWh for potential interconnect costs and transmission cost for interstate sales. While a detailed feasibility analysis of electricity sales was not included in the Study scope and negotiating terms of a Power Purchase Agreement with a utility can take between 3 to 5 years (per PSE), the revenue potential from the sale of electricity may be volatile in its own right due to factors within the wholesale/resale markets.

The Economic analysis results presented in Table 4-8 also include revenue from ferrous metal sales. Based on input from facility operators, metal sales are assumed to be $40 per ton based on input from Spokane WtE facility operator who stated that market rates fluctuate dramatically over time. The metals recovery is assumed to be about 5% of the incoming feedstock based on waste composition estimates provided for the three Study tonnage scenarios. There is a 20% parasitic load assumed for operation of the Mass Burn facility. Electricity recovered from Mass Burn is approximately 550 kWh/ton of waste without the parasitic load.

4.3.4 Financial Risk

Mass Burn has financial risk with further discounted electricity rates impacting revenue potential, higher costs to comply with CCA cap-and-trade regulations and potential increased costs due to future regulatory requirements as further described below:

- Washington State's CETA restricts future grid electricity sales to retail customers limiting sales to in-State wholesale customers and district heating or interstate sales. The Study assumed a discounted rate for electricity sales and any lower rates for Revenue would likely deem option infeasible.
- The CCA requires cap and trade offset purchases estimated at an additional $4.92 to $7.97 per ton (based on Environmental criteria results for process and transport LCA impacts on Global Warming Potential for each tonnage scenario and recent cap and trade auction pricing).
- Significant regulatory changes may impact future costs to operate (i.e. new USEPA emission standards announced in January 2024 to strengthen Clean Air Act standards for large facilities that burn MSW).
- If there are significant reductions in waste disposal in the future (more than projected for design purposes), the effective cost per ton would be higher during the debt service period. Conversely, the effective cost per ton should be lower after the debt service period.

In addition, the WEBR component of Mass Burn would also have some Financial Risk with short term contracts that may have future rate increases when up for renewal (beyond projected inflation rate increase). Significant regulatory changes may also impact future WEBR rates.

4.3.5 Cost Per Ton

The Cost per Ton was calculated by adding the annualized Capital Costs (at 4% interest over 30 years assuming municipal funding at 2.5% bond purchase cost) to the annual Operating Cost and subtracting the annual Revenues from both the electricity and ferrous metal sales. The net annual cost is then divided by the annual tonnages to obtain 2023, 2040, 2050 and 2060 Costs per Ton. It should be noted that the bond financing (or debt service payments) for a potential $1 billion facility over a 30-year period would mean that the debt service payments would extend beyond the 20-year planning period. The effective cost per ton would be higher for a Mass Burn facility during the debt service period if the incoming tonnage is lower than that projected by the SWD, and vice versa. It should also be noted that after the 30-year debt service payments have concluded, the effective cost per ton should potentially be lower since annualized capital costs are no longer required. For example, the Metro Vancouver WtE facility is now the least expensive disposal option ($67/ton) in the region because the debt service for the capital has already been paid off.

4.3.6 Economic Criteria Summary

Table 4-6 provides a summary of the results of evaluating the Economic sub-criteria for the Mass Burn option and all tonnage scenarios in 2040$ (start of Study period). To assess the economics of the Mass Burn option for each tonnage scenario, the Economic sub-criteria evaluate the Capital Cost, Operating Cost (including ash disposal), commodity sale Revenue for electricity and ferrous metal and unit processing Cost per Ton.

The Cost per Ton (2040$) was calculated by adding the annualized Capital Costs (at 4% interest over 30 years assuming municipal funding at 2.5% bond purchase cost) to the Operating and Disposal Cost and subtracting the Revenue from both the electricity and ferrous metal sales. The net annual cost is then divided by the annual tonnages to obtain 2023, 2040, 2050 and 2060 costs per ton. Results of the calculations are shown in Table 4-6 below. Cost assumptions and results are also included in the Appendix B - Comparative Evaluation Summary Matrices for each of the disposal options.

Table 4-6: Summary of Economic Criteria for a Mass Burn Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capital Costs (2040$)[1]	$1.8B	$1.2B	$738M
Capital Costs (Annualized)[2]	$132M	$87M	$54M
Operating Cost (Annual)[3]	$73M	$54M	$36M
Residuals Disposal Cost (Annual)[4]	$35M	$23M	$13M
Annual Revenue (2040$) – Electricity[5]	$11M	$7.3M	$4.0M
Annual Revenue (2040$) – Metals[6]	$3.7M	$2.4M	$1.3M
Total Annual Cost in 2040$[7]	$225M	$154M	$98M
Annual Cost/Ton (2023$)[8]	$123.31	$128.71	$148.40
Annual Cost/Ton (2040$)[8]	$221.31	$230.99	$266.32
Annual Cost/Ton (2050$)[8]	$228.97	$247.08	$315.56
Annual Cost/Ton (2060$)[8]	$226.24	$272.16	$385.03

[1] Includes equipment, building, infrastructure, and estimated land acquisition costs. Inflation assumed at 3.5% annual.
[2] Annual cost based on debt service assumed at 4% for 30-year term per municipal funding and 2.5% bond purchase cost.
[3] Includes labor, maintenance, materials, regular facility and equipment upgrades. Inflation assumed at 3.5% annual.
[4] Estimated fly and bottom ash disposal at 20% of total tons, $97/ton Ash Transport & Disposal cost in 2023$,
[5] Assumes $0.02/KWh based on current rate for Spokane WtE facility discounted for potential interconnect costs and transmission costs for interstate sales and 20% parasitic load.
[6] Assumes 5% metal recovery at $40/ton for metal sales including transport.
[7] Equals Capital Costs (Annualized) + Operating Costs + Residuals Disposal – Annual Revenues
[8] Equals Total Annual Cost/Total Tonnage

4.4 Operating History Criteria

4.4.1 Proven Performance

There have been over 2,000 Mass Burn facilities operating worldwide since the early 1960s, mostly in East Asia and Europe. Japan manages 70% of its solid waste through Mass Burn facilities.

In the US, uncontrolled burning of MSW was banned when the federal Clean Air Act (CAA) came into effect in 1970 and existing incineration facilities at that time faced new standards and restrictions were placed on particulate emissions. The facilities that did not install the technology needed to meet the CAA requirements were closed. Combustion of MSW grew in the 1980s. By the early 1990s, the United States (US) combusted more than 15 percent of all MSW. The majority of non-hazardous waste incinerators were recovering energy by this time and had installed pollution control equipment. In the 1990s, the USEPA enacted Maximum Achievable Control Technology (MACT) regulations to address mercury and dioxin emissions. As a result, most existing facilities had to be retrofitted with newer air pollution control systems or shut down[56].

MSW combustion accounts for a small portion of American waste management for a multitude of reasons. Generally speaking, regions of the world where populations are dense and land is limited (such as many European countries and Japan), have greater adoption of combustion with energy recovery due to space constraints. As the US encompasses a large amount of land, space limitations have not been as important a factor in the adoption of combustion with energy recovery. Landfilling in the US is often considered a more viable option, especially in the short term, due to the low economic cost of building an MSW landfill versus an MSW combustion facility. The upfront money needed to build a Mass Burn facility can be significant and economic benefits may take several years to be fully realized. In Europe, policies such as landfilling bans and surcharges on landfills have made alternative disposal technologies such as Mass Burn economically feasible.

Another factor in the slow growth rate of MSW combustion in the US is public opposition to the facilities. These facilities have not always had air emission control equipment as discussed above, thus gaining a reputation as high polluting. In addition, many communities do not want the increased traffic from trucks or to be adjacent to any facility handling municipal waste.

According to the USEPA, in 2017 there were 75 WtE facilities operating in the US since the 1970s that recovered energy from the combustion of MSW. These facilities existed in 25 states, with the majority of them being located within the Northeast mainly in the eastern US where landfill capacity is limited and landfill tip fees are high.[3]

Following are Mass Burn facilities in the Western US and in Canada:

- Vancouver, British Columbia
  - (850 tpd / 310,250 tpy)
- Spokane, Washington
  - (800 tpd / 292,000 tpy)
- Portland, Oregon (Marion County)
  - 550 tpd / 200,750 tpy)
- Long Beach, California – Closed in early 2024
  - (1,380 tpd / 503,700 tpy)

[56] Energy Recovery from the Combustion of Municipal Solid Waste (MSW) | US EPA

- Stanislaus, California – Closed in December 2024
  - (800 tpd / 292,000 tpy)

The Long Beach Southeast Resource Recovery Facility closure was due to 1) Assembly Bill 1857 removing landfill diversion credit for WtE facilities which reduced feedstock, 2) the Power Purchase Agreement with local utility, Southern California Edison expired in 2018 resulting in lower rates and 3) higher costs to operate the facility.

The Stanislaus facility was the last Mass Burn facility in California which closed in December 2024 after 36years in operation. That facility has been impacted by Assembly Bill 1857 removing landfill diversion credit for WtE facilities which reduced feedstock and a zero-waste plan that would end acceptance of ash at a local landfill (in order to extend the life of the landfill for MSW disposal).[57]

Reworld, the owner and operator of the Portland, Oregon Mass Burn facility in Marion County announced plans to close its facility by December 31, 2024, however, the plant is currently operating. Oregon recently passed Senate Bill 488 which increases the stringency of air emissions regulations and limits the amount of regulated medical waste that the incinerator can accept which has impacted operations.[58]

It should be noted that according to the EIA, the number of facilities has been declining over the last 20 years. In 2022, 60 Mass Burn plants were operating in the U.S., with the majority located in urban areas along the East Coast. Approximately 90 percent of the energy produced by Mass Burn plants was being delivered to the electric grid. The remaining 10 percent consists of steam that is sent to nearby industrial plants and institutions.[59]

4.4.2 Safety, Environmental and Regulatory Compliance

Mass Burn facilities are continuing to improve in terms of Safety, Environmental and Regulatory Compliance. Older facilities are being shut down and newer facilities are better equipped with safety features and are much cleaner burning. It should be noted that a recent fire occurred at the 40-year-old Miami-Dade County Resources Recovery Facility in February 2023. The fire was believed to have started on a conveyor belt and while investigators concluded the fire was accidental, they could not pinpoint the exact cause and instead stated that the fire was most likely mechanical or electrical in nature.[60]. Miami-Dade County has initiated a permitting process to replace the facility with a modern Mass Burn facility, with a location to be determined.

Over the last 40 years of Mass Burn facilities operating in the US, they have significantly reduced their emissions (air, water and solids) to meet ever increasing regulatory standards, and use of water, chemicals, and reagents, improving recovery of energy, metals and minerals from bottom ash (enabling the use of bottom ash as an aggregate where allowed in regulation). Although emissions have significantly decreased over time and standards have become stricter for Mass Burn, there are still emissions that have higher cancer related potential when compared to WEBR in the Study's LCA, primarily due to the combustion of plastics. It is noted in Section 4.2.2 that the available LCA model used for the Study includes data from older and newer facilities.

In terms of Safety, Environmental and Regulatory Compliance, long operating facilities that upgrade periodically and keep up with regulatory requirements (particularly in meeting MACT and BACT air standards) have good safety and regulatory compliance records.

[57] https://www.wastedive.com/news/reworld-marion-oregon-closure-letter-incinerator/729984/
[58] SB0488
[59] EIA calls WtE sector 'small but stable' - Waste Today
[60] Exclusive new photos show aftermath of massive fire at Doral waste-to-energy plant – NBC 6 South Florida (nbcmiami.com)

4.4.3 Operating History Criteria Summary

Table 4-7 summarizes the Operating History results for Mass Burn technology for all tonnage scenarios. The sub-criteria considered for Operating History includes an assessment of Proven Performance, Safety, Environmental and Regulatory compliance.

Table 4-7: Summary of Operating History for Mass Burn Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Proven Performance	• Over 40 years of performance at operational scales required. • There has been a decline in number of facilities in the US although not worldwide likely due to landfilling being a less costly alternative.		
Safety Record	• Long operating facilities that upgrade periodically have a good Safety Record. • Recent fire occurred at Miami-Dade Mass Burn facility, most likely caused by a "mechanical or electrical event" on a conveyor belt, with the exact ignition source not definitively determined.[1]		
Environmental and Regulatory Compliance Record	• Long operating facilities that keep up with regulatory requirements - such as MACT and BACT standards – maintain environmental compliance. • New facilities are subject to increasingly more stringent air emission standards, Environmental and Regulatory Compliance requirements, and safety standards.		
[1] Exclusive new photos show aftermath of massive fire at Doral waste-to-energy plant – NBC 6 South Florida (nbcmiami.com)			

4.5 Logistics Criteria

4.5.1 Operating Life of Facilities

The average Operating Life of Mass Burn facilities is 30 to 40 years and can last longer with ongoing upgrades to keep up with regulatory requirements and to extend Operating Life. Operating Costs assumed for this Study include regular facility and equipment upgrades.

4.5.2 Siting/Design/Permitting/Construction Considerations

The Siting, Design, Permitting and Construction of a Mass Burn facility is expected to take a significant amount of time due to its complexity and potential public concerns. It is estimated to take approximately 7-10 years for project implementation (4 to 6 years for siting and permitting, 1 to 2 years financing and design, and 2 years for construction) and could take longer depending on input during the siting, environmental review and air permitting process.

Permitting[61]

The permitting process for a Mass Burn facility would include preparation of a Notice of Construction (NOC) and a Prevention of Significant Deterioration (PSD) permit for air quality control which are critical steps in the permitting process. Puget Sound Clean Air Agency (PSCAA) has jurisdiction for regulating sources of air pollution in the County and PSCAA Regulation I, Section 6.3 requires a NOC application be submitted for all new or modified air pollution sources prior to construction. The proposed Mass Burn facility will be considered a new major source under the New Source Review permitting program based on potential emission levels, and as such will be required to complete complex air quality analyses and secure a PSD construction permit through Ecology. 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 PSD permitting process requires completion of air quality analyses including BACT analyses for 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 lands (includes areas such as national parks, national wilderness areas, and national monuments), visibility analyses to determine impacts at the Class I area, and a toxic air contaminant impact analysis.

These analyses will need to be repeated to address any adverse impacts and to satisfy permitting authorities and FLM responsible for the Class I areas and the public. In addition, new facilities will need to meet ever more stringent new emission control requirements and technologies required by USEPA, State and local regulatory agencies. In January 2024, new USEPA emission standards were announced to strengthen CAA standards for large facilities that burn MSW. These requirements will be to reduce the emission limits significantly for Large Municipal Waste Combustors (LMWC) both under the Emission Guidelines (EG) and the New Source Performance Standard (NSPS) Limits (see paragraph below for proposed requirements). Basically, these facilities will need to implement BACT technology to reduce PM, Mercury and Dioxin Furans, Acid Gases, NOx, and CO. Some of these will be specific technologies and others will be Best Practices.

The new facility must also comply with applicable federal NSPS and National Emission Standards for Hazardous Pollutants (NESHAP). In particular, the municipal waste combustors to be installed will be subject to 40 Code of Federal Register 60, Subpart Eb. These regulations describe emission standards, monitoring requirements and performance testing, and siting requirements. The siting requirements include the necessity for a detailed Materials Separation Plan to be completed with a public review process. The facility will be required to obtain a Title V permit. A Title V permit application can be submitted after the PSD Construction permit is issued.

Several local jurisdiction permits for land use need to be obtained prior to facility construction. An ash monofill must be identified for ash disposal and a permit modification for that facility might be required for accepting additional ash. Local building and construction permits are required for construction of the facility. Other permits and approvals that are likely to be required for the facility operation include a National Pollutant Discharge Elimination System permit if discharging to surface or ground water. An industrial wastewater discharge permit may be required if the water is going to a municipal sewer system.

As previously discussed in Section 4.1.1, the CETA restricts selling electricity to the grid for retail customer use in Washington State but allows for interstate electricity sales or in-State sales to wholesale customers or district heating, if deemed feasible. A Power Purchase Agreement will be needed with PSE to sell electricity to the grid which is a three to five-year process according to PSE.

[61] Waste-to-Energy & Waste Export by Rail Transportation Study - King County Solid Waste Division

4.5.3 Compatibility with Current Collection System

Mass Burn is an option that can receive MSW seamlessly without requiring any pre-treatment and minimal pre-processing for waste acceptance. Some screening is typically undertaken to reduce the size of incoming bulky items and large inerts as much as possible to feed the refuse chute. Screening is expected to be minimal for the facility since most waste is anticipated to be received from a Mixed Waste Processing Facility. Waste is to be delivered from waste collection and transfer trucks, unloaded into bunkers and fed into the combustion units with a grapple crane. Therefore, compatibility with the County's existing waste management system is considered high. Extreme lows and highs in waste flows can sometimes be difficult for logistics in a Mass Burn facility.

To accommodate high flows, adequate storage should be planned. Typically, between two to three days' worth of storage is inherent in any facility design. Also, with modular units, one unit can be shut down for maintenance if low incoming waste loads (i.e., during the winter months) are anticipated. The facility can be designed to accommodate the addition of modular units, if needed in the future, due to increased waste flow rates.

4.5.4 Logistics Criteria Summary

Table 4-8 provides a summary of results in evaluating Logistics and system Compatibility for all Mass Burn disposal option tonnage scenarios. The Logistics criterion includes an assessment of sub-criteria such as the Operating Life of facilities (in years); Siting, Permitting, Design, and Construction requirements; and Compatibility with Current Collection System for each Mass Burn disposal option tonnage scenario.

Table 4-8: Summary of Logistics Criteria for Mass Burn Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Operating Life of Facility (years)	Based on projected waste disposal volumes, 20-40 years		
Siting/Design/Permitting/ Construction Considerations	Siting and permitting difficult. 7-10 years to site, permit, design and construct: • 4-6 years to site • 1-2 years financing and design • 2 years construction Factors depend on size of facility, local and state ordinances, and community involvement.		
Compatibility with Current Collection System	High compatibility. No or minimal pre-processing required.		

4.6 Social Criteria

4.6.1 Environmental and Social Justice/Equity (ESJ)

While ESJ considerations will be an important part of future siting for a Mass Burn facility, an in-depth analysis of local equity issues was outside the scope of this Study and instead would be explored in future siting studies. As part of the siting process, communities are to be identified around potential facility locations and transport corridors to evaluate per USEPA's Environmental Justice Screening and Mapping Tool and the Washington Environmental Health Disparities Map.

Consideration is to be given to exacerbation of an existing disparity in communities when selecting a suitable location for a Mass Burn facility. Zoning and land use compatibility are primary factors for screening during the siting process and for a Mass Burn facility that would typically require Industrial zoning. A future siting study could evaluate where Mass Burn facilities in the US, Asia and Europe have been located in determining siting criteria.

Environmental impacts will be greater for frontline communities and Economic impacts will be greater for low-income households because cost increases represent a higher share of their income than for other households.

4.6.2 Local Traffic Impacts

Traffic levels for a Mass Burn facility would be comparable to those for a WEBR IMF and assumes a 9% increase for peak traffic (see Section 3.7.2 - Local Traffic Impacts for WEBR). Round trip traffic levels assumed an average trailer load of 28 tons (per SWD), 362 operating days per year, a 9% increase for peak loads and for Mass Burn a 20% increase for traffic from trucks leaving the facility for disposal of ash and a 5% increase for trucks transporting to metals recyclers. The estimated number of truck trips (round-trip) entering and leaving the facility is 262 trucks per day for the high tonnage/low diversion scenario, 180 trailers per day for the medium tonnage/medium diversion scenario and 96 trucks per day for the low tonnage/high diversion scenario as shown on Table 4-9.

4.6.3 Local Job Creation

A Mass Burn facility would create local full-time jobs, as a technical team would be required to build and operate the new facility. The following categories were developed for consideration in comparing the Study disposal options based on skill/training and compensation level. Potential skill categories are:

Minimal skill. Requires no prior skill and minimal on-the-job training. Estimated to be between 4 and 6 jobs depending on tonnage requirements.

Technical skill. Requires an associate's degree, technical certificate, or similar level of on-the-job technical training. Estimated to be between 24 and 28 jobs depending on tonnage requirements.

Advanced skill. Requires Bachelor, Masters, or other advanced degree or equivalent level of on-the-job training and years of experience. Estimated to be between 15 and 20 jobs depending on tonnage requirements.

Jobs at all skill levels would be required to operate a Mass Burn facility as presented in Table 4-9.

4.6.4 Other Potential Neighborhood Impacts

In terms of Other Potential Neighborhood Impacts based on a qualitative comparison between options, air and noise should be medium, odor should be low and there should be no groundwater impact. An environmental concern associated with the Mass Burn process is air emissions. Although substantially reduced through regulatory requirements, air emissions could impact local air quality which typically causes public concern. Emission levels are usually well below acceptable levels for industrial zone facilities.

Air – Medium Impact.

Air impacts primarily due to CO_2, CO, NOx, VOC's, SO_2 emissions. Substantially reduced through regulatory requirements.

Odor – Low Impact.

The primary source of odors are the trucks that enter the facility, the tipping floor where raw garbage is stored, any ash residue and potentially odor originating from the stacks (all are scrubbed, and odor should be at a minimum). Facility is enclosed which significantly contains odor.

Noise – Medium Impact.

The primary source of noise are trucks entering the facility. In addition, highway use and road wear would increase within the neighboring areas. Some blower fans (pull emissions from the incinerator through the air pollution controls and up the stack) can also be loud. Facility is enclosed which minimizes exterior noise.

Groundwater – No Impact.

No impact to the neighborhood and surrounding community's groundwater is expected.

4.6.5 Social Criteria Summary

Table 4-9 provides a summary of Social impacts and benefits (with job creation) for each Mass Burn disposal option tonnage scenario. The sub-criteria considered in this evaluation includes ESJ considerations, Local Traffic Impacts, Local Jobs Created for full time employees, and Other Potential Neighborhood Impacts.

Table 4-9: Summary of Social Criteria for Mass Burn Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
ESJ/Equity	• Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. • Environmental impacts will be greater for frontline communities. • Economic impacts greater for low-income households because cost increases represent a higher share of their income than for other households.		
Local Traffic Impacts (Number of Truck Trips/Day)[1]	262	180	96
Local Job Creation[2]	54 jobs created Minimal Skill: 6 Jobs Technical Skill: 28 Jobs Advanced Skill: 20 Jobs	48 jobs created Minimal Skills: 5 Jobs Technical Skills: 26 Jobs Advanced Skills: 17 Jobs	43 jobs created Minimal Skills: 4 Jobs Technical Skills: 24 Jobs Advanced Skills: 15 Jobs
Other Potential Neighborhood Impacts (Air, Odor, Noise, Groundwater).	• Air: Medium Impact • Odor: Low Impact • Noise: Medium Impact • Groundwater: No Impact		

[1] Assumes 9% increase for peak tonnage days. To and from Mixed Waste Processing Facility, IMF for ash disposal (20% of total tonnage) and metals (5% of total tonnage) recycler.
[2] Description of minimal, technical and advanced skills included in Section 4.7.3 above.

As presented in Table 4-9, the category with the highest number of jobs requires technical skills which may be highly valued as a meaningful career for people without a bachelor's degree.

4.7 Capacity Criteria

4.7.1 Capacity/Minimum Waste Requirements

Mass Burn technology has the capacity to handle each of the Study tonnage scenarios with facilities operating within the low to high tonnage range.

4.7.2 Waste Type Composition and Acceptance

Mass Burn facilities have high flexibility with changing waste compositions. The proportion of combustible materials in the three diversion scenarios does not have a material effect on operations as all three waste compositions are consistent with waste that is currently being processed in Mass Burn facilities. In comparing the tonnage scenarios, the low tonnage/high diversion scenario would have less variability in heating value so would have the most flexibility.

Most of the metal that is intact in the ash will be extracted with variations in energy value depending on the tonnage scenario.

4.7.3 Tonnage Flexibility

Mass Burn facilities generally combust MSW from the residential and commercial sectors as received with no pre-treatment and minimal pre-processing. A screening process is typically used to reduce the size of incoming bulky items which are then shipped to landfills for final disposal. Most of the bulky items are expected to be removed at the Mixed Waste Processing Facility prior to receipt at the Mass Burn facility.

Mass Burn facilities are built with multiple processing lines which allows them to reduce waste flows when there is little demand for waste disposal or when annual maintenance is required. Reducing processing capacity by 50% for short periods of time is manageable. Mass Burn facilities are limited by their maximum design capacity which is influenced by the heating value of the materials being combusted. Standard operating procedures will dictate the waste mix in the bunker to produce a feedstock that has a consistent heating value which can be optimized with an experienced operator. Therefore, there is flexibility in fluctuating volumes because these facilities could adapt to lower waste flows but have more limiting factors when the waste flows are close to their maximum design capacity. Facilities can be designed initially to accommodate the addition of modular operating units if needed to meet increased tonnage demand on a consistent basis. If future tonnages significantly change from what was assumed in designing the facility, equipment may need to be taken offline or added.

Also considered under the Flexibility sub-criteria is how options handle one-time emergencies or catastrophic events which for Mass Burn are addressed in the design of back-up systems such as redundant process lines, equipment and storage (on-site or alternative sites). A back-up alternative facility should be identified for emergencies or failures.

4.7.4 Residual Waste Management

Residuals management for Mass Burn facilities would be required for ash residuals from the combustion process. Rejected waste such as oversized or non-combustible items will also require transport to a landfill (assumed to be minimal as waste is received from a Mixed Waste Processing Facility) and recyclables such as recovered metals will need to be hauled away for off-site recycling. As mentioned above, bottom ash residues are increasingly being cleaned and treated as an aggregate replacement and, if allowed under regulation and implemented, would mean a decrease in ash disposal and would provide revenue.

4.7.5 Capacity Criteria Summary

Table 4-10 provides a summary of the Capacity criterion evaluated for Mass Burn for each tonnage scenario which includes Capacity/Minimum Waste Required, Waste Type Composition and Acceptance, Tonnage Flexibility and Residual Waste Management.

Table 4-10: Summary of Capacity Criteria for Mass Burn Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capacity/Minimum Waste Required	Technology is capable of processing amount of waste for these tonnage scenarios including projected amounts between 366,266 and 1,366,618 tpy through 2060.		
Waste Type Composition and Acceptance	• High waste acceptance. • All non-hazardous MSW accepted. • Broad acceptable criteria. Can take a broad range of energy values and material types. • Mass Burn can accept a wider range of acceptable wastes than can Pyrolysis, Gasification and RDF where end users have very specific feedstock requirements. • Most of the metal that is intact in the ash will be extracted. • A screening process is typically used to reduce the size of incoming bulky items and large inerts from the refuse feed chute. • Bulky items would need to be pre-processed ahead of time before they enter the refuse feed chute.		
Tonnage Flexibility	• High flexibility. • Has a broad acceptable criterion. Can take a broad range of energy values and material types from both residential and commercial sectors. • One-time emergencies or catastrophic event addressed in design of back-up systems such as redundant process lines, equipment and storage (on-site or alternative sites). • A back-up alternative facility should also be identified for emergencies or failures.		
Residuals Waste Management (Disposal or Further Processing)	• Residual ash would need to be disposed of in a separate ash monofill. • Rejected waste such as oversized or non-combustible items will also require transport to a landfill (assumed to be minimal).		

4.8 Mass Burn Evaluation Summary

The advantages and disadvantages associated with implementing a Mass Burn option for the county's long-term disposal solution are provided below.

Summary of Advantages

- Reduces the volume of waste that ends up in landfills while also generating energy from the thermal conversion of MSW.
- Established technology and industry expertise for quantities and types of waste projected for King County.
- Minimal pre-processing required of incoming materials and can process broad feedstock types.
- Reduction in residual waste volume by up to 90% and tonnage by 75%.
- Potential Revenue from sale of recovered metal, heat and/or electricity.

Summary of Disadvantages

- Capital costs are high ($230.99/ton for medium tonnage scenario in 2040$), requiring energy markets and economies of scale to ensure financial feasibility.
- Effective cost per ton increases if tonnages are less than projected during debt service period. Conversely, at the end of the debt service period, the effective cost per ton should decrease by a margin that removes the capital debt service cost.
- CETA restricts electricity from Mass Burn facilities from being sold to retail customers in WA, can be used for facility, interstate electricity sales or in-State wholesale customers or district heating; subject to CCA cap-and-invest program as the law was upheld by voters in November of 2024.
- Process produces emissions that require proper treatment and management.
- Residuals include fly ash and bottom ash waste that will likely require treatment for reuse or proper disposal.
- Siting and permitting difficult, typically high level of public opposition due to air pollution concerns.
- Environmental criteria LCA found impacts on, Global Warming Potential and Human Health impacts for Cancer Potential and environmental benefits for Non-Renewable Energy Demand, Water Consumption, Acidification Potential and Smog Formation.

5.0 GASIFICATION

5.1 Introduction

Gasification is a process that transforms MSW, using heat and limited oxygen into usable products, typically syngas that can be used as a fuel, industrial chemicals such as ammonia and methanol, fertilizer and solid residuals that can be used as a fill material for construction, roadbeds, etc.

Unlike Mass Burn, the temperature of the heat is several hundred degrees lower and front-end processing is typically required to create a suitable feedstock that can be thermally transformed. The processing can include shredding equipment to meet sizing specifications, magnets and eddy current separators to remove ferrous and non-ferrous metals, and densifiers to remove inert materials such as glass, rocks and masonry. This results in a feedstock with improved thermal properties of the waste stream. This pre-processing is similar to producing RDF which is discussed in Section 7.0.

A Gasification facility that processes MSW is uncommon. Most Gasification facilities are demonstration or pilot plants that process under 20,000 tpy of a homogeneous feedstock such as biomass (organics/wood waste), plastics, coal or tires. Using Gasification technologies to process MSW is considered developing and not commercially proven. The variability of the materials being heated affects the compounds in the syngas.

The largest Gasification facility in North America is in Edmonton, Canada (capacity of 110,000 tons/year) with limited operations over the past 10 years and is scheduled for retirement. The syngas quality is unpredictable from heterogeneous materials such as MSW. It should be noted that the footprint for a Gasification facility depends on land availability, access and infrastructure needs and tonnage requirements. It was estimated that between 30 and 42 acres would be required for the high tonnage scenario, between 18 and 30 acres for the medium tonnage scenario and between 12 and 24 acres for the low tonnage scenario.

At a Gasification facility, solid waste would be deposited on the tipping floor and loaders would be used to maneuver the waste into pre-processing pits. Conveyors would move the waste from the pits to the pre-processing equipment which consists of shredders, screens, densifiers, magnets and eddy current separators. Figure 5-1[62] is a photo of the pre-processing system used to process mixed waste at the Edmonton Integrated Process and Transfer Facility.

Figure 5-1: Waste processing equipment at the Edmonton Integrated Process and Transfer Facility.

The feedstock is placed into the Gasification vessel and is heated under low oxygen conditions. This allows the processed waste to volatilize and produce syngas. As mentioned previously, the temperature in the Gasification vessel is lower than a Mass Burn facility. As the VOC's are emitted, residual solids (20% to 25% of the feedstock by weight) are removed which would then require disposal or some form of stabilization for other uses.

Syngas is collected and purified in subsequent cleaning and conditioning steps that is then

[62] Tetra Tech (2016). *IPTF pre-processing equipment to support Enerkem plant* [Photograph].

converted to its desired commodity. The syngas contains hydrogen, carbon monoxide, carbon dioxide, and other trace gases which can be used to generate a variety of chemicals or fuels, such as methanol, synthetic gasoline, diesel, or RNG. The characteristic of the syngas is very dependent on the type of materials being thermally treated. The variability of the MSW stream is a major obstacle for a Gasification system to produce a consistent syngas for purification. Syngas also has hydrocarbon-like properties that allow it to be used as a fuel to drive engines and turbines to generate electricity and to be used internally or sold to a local electricity grid.

Gasification residuals are rich in carbon compounds and can be used in other applications such as an agricultural supplement. However, the chemical composition of the residuals is a function of the materials being gasified and, in several instances, include hazardous compounds that are not appropriate for land application and requires disposal in an ash monofill.

As previously noted, a detailed comparison analysis for Gasification (with residual waste export by rail) was performed and the results provided in this Study. After reviewing the results for the Gasification option provided in the following sections, SWD and representatives of MSWAC and SWAC **recommended that this long-term disposal option not be further considered** due to the technology's inability to manage the estimated King County 2040 tonnages and/or waste material types.

5.2 Environmental Criteria

Unlike Mass Burn, Gasification uses little to no air (or oxygen) in the Gasification vessel. This significantly reduces the amount of air emissions released into the environment, thereby reducing the impact on air quality that could potentially affect the health of people, animals, and plants. Air pollution control equipment would still be employed to remove contaminants from the emissions, but capacity of that equipment should be less than for Mass Burn. However, if the syngas is combusted after the Gasification process, that syngas would go through a combustion chamber where air is added to complete the combustion process. The amount of air needed for syngas combustion is a lower amount than what is needed in Mass Burn so the amount of emission produced is proportionally less. A Gasification facility would likely be viewed as an advanced thermal treatment facility that is better than Mass Burn because there should be significantly less emissions and it produces a commodity such as methanol.

The Gasification process releases less contaminants when there is a homogeneous incoming feedstock, such as wood waste/biomass. Extra facilities and processes are required to treat and convert the resulting syngas, or to control the flue gas emissions if syngas is combusted.

Metals can be recovered and recycled from the pre-processing step and the residuals of the Gasification process. Some jurisdictions may allow the residual to be used as a construction aggregate substitute. However, in general, the residual should be disposed of at an ash monofill as was assumed for this Study.

A human health risk assessment would likely be required as part of the environmental impact assessment for any proposed Gasification plant.

There are environmental impacts from air emissions from transporting MSW and bulk reagents to the facility. The residual ash will need to be hauled to an ash monofill and waste rejects such as oversized or non-combustible items will also require transport to a MSW landfill. For the Study, WEBR was assumed for transport of ash and waste rejects to a landfill.

As previously discussed in Section 4.1.1, CETA and CCA policies imposing restrictions on the sale of non-renewable energy and requiring cap and trade offsets, make it difficult for any combustion technology (Mass Burn, Gasification or Pyrolysis) to be economically feasible in Washington.

5.2.1 Environmental Criteria Analysis

Because Gasification facilities that process MSW are uncommon, reliable environmental impact data are not available for a significant number of MSW materials. As a result, the LCA environmental impacts of Gasification for MSW could not be analyzed as a whole or compared to other disposal options for the Study.

Other sub-criteria considered for Environmental includes Resource Conservation and Compatibility with Waste Prevention and Recycling.

5.2.2 Resource Conservation

The Gasification process creates usable products such as syngas that can be used as a fuel, processed into industrial chemicals such as ammonia and methanol, and converted to RNG.

5.2.3 Compatibility with Waste Prevention & Recycling

Before any feedstock is processed, metals are removed for recycling (estimated at 5% of tonnage processed). Knowing this may impact recycling behaviors from the general public if they are aware that recyclables would be converted to usable products which may lower consumer recycling rates. However, if recycling and other waste prevention measures are a lower cost than Mass Burn, that should incentivize increased recycling and waste prevention. In communities with Mass Burn facilities being used as the primary source of disposal, these communities typically have higher recycling rates in place

Table 5-1: Summary of Metal Recycled from Gasification Disposal Options

Environmental Factor	Units	High Tonnage Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Metal recycled	Tons	50,918	33,348	18,360

5.3 Economic Criteria

5.3.1 Capital Costs

Capital Costs for Gasification facilities were estimated using cost factors based on the processing capacity for a 110,000 ton per year gasification facility located in Edmonton, Canada. The Alberta facility began operations in 2013 and is one of the largest Gasification facilities built in the past decade. The capital cost per ton was $1,600 in 2013. Taking into consideration CPI increases, the capital cost per ton was estimated to rise to approximately $2,000 in 2023 for a 110,000 ton per year facility. For the three tonnage scenarios, the unit costs were reduced due to economies of scale for the higher tonnage scenarios by $100 per ton, cumulatively for each increase in tonnage scenario with the highest cost applied to the lowest tonnage scenario (then decreasing with economies of scale). Adjusted for tonnage, the Capital Costs ranged from $1,900 per ton (low tonnage scenario) to $1,700 per ton (high tonnage scenario) in 2023 dollars.

Although a specific location for a facility has not been identified and land costs are highly dependent on location, estimates were developed for potential land acquisition costs based on $40/square foot or $1,742,400/acre (provided by SWD from the County's real estate group) and assumptions of 42 acres for the high tonnage facility, 30 acres for the medium tonnage facility and 24 acres for the low tonnage facility. The acreage requirements for the facilities vary depending on access, infrastructure and buffer requirements with the high tonnage ranging from 30 to 42 acres, the medium tonnage ranging from 18 to 30 acres and the low tonnage ranging from 12 to 24 acres. The high end of the acreage requirements was assumed in calculating potential property acquisition costs.

The estimated total Capital Costs, including equipment, buildings, infrastructure, and estimated land acquisition costs ($1,742,400/acre) were then calculated to 2040 dollars using an annual inflation rate of 3.5 percent for the three tonnage scenarios.

5.3.2 Operating Costs

Gasification processes consume more electrical energy or fossil fuels to operate the facility than Mass Burn, resulting in increased Operating Costs and decreased available revenue. More material handling from the pre-processing is also required which results in a higher Operating Cost. For this option, it is assumed that Operating Costs would be 25% higher than Mass Burn.

The Operating Costs for Gasification facilities were estimated using the same 110,000 ton per year Gasification facility in Canada. Adjusted for tonnage, the Operating Costs for Gasification ranged from $50 per ton (high tonnage scenario) to $69 per ton (low tonnage scenario) in 2023 dollars. The annual Operating Costs include labor, maintenance, materials, and allowance for facility and equipment upgrades. An annual inflation rate of 3.5 percent for the three tonnage scenarios was used for projecting costs for the Study period of 2040 to 2060. Ash T&D costs were estimated based on current ash disposal rates for Spokane WtE facility adjusted for available WEBR transport costs at $97/ton (in 2023$). Disposal of residual MSW is anticipated to be insignificant as the materials received at the facility will have been processed at a Mixed Waste Processing Facility.

5.3.3 Revenue

Revenue from Gasification facilities is typically generated through the sale of methanol and from metals pulled from the incoming waste stream. The Gasification facility in Edmonton was designed to transform syngas into methanol. According to the project developer, gasifying one ton of solid waste produces 418 liters of methanol. Assuming there is a 40% parasitic load for the facility, the methanol production is estimated at 66 gallons per ton of waste processed. Potential Revenue from the sale of methanol is estimated at 50% of the average price of 1 gallon of methanol ($1.65 per gallon or $0.43/L – methanex.com). The discounted market rate accounts for any transport costs. The Revenue from producing methanol is academic and not commercially proven.

Based on input from facility operators, metal sales are assumed to be $70 per ton (higher than Mass Burn due to better quality metals being pulled off during pre-processing) and represent about 5% of the incoming feedstock.

5.3.4 Financial Risk

There are two major financial risks that King County could face should they choose Gasification as a disposal option. As noted previously, there are no proven operations at the tonnage needed to manage King County's waste stream. The second is that any commodity sales may be limited due to the need for clean, homogeneous feedstock requirements which are not conducive to processing MSW. Therefore, the County would run the risk of not being able to sell the commodities on the market.

5.3.5 Cost Per Ton

The unit processing cost was calculated by adding the annualized Capital Costs (at 4% interest over 30 years assuming municipal funding at 2.5% bond purchase cost) to the Operating Cost and subtracting the Revenue from both the methanol and ferrous metal sales. The net annual cost is then divided by the annual tonnages to obtain 2023, 2040, 2050 and 2060 costs per ton.

5.3.6 Economic Criteria Summary

Table 5-2 provides a summary of results in evaluating the Economic considerations for the Gasification disposal option and all tonnage scenarios in 2040$ (start of Study period). To assess the Economics of the Gasification option, the Economic sub-criteria evaluate the Capital Cost, Operating Cost (including residuals disposal), commodity sale Revenue (methanol and metals), and unit processing Cost per Ton.

The unit processing cost ($2040) was calculated by adding the annualized Capital Costs (at 4% interest over 30 years assuming municipal funding at 2.5% bond purchase cost) to the Operating and Disposal cost and subtracting the Revenue from both the electricity and ferrous metal sales. The net annual cost is then divided by the annual tonnages to obtain 2023, 2040, 2050 and 2060 costs per ton. The unit Cost per Ton for the high and medium tonnage scenarios decrease over time with higher tonnages projected for the later years (tonnage increases are higher than assumed inflation). Results of the calculations are shown in Table 5-2 below. Cost assumptions and results are also included in Appendix B - Comparative Evaluation Summary Matrices for each of the disposal options.

Table 5-2: Summary of Economic Criteria for Gasification Disposal Options

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capital Costs (2040$)[1]	$3.3B	$2.3B	$1.3B
Capital Costs (Annualized)[2]	$243M	$169M	$100M
Operating Cost (Annual)[3]	$91M	$67M	$45M
Residuals Disposal (Annual)	$43M	$28M	$15M
Annual Revenue (2040$) - Methanol	$99M	$72M	$40M
Annual Revenue (2040$) - Recycling	$6.4M	$4.2M	$2.3M
Total Annual Cost in 2040$[4]	$272,155,704	$187,607,086	$118,527,088
Annual Cost/Ton (2023$)[, 5]	$148.91/ton	$156.74/ton	$179.86/ton
Annual Cost/Ton (2040$)[, 5]	$267.25/ton	$281.29/ton	$322.78/ton
Annual Cost/Ton (2050$)[, 5]	$213.82/ton	$265.57/ton	$344.36/ton
Annual Cost/Ton (2060$)[, 5]	$180.31/ton	$254.24/ton	$374.70/ton

[1] Includes equipment, building, infrastructure, and estimated land acquisition costs. Inflation assumed at 3.5% annual.
[2] Annual cost based on debt service assumed at 4% for 30-year term per municipal funding.
[3] Includes labor, maintenance, materials, regular facility and equipment upgrades. Inflation assumed at 3.5% annual.
[4] Equals Capital Costs (annualized) + Operating Costs + Residuals Disposal - Annual Revenues
[5]Equals Total Annual Cost/Total Tonnage

5.4 Operating History Criteria

5.4.1 Proven Performance

Gasification technologies have been used for a narrow band of applications over a long period of time. As noted earlier, Gasification has been used where syngas (which contains hydrogen and methane) and/or char have been used for financial or environmental reasons. As such, technical developments in the technology have expanded in recent years for select homogeneous feedstock but actual use of Gasification for MSW is rare. Therefore, most Gasification facilities are demonstration or pilot plants under 20,000 tpy and process a homogeneous feedstock such as biomass (organics/wood waste), plastics, coal or tires. Using Gasification technologies to process MSW is considered developing and not commercially proven at this time.

As it relates to this Study, there are no known operating plants at the proposed processing capacity needed for any of the three tonnage scenarios. The largest facility known in North America is the previously identified 110,000 tpy facility in Edmonton, Canada. This facility has had limited operations over the previous 10 years and is currently non-operational and scheduled to be retired.

5.4.2 Safety, Environmental and Regulatory Compliance

There are no known Gasification facilities currently in operation at the tonnage levels required for comparison purposes.

5.4.3 Operating History Criteria Summary

Table 5-3 summarizes the Operating History results for Gasification technology for all tonnage scenarios. The sub-criteria considered for the Operating History includes an assessment of Proven Performance, Safety, Environmental and Regulatory Compliance. As noted in the table, there are no known Gasification facilities currently in operation at the tonnage levels required for comparison purposes**.**

Table 5-3: Summary of Operating History Criteria for Gasification Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Proven Performance	No operating plants at proposed processing capacity. Largest facility known is 110,000 tpy and currently non-operational and about to be retired.		
Safety Record	No facilities currently in operation for comparison purposes.		
Environmental and Regulatory Compliance Record	No facilities currently in operation for comparison purposes.		

5.5 Logistics Criteria

Gasification will require preprocessing to ensure the feedstock meets sizing requirements and inert materials are removed. According to the Edmonton, Canada reference facility, this represents 40% of the Capital Costs and increases Operating Costs. This option is not as seamless as Mass Burn and there are technical and operation risks since facilities at the three tonnage scenarios proposed for King County have not been built and are not commercially proven.

5.5.1 Operating Life of Facilities

There are no known commercial operations of Gasification facilities to determine the average Operating Life of a facility for the three tonnage scenarios.

5.5.2 Siting/Design/Permitting/Construction Considerations

Even though there are no known commercial operations to compare to, it is generally understood that the siting and permitting of a potential Gasification facility in Washington State would be a difficult process. The Gasification facility is estimated to take seven to ten years to site, design and construct. This includes four to six years for siting, one to two years to obtain financing and design specs and two years for facility construction. Factors would depend on the size of facility, local and state ordinances, and community involvement. Industrial zoning, distance to sensitive receptor locations[63], ESJ and environmental impacts are to be considered in the siting process. Washington State's CETA and CCA regulations do not affect methanol production.

The permitting process is expected to take a significant amount of time due to its complexity and would be similar to the Mass Burn option (see Section 4.6.2). The permitting process for a Gasification facility would include preparation of a NOC issued by PSCAA and a PSD permit administered by Ecology for air quality control which are critical and lengthy steps in the permitting process. Several permits for land use need to be obtained prior to facility construction. It should be noted that while ash is classified as non-hazardous by the time it leaves the facility, it will still need to be disposed of at an approved ash monofill, Building and construction permits are required during the construction of the Gasification facility. An industrial wastewater discharge permit may be required if the water is going to the County wastewater system.

The new facility must comply with applicable federal NSPS and NESHAP. These regulations describe emission standards, monitoring requirements and performance testing, and siting requirements. The siting requirements include the necessity of a detailed Materials Separation Plan be completed with a public review process.

The facility will be required to obtain a Title V permit which permit application can be submitted to PSCAA after the PSD construction permit is issued.

In January 2024 new USEPA emission standards were announced to strengthen Clean Air Act standards for large facilities that burn MSW. These requirements will be to reduce the emission limits significantly for LMWC both under the EG and the NSPS Limits. (see excerpt below for proposed emission limits) Basically, these facilities will need to implement BACT technology to reduce PM, Mercury and Dioxin Furans, Acid Gases, NOx, and CO. Some of these will be specific technologies and others will be Best Practices.

5.5.3 Compatibility with Current Collection System

Gasification is an option that transforms MSW into usable products, typically syngas that can be used as a fuel, processed into industrial chemicals such as ammonia and methanol, and converted to RNG. The solid residuals can be used as a sub-base for construction of roadbeds. However, a Gasification facility that processes MSW is uncommon. Most Gasification facilities are demonstration or pilot plants under 20,000 tpy and process a homogeneous feedstock. The technology also requires pre-processing of incoming waste to support the Gasification units. Therefore, Compatibility with the Current Collection System is considered low.

5.5.4 Logistics Criteria Summary

Table 5-4 provides a summary of results in evaluating the Logistics criteria for all Gasification disposal option tonnage scenarios. The Logistics criterion includes an assessment of sub-criteria such as the Operating Life of facilities (in years), Siting, Permitting, Design and Construction considerations, and Compatibility with the Current Collection Systems for each Gasification disposal option tonnage scenario.

[63] Sensitive receptors are children, elderly, people suffering from asthma, and others who are at a heightened risk of negative health outcomes due to exposure to pollution. Sensitive receptor locations may include hospitals, schools, day care centers, and similar locations where people congregate.

Table 5-4: Summary of Logistics Criteria for Gasification Disposal Option

<table>
<tr><th></th><th>High Tonnage/
Low Diversion</th><th>Medium Tonnage/
Medium Diversion</th><th>Low Tonnage/
High Diversion</th></tr>
<tr><td>Operating Life of Facility (years)</td><td colspan="3">No known commercial operations to compare to.</td></tr>
<tr><td>Siting/Design/Permitting/Construction Considerations</td><td colspan="3">Siting and Permitting is difficult.
7-10 years to Site, Permit, Design and Construct:
• 4-6 years to site
• 1-2 years financing and Design
• 2 years Construction
Factors depend on size of facility, local and state ordinances, and community involvement.</td></tr>
<tr><td>Compatibility with Current Collection System</td><td colspan="3">Low compatibility.
Requires pre-processing of incoming waste to support Gasification units.</td></tr>
</table>

5.6 Social Criteria

A Gasification facility would create Local Jobs, as a technical team would be required to build and operate the new facility. The facility would generate products which could be used for local and larger regional use. The sale of methanol and metal should be a boost to the local economy and help off-set Capital and Operating Costs.

An environmental concern associated with the Gasification process includes emissions that could impact local air quality and therefore cause public disapproval. Emission levels are usually well below acceptable levels for industrial zone facilities. Other Potential Neighborhood Impacts are related to traffic and noise. ESJ considerations would be similar to Mass Burn for siting a new facility as noted below.

5.6.1 Environmental and Social Justice/Equity (ESJ)

ESJ considerations will be an important part of future siting for a Gasification facility. As part of the siting process, communities are to be identified around potential facility locations and transport corridors to evaluate per USEPA's Environmental Justice Screening and Mapping Tool and the Washington Environmental Health Disparities Map.

Environmental impacts will be greater on front-line communities and economic impacts will be greater for low-income households as cost increases represent a higher share of their income than for other household types.

5.6.2 Local Traffic Impacts

Traffic levels for the Gasification facility are comparable to Mass Burn. Assuming the average trailer load is 28 tons, the average number of vehicles entering the facility would be on the order of 103 trailers per day for the low tonnage scenario, 186 trailers per day for the medium tonnage scenario and 281 trailers per day for the high tonnage scenario as shown on Table 5-5.

The number of truck trips per day includes travel to and from the Mixed Waste Processing Facility, travel to an IMF for disposal (24% of the total tonnage) and travel to a metals recycler (5% of total tonnage). It also assumes 362 workdays per annum. Traffic impacts will be shifted from the vicinity of CHRL to the vicinity of the Gasification facility and are, therefore, expected to be similar to that at CHRL.

In addition, highway use and road wear would increase within the neighboring areas.

5.6.3 Local Job Creation

The number of jobs created for a Gasification facility are assumed to be similar to a Mass Burn facility as both would have similar operations. This includes (1) front-end material handling, (2) some pre-processing, loading, and operating the combustion unit(s), (3) post processing of the materials and (4) residuals management. Depending on the combustion units needed, there may be higher full-time equivalents (FTEs) required for Gasification.

The following categories were developed for consideration in comparing the Study disposal options based on skill/training and compensation level. Potential skill categories include:

- **Minimal skill.** Requires no prior skill and minimal on-the-job training. Estimated to be between 4 and 6 jobs depending on tonnage requirements.
- **Technical skill.** Requires an associate's degree, technical certificate, or similar level of on-the-job technical training. Estimated to be between 24 and 28 jobs depending on tonnage requirements.
- **Advanced skill.** Requires Bachelor, Masters, or other advanced degree or equivalent level of on-the-job training and years of experience. Estimated to be between 15 and 20 jobs depending on tonnage requirements.

5.6.4 Other Potential Neighborhood Impacts

For Gasification, the Other Potential Neighborhood Impacts based on a qualitative comparison between options will range from no impact to medium impact. Additional context relating to each of the environmental concerns as they relate to Gasification are provided below.

Air – Medium Impact.

Air emissions from Gasification are primarily CO_2, CO, NOx, VOC's, SO_2 which are substantially reduced through regulatory requirements and are highly dependent on how biogases are used. Emission levels are usually well below acceptable levels for industrial zone facilities. Some air emissions may come after final scrubbing of biogas, dependent on what process is employed on the backend.

Odor – Low Impact.

The primary source of odors are the trucks that enter the facility, the tipping floor where raw garbage is stored, any ash/residue and potentially odor originating from the stacks (most are scrubbed, and odor should be at a minimum). The facility is enclosed which significantly contains odor.

Noise – Medium Impact.

The primary source of noise are trucks along traffic routes and entering the facility. Some blower fans (pull emissions from the incinerator through the air pollution control system and up the stack) can also be loud. The facility will be enclosed, which minimizes exterior noise.

Groundwater – No impact

No groundwater impact to the neighborhood and surrounding community's groundwater is expected from a Gasification facility.

5.6.5 Social Criteria Summary

Table 5-5 provides a summary of the results in evaluating the Social criteria for each tonnage scenario. The sub-criteria considered in this evaluation includes ESJ/Equity considerations, Traffic Impacts (truck trips), number of Local Jobs Created and Other Potential Neighborhood Impacts.

Table 5-5: Summary of Social Criteria for Gasification Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
ESJ/Equity	• Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. • Environmental impacts will be greater for frontline communities. • Economic impacts greater for low-income households because cost increases represent a higher share of their income than for other households.		
Local Traffic Impacts (Number of Truck Trips/Day)[1]	281	186	103
Local Job Creation[2]	54 jobs created. Minimal Skill: 6 Jobs Technical Skill: 28 Jobs Advanced Skill: 20 Jobs	48 jobs created. Minimal Skill: 5 Jobs Technical Skill: 26 Jobs Advanced Skill: 17 Jobs	43 jobs created. Minimal Skill: 4 Jobs Technical Skill: 24 Jobs Advanced Skill: 15 Job.
Other Potential Neighborhood Impacts (Air, Odor, Noise, Groundwater).	• Air: Medium Impact. • Odor: Low Impact. • Noise: Medium Impact. • Groundwater: No Impact		

[1] Assumes 9% increase for peak tonnage days. To and from Mixed Waste Processing Facility, IMF for ash disposal (24% of total tonnage) and metals (5% of total tonnage) recycler.
[2] Description of minimal, technical and advanced skills included in Section 5.6.3 above.

5.7 Capacity Criteria

5.7.1 Capacity/Minimum Waste Requirements

Gasification technology is still in development in North America. There are currently no Gasification facilities capable of processing the projected amount of waste in 2040 or that projected by 2060 for the three tonnage scenarios provided by King County: (1) 366,266 tpy for the high diversion/low tonnage scenario in 2060, (2) 811,014 tpy for the medium diversion/medium tonnage scenario in 2060 and (3) 1,366,618 tpy for the low diversion/high tonnage scenario in 2060.

5.7.2 Waste Type Composition and Acceptance

As previously noted, a Gasification facility that processes MSW is uncommon (low waste acceptance), considered developing and not commercially proven at the scale needed to manage King County's waste. Typically, a Gasification facility processes homogeneous feedstock such as biomass (organics/wood waste), plastics, coal or tires, and the thermal characteristics of the waste streams would be similar for the three waste diversion scenarios. Because there are no commercial operations of the type and processing capacity needed for King County, the flexibility in changing waste compositions and how these facilities would perform is unknown.

For a Gasification facility, pre-processing of the waste is required. This includes shredding equipment to meet sizing specifications, magnets and eddy current separators to remove ferrous and non-ferrous metals, and densifiers to remove inert materials such as glass, rocks and masonry to create feedstock with improved thermal properties.

5.7.3 Tonnage Flexibility

A Gasification facility would likely be built in a similar manner as Mass Burn. Mass Burn facilities are built with multiple processing lines which allows them to reduce waste flows when there is reduced demand for waste disposal or when annual maintenance is required. Reducing processing capacity by 50% for short periods of time should be manageable. Facilities can be designed initially to accommodate the addition of modular operating units if needed to meet increased tonnage demand on a consistent basis. If future tonnages significantly change from what was assumed in designing the facility, equipment may need to be taken offline or added.

Gasification facilities are limited by the materials in the waste stream which would influence the production of the target commodity. This technology is not widely used for MSW and that may pose challenges for finding an experienced operator. Therefore, the flexibility with fluctuating volumes is low because there are very few commercial operations of this type and processing capacity.

Also considered under the Flexibility sub-criteria is how options handle one-time emergencies or catastrophic event which should be addressed in design of back-up systems such as redundant process lines, equipment and storage (on-site or alternative sites) and a back-up alternative facility should also be identified for emergencies or failures.

5.7.4 Residual Waste Management

Similar to Mass Burn, Gasification technology results in the need to dispose of residual wastes, including ash which must be disposed of within an ash monofill as the ash residuals may contain hazardous compounds. Rejected waste such as oversized or non-combustible items will also require transport to a landfill for final disposal. Recyclables such as recovered metals will need to be hauled away for off-site recycling.

5.7.5 Capacity Criteria Summary

Table 5-6 provides a summary of the results in evaluating the Capacity sub-criteria for each Gasification disposal option tonnage scenario. This criterion considers sub-criteria evaluated for each tonnage scenario such as the Capacity/Minimum Waste Requirements, Waste Type Composition and Acceptance, Tonnage Flexibility, and Residual Waste Management.

Table 5-6: Summary of Capacity for Gasification Disposal Options

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capacity/Minimum Waste Requirements	Technology is still in development. Not capable of processing amount of waste from these tonnage scenarios including projected amounts between 366,266 and 1,366,618 tpy through 2060.		
Waste Type Composition & Acceptance	• Low waste acceptance. • Processes homogeneous feedstock. Processing MSW is considered developing and not commercially proven. • Thermal characteristics of the waste streams should be similar for the three waste diversion scenarios. • Pre-processing required.		
Tonnage Flexibility	• Low Flexibility. • Most Gasification facilities are demonstration or pilot plants that process under 20,000 tpy, none operating at the tonnage required so flexibility with higher tonnages is low. • One-time emergencies or catastrophic event addressed in design of back-up systems and back-up alternative facility should also be identified.		
Residual Waste Management	• Residuals disposal likely required in an ash monofill. Market for biochar end-product uncertain. • Rejected waste such as oversized or non-combustible items will also require transport to a landfill. • Recyclables such as recovered metals will need to be hauled away for off-site recycling.		

5.8 Gasification Evaluation Summary

Compared to the Mass Burn option, Gasification systems are more complex, more expensive, have more moving parts and more operational risk as there are no operating facilities at the scale required for King County. Advantages are increased value of the commodity generated and less air emissions. A summary of the advantages and disadvantages of Gasification is provided below.

Summary of Advantages

- Gasification can generate revenue from either the gas stream (syngas) or from bio-char.
- Reduction of incoming waste tonnage by up to 70%.
- Potential revenue from sale of a valued commodity such as Methanol and metal.
- Less air emissions compared to Mass Burn.

Summary of Disadvantages

- Not a proven technology for MSW at the commercial scale needed.
- Process produces emissions that require proper treatment and management.

- Syngas generation will require clean up and markets for commodities such as methanol and hydrogen.
- Usability of char is currently unpredictable and likely requires direct disposal at an ash monofill.
- Capital and Operating Costs are higher than Mass Burn ($281.29 for medium tonnage scenario in 2040$), requiring economies of scale and markets for its products to be financially feasible.
- As with Mass Burn, high level of public opposition should be expected to address air pollution concerns.

6.0 PYROLYSIS

6.1 Introduction

Pyrolysis is a thermal depolymerization process that uses high heat, high pressure, and no oxygen to produce products such as syngas, oils, solid carbon or char (used as a solid fuel, soil amendment, and for industrial processes), and other chemicals. Pyrolysis also converts waste plastic into various types of hydrocarbons. It has the potential to divert plastics destined for the landfill, displace virgin fossil fuel production, and reduce GHG emissions. Hydrocarbons, including crude oil produced by Pyrolysis, can be marketed as feedstock for oil refineries, petrochemical processors, or consumed on site.

Large scale Pyrolysis facilities for MSW are rare. Pyrolysis, like Gasification, is best suited for a homogeneous feedstock such as plastic materials or wood waste. These types of homogeneous facilities have been able to achieve performances that are more efficient in terms of energy efficiency, carbon intensity, and resource productivity. However, capital and operating costs remain high as the technology is still developing and not commercially proven, particularly for MSW feedstock.

The waste stream would need to be preprocessed to produce a uniform sized feedstock with little to no inert materials. The feedstock would then be fed into the Pyrolysis unit where it would be heated to volatilize the combustible materials in a high-pressure environment. Outputs from Pyrolysis can include marketable crude oil, solid carbon residuals, non-condensable gases, and dissolved organics. The performance specifications for these outputs are based on Pyrolysis of clean (contaminant free) feedstock. The varied characteristics of the waste stream make it difficult to predict which compounds are produced and how much of the desired compounds can be collected. This is why Pyrolysis is better suited for homogeneous waste streams such as wood, plastics or tires.

As previously noted, a detailed comparison analysis for Pyrolysis (with residual waste export by rail) was performed and the results provided in this Study. After reviewing the results for the Pyrolysis option presented in the following sections, SWD and representatives of MSWAC and SWAC **recommended that this long-term disposal option not be further considered** due to the technologies inability to manage the estimated King County 2040 tonnages and/or waste material types.

6.2 Environmental Criteria

Similar to Mass Burn, Pyrolysis has comparable environmental concerns including emissions that could impact air quality potentially affecting the health of people, animals, and plants. Air pollution control equipment is therefore deployed to remove contaminants from the emissions.

Pyrolysis is a specialized WtE process that requires a more consistent homogeneous feedstock and requires less or no oxygen compared to a Mass Burn process. This in turn results in less flue gas being generated from the Pyrolysis process, approximately 20% of the amount of flue gas generated by Mass Burn. Less flue gas suggests that less environmental impacts would occur. Thus, Pyrolysis may have five times less environmental impacts from an air pollution perspective when compared to Mass Burn.

There will be other environmental impacts from air emissions from transporting MSW and bulk reagents to the facility. The residual ash will need to be hauled to an ash monofill and waste rejects such as oversized or non-combustible items will also require transport to a MSW landfill. For the Study, WEBR was assumed for transport of ash residuals to a landfill.

As previously discussed in Section 4.1.1, CETA and CCA policies imposing restrictions on the sale of non-renewable energy and requiring cap and trade offsets, make it difficult for any combustion technology (Mass Burn, Gasification or Pyrolysis) to be economically feasible in Washington.

6.2.1 Environmental Criteria Analysis Results

Because large-scale Pyrolysis facilities that process MSW are rare, reliable environmental impact data are not available for a significant number of MSW materials. As a result, the environmental impacts of Pyrolysis for MSW in King County could not be analyzed as a whole or compared to other disposal options in an LCA approach.

Other sub-criteria considered for Environmental includes Resource Conservation and Compatibility with Waste Prevention and Recycling.

6.2.2 Resource Conservation

The Pyrolysis process creates products such as syngas, marketable crude oils, solid carbon residuals, non-condensable gases or char (used as a solid fuel, soil amendment, and for industrial processes), dissolved organics and other chemicals. Pyrolysis also converts waste plastic into various types of hydrocarbons.

6.2.3 Compatibility with Waste Prevention & Recycling

Before any feedstock is processed, metals are removed for recycling. Knowing this may impact recycling behaviors from the general public if they are aware that recyclables would be converted to usable products which may lower consumer recycling rates. However, if recycling and other waste prevention measures are a lower cost than Mass Burn, that should incentivize increased recycling and waste prevention.

Table 6-1: Summary of Metal Recycled from Pyrolysis Disposal Options

Environmental Factor	Units	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Metal recycled	Tons	50,918	33,348	18,360

6.3 Economic Criteria

Capital Costs for a Pyrolysis facility varies significantly depending on the incoming feedstock and there are no reference operating facilities near the capacity needed for the Study. Since the components and feedstock are similar to Gasification, the unit Capital and Operating Costs for Gasification were applied to the Pyrolysis Economic analysis. High level cost estimates for a Pyrolysis facility are summarized in Table 6-2.

Revenue from Pyrolysis is based on electricity and recovered metal sales. Revenue from electricity is based on the assumptions used for the Mass Burn economic analysis with a 20% loss for heating of the Pyrolysis units. The net revenue is summarized in Table 6-2.

6.3.1 Capital Costs

There are no Pyrolysis reference facilities operating near the capacity needed for the Study. Since the components and feedstock are similar to Gasification, the unit Capital Costs for Gasification were applied to calculate the Capital Cost per Ton. Adjusted for tonnage, the Capital Costs per ton range from $1,700 per ton (high tonnage scenario) to $1,900 per ton (low tonnage scenario) in 2023 dollars.

Although a specific location for a facility has not been identified and land costs are highly dependent on location, estimates were developed for potential land acquisition costs based on $40/square foot or $1,742,400/acre (provided by SWD from the County's real estate group). The acreage requirements for the facilities vary depending on access, infrastructure and buffer requirements with the high tonnage ranging from 30 to 42 acres, the medium tonnage ranging from 18 to 30 acres and the low tonnage ranging from 12 to 24 acres. The high end of the acreage requirements was assumed in calculating potential property acquisition costs.

The estimated total Capital Cost per Ton, including equipment, buildings, infrastructure, and estimated land acquisition costs ($1,742,400/acre) were then calculated to 2040 dollars using an annual inflation rate of 3.5 percent for the three tonnage scenarios.

6.3.2 Operating Costs

Similar to Gasification, the Pyrolysis processes consume more electrical energy or fossil fuels to operate the facility than Mass Burn, resulting in increased Operational Costs and decreased available Revenue. More material handling from the pre-processing is also required which results in a higher Operating Cost. For this option, it is assumed that Operating Costs would be 25% higher than Mass Burn.

Adjusted for tonnage, the Operating Costs ranged from $50 per ton (high tonnage scenario) to $69 per ton (low tonnage scenario) in 2023 dollars. The annual Operating Costs include labor, maintenance, materials, and allowance for facility and equipment upgrades. An annual inflation rate of 3.5 percent for the three tonnage scenarios was used for projecting costs for the Study period of 2040 to 2060.

In order to calculate the annual disposal costs for the ash residuals, it was assumed that 24 percent of the feedstock would be considered residuals for each tonnage scenario. Ash T&D costs were estimated based on current ash disposal rate for Spokane WtE facility adjusted for available WEBR transport costs at $97/ton (in 2023$). Disposal of residual MSW is anticipated to be insignificant as the materials received at the facility will have been processed at the Mixed Waste Processing Facility.

6.3.3 Revenue

Although Pyrolysis is capable of producing a variety of end products such as syngas, oils, solid carbon or char, the varied characteristics of the waste stream make it difficult to predict which compounds are produced and how much of the desired compounds can be collected. This is why Pyrolysis is better suited for homogenous waste streams such as wood, plastics or tires.

To simplify the process, syngas and residuals are typically combusted to produce heat which could then be used to produce steam to power turbines. Producing heat is also more predictable which is why energy generation was assumed for revenue potential. For the sale of electricity, it is assumed that energy sales are 20% less than the Mass Burn estimates. This is because more energy is needed to preprocess the material (utilizing more parasitic loads). In addition, the combustion temperature is not as high as Mass Burn so there is less recovered energy.

Similar to Gasification, metal sales are assumed for Pyrolysis to be $70 per ton (higher than Mass Burn due to better quality metals being pulled off during pre-processing), including transport, and represent about 5% of the incoming feedstock.

6.3.4 Financial Risk

There are two major financial risks that King County could face should they choose Pyrolysis as a disposal option. As noted previously, there are no proven operations at the tonnage scale needed to manage King County's waste stream. The second is that there is a potential risk of nominal electricity sales to offset costs due to Washington State CETA restrictions and/or CCA legislation.

6.3.5 Cost Per Ton

The unit processing cost was calculated by adding the annualized Capital Costs (at 4% interest over 30 years, assuming municipal funding at 2.5% bond purchase cost) to the Operating Cost and subtracting the Revenue of both the electrical and ferrous metal sales. The net annual cost is then divided by the annual tonnages to obtain 2023, 2040, 2050 and 2060 Costs per Ton.

6.3.6 Economic Criteria Summary

Table 6-2 provides a summary of results in evaluating the Economic considerations for the Pyrolysis disposal option and all tonnage scenarios in 2040$ (start of Study period). To assess the economics of the Pyrolysis option, the Economic sub-criteria evaluate the Capital Cost, Operating and Disposal cost (includes residuals disposal), commodity sale Revenue (electricity and metal), and unit processing Cost per Ton (2023-2060).

The unit processing cost ($2040) was calculated by adding the annualized Capital Costs (at 4% interest over 30 years assuming municipal funding at 2.5% bond purchase cost) to the Operating Cost and subtracting the Revenue from both the electrical and ferrous metal sales. The net annual cost is then divided by the annual tonnages to determine 2023, 2040, 2050 and 2060 Costs per Ton. Results of the calculations are shown in Table 6-2 below. Cost assumptions and results are also included in the Appendix B - Comparative Evaluation Summary Matrices for each of the disposal options.

Table 6-2: Summary of Economic Considerations for a Pyrolysis Disposal Options

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capital Costs (2040$)[1]	$3.3B	$2.3B	$1.3B
Capital Costs (annualized)[2]	$243M	$169M	$100M
Operating Cost (annual)[3]	$91M	$67M	$45M
Ash Residuals Disposal (annual)	$43M	$28M	$15M
Annual Revenue (2040$) - Electricity	$9.0M	$5.9M	$3.2M
Annual Revenue (2040$) - Recycling	$6.4M	$4.2M	$2.3M
Total Annual Cost (2040$)	$361,743,991	$253,664,508	$154,896,199
Annual Cost/Ton (2023$)[4]	$197.93/ton	$211.92/ton	$233.65/ton
Annual Cost/Ton (2040$)[4]	$355.22/ton	$380.33/ton	$419.33/ton
Annual Cost/Ton (2050$)[4]	$320.93/ton	$392.27/ton	$481.75/ton
Annual Cost/Ton (2060$)[4]	$310.75/ton	$416.31/ton	$569.78/ton

[1]Includes equipment, building, infrastructure, and estimated land acquisition costs. Inflation assumed at 3.5% annual.
[2]Annual cost based on debt service assumed at 4% for 30-year term per municipal funding.
[3]Includes labor, maintenance, materials, allowance for facility and equipment upgrades. Inflation assumed at 3.5% annual.
[4]Equals Annualized Capital + Operating Costs – Revenue.

6.4 Operating History Criteria

Pyrolysis technologies have been used for a narrow band of applications. As noted earlier, Pyrolysis has been used where syngas (which contains hydrogen and methane), bio-oil and/or char have been used for financial or environmental reasons. As such, technical developments in the technology have expanded over the most recent years, but the use of Pyrolysis for MSW is rare.

There is currently no commercial scale Pyrolysis facility for mixed MSW. There are some small-scale facilities for materials such as plastics and C&D wood. These facilities are relatively small in processing volume and have not been operating for more than 10 years. Table 6-3 identifies the lack of Operating History impacts as there are no existing commercial scale Pyrolysis disposal facilities for mixed MSW. There are no operating plants capable of managing the proposed processing capacities.

6.4.1 Proven Performance

As it relates to this Study, the only known Pyrolysis facilities in North America are demonstration plants that process under 20,000 tpy, far less than would be needed to manage King County's waste stream.

6.4.2 Safety, Environmental and Regulatory Compliance

There are currently no known Gasification facilities currently in operation at the tonnage levels required for comparison purposes.

6.4.3 Operating History Criteria Summary

Table 6-3 provides a summary of results in evaluating the Operating History for each Study tonnage scenario. The sub-criteria considered for the Operating History includes an assessment of Proven Performance, Safety record, Environmental Compliance, and Regulatory Compliance for each Study tonnage scenario.

Table 6-3: Summary of Operating History Impacts for Pyrolysis Disposal Options

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Proven Performance	Only known facilities are demonstration plants that are under 20,000 tpy.		
Safety Record	No facilities currently in operation with similar tonnage ranges.		
Environmental and Regulatory Compliance	No facilities currently in operation with similar tonnage ranges.		

6.5 Logistics Criteria

Similar to Gasification, Pyrolysis will require preprocessing to ensure the feedstock meets sizing requirements and inert materials are removed. This option is not as seamless as Mass Burn and there are technical and operational risks since facilities of these three tonnage scenario sizes have not been built and are not commercially proven.

A Pyrolysis facility will have similar considerations and requirements of a Gasification facility. The Siting, Permitting, Design and Construction of a facility is expected to take a significant amount of time due to its complexity.

6.5.1 Operating Life of Facilities

There are no known commercial operations of Gasification facilities to determine the average Operating Life of a facility for the three tonnage scenarios.

6.5.2 Siting/Design/Permitting/Construction Considerations

Even though the only known commercial operations of Pyrolysis facilities are demonstration plants processing under 20,000 tpy, it is generally understood that the siting and permitting of a potential Pyrolysis facility in Washington State would be a difficult process. The Pyrolysis facility could take seven to ten years to site, design and construct. This includes four to six years for siting, one to two years to obtain financing and design specs and two years for facility construction. Factors would depend on the size of the facility, local and state ordinances, and community involvement. Industrial zoning, distance to sensitive receptor locations, ESJ and environmental impacts are to be considered in the siting process.

The permitting process is expected to take a significant amount of time due to its complexity and would be similar to the Mass Burn option (see Section 4.5.2). The permitting process for a Gasification facility would include preparation of a NOC issued by PSCAA and a PSD permit administered by Ecology for air quality control which are critical and lengthy steps in the permitting process. Several permits for land use need to be obtained prior to facility construction. Disposal at an ash monofill might be required if the residual has contaminants that are considered hazardous. Building and construction permits are required during the construction of the Gasification facility. An industrial wastewater discharge permit may be required if the water is going to the County wastewater system.

The new facility must comply with applicable federal NSPS and NESHAP. These regulations describe emission standards, monitoring requirements and performance testing, and siting requirements. The siting requirements include the necessity of a detailed Materials Separation Plan be completed with a public review process.

The facility will be required to obtain a Title V permit. A Title V permit application can be submitted after the PSD construction permit is issued.

Regulatory drivers impacting feasibility would include CETA (restricting utility sales to retail customers due to not meeting renewable energy definition), CCA (requiring cap-and-trade credit purchases) and new 2024 USEPA air pollution standards. In January 2024, new USEPA emission standards were announced to strengthen Clean Air Act standards for large facilities that burn MSW. These requirements will be to reduce the emission limits significantly for LMWC both under the EG and the NSPS Limits. Basically, these facilities will need to implement BACT technology to reduce PM, Mercury and Dioxin Furans, Acid Gases, NOx, and CO. Some of these will be specific technologies and others will be Best Practices.

6.5.3 Compatibility with Current Collection System

Pyrolysis is a thermal depolymerization process that uses high heat, high pressure, and little to no oxygen to produce products such as syngas, marketable crude oils, solid carbon, non-condensable gases or char (used as a solid fuel, soil amendment, and for industrial processes), and other chemicals.

Most Pyrolysis facilities are demonstration or pilot plants under 20,000 tpy and process a homogeneous feedstock. The technology also requires pre-processing of incoming waste to support the Pyrolysis units. Therefore, Compatibility with the Current Collection System is considered low.

6.5.4 Logistics Criteria Summary

Table 6-4 provides a summary of results in evaluating the Logistics criteria for all Pyrolysis disposal option tonnage scenarios. The Logistics criterion includes an assessment of sub-criteria such as the Operating Life of Facilities (in years), Siting, Permitting, Design and Construction Considerations, and Compatibility with the Current Collection System for each Pyrolysis disposal option tonnage scenario.

Table 6-4: Summary of Logistics for Pyrolysis Disposal Options

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Operating Life of Facility (years)	No known commercial operations to compare to.		
Siting/Design/Permitting/Construction Considerations	7-10 years to site, Design and construct • 4-6 years to site • 1-2 years financing and Design • 2 years Construction		
Compatibility with Current Collection System	Low compatibility. Requires pre-processing of incoming waste to support Pyrolysis units.		

6.6 Social Criteria

A Pyrolysis facility would create Local Jobs, as a technical team would be required to build and operate the new facility. The facility should generate product(s) which would be used for local use, to run the facility or for sale to markets. The sale of energy and metals would boost the local economy and help offset facility capital and operation costs.

An environmental concern associated with the Pyrolysis process includes emissions that could impact local air quality and therefore cause public disapproval. Emission levels are usually well below acceptable levels for industrial zone facilities. Other Potential Neighborhood Impacts are related to traffic and noise.

6.6.1 Environmental and Social Justice/Equity (ESJ)

ESJ considerations will be an important part of future siting for a Pyrolysis facility. As part of the siting process, communities are to be identified around potential facility locations and transport corridors to evaluate per USEPA's Environmental Justice Screening and Mapping Tool and the Washington Environmental Health Disparities Map.

Environmental impacts will be greater on front-line communities and economic impacts will be greater for low-income households as cost increases represent a higher share of their income than for other household types.

6.6.2 Local Traffic Impacts

Traffic levels for the Pyrolysis facility are comparable to Mass Burn. Assuming the average trailer load is 28 tons, the average number of vehicles entering the facility would be on the order of 103 trailers per day for the low tonnage scenario, 186 trailers per day for the medium tonnage scenario and 281 trailers per day for the high tonnage scenario as shown on Table 6-5.

The number of truck trips per day includes travel to and from the Mixed Waste Processing Facility, travel to an IMF for disposal (24% of the total tonnage) and travel to a metal recycler (5% of total tonnage). It also assumes 362 workdays per annum. Traffic impacts will be shifted from the vicinity of CHRL to the vicinity of the Pyrolysis facility and are, therefore, expected to be similar to that at CHRL.

6.6.3 Local Job Creation

The number of jobs created for a Pyrolysis facility are assumed to be similar to a Mass Burn facility as both would have similar operations. This includes (1) front-end material handling, (2) some pre-processing, loading, and operating the combustion unit(s), (3) post processing of the materials and (4) residuals management. Depending on the combustion units needed, there may be higher FTEs required for Pyrolysis.

The following categories were developed for consideration in comparing the Study disposal options based on skill/training and compensation level. Potential skill categories include:

- **Minimal skill.** Requires no prior skill and minimal on-the-job training. Estimated to be between 4 and 6 jobs depending on tonnage requirements.
- **Technical skill.** Requires an associate's degree, technical certificate, or similar level of on-the-job technical training. Estimated to be between 24 and 28 jobs depending on tonnage requirements.
- **Advanced skill.** Requires Bachelor, Masters, or other advanced degree or equivalent level of on-the-job training and years of experience. Estimated to be between 15 and 20 jobs depending on tonnage requirements.

6.6.4 Other Potential Neighborhood Impacts

For Pyrolysis, the Other Potential Neighborhood Impacts based on a qualitative comparison between options will range from no impact to medium impact. An environmental concern associated with the Pyrolysis process is air emissions. Although substantially reduced through regulatory requirements, air emissions could impact local air quality which typically causes public concern. Emission levels are usually well below acceptable levels for industrial zone facilities. Additional context relating to each of the environmental concerns as they relate to Pyrolysis are provided below.

Air – Medium Impact.

Air emissions from Pyrolysis are primarily CO_2, CO, NOx, VOC's, SO_2 emissions which are substantially reduced through regulatory requirements. Dependent on how biogases are used, some air emissions may come after final scrubbing of biogas, dependent on what process is employed on the backend.

Odor – Low Impact.

The primary source of odors are the trucks that enter the facility, the tipping floor where raw garbage is stored, any ash/residue and potentially odor originating from the stacks (most are scrubbed, and odor should be at a minimum). In addition, highway use and road wear would increase within the neighboring areas. Facility is enclosed which significantly contains odor.

Noise – Medium Impact.

The primary source of noise is trucks along traffic routes and entering the facility. Some blower fans (pull emissions from the incinerator through the air pollution controls and up the stack) can also be loud. The facility is enclosed which minimizes exterior noise.

Groundwater – No Impact.

No impact to the neighborhood and surrounding community's groundwater is expected.

6.6.5 Social Criteria Summary

Table 6-5 provides a summary of the results in evaluating the Social criteria for each tonnage scenario. The sub-criteria considered in this evaluation includes ESJ/Equity considerations, Traffic Impacts (truck trips), number of Local Jobs Created and Other Potential Neighborhood Impacts.

Table 6-5: Summary of Social Sub-criteria for Pyrolysis Disposal Options

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
ESJ/Equity	• Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. • Environmental impacts will be greater for frontline communities. • Economic impacts greater for low-income households because cost increases represent a higher share of their income than for other households.		
Local Traffic Impacts (Number of Truck Trips/Day)[1]	281	186	103
Local Job Creation[2]	54 jobs created. Minimal Skill: 6 Jobs Technical Skill: 28 Jobs Advanced Skill: 20 Jobs	48 jobs created. Minimal Skill: 5 Jobs Technical Skill: 26 Jobs Advanced Skill: 17 Jobs	43 jobs created. Minimal Skill: 4 Jobs Technical Skill: 24 Jobs Advanced Skill: 15 Jobs
Other Potential Neighborhood Impacts (Air, Odor, Noise, Groundwater).	• Air: Medium Impact • Odor: Low Impact • Noise: Medium Impact • Groundwater: No Impact		

[1] Assumes 9% increase for peak tonnage days. To and from Mixed Waste Processing Facility. IMF for ash disposal (24% of total tonnage) and metals (5% of total tonnage) recycler.
[2] Description of minimal, technical and advanced skills included in Section 6.6.3 above.

6.7 Capacity Criteria

6.7.1 Capacity/Minimum Waste Requirements

Pyrolysis technology is still in development in North America. There are currently no facilities capable of processing the projected amount of waste in 2040 or that projected by 2060 for the three tonnage scenarios provided by King County: (1) 366,266 tpy for the high diversion/low tonnage scenario in 2060; (2) 811,014 tpy for the medium diversion/medium tonnage scenario in 2060; and (3) 1,366,618 tpy for the low diversion/high tonnage scenario in 2060.

6.7.2 Waste Type Composition and Acceptance

As previously noted, Pyrolysis facility technology is still in development and not commercially proven at the scale needed to manage King County's waste (low waste acceptance). Typically, for a Pyrolysis facility, preprocessing of the waste stream is needed to produce a uniform sized feedstock with little to no inert materials. Because there are no commercial operations of the type and processing capacity needed for King County, the flexibility in changing waste compositions and how these facilities would perform is unknown.

For a Pyrolysis facility, outputs include marketable crude oil, solid carbon residuals, non-condensable gases, and dissolved organics. The performance specifications for these outputs are based on Pyrolysis of clean (contaminant free) feedstock.

6.7.3 Tonnage Flexibility

A Pyrolysis facility would likely be built in a similar manner as Mass Burn. Mass Burn facilities are built with multiple processing lines which allows them to reduce waste flows when there is reduced demand for waste disposal or when annual maintenance is required.

Pyrolysis facilities are limited by the materials in the waste stream which would influence the production of the target commodity. This technology is not widely used for MSW, thereby posing challenges in finding an experienced operator. Therefore, the flexibility with fluctuating volumes is low because there are very few commercial operations of this type and processing capacity.

One-time emergencies or a catastrophic event should be addressed in the design of back-up systems such as redundant process lines, equipment and storage (on-site or alternative sites) and a back-up alternative facility should also be identified for emergencies or failures.

6.7.4 Residual Waste Management

Similar to Mass Burn, Pyrolysis technology results in the need to dispose of residual wastes, including ash which must be disposed of in an ash monofill as the ash residuals may contain hazardous compounds. Rejected waste such as oversized or non-combustible items will also require transport to a landfill for final disposal. Recyclables such as recovered metals will need to be hauled away for off-site recycling.

6.7.5 Capacity Criteria Summary

Table 6-6 provides a summary of the results in evaluating the Capacity criterion for each Pyrolysis disposal option tonnage scenario. This criterion considers sub-criteria evaluated for each tonnage scenario including Capacity/Minimum Waste Requirements, Waste Type Composition and Acceptance, Tonnage Flexibility, and Residual Waste Management.

Table 6-6: Summary of Capacity for Pyrolysis Disposal Options

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capacity/Minimum Waste Requirements	Technology is still in development. Not capable of processing amount of waste from these tonnage scenarios including projected ranges between 366,266 and 1,366,618 tpy by 2060.		
Waste Type Composition & Acceptance	• Low waste acceptance. • A Pyrolysis facility that processes MSW is uncommon, considered developing and not commercially proven. • Preprocessing of waste stream needed to produce a uniform sized feedstock with little to no inert materials.		
Tonnage Flexibility/Scalability	• Low Flexibility. • Most Pyrolysis facilities are demonstration or pilot plants that process under 20,000 tpy, none operating that process MSW at the tonnage required so flexibility with higher tonnages is low. Best suited for a homogeneous feedstock such as plastic materials or wood waste. • One-time emergencies or catastrophic event addressed in design of back-up systems. • Back-up alternative facility should also be identified.		
Residual Waste Management	• Residual ash disposal required in an ash monofill. • Rejected waste such as oversized or non-combustible items will also require transport to a landfill although amounts insignificant due to incoming feedstock having been through a Mixed Waste Processing Facility. • Recyclables such as recovered metals will need to be hauled away for off-site recycling.		

6.8 Pyrolysis Evaluation Summary

Compared to the Mass Burn option, Pyrolysis systems are more complex, more expensive, have more moving parts, and have more operational risk as there are no operating facilities at the scale required for King County. These risks can be offset by the increased value of the commodity generated and lesser air pollution impacts. Advantages are increased value of the commodity generated and lesser air emissions. A summary of the advantages and disadvantages of Pyrolysis is provided below.

Summary of Advantages

- Depending on state and/or local regulations and end-market requirements, Pyrolysis can generate revenue from either the gas stream (syngas) or from bio-char. Energy generation from syngas is more predictable, which is what was assumed for potential revenue for the Study.
- Reduction of incoming waste tonnage by up to 70%.
- Potential revenue from sale of heat and electricity and recovered metals.

Summary of Disadvantages

- Not a proven technology for MSW at the commercial scale needed.
- Process produces emissions that require proper treatment and management although air emissions are less than Mass Burn.
- Syngas generation will require clean up, and cost for the products are more expensive than virgin materials.
- Quality of char is currently unpredictable and may require direct disposal at a landfill.
- Capital Costs are high ($380.33/ton in 2040$ for medium tonnage scenario), requiring energy markets and significant economies of scale to ensure financial feasibility.
- High level of public opposition due to air pollution concerns.

7.0 REFUSE DERIVED FUEL

7.1 Introduction

Refuse Derived Fuel (RDF) is a technology where a product is manufactured from heterogeneous MSW with the goal of producing a more homogeneous fuel with an increased heating value per pound and fewer contaminants that produce air emissions.

Raw (as-received) MSW is shredded and screened to produce a more uniform-sized product, with the intent of retaining higher BTU materials such as paper, cardboard, and plastic. Sometimes focused air jets are used to separate lightweight materials such as paper and plastic. Ferrous metals can be removed with a magnet while aluminum can be removed with an eddy current separator. Removal of metals, which are non-combustible, increases the heating value of the RDF. Heating value can also be increased by removing other non-combustible inert materials such as broken glass, dirt, rocks, and concrete. This can be accomplished through size separation via trommels and disk screens that allow smaller particles to drop out of the mix. Food waste can also be removed by the waste generator and processed separately with other organics such as wood and yard waste, which are typically composted. The remaining material is shredded again into the final product dimensions, before going through a hydrolyzation or drying process to dehydrate and stabilize any organic material. After drying or hydrolyzation, RDF material is screened again, before being further processed into fuel pellets if so desired. RDF can also be used as a loose material called “fluff”. Pellets reduce transportation costs, but this adds additional steps and cost to the manufacturing process. Figure 7-1 presents a typical RDF process.

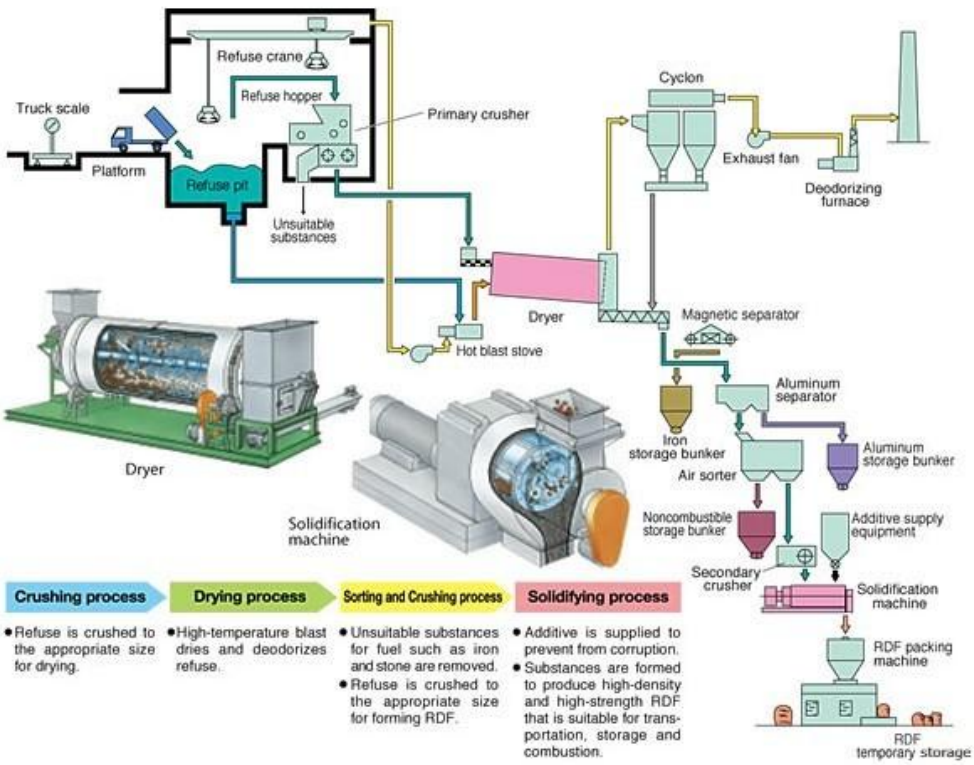

Figure 7-1: Typical RDF Process

For the Study, it is anticipated that some pre-processing will be undertaken at the SWD Mixed Waste Processing Facility whereby recyclables (packaging, metals, paper etc.) are removed from the waste stream, most organics are screened out and composted, and most inert materials are removed and disposed in a landfill. The remaining portion of the waste stream is then further processed to produce the RDF.

RDF has been successfully used as a fuel in industrial operations such as electricity-generating plants (including Mass Burn plants, 13 known in the US[64]) and cement kilns. The use of RDF displaces fossil fuels such as coal and natural gas, can reduce certain air emissions, and diverts waste from landfills. In Europe, where there are severe restrictions on the use of landfills, RDF is often used to supplement fossil-based fuels. A large bulk of the waste stream can be used as feedstock for RDF as the end-product includes all combustible material. Feedstock may also include material such as asphalt roofing, carpet, tire waste and wood waste from C&D sectors.

The quality of the end product depends on the incoming feedstock and desired fuel characteristics required by the user. For example, chlorine is a deleterious material in Portland cement. Research suggests that food waste could be a significant source of chlorides in MSW. There will likely be significant technical and economic challenges to process raw garbage to remove chlorine from RDF intended as cement kiln fuel which is a primary market for RDF.

Ash Grove Cement operated a cement kiln in south Seattle that was reported to burn tire derived RDF or tire derived fuel (TDF). No corroborating information was made available by Ash Grove, Ecology, or the PSCAA regarding the type of TDF; the relative proportions of TDF and fossil fuels burned; or whether Ash Grove considered burning other types of RDF manufactured from MSW. Another company, Lehigh Cement, reportedly burned TDF at one time in its now (2023) mothballed cement kiln in Seattle.

A large amount of maintenance is required to ensure optimal operation. In particular, the initial shredding process can be harsh on machinery, as a wide variety of materials need to be broken down. As such, the knives of the shredder tend to wear out every 1 to 2 months requiring frequent and diligent maintenance to maintain processing rates.

Impediments to the development of RDF facilities processing MSW at scale include technical (chloride removal requirements for cement kilns, a target market), permitting (users needing to obtain solid waste facility permits) and competition (common feedstock such as C&D debris diverted from solid waste stream to comply with C&D ordinances and/or enhance financials) which create limited markets for RDF.

Currently, there is no known facility in King County, or even the entire state of Washington, that uses MSW RDF in a quantity that would even remotely approach the amount projected to be generated under the Study tonnage scenarios (300,000 to 800,000 tpy). Thus, there is currently no significant market for RDF in the State.

As previously noted, a detailed comparison analysis for RDF was performed and the results provided in this Study. After reviewing the results for the RDF option presented in the following sections, SWD and representatives of MSWAC and SWAC **recommended that this long-term disposal option not be further considered** due to the technologies inability to manage the estimated King County 2040 tonnages and/or waste material types.

[64] ASSESSMENT OF MUNICIPAL SOLID WASTE ENERGY RECOVERY TECHNOLOGIES-FINAL REPORT-3-8-2021 (002).pdf

7.2 Environmental Criteria

Environmental issues at an RDF-manufacturing plant will be similar to those for a transfer station/Material Recovery Facility (MRF). These include dust and odor; water pollution from contaminated washdown water or rainfall that has been in contact with garbage; noise; traffic; and zoning issues such as those that prohibit locating such facilities in the vicinity of schools and hospitals.

Environmental issues for an RDF-fired plant will be similar to those for a Mass Burn plant, with air emissions being the primary concern. Air emissions from a plant burning just RDF will be different than those from a cement kiln that uses RDF to supplement its primary fossil fuel. Because metal items of any significant size will be removed and recycled during the RDF-manufacturing process, there should be little metal in the final cement product (if so used) or in the ash in coal fired electrical generation facilities. Because many non-combustible and inert materials are removed during the RDF process, there should be less residuals requiring disposal than from a Mass Burn plant. In the case of a cement kiln, the bulk of the ash and any remaining metal would likely be incorporated into the cement product.

A human health risk assessment would likely be required as part of the environmental impact assessment for any proposed RDF-burning plant.

Most RDFs are engineered to be co-fired with fossil fuels (such as coal or natural gas) as a solid fuel. While the energy content of RDF is about 20% to 25% lower than coal on a per ton basis, it represents 70% fewer GHG emissions resulting from manufacturing and combustion. Because coal must be shipped by rail from states from the east such as Wyoming and Montana, transportation costs become significant compared to other fossil fuels. This fact, in combination with strict air pollution laws, makes coal a relatively uncommon fuel in Washington State. Therefore, the market demand for RDF to supplement coal appears at this time to be rather low.

There will be other environmental impacts such as air emissions from transporting MSW and RDF to/from the Mixed Waste Processing Facility and RDF facility. Any residuals, non-combustibles, or rejected oversized material will need to be hauled out of County to a regional landfill. Recyclables such as recovered metals will need to be hauled away for off-site recycling.

7.2.1 Environmental Criteria Analysis Results

Table 7-1 summarizes the net results by Environmental factor for RDF while Table 7-2, Table 7-3 and Table 7-4 break down the results by Process, Transport and Offsets for the high, medium and low tonnage scenarios. Positive figures represent a harm or impact, while negative figures represent a benefit or offset by avoiding an environmental harm. The summary includes impacts from facility operations, avoided impacts from replacing bituminous coal with refuse-derived fuel, impacts of exporting residuals by rail to landfill, and impacts of transporting metals to recycling by electric truck. RDF environmental impact results presented in Table 7-1, Table 7-2, Table 7-3, and Table 7-4 are influenced by Process impacts from facility operations that produce fuel from processing putrescible solid waste as well as plastics, exportation of inerts by rail to landfill (partly by diesel) and impacts of transporting metals to recycling by electric truck that all contribute to Non-Renewable Energy Demand, Water Consumption, Acidification Potential, Global Warming Potential and to a lesser degree to Smog Formation Potential impacts.

Taking into account offsets for RDF, it provides a net environmental benefit for all environmental parameters due to avoided impacts for replacing bituminous coal except for Water Consumption. Environmental benefits or offsets for Water Consumption were not considered in the Study findings because the majority of credit for grid electricity replacement would be due to avoiding upstream and process impacts of hydroelectric power, reducing evaporation in reservoirs (considered water consumption), which is considered a baseload power source in Washington so would not be replaced. It should be noted that the Study did not include a feasibility study to determine the electricity sales end user so if the end user is outside the EIA region modeled for the Study, the results will be different.

Human Health Toxicity - Cancer Potential is high for RDF as cancer potential measured in the LCA as a hazard present (type and quantity of chemicals emitted, not exposed) is derived primarily from combustion of plastics and to a much smaller extent metals. Combusting plastics releases toxins such as furans, dioxins and other substances which are known to cause cancer. The Cancer toxicity measurement units used are a way to standardize the potential cancer-related impacts of many different toxic chemicals based on their characteristics into a single measure per mass of the chemical. The Cancer Potential parameter multiplies the unit impacts by the total mass of chemicals released into the environment to estimate the potential increase in cancer-related morbidity in the total human population, assuming equivalent exposure. However, a LCA study can only measure hazard presence (type and quantity of chemicals emitted) and not exposure, so results should be interpreted as comparing the production of chemicals associated with cancer, not morbidity. The Cancer Potential results are not about causation or actual cases of cancer. The LCA model cannot assess human exposure to the chemicals released, only the amount of chemicals released and their toxicity.

Table 7-1: Summary of Environmental Criteria for RDF Disposal Option

Environmental Factor	Units	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Non-renewable energy demand (Energy Production)	MJ	(2,300,138,385)	(1,614,430,251)	(764,564,011)
Water consumption (Water Quantity)	L H_2O	54,108,002	32,848,079	16,180,730
Acidification potential (Air Quality)	kg SO_2 eq	(2,099,758)	(1,444,091)	(690,950)
Global warming potential (Climate Change)	MT CO_2 eq	(215,377)	(151,058)	(71,632)
Smog formation potential (Air Quality)	kg O_3 eq	(15,602,688)	(10,664,550)	(5,109,028)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	13,103,354	10,487,991	3,796,968

Table 7-2: Summary of RDF Environmental Sub-criteria for High Tonnage/Low Diversion Scenario by Process, Transport and Offsets/Avoided Impacts

Environmental Factor	Units	Process (RDF)	Transport	Offsets	Net Total
Non-renewable energy demand (Energy Production)	MJ	552,019,351	8,713,632	(2,860,871,368)	(2,300,138,385)
Water consumption (Water Quantity)	L H_2O	51,994,580	2,113,421	N/A[1]	54,108,002
Acidification potential (Air Quality)	kg SO_2 eq	84,475	51	(2,184,284)	(2,099,758)
Global warming potential (Climate Change)	MT CO_2 eq	79,432	672	(295,481)	(215,377)
Smog formation potential (Air Quality)	kg O_3 eq	10,068	732,167	(16,344,922)	(15,602,688)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	13,103,354	0	(1)	13,103,354

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Table 7-3: Summary of RDF Environmental Criteria for Medium Tonnage/Medium Diversion Scenario by Process, Transport and Offsets/Avoided Impacts

Environmental Factor	Units	Process (RDF)	Transport	Offsets	Net Total
Non-renewable energy demand (Energy Production)	MJ	338,940,156	6,342,963	(1,959,713,371)	(1,614,430,251)
Water consumption (Water Quantity)	L H_2O	31,458,069	1,390,009	N/A[1]	32,848,079
Acidification potential (Air Quality)	kg SO_2 eq	52,120	36	(1,496,247)	(1,444,091)
Global warming potential (Climate Change)	MT CO_2 eq	50,859	489	(202,406)	(151,058)
Smog formation potential (Air Quality)	kg O_3 eq	6,077	525,739	(11,196,366)	(10,664,550)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	10,487,992	0	(0)	10,487,991

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Table 7-4: Summary of RDF Environmental Sub-criteria for Low Tonnage/High Diversion Scenario by Process, Transport and Offsets/Avoided Impacts

Environmental Factor	Units	Process (RDF)	Transport	Offsets	Net Total
Non-renewable energy demand (Energy Production)	MJ	171,768,982	3,023,652	(939,356,644)	(764,564,011)
Water consumption (Water Quantity)	L H_2O	15,429,207	751,524	N/A[1]	16,180,730
Acidification potential (Air Quality)	kg SO_2 eq	26,234	18	(717,202)	(690,950)
Global warming potential (Climate Change)	MT CO_2 eq	25,155	233	(97,020)	(71,632)
Smog formation potential (Air Quality)	kg O_3 eq	2,819	254,949	(5,366,795)	(5,109,028)
Human Health Toxicity - Cancer Potential (Human Health)	CTUh	3,796,968	0	(0)	3,796,968

[1] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets.

Other sub-criteria considered for Environmental includes Resource Conservation and Compatibility with Waste Prevention and Recycling.

7.2.2 Resource Conservation

The RDF process creates a fuel with increased heating value that is used in industrial operations such as electricity-generating plants (including Mass Burn plants) and cement kilns.

7.2.3 Compatibility with Waste Prevention & Recycling

During the RDF process, before any feedstock is processed, metals are removed for recycling. Knowing this may impact recycling behaviors from the general public if they are aware that recyclables would be converted to usable products which may lower consumer recycling rates. However, if recycling and other waste prevention measures are a lower cost than Mass Burn, that should incentivize increased recycling and waste prevention.

Table 7-5: Summary of Metal Recycled from RDF Disposal Options

Environmental Factor	Units	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Metal recycled	Tons	50,918	33,348	18,360

7.3 Economic Criteria

7.3.1 Capital Costs

Capital costs for an RDF facility were based on a feasibility study for a 100 tpd plant in the Metro Vancouver, Canada area. The costs were then adjusted for each of the three specific tonnage scenario throughputs. The estimated total Capital Costs, including equipment, buildings, infrastructure, and estimated land acquisition costs ($1,742,400/acre) were then calculated to 2040 dollars using an annual inflation rate of 3.5 percent for the three tonnage scenarios. Adjusted for tonnage, the Capital Costs per ton ranged from $250 per ton (high tonnage scenario) to $350 per ton (low tonnage scenario) in 2023 dollars.

Although a specific location for a facility has not been identified and land costs are highly dependent on location, estimates were developed for potential land acquisition costs based on $40/square foot or $1,742,400/acre (provided by SWD from the County's real estate group). The acreage requirements for the facilities vary depending on access, infrastructure and buffer requirements with assumptions made for the high tonnage scenario of 15 acres, the medium tonnage scenario of 10 acres and the low tonnage scenario of 5 acres.

7.3.2 Operating Costs

Operating Costs for an RDF facility include labor, maintenance, materials, and facility and equipment upgrades. An annual inflation rate of 3.5 percent for the three tonnage scenarios was used. Adjusted for tonnage, the Operating Costs ranged from $40 per ton (high tonnage scenario) to $60 per ton (low tonnage scenario) in 2023 dollars.

In order to calculate the annual disposal costs for non-marketable inert materials, it was assumed that 15 percent of the feedstock would be considered residuals for the low tonnage scenario and that 20 percent of the feedstock would be considered residuals for the high and medium tonnage scenarios. The T&D cost for WEBR was assumed at $60 per ton (in 2023$) for the high and medium tonnage scenario and $65 per ton for the low tonnage scenario.

7.3.3 Revenue

Revenue from RDF facilities is typically generated through the sale of the homogeneous fuel source (RDF itself) and from metals pulled from the incoming waste stream. RDF sales are estimated at a price point of $20/ton (in 2023$) as a fuel replacement for coal in the cement industry. Similar to Gasification and Pyrolysis, metal sales are assumed to be $70 per ton (higher than Mass Burn due to better quality metals being pulled off during pre-processing), including transport, and represent about 5% of the incoming feedstock. Note that the Revenue created via sales of RDF is dependent on end-market demands and can vary depending on the price point of comparable feedstocks and relevant legislation (e.g., carbon levies, low carbon fuel policy). Therefore, significant consultation is required prior to the implementation of an RDF manufacturing system to ensure viable, long-term end-markets for the RDF.

7.3.4 Financial Risk

There are a number of Financial Risks that King County could face should they choose RDF as a disposal option. The market potential to sell the RDF in Washington State would be limited due to permitting impediments (end users needing solid waste facility permits) and technical issues with chlorides (from salt content in MSW) requiring limited use for cement kilns which would be the targeted end users. Additionally, RDF requires preprocessing and removal of low energy value waste components (i.e., inerts such as glass and rocks) which would need to be landfilled. The limitations of the sale of the RDF to end markets would require on-site storage or landfilling of whatever fuels are not sold.

If the RDF cannot be sold to a willing end market, then this technology type would not be a viable disposal option. As noted, the alternative for lack of markets would be disposal in a landfill or via the WEBR option for $60-$65/ton. The County should continue to monitor future regulatory drivers legislated by the state to reduce fossil fuel use which could provide incentives for RDF use in the future.

7.3.5 Cost per Ton

The unit processing cost was calculated by adding the annualized Capital Costs (at 4% interest over 30 years assuming municipal funding at 2.5% bond purchase cost) to the Operating Cost and subtracting the Revenue from both the RDF and ferrous metal sales. The net annual cost is then divided by the annual tonnages to obtain 2023, 2040, 2050 and 2060 costs per ton.

7.3.6 Economic Criteria Summary

Table 7-5 provides a summary of results in evaluating the Economic considerations for the RDF disposal option and all tonnage scenarios. To assess the economics of the RDF option and determine a comparative Cost per Ton impact, the Economic sub-criterion evaluates the Capital Cost, Operating Cost (including residuals disposal), commodity sale Revenue of RDF and metal, and unit processing Cost per Ton (2023-2060).

The unit processing cost ($2040) was calculated by adding the annualized Capital Costs (at 4% interest over 30 years assuming municipal funding at 2.5% bond purchase cost) to the Operating Cost and subtracting the Revenue from both the RDF and ferrous metal sales. The net annual cost is then divided by the annual tonnages to obtain 2023, 2040, 2050 and 2060 costs per ton. Results of the calculations are shown in Table 7-5 below. Cost assumptions and results are also included in the Appendix B - Comparative Evaluation Summary Matrices for each of the disposal options.

Table 7-5: Summary of Economic Criteria for RDF Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capital Costs (2040$)[1]	$515M	$400M	$252M
Capital Costs (annualized)[2]	$38M	$29M	$18M
Annual Operating Cost (2040$)[3]	$73M	$60M	$40M
MSW Residuals Disposal Cost (annual)	$21.9M	$14.4M	$6.4M
Annual Revenue (2040$) – RDF	$15.3M	$10M	$5.9M
Annual Revenue (2040$) – Metals	$6.4M	$4.2M	$2.3M
Total Annual Cost (2040$)[4]	$111,149,074	$89,302,465	$56,268,008
Annual Cost/Ton (2023$)[5]	$60.82/ton	$74.61/ton	$85.38/ton
Annual Cost/Ton (2040$)[5]	$109.14/ton	$133.90/ton	$153.23/ton
Annual Cost/Ton (2050$)[5]	$115.55/ton	$154.93/ton	$195.73/ton
Annual Cost/Ton (2060$)[5]	$128.28/ton	$183.36/ton	$255.73/ton

[1]Includes equipment, building, infrastructure, and estimated land acquisition costs. Inflation assumed at 3.5% annual.
[2]Annual cost based on debt service assumed at 4% for 30-year term per municipal funding.
[3]Includes labor, maintenance, materials, facility, and equipment upgrades.
[4]Equals Annualized Capital + Operating Costs + Disposal Costs – Revenue.
[5]Total Annual Cost/Total Tonnage

7.4 Operating History Criteria

RDF plants have been operational in the US and Canada for many years. Typically, the RDF technology has been used where waste is treated onsite or in most cases combusted offsite in cement plants. RDF is typically used in cement plants as an alternative to coal and coke. In the US, the production of RDF is typically undertaken to utilize the energy content of waste that cannot be recycled or is required to be landfilled. Most sources of RDF in the US are from the industrial sector where there is a relatively consistent mix of combustible materials that can be sorted and shredded. In Europe, with the closure of most landfills, RDF has been undertaken as a more preferred option to both MSW and industrial waste sources as they have limited access (or total ban) for disposal at landfills or where fossil fuels are either expensive or unavailable.

7.4.1 Proven Performance

As it relates to this Study, the only proven performance metrics in North America for RDF have occurred on a small scale. There are no facilities currently operating in the similar tonnage ranges necessary to meet King County's disposal needs for the three tonnage scenarios.

7.4.2 Safety, Environmental and Regulatory Compliance

There are currently no known RDF facilities currently in operation at the tonnage levels required for comparison purposes.

7.4.3 Operating History Criteria Summary

Table 7-6 provides a summary of results in evaluating the Operating History for each Study tonnage scenario. The sub-criteria considered for Operating History includes an assessment of Proven Performance, Safety Record, Environmental Compliance and Regulatory Compliance for each Study tonnage scenario.

Table 7-6: Summary of Operating History Criteria for RDF Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Proven Performance	Proven performance at small scale. No plants currently operating in similar tonnage ranges. There are RDF-based incinerators operating at scale that were not considered under Mass Burn due to the additional processing needs and higher costs.		
Safety Record	No plants currently operating in similar tonnage ranges.		
Environmental and Regulatory Compliance	No plants currently operating in similar tonnage ranges.		

7.5 Logistics Criteria

7.5.1 Operating Life of Facilities

The Operating Life of an RDF facility is expected to be similar to Mass Burn between 20 and 40 years. This is based on the smaller 100 tpd facility located in Metro Vancouver, Canada.

7.5.2 Siting/Design/Permitting/Construction Considerations

Siting and permitting of a potential RDF facility in Washington State is considered medium difficulty, especially if co-located at an existing transfer station or Mixed Waste Processing Facility. The RDF facility should take less time to permit than the other new facility Study options as it does not require the air permits that the other options require and would be similar to a transfer station/MRF, estimated to take five to seven years to site, design and construct. This includes three to five years for siting, one year to design and one year for facility construction. Factors would depend on the ability to site a facility (co-location with an existing transfer station or other solid waste facility making it less difficult), the size of facility, local permits and community involvement.

Industrial zoning, distance to sensitive receptor locations, ESJ and environmental impacts would also need to be considered in the siting process. It should be noted that RDF facilities in Washington may be considered waste processors (based on the feedstock content – if it includes MSW components such as plastic vs. just wood waste) and, thereby, need to obtain solid waste facility permits which is an impediment. Historically, the financial benefit of using RDF was not enough to justify the solid waste facility permitting costs for cement plants.

7.5.3 Compatibility with Current Collection System

RDF is a type of fuel produced from MSW. The MSW, which is typically taken from industrial or commercial sites, is first shredded, then dried and baled before being burned to produce electricity. As previously noted, there are challenges to marketing RDF due to variations in the waste stream composition by location (hot and dry vs. wet and humid clients, etc.).

There are less stringent feedstock requirements compared to Gasification and Pyrolysis technologies. Therefore, compatibility with the County's existing waste management system is considered to be medium.

7.5.4 Logistics Criteria Summary

Table 7-7 provides a summary of results in evaluating the Logistics criteria for all RDF disposal option tonnage scenarios. The Logistics criterion includes an assessment of sub-criteria including Operating Life of facilities (in years), Siting, Permitting, Design, and Construction requirements for each RDF disposal option tonnage scenario.

Table 7-7: Summary of Logistics for RDF Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Operating Life of Facility (years)	20 to 40 years based on smaller operating facilities.		
Siting/Design/Permitting/ Construction Considerations	5-7 years to site, design, and construct • 3 to 5 years for siting • 1 year financing and design • 1 year construction		
Compatibility with Current Collection System	Medium Compatibility. Less stringent feedstock requirements compared to Gasification and Pyrolysis.		

7.6 Social Criteria

As with Mass Burn, Gasification and Pyrolysis, an RDF facility would create local jobs, as a technical team would be required to build and operate the new facility. The facility would generate product which could be used for local and out-of-state use, to run the facility or for sale. As with Mass Burn, Gasification and Pyrolysis, a RDF facility has recycling capability such as metal recovery.

7.6.1 Environmental and Social Justice/Equity (ESJ)

ESJ considerations will be an important part of future siting for a Pyrolysis facility. As part of the siting process, communities are to be identified around potential facility locations and transport corridors to evaluate per USEPA's Environmental Justice Screening and Mapping Tool and the Washington Environmental Health Disparities Map.

Any construction and operation of an RDF facility would have a greater ESJ impact on front-line communities and economic impacts are also anticipated to be higher for low-income households as cost increases represent a higher share of their income than for other household types.

7.6.2 Local Traffic Impacts

Traffic levels for the RDF facility are expected to be almost twice the level of Mass Burn due to 75 to 80 percent of the material received is processed into the end-product and the remainder sent to disposal or a metals recycler. Assuming the average trailer load is 28 tons, the average number of vehicles entering the facility would be on the order of 160 trailers per day for the low tonnage scenario, 288 trailers per day for the medium tonnage scenario and 436 trailers per day for the high tonnage scenario as shown on Table 7-8.

The number of truck trips per day includes travel to and from the Mixed Waste Processing Facility, travel to an IMF for residuals disposal (15-20% of the total tonnage, dependent on disposal scenario), travel to a metal recycler (5% of total tonnage) and travel to RDF markets (between 75 and 80% of the total tonnage). It also assumes 362 workdays per annum and all material received leaves the facility for disposal, recycling or end- product markets. Traffic impacts will be shifted from the vicinity of CHRL to the vicinity of the RDF facility and are, therefore, expected to be similar to that at CHRL.

7.6.3 Local Job Creation

The number of jobs created for an RDF facility are assumed to be approximately 13 percent less than either a Mass Burn, Gasification or Pyrolysis facility. This includes (1) front-end material handling, (2) some pre-processing, loading, and operating the combustion unit(s), (3) post processing of the materials and (4) residuals management.

The following categories were developed for consideration in comparing the Study disposal options based on skill/training and compensation level. Potential skill categories include:

- **Minimal skill.** Requires no prior skill and minimal on-the-job training. Estimated to be between 4 and 6 jobs depending on tonnage requirements.
- **Technical skill.** Requires an associate's degree, technical certificate, or similar level of on-the-job technical training. Estimated to be between 18 and 22 jobs depending on tonnage requirements.
- **Advanced skill.** Requires Bachelor, Masters, or other advanced degree or equivalent level of on-the-job training and years of experience. Estimated to be between 15 and 19 jobs depending on tonnage requirements.

7.6.4 Other Potential Neighborhood Impacts

For RDF, the other potential neighborhood impacts based on a qualitative comparison between options will range from no impact to low impact. An environmental concern associated with the Pyrolysis process is air emissions, primarily equipment emissions. Although substantially reduced through regulatory requirements, air emissions could impact local air quality which typically causes public concern. Emission levels are usually well below acceptable levels for industrial zone facilities. Additional context relating to each of the environmental concerns as they relate to Pyrolysis are provided below.

Air – Low Impact

Local air impacts are primarily equipment air emissions.

Odor – Low Impact

The primary source of odors are the trucks that enter the facility and the tipping floor. The facility is enclosed which significantly contains odor.

Noise – Medium Impact

The primary source of noise are trucks along traffic routes and entering the facility. In addition, highway use and road wear would increase within the neighboring areas. The facility is enclosed which minimizes exterior noise.

Groundwater – No Impact

No impact to the neighborhood and surrounding community's groundwater is expected.

7.6.5 Social Criteria Summary

Table 7-8 provides a summary of the results in evaluating the Social criteria for each tonnage scenario. The sub-criteria considered in this evaluation includes ESJ/Equity Considerations, Traffic Impacts (truck trips), Local Job Creation and Other Potential Neighborhood Impacts.

Table 7-8: Summary of Social Criteria for RDF Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
ESJ/Equity	• Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. • Environmental impacts will be greater for frontline communities. • Economic impacts greater for low-income households because cost increases represent a higher share of their income than for other households.		
Local Traffic Impacts (Number of Truck Trips/Day)[1]	436	288	160
Local Job Creation[2]	47 jobs created. Minimal Skill: 6 Jobs Technical Skill: 22 Jobs Advanced Skill: 19 Jobs	42 jobs created. Minimal Skill: 5 Jobs Technical Skill: 20 Jobs Advanced Skill: 17 Jobs	37 jobs created. Minimal Skill: 4 Jobs Technical Skill: 18 Jobs. Advanced Skill: 15 Jobs
Other Potential Neighborhood Impacts (Air, Odor, Noise and Groundwater).	• Air – Low Impact. • Odor – Low Impact. • Noise – Medium Impact. • Groundwater – No Impact.		

[1] Assumes 9% increase for peak tonnage days to and from Mixed Waste Processing Facility; to IMF for WEBR residuals disposal (15 to 20% of total tonnage), to metals (5% of total tonnage) recycler and RDF markets (75 to 80% of total tonnage).
[2] Description of minimal, technical and advanced skills included in Section 7.6.3 above.

7.7 Capacity Criteria

There are two aspects of determining the capacity and processing flexibility of utilizing RDF as a disposal option. The first is the production of the RDF materials and the second is the utilization of the RDF materials in an industrial application.

The production of the RDF materials is dependent on its source material, in this case MSW. MSW will be delivered to the processing facility, which is then stored in a bunker or pit, and then moved to the processing line to be shredded, screened and sorted to the specifications required by the end user. It should be noted that the specifications may be different depending on the needs of the end user. To attain the desired specifications, supplemental material may be needed from non-MSW sources.

The extraction and handling of residuals from the RDF production is dependent on the overall purpose of the facility. As noted, organics may be extracted at the front end of the process (i.e., to potentially be used to produce biogas and compost), and inerts may be pulled out to increase the energy value of the RDF product. It will be important to ensure that none of these facility components have an impact on the run time of the processing line.

The utilization of RDF may also have an impact on the capacity of the production facility. If the end user (i.e., a cement plant), is down for maintenance or product formula, the transportation and storage of the RDF will need to be designed to allow for these types of fluctuations.

7.7.1 Capacity/ Minimum Waste Requirements

As previously noted, RDF has been successfully used as a fuel in industrial operations such as electricity-generating plants (including Mass Burn plants) and cement kilns. The biggest impact on capacity for RDF is the lack of markets to take the projected materials under the Study's three tonnage scenarios. Most RDF feedstock in North America is from industrial, commercial and institutional (ICI) or C&D sources. The primary reason is that only high energy materials can consistently be converted to RDF and are, thereby, attractive to the end users. These sources of RDF feedstock material are always looking for non-landfill destinations for their sorted materials to enhance their financials and to comply with C&D waste diversion requirements and will continue to be competitive with any RDF facility constructed by King County. The market for RDF is currently assumed to be limited in Washington State. Impediments to its development include competition for feedstock.

With this noted, RDF technology is capable of processing the amount of waste from the three tonnage scenarios.

7.7.2 Waste Type Composition and Acceptance

An RDF plant is technically a Mixed Waste Processing Facility with an end product; therefore, feedstock selection will vary based on material extraction protocols to meet end user requirements. Raw (as-received) MSW is pre-processed (shredders, screens, air jets) to produce a more uniform-sized product, with the intent of retaining higher-BTU materials such as paper, cardboard, and plastic. Ferrous metals can be removed with a magnet while aluminum can be removed with an eddy current separator. Removal of metals, which are non-combustible, increases the heating value of the RDF. Heating value can also be increased by removing other non-combustible inert materials such as broken glass, dirt, rocks, and concrete. There may be significant technical and economic challenges in processing raw garbage to remove chlorine (in food waste) from RDF intended as cement kiln fuel (targeted market).

7.7.3 Tonnage Flexibility

The biggest impact on tonnage flexibility for RDF is the lack of markets (due to technical and permitting challenges) to take the projected materials under the Study's three tonnage scenarios. Competition is another factor. As previously noted, most RDF feedstock in North America comes from ICI or C&D sources due to their high energy materials that can consistently be converted to RDF and are attractive to the end users. Recipients for the RDF feedstock materials may seek out non-landfill destinations for their sorted materials to enhance their financials and/or to comply with C&D diversion requirements. These entities may compete with each other for any MSW-based RDF produced by King County.

The critical requirements for the production of RDF products are the storage space (feed and product), the capacity of the production line, and ability to transport the material to the end user. With proper design, an RDF processing facility should allow for fluctuations in production and storage. Dual (or more) processing lines would offer more flexibility and extensions of shifts (assuming the facility would be designed to operate 12 to 16 hours per day) would allow the facility to meet any fluctuations in demand. An RDF facility may need to blend or treat the feedstock with another waste stream (i.e. tire fluff) in order to produce a more consistent BTU/energy level to satisfy end consumers increasing volume to be sold.

One-time emergencies or catastrophic event should be addressed in the design of back-up systems such as redundant process lines, equipment and storage (on-site or alternative sites) and a back-up alternative facility should also be identified for emergencies or failures.

7.7.4 Residual Waste Management

Unlike Mass Burn, Gasification and Pyrolysis, RDF does not result in the need to dispose of ash waste in an ash monofill. Instead, many non-combustible and inert materials that are removed during the RDF process can be sent to recycling markets or landfilled. It is assumed for the Study that 15% of residual waste will be sent to a WEBR landfill for the low tonnage scenario and 20% for the medium and high tonnage scenarios.

7.7.5 Capacity Criteria Summary

Table 7-9 provides a summary of the results in evaluating the Capacity criterion for each RDF disposal option tonnage scenario. This criterion considers sub-criteria including Capacity/Minimum Waste Requirements, Waste Type Composition and Acceptance, Tonnage Flexibility and Residual Waste Management.

Table 7-9: Summary of Capacity Criteria for RDF Disposal Option

	High Tonnage/ Low Diversion	Medium Tonnage/ Medium Diversion	Low Tonnage/ High Diversion
Capacity/Minimum Waste Requirements	Technology is capable of processing amount of waste from tonnage scenario including projected ranges between 366,266 and 1,366,618 tpy by 2060.		
Waste Type Composition & Acceptance	• Medium waste acceptance. • An RDF plant is technically a Mixed Waste Processing Facility with an end product; therefore, feedstock selection will vary based on material extraction protocols to meet end-user requirements.		
Tonnage Flexibility/Scalability	• Low Flexibility. • Biggest impact on tonnage capacity for RDF is the lack of markets (due to technical and permitting challenges) to take the projected materials under the Study's three tonnage scenarios (75 to 80 percent of total tonnage). Competition is another factor. • RDF facility may need to blend or treat the feedstock with another waste stream (i.e. tire fluff) in order to produce a more consistent BTU/energy level to satisfy end consumers increasing volume to be sold.		
Residuals Management (Disposal or Further Processing)	• Many non-combustible and inert materials that are removed during the RDF process can be sent to recycling markets or landfilled. • There will be no ash generated from an RDF facility requiring disposal.		

7.8 RDF Evaluation Summary

In conclusion, because of the lack of existing RDF manufacturing facilities and proven, viable end markets for RDF, the choice of RDF as the primary option for disposing of King County's MSW is considered to be challenging and risky. **Below is a summary of** the advantages and disadvantages of RDF disposal.

Summary of Advantages

- Replaces coal resulting in environmental benefits but higher human health impacts.
- Minimal preprocessing required of incoming materials and can manage most feedstocks.
- Environmentally friendly alternative to traditional fossil fuels.
- Potential to create a significant revenue if fuel end-markets are secured.
- Cost effective option at $109 - $153/per ton (2040$) if stable markets are available. If markets are not available, the option is not viable (as landfill disposal would be the alternative).

Summary of Disadvantages

- Performance is proven only at a small scale for homogeneous feedstock.
- No plants are currently operating at the lowest projected Study tonnage scenario.
- End markets need to be developed for projected quantities of end product (75 to 80 percent of total tonnage).
- A long-term guaranteed market is a necessity as there is no economic disposal option for RDF. Most feedstock agreements are short-term.

- Feedstock quality variance may affect end product value depending on end market requirements.
- High amount of maintenance required to maintain good operation.

8.0 OPTIONS COMPARATIVE EVALUATION

A high-level summary of the comparative evaluation for the five disposal options described in Sections 3.0 through 7.0 for the low, medium and high tonnage scenarios is included in Section 1.3 with more detailed summaries included in Appendix B – Comparative Evaluation Summary Matrices.

As stated in Section 1.3, Gasification, Pyrolysis and RDF have been removed from further consideration as a long-term disposal option based on their inability to manage the projected tonnages for King County due to unproven performance for Gasification and Pyrolysis and a lack of markets for RDF.

This section provides a comparative analysis of the two remaining disposal options, WEBR and Mass Burn, as previously described in Sections 3.0 and 4.0 of the Study. Table 8-2 provides a summary of the analysis results for WEBR and Mass Burn by sub-criteria **for the medium tonnage scenario** with how each option achieves criteria goals and commentary on how the options compare to one another. The following Table 8-1 is a guide to reviewing Table 8-2.

Table 8-1: Guide to Reviewing Table 8-2

Criteria	Sub-criteria	OPTION 1	OPTION 2	Primary Sources and Comparison Results
The primary criteria name and goal are listed in this column.	The descriptive name of the sub-criteria is listed here and aligns with their corresponding results to the immediate right.	The results for each sub-criteria are listed here for Option 1 – WEBR and are color coded per the legend at the top of the table based on how they comparatively achieved the goal identified in the first column. [1]	The results for each sub-criteria are listed here for Option 2 – Mass Burn and are color coded per the legend at the top of the table based on how they comparatively achieved the goal identified in the first column.[1]	This column describes the primary source of impacts for the corresponding sub-criteria and provides a brief summary of the Study's comparative findings.

[1] The colors in this table indicate how options compared in achieving goals for the primary criteria based on Study findings for each sub-criterion. Green indicates a higher goal achievement, Orange indicates a lower goal achievement and Yellow indicates a similar goal achievement. It does not measure goal achievement compared to the status quo. For example, Option 1 could be a positive result compared to the status quo (landfilling at CHRL) but still score lower on the goal than Option 2.

Table 8-2: Summary of Analysis of Findings for WEBR and Mass Burn Options (Medium Tonnage Scenario)

Color Legend:	Green = Higher Goal Achievement	Orange = Lower Goal Achievement	Yellow = Similar Goal Achievement

Criteria	Sub criteria	WEBR	Mass Burn	Primary Sources and Comparison Results
Environmental (Net Total of Process and Transport Impacts and Offsets) [65] **Goal:** Reduce environmental impacts or provide environmental benefit	Non-Renewable Energy Demand (MJ) - (Energy Production) Process Transport Offsets Net Total	 506,768,197 72,606,823 (39,379,260) 539,995,760	 595,243,864 14,266,028 (1,295,270,427) (685,760,535)	**WEBR**: Direct use of fossil fuels and electricity in landfill operations Process and Transport; minimal Offsets from electricity sold to grid compared to direct facility uses. **Mass Burn**: Direct use of fossil fuels and electricity during Process; major Offsets from energy sold to grid. **Summary**: In Washington State, while Mass Burn is not considered renewable energy by law, the energy that it does generate offsets the fossil fuel and nuclear portion of the electricity grid, creating a net decrease in Non-Renewable Energy Demand. WEBR does not.
	Water Consumption (L H20) - (Water Quantity) Process Transport Offsets[66] Net Total	 28,369,580 2,101,637 N/A 30,471,217	 26,707,074 1,624,995 N/A 28,332,069	**WEBR**: Operations Process water usage at landfill. **Mass Burn**: Process water usage at Mass Burn facilities. **Summary**: Water Consumption due to Process and Transport impacts are similar between WEBR and Mass Burn. Offsets are excluded for Water Consumption as LCA model was designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with Water Consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude Water Consumption associated with electricity offsets.
	Acidification Potential (kg SO2 eq) - (Air Quality) Process Transport	 354,591 344	 107,459 74	**WEBR**: Fossil fuels for landfill equipment (on-road diesel); Offsets from replacing fossil fuels for electricity generation. **Mass Burn**: Process combustion (includes emissions scrubbers) and electricity input; Offsets from replacing fossil fuels for electricity generation.

[65] Positive environmental value represents impacts (poor result) and negative environmental value represents avoided impacts or offsets (good result).
[66] Excludes offsets as model designed to use a single electricity grid mix, developed to closely reflect the regional mix including a high proportion of hydropower. Hydropower is associated with water consumption due to evaporation from reservoirs. However, since hydropower is considered to be baseload electricity and may not be displaced by a new source of grid electricity (such as from Mass Burn), results exclude water consumption associated with electricity offsets

Criteria	Sub criteria	WEBR	Mass Burn	Primary Sources and Comparison Results
	Offsets Net Total	(12,354) 342,581	(155,397) (47,865)	**Summary**: Diesel usage from landfill equipment makes WEBR increase net Acidification Potential; impact created outside King County. Mass Burn generates so much energy that it Offsets the fossil fuel portion of the electricity grid, which creates a larger net decrease in Acidification Potential than WEBR; impact largely created outside King County.
	Global Warming Potential (MT CO_2 eq) - (Climate Change) Process Transport Offsets Net Total	 63,750 5,619 (13,782) 55,588	 93,736 1,103 (76,444) 18,395	**WEBR**: The portion of methane not captured as LFG in collection systems and fossil fuels used in landfill equipment during Process and Transport; Offsets (including avoided production impacts) from replacing fossil fuels for electricity generation and replacing conventional natural gas with RNG. **Mass Burn**: Combustion of plastics in the facility Process; Offsets (including avoided production impacts) from replacing fossil fuels for electricity generation. **Summary**: Both WEBR and Mass Burn increase Global Warming Potential. WEBR process and both offset impacts largely created outside King County. **Note**: Following IPCC standards, CO_2 associated with burning organics is not counted toward Global Warming Potential, and organics that do not decompose in the landfill are counted as a carbon sink.
	Smog Formation Potential (kg O3 eq) - (Air Quality) Process Transport Offsets Net Total	 30,566 5,352,929 (368,499) 5,014,996	 530,228 1,109,299 (3,650,455) (2,010,928)	**WEBR**: Diesel used in rail transport. **Mass Burn**: Offsets that reduce fossil fuel used to generate grid energy. **Summary**: Fuel usage from rail transport makes WEBR increase impact; impact largely created outside King County. Mass Burn generates so much energy that it Offsets the fossil fuel and biofuel portion of the electricity grid, which creates a net decrease in Smog Formation Potential; impact largely created outside King County.
	Human Health Toxicity - Cancer Potential (CTUh) - (Human Health) Process Transport Offsets Net Total	 7 0 (0) 7	 10,519,047 0 (0) 10,519,046	**WEBR:** Minimal impacts. **Mass Burn**: Burning of plastics in Mass Burn releases toxic chemicals that have the potential to harm human health by increasing cancer potential. * This is not about causation or actual cases. Comparative toxic units (CTUh) are a way to standardize the potential cancer-related impacts of many different toxic chemicals based on their characteristics into a single measure per mass of the chemical. The Cancer Potential parameter multiplies these unit impacts by the total mass of chemicals released into the environment to estimate the potential increase in cancer-related morbidity in the total human population, assuming

Criteria	Sub criteria	WEBR	Mass Burn	Primary Sources and Comparison Results
				equivalent exposure. However, a LCA study can only measure hazard presence (type and quantity of chemicals emitted) and not exposure, so results should be interpreted as comparing the production of chemicals associated with cancer, not morbidity. **Summary**: Mass Burn creates significantly more Cancer Potential than WEBR; impact created inside King County.
	Resource Conservation	Converts LFG to electricity or RNG.	Generates electricity and/or industrial/residential heating.	Both options provide resource recovery opportunities with Mass Burn potential to generate more.
	Compatibility with Waste Prevention & Recycling	No further opportunity for waste prevention or recycling.[67]	Metals removed for recycling.	Mass Burn is more compatible than WEBR. Metals removed for recycling could impact recycling behaviors for public knowing recyclables converted to usable products which may lower consumer recycling rates. However, if recycling and other waste prevention measures are a lower cost than Mass Burn, that should incentivize increased recycling and waste prevention.
Economic **Goal:** Minimize costs	Total Capital Costs (2040$) Annualized Capital Costs (2040$)[68]	$3,378,549 (Total) $337,855 (Annualized)	$1,182,371,054 (Total) $86,707,211 (Annualized)	Mass Burn has higher Capital Cost than WEBR.
	Annual Operating & Disposal Costs (2040$)	Total Cost Transport and Disposal (T&D) + Equipment Depreciation: $72,155,415 T & D Only: $71,817,560[69] Equipment Depreciation Only: $337,855	$53,863,170 (Operations) $23,221,011 (Ash Disposal)	Mass Burn has higher annual Operating and Disposal Cost than WEBR.
	Revenue (2040$)	Electricity or RNG sales from converted LFG included in Cost per Ton.	Electricity Sales (annual): $7,336,453 Recycling Sales (annual): $2,393,919	Both options generate Revenue.
	Cost Per Ton (2040$)[70]	$108.19	$230.99	Mass Burn has higher Cost per Ton than WEBR.

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[67] Waste would be taken to a transfer station/Mixed Waste Processing facility first before being exported by rail for final disposal. Because of this, there would be no opportunity for further waste prevention or recycling once it is exported by rail (WEBR).
[68] 3Annualized capital cost based on 10-year amortization for WEBR and 30-year municipal bond financing at 4% for non-WEBR options.
[69] Rail T&D Cost based on recent legacy contract rates for higher tonnage contracts at $60/ton in 2023$adjusted to 2040$.Disposal cost approximately 30% of T&D cost based on recent procurement data for WEBR contracts.
[70] 4Cost Per Ton = Annualized Capital + Annual Operating & Disposal – Annual Revenue / Total Tons

Criteria	Sub criteria	WEBR	Mass Burn	Primary Sources and Comparison Results
	Financial Risk	Potential that rates from short term contracts (5 to 10-year terms) increase in the future when up for renewal (beyond projected inflation rate increase).[71] Significant regulatory changes may impact future rates. Study assumes use of existing IMF infrastructure. Containers and any IMF improvements included in rail T&D rate.	Further discounted electricity sales rate potential due to CETA restrictions limiting in-State sales or for selling out-of-state; higher costs to comply with the CCA cap-and-trade regulations and potential increased costs due to future regulatory requirements. Significant regulatory changes may impact future rates. The effective cost per ton would increase with lower tonnages than projected during the debt service period and, conversely, should decrease after the debt service period is over. Potential that rates from short term contracts for WEBR component of Mass Burn increase in the future. In case of emergency or catastrophic event, back-up disposal option would be WEBR or direct haul to a landfill.	WEBR and WEBR component of Mass Burn have some Financial Risk with short term contracts that may have future rate increases when up for renewal (beyond projected inflation rate increase). Mass Burn has greater Financial Risk than WEBR with potential for further discounted electricity sales rate and increased costs due to future regulatory requirements. Effective cost per ton would also vary with changes in projected tonnages during the debt service period to cover fixed capital costs and should decrease after the debt service period is over.
Operating History **Goal:** Proven Operating	Proven Performance (Years of operations)	30+	40+	Both have Proven Performance.
	Safety Record	Decades of industry safety-centered approach to investments and operations.	Long operating facilities with periodic updates have a good safety record.	Similar safety record for both options.

[71] Railroads indicated preferred contract terms of 5 to 10 years when interviewed. However, existing and recently executed WEBR contracts between municipalities and waste companies have been longer terms,10 years terms with 1-to-5-year renewal clauses between parties. Contracts between waste companies and respective railroads are not public information unlike the contracts between public entities and the respective waste companies.

Criteria	Sub criteria	WEBR	Mass Burn	Primary Sources and Comparison Results
History, Safety, Environmental and Regulatory Compliance.	Environmental Compliance	Rail Industry Climate Challenge implemented by the FRA to reach net-zero GHG emissions by 2050.	Good environmental records and Regulatory Compliance with MACT and BACT standards.	Similar Environmental Compliance for both options.
	Regulatory Compliance	The BNSF and UPRR Company comply with local, state, and federal regulations.	Upgrades to emission control systems and safety mechanisms per regulatory requirements.	Similar Regulatory Compliance for both options.
Logistics **Goal:** Ensure option/technology is logistically feasible.	Operating Life of Facilities (Years)	Over 300 years (Combined life span of all three Northwest end destination regional landfills)	20-40 years	WEBR has longer Operating Life than Mass Burn.
	Siting/Design/Permitting/Construction Considerations	Does not require Siting, Design or Construction of new facility.	Difficult Siting and Permitting 7-10 years	Mass Burn is more difficult to Site, Design, Permit and Construct than WEBR.
	Compatibility w/Current Collection System	High	High	Both options have similar Compatibility with Current Collection System.
Social **Goal:** Minimize Social impacts and provide social benefits.	Environmental & Social Justice/Equity	Impacts on communities near IMF and around rail line to be considered when rail program is selected. Increased congestion near IMF and longer wait times at railroad crossings to be analyzed when location of Mixed Waste Processing Facility and IMF are identified. Environmental impacts greater for frontline communities. Economic impacts greater for low-income households.	Future siting to identify communities around potential facility locations and transport corridors and evaluate per USEPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. Environmental impacts greater for frontline communities. Economic impacts greater for low-income households.	Mass Burn has higher ESJ potential impacts inside King County than WEBR with constructing a new facility. Any additional studies would analyze and address potential ESJ impacts.
	Local Traffic Impacts (truck trips/day)	144	180	Mass Burn has higher traffic impacts than WEBR.
	Local Job Creation (Number of jobs)	10	48	Mass Burn creates more jobs than WEBR.
		Air - Low Impact	Air - Medium Impact	Mass Burn has higher Other Potential Neighborhood Impacts for Air than WEBR.

Criteria	Sub criteria	WEBR	Mass Burn	Primary Sources and Comparison Results
	Other Potential Neighborhood Impacts (Air, Odor, Noise, Groundwater)	Odor - Low Impact Noise - Medium Impact Groundwater - No Impact (at IMF)	Odor - Low Impact Noise - Medium Impact Groundwater - No Impact	Odor, Noise and Groundwater neighborhood impacts similar with both options.
Capacity **Goal:** Ensure needed Capacity and Flexibility.	Capacity/Minimum Waste Requirements	Technology capable of processing amount of waste from this tonnage scenario. Both serving railroads indicated that tonnage scenario volume could be accepted although traffic and congestion as capacity is used on railroads can be a factor in the future	Technology capable of processing amount of waste from this tonnage scenario.	Similar current Capacity/Minimum Waste Requirements for both options.
	Waste Type Composition & Acceptance	Non-hazardous waste	Non-hazardous waste	Similar Waste Type Composition & Acceptance for both options.
	Tonnage Flexibility (Scalability)	High Flexibility	Medium Flexibility Has ability to ramp up or down operations but not as flexible in addressing significant changes in tonnage as WEBR.	WEBR has higher Tonnage Flexibility than Mass Burn.
	Residual Waste Management (Disposal or further processing)	No residual waste generated.	Ash and rejected waste disposal required. Recycling of residual metals.	Mass Burn has Residuals Waste Management. WEBR does not.

A discussion of the comparative results for WEBR and Mass Burn is provided for each major Study criteria in the following subsections.

8.1 Operating History and Logistics

Both WEBR and Mass Burn have Proven Performance of 30 to 40 years, similar Safety records, similar Environmental Compliance and similar Regulatory Compliance.

WEBR has a longer Operating Life over Mass Burn with the three WEBR end destination landfills having a combined remaining disposal capacity of over 300 years. Mass Burn facilities have an Operating Life of 20 to 40 years without significant upgrades.

Mass Burn is more difficult to site and permit than WEBR with an estimated 7 to 10 years duration for Siting, Design, Permitting and Construction. WEBR does not require Siting, Design or Construction of a new facility.

Both WEBR and Mass Burn have high Compatibility with the Current Collection System.

8.2 Social

Mass Burn has higher ESJ potential impacts with constructing a new facility than the WEBR option which assumes the use of existing IMFs for rail transport and existing landfills for disposal. For WEBR, potential ESJ impacts would need to be considered along rail and truck transport routes in future siting and permitting studies.

- Mass Burn has higher traffic impacts than WEBR due to truck trips leaving the facility for ash residuals disposal and metals recycling.
- Mass Burn creates more jobs than WEBR.
- Other Potential Neighborhood Impacts for odor, noise and groundwater at a Mass Burn facility and WEBR IMF are similar. Other Potential Neighborhood Impacts for Air are higher for Mass Burn than WEBR primarily due to CO_2, CO, NOx, VOC's, SO_2 emissions although substantially reduced through regulatory requirements.
- Impacts are greater for WEBR to transport and dispose at end destination landfills than for Mass Burn.

8.3 Capacity

Both Mass Burn and WEBR options are capable of processing the waste tonnages projected for King County and accept a broad range of MSW.

- Mass Burn is not as flexible as WEBR with significant ramping up or down of tonnages. Equipment may need to be taken offline or added.
- Mass Burn has Residuals Waste Management and WEBR does not.

8.4 Economics

While it was beyond the scope of this study to analyze the economic impacts to affected rate payers, Mass Burn has significantly higher Capital Cost and annualized Operation Costs and Cost per Ton (accounting for Revenue) than WEBR, which means Mass Burn would increase rates higher than WEBR. Revenue potential for Mass Burn is limited to electricity sales out of State and/or in-State to wholesale or district heating customers due to CETA restrictions. In 2040$, Mass Burn is projected to be $230.99/ton while WEBR is projected to be less than half of Mass Burn, at $108.19/ton.

Projected costs over the study period show the Cost per Ton converging as Mass Burn has a flatter growth rate since the majority of costs are Capital Costs which remain constant over an assumed 30-year debt service term. Other costs increase with assumed inflation rate (see Figure 8-1). Additional cost comparisons are included in Appendix B – Comparative Evaluation Summary Matrices.

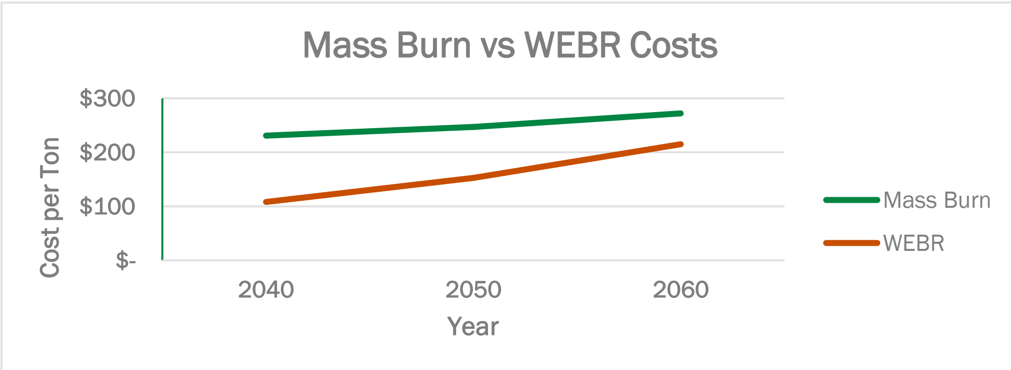

Figure 8-1: Projected Cost of Mass Burn and WEBR Over 30 Years

WEBR and the WEBR component of Mass Burn have Financial Risk with short term contracts of 5 to 10 years with potential for future rate increases above assumed inflation rate. Mass Burn has Financial Risk with further discounted electricity rates impacting revenue potential, higher costs to comply with CCA cap-and-trade regulations (estimated at $4.92 to $7.97 per ton) and potential increased costs due to future regulatory requirements. If there are significant reductions in waste disposal in the future for Mass Burn (more than projected for design purposes), the effective Cost per Ton would be higher to cover the debt service and conversely should be lower after the debt service period is over.

8.5 Environmental

The Environmental sub-criteria evaluated for the Study included Non-renewable Energy Demand, Water Consumption, Acidification Potential, Global Warming Potential, Smog Formation Potential and Human Health Toxicity – Cancer Potential. As previously discussed, an LCA approach was used to analyze the Environmental criteria with impact parameters selected to represent modeled outputs widely used in LCA and scientific literature.

Environmental analysis results are broken down into Process and Transport impacts (which include upstream and direct impacts) and Offsets (avoided impacts). Offsets assume that electricity and RNG sold by a Mass Burn or WEBR facility will displace other energy generators, thereby offsetting the direct impacts of grid electricity and the upstream impacts of both grid electricity and natural gas production. The sum of the Process and Transport impacts minus Offsets results in a Net Total of directional impacts for each Environmental sub-criteria that are presented in Table 8-2.

The results of the LCA performed for the Study show that both WEBR and Mass Burn options create net environmental impacts for Global Warming Potential, although the impacts are higher for WEBR. WEBR shows net environmental impacts and Mass Burn net environmental benefits (avoided impacts) for Non-renewable Energy Demand, Acidification Potential, and Smog Formation Potential. It is noted in Table 8-2 that many of the WEBR environmental impacts are created outside of King County because the vast majority of WEBR activities occur outside King County. The electricity offsets for Mass Burn are the biggest factor in its comparative impacts being lower than WEBR for the environmental parameters considered in the Study. As Mass Burn generates more energy than it consumes, it reduces net energy demand while WEBR increases it.

The WEBR and Mass Burn options have similar results for the Process and Transport impacts for Water Consumption. Environmental benefits for Water Consumption associated with generated energy Offsets were not considered in the Study findings because the majority of credit for grid electricity replacement would be due to avoiding upstream and process impacts of hydroelectric power, reducing evaporation in reservoirs (considered Water Consumption), which is considered a baseload power source in Washington so would not be replaced.

For Human Health – Cancer Potential, Mass Burn creates significantly more cancer potential than WEBR as measured in the LCA as a hazard present (type and quantity of chemicals emitted, not exposed) primarily due to the combustion of plastics, which are combusted inside King County. The Cancer toxicity measurement units used are a way to standardize the potential cancer-related impacts of many different toxic chemicals based on their characteristics into a single measure per mass of the chemical. The Cancer Potential parameter multiplies the unit impacts by the total mass of chemicals released into the environment to estimate the potential increase in cancer-related morbidity in the total human population, assuming equivalent exposure. However, a LCA study can only measure hazard presence (type and quantity of chemicals emitted) and not exposure, so results should be interpreted as comparing the production of chemicals associated with cancer, not morbidity. As noted in Table 8-2, the Cancer Potential results are not about causation or actual cases of cancer.

Another sub-criterion for Environmental included Resource Conservation. Both WEBR and Mass Burn provide resource conservation opportunities by generating electricity or RNG, with Mass Burn having the potential to generate more than WEBR.

The last sub-criterion for Environmental was Compatibility with Waste Prevention & Recycling, which found Mass Burn more compatible due to metals recycling. Knowing this could impact public recycling behavior if they are aware that disposed recyclables will be converted to usable products which may lower consumer recycling rates. However, if recycling and other waste prevention measures are a lower cost than Mass Burn, that should incentivize increased recycling and waste prevention.

9.0 SUMMARY FINDINGS AND NEXT STEPS

9.1 Summary of Key Findings

The most important key finding for the Study is that Mass Burn and WEBR are the only two viable options of the five evaluated to consider in meeting King County's long-term disposal needs after the closure of the CHRL. Gasification, Pyrolysis and RDF have been removed from further consideration based on their inability to manage the projected tonnages for King County due to unproven performance for Gasification and Pyrolysis and a lack of markets for RDF.

A summary of additional key findings for the Mass Burn and WEBR options are as follows:

WEBR

- WEBR costs are significantly lower than Mass Burn for the Study period (estimated $108.19/ton vs. $230.99/ton vs. for the medium tonnage scenario in 2040$) based on current contract pricing for rail T&D. WEBR is a variable cost based on tonnage and rate for contract term duration.
- WEBR is an established disposal option for other municipalities in Washington State with a proven track record of over 30 years.
- There is existing adequate IMF, rail and landfill capacity for King County's three projected tonnage scenarios according to railroad representatives and landfill operators.
- To minimize their risk, railroads typically want contracts of 5 to 10 years. This affects future pricing projections and exposes the County to higher disposal cost risk in the future as railroad pricing increases would likely be passed on to the waste companies contracted with the County for WEBR. While the railroad contract may need to be renegotiated every 5 to 10 years, that process would be the responsibility of the contractor and not the County.
- Additional traffic and rail congestion as capacity is used on railroads will increase traffic delays at grade crossings and may impact capacity availability in the future.
- In recent years, Snohomish and Skagit counties have had to close transfer stations due to service interruptions by BNSF Railway. Existing contracts cover alternative disposal due to service interruptions which provisions should be considered in a future WEBR contract for King County.
- Life cycle environmental impacts are similar to or higher than Mass Burn for the environmental parameters evaluated except for human health – cancer potential which was determined to be lower for WEBR. However, more of the impacts are created outside King County because waste is exported.

Mass Burn

- Mass Burn costs are much higher than WEBR for the Study period (estimated $230.99/ton vs. $108.19/ton for the medium tonnage scenario in 2040$), typically requiring energy markets and economies of scale to ensure financial feasibility. Mass Burn has a fixed cost component to the rate which effective cost per ton would be higher with lower than projected tonnages and lower after the capital cost debt service period.
- Mass Burn facilities reduce the volume of waste that ends up in landfills while also generating energy from the thermal conversion of MSW.
- Mass Burn is an established technology with a proven track record of 40 plus years for quantities and types of waste projected for King County.
- Siting and permitting is difficult; typically with a high level of public opposition due to air pollution concerns.

- The CETA restricts electricity from WtE facilities for grid sale to retail customers in Washington State. Discounted revenue potential for interstate sale of electricity was assumed for the Study. WtE facilities are subject to CCA cap-and-invest program which would subsequently increase the cost for Mass Burn.
- Process produces air emissions that require proper treatment and management and intensive permitting. Mass Burn facilities are required to comply with federal Clean Air Act, State and local air pollution district requirements for meeting air emission standards.
- Residuals include ash waste (estimated 20% of total waste by weight) that requires treatment and disposal at an ash monofill by WEBR at a landfill outside of King County (WEBR). All three WEBR landfills considered in the Study have ash monofills which were assumed to be used for the disposal of ash disposal in the Study options. Ash transport by WEBR is subject to the same renegotiation as waste transport by WEBR, noted above.
- Life cycle environmental impacts are similar to or less than WEBR for the environmental parameters evaluated except for human health – cancer potential which was determined to be higher for Mass Burn. However, more of the impacts are created inside King County at the facility.

9.2 Next Steps

Once the Long-Term Waste Disposal Options Study Report is finalized, it will be shared with the King County solid waste advisory committees and published on the SWD website[72]. SWD will also present the findings as an informational status update on long-term disposal planning. The Study's early findings were presented by SWD to the Sound Cities Association in late 2024 and the final results will be presented to cities in 2025.

During Calendar Year 2025, SWD is planning a scoping period for the SEPA process which includes an opportunity for stakeholders to provide input on the SEPA analysis to be performed. The SEPA process in support of the Study is to provide additional programmatic environmental impact analyses on the WEBR and Mass Burn options to facilitate decision-making. Throughout the SEPA process for the two options, King County will provide progress report updates to MSWAC and SWAC.

It is anticipated that in Calendar Year 2026, King County will release for public comment its draft SEPA EIS with the final EIS expected to be completed by the end of Calendar Year 2026. After the EIS findings, ILA partners will provide their long-term disposal recommendation through MSWAC, and a recommendation letter will be sought from SWAC. The County Executive will take into consideration MSWAC and SWAC recommendations in making the final decision on which option best meets the long-term disposal needs of the County. That decision will be added to King County's updated Comp Plan, which will then kick off the updated Comp Plan adoption process currently anticipated to conclude in Calendar Year 2028.

The process described above can be found in Figure 9-1 below, which timelines are subject to change, but the process should remain the same.

[72] King County Solid Waste Division - King County, Washington

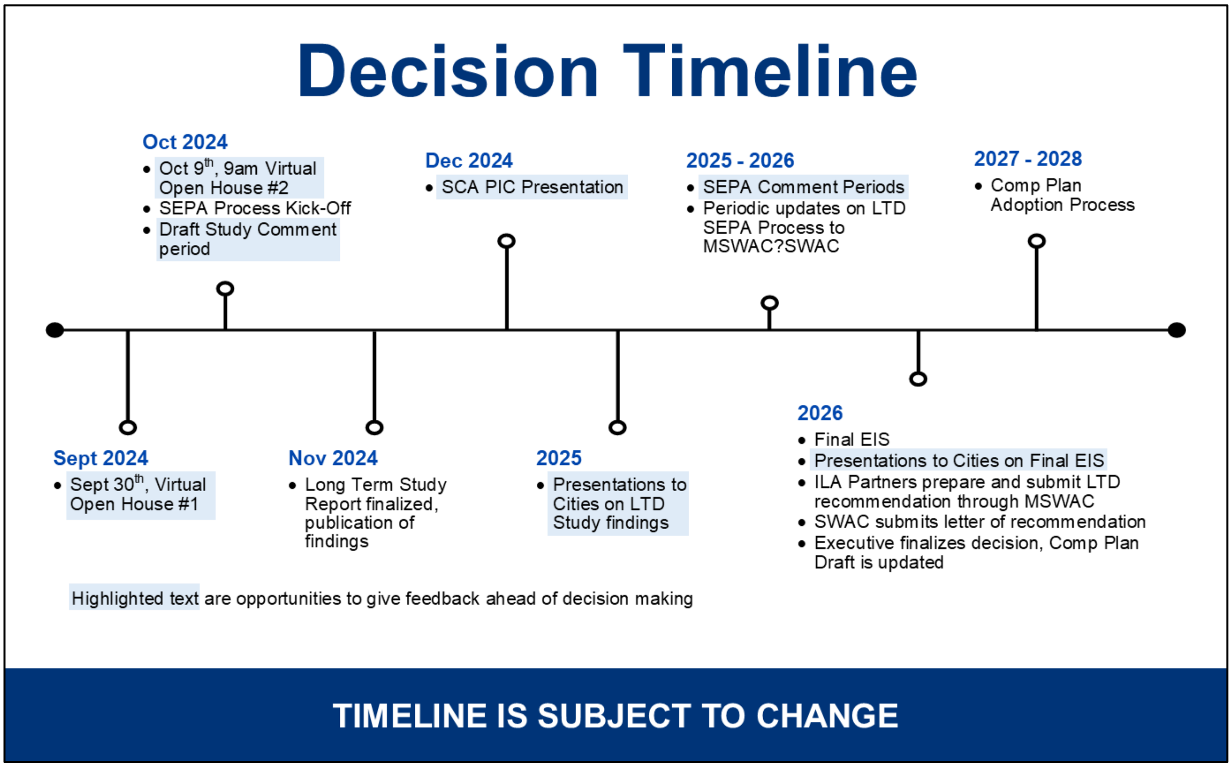

Figure 9-1: Decision Timeline

The updated Comp Plan will be submitted for Public Review (60 days) and Ecology Review (120 days). After Ecology completes their review, the Comp Plan will need to go through a series of approvals, starting with the King County Executive (~120 days), then moving on to the King County Council (~120 days), King County cities (120 days), then finally Ecology (45 days). Once the updated Comp Plan has been officially adopted, an implementation schedule for either WEBR or Mass Burn will be developed with timelines to provide for seamless transition from CHRL operations to the preferred disposal option.

For WEBR, the implementation process would include discussions with waste companies that manage WEBR contracts, the railroad companies and other municipalities with WEBR contracts prior to developing an RFP for the WEBR program which should include contract terms and provisions. Procurement of equipment to support the WEBR program would also have to be considered in the implementation schedule.

For Mass Burn, the implementation process would include a siting study, project level SEPA documentation and permitting process (refer to Section 4.5.2). Future siting should include establishing screening criteria and identifying communities around potential facility locations and transport corridors and evaluation per EPA's Environmental Justice Screening and Mapping Tool and Washington Environmental Health Disparities Map. An ESJ analysis should consider exacerbation of existing disparities in potentially affected communities. The Mass Burn option would also require a feasibility study of electricity sales potential for out-of-state or in-state wholesale customers or district heating and a market study for metal recyclables as end-products. An RFP for a WEBR program to dispose of ash would be required similar to the WEBR option (for less tonnage).

For both WEBR and Mass Burn, a rate setting and financial study would be needed once specifics of each option are developed.