City of Baltimore

RECYCLING AND SOLID WASTE MANAGEMENT MASTER PLAN

Task 7 Report

Managing What's Left

15 April 2020

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ABBREVIATIONS AND ACRONYMS

Formal names for offices, agencies, institutions, and programs are capitalized; technical terms are in lower case.

AD	anaerobic digestion; anaerobic digestor
BCCA	Baltimore Clean Air Act
BCPS	Baltimore City Public Schools
BFWRS	Baltimore Food Waste and Recovery Strategy
BRWWTP	Back River Wastewater Treatment Plant
BRESCO	Baltimore Refuse Energy Systems Co. (now Wheelabrator)
BSP	Baltimore Sustainability Plan
BZWP	Baltimore Zero Waste Plan
CAP	Baltimore City Climate Action Plan
CAPEX	capital expenditure
C&D	construction and demolition
DP3	Baltimore City Disaster Preparedness and Planning Project
DPW	Baltimore City Department of Public Works
GHG	greenhouse gas
HDPE	high density polyethylene; no. 2 plastic
ICI	industrial, commercial, and institutional (sectors)
ILSR	Institute for Local Self Reliance
LWBB	Less Waste, Better Baltimore (Plan)
MBT	Mechanical Biological Treatment
MDE	Maryland Department of the Environment
MDP	maximum diversion potential
MES	Maryland Environmental Service
MFB	multi-family building
MRF	materials recovery facility
MSW	municipal solid waste
MTCO2E	metric tons (tonnes) of carbon dioxide equivalent
MWP	mixed waste processing
NMWDA	Northeast Maryland Waste Disposal Authority
NWTS	Northwest Transfer Station
OPEX	operating expenditure
O&M	operation and maintenance
PET/PETE	polyethylene terephthalate; no. 1 plastic
PPP/3P/P3	public-private partnership
PWWTP	Patapsco Wastewater Treatment Plant
QRL	Quarantine Road Landfill
RNG	renewable natural gas
RORO	roll-on, roll-off container
SFH	single family home
SRF	solid recovered fuels
SSR	single-stream recycling; single-stream recyclables
SSO	source separated organics
U.S. EPA	United States Environmental Protection Agency
WARM	Waste Reduction Model (U.S. EPA)
WMRA	Waste Management Recycle America
WTE	waste to energy
ZWA	Zero Waste Associates

1. INTRODUCTION

1.1 Overview and Approach

This Task 7 Report was prepared by Geosyntec Consultants, Inc. of Columbia, MD for the City of Baltimore Department of Public Works (DPW) as part of a master planning effort titled the "Less Waste, Better Baltimore" (LWBB) Plan. The LWBB Plan is intended to:

1. Outline a clear and attainable future vision for improving the solid waste and recycling system in Baltimore over both the near- and long-term, with the goal of maximizing waste reduction, reuse/repair, recycling, and sustainable management of materials;
2. Develop actionable strategies to achieve this goal; and
3. Identify potential impacts on existing solid waste management systems, including programmatic and infrastructure needs, investment challenges, and associated policy or regulatory initiatives.

In this Report, the capitalized term "City" is used specifically to refer to Baltimore City Government, which includes DPW and other departments and offices (e.g., Planning, Sustainability, and Health) but does not include Baltimore City Public Schools (BCPS). Use of "Baltimore" or the lower case term "city" refers to Baltimore City as a whole.

Background

Several technical and strategic planning documents have been prepared as part of LWBB Plan development to inform and guide the focus of the review of options in Task 7. All documents approved as final by DPW are posted on the LWBB website. To date, the following documents have been prepared as part of the LWBB Plan:

1. Task 0 – Waste Sort: Geosyntec conducted a two-season waste sort (January and June 2019) to establish more reliable and up-to-date data on waste characteristics and quantities generated in Baltimore.
2. Task 1 – Community Meetings: To involve residents and other stakeholders in developing the LWBB Plan, DPW solicited community input through four facilitated community meetings held between February and June 2019. DPW also solicited input through email submittals to its dedicated email address.
3. Task 1 – Online Survey: Parallel to the community meetings, DPW published an online survey to solicit input from stakeholders. Over 2,000 survey responses were received and summarized in a report in April 2019.
4. Task 3 – Comprehensive Description of Existing Solid Waste Management System: Final report published July 2019.
5. Task 4 – Benchmarking: Final report published September 2019.
6. Task 5 – Potential Improvements to the Current Diversion/ Recycling System: This report documents potential options for the City to consider which, if implemented, would improve waste diversion and recycling rates within the residential and commercial sectors. The final Task 5 Report was released concurrent with this Task 7 Report.

This Task 7 Report, which is the ninth in the series of LWBB Plan reports, outlines options for environmentally and fiscally responsible management of "what's left," that is the waste that cannot realistically be prevented from being generated or diverted from disposal under one or more options assessed in the Task 5 Report.

Basis for Analysis in Task 7

The Task 5 Report summarized and analyzed in detail the options available to the City to reduce and divert waste from disposal. The Task 5 Report was written in the context of assessing the City's ability to meet the waste reduction/diversion goals established in the Baltimore Sustainability Plan (BSP) and Baltimore Food Waste and Reduction Strategy (BFWRS). Although the Task 5 Report focused on programs that could be directly implemented or managed by DPW (i.e., that primarily impact the residential sector), it also assessed reduction/diversion measures in the commercial sector. Altogether, it was estimated that an overall waste diversion rate of 83% could be achieved by 2040 if the City were to implement the full combination of options resulting in the maximum diversion potential (MDP). This compares to the 50% overall diversion rate achieved in 2017.

The expected rate at which recycling/diversion options achieve their MDP has significant bearing on the quantity of waste requiring disposal in any given year. Based on the Task 5 analysis, it is estimated that many of the options will take several years to fully mature and reach their full diversion potential. The timeline associated with post-implementation performance of each option were assessed in terms of the short term (generally, the next 5-10 years), medium term (generally, the next 10-15 years) or long term (generally, the next 15-20 years). The estimated timeline accounts for the expected time lag between program implementation and seeing noticeable improvements as a result of the affected population responding and adapting to it. A simple S-curve model was used to account for the time lag. Therefore, the quantity of waste requiring disposal is expected to decrease relatively slowly at first, but then accelerate significantly over time as the full impacts of waste reduction and diversion measures begin to be felt. Over the same period, waste generation in Baltimore is expected to increase slowly over time to reflect projected population increases. Analysis of total waste disposal needs in Task 7 thus needs to reflect the dynamic nature of the evolving waste stream expected through 2040.

As introduced above, it is important to note that that solid waste management in Baltimore, like most jurisdictions, operates within two distinct spheres. The City's "sphere of control" represents the portion of the waste stream that is under their direct control, primarily waste collected by DPW from the residential sector. Assessing changes to programs and systems within this sphere is relatively straightforward and actionable. However, Baltimore also relies on waste management services and facilities that are privately owned and/or are located outside the City's jurisdictional limits. Although the City does not have direct control over these operations within the commercial sector, they are nonetheless influenced by the City's priorities, policies, and regulations and, therefore, are considered to be within their "sphere of influence." Assessing changes to programs and systems within the City's sphere of influence is not as straightforward as for those within their sphere of control.

1.2 Scope and Purpose

Consistent with the methodology outlined above and the scope of work for Task 7, the purpose of this Report is to:

1. Document potential options for the City to consider for management of residual waste (i.e., what's left) following the waste diversion efforts to be implemented within the residential and commercial sectors in accordance with Task 5. Under these assumptions for the anticipated amount of residual waste for disposal, options for consideration in Task 7 include:
   A. Maximizing the use of DPW's Quarantine Road Landfill (QRL);
   B. Continued use of Wheelabrator Baltimore, the waste-to-energy (WTE) incinerator previously known as BRESCO;
   C. Constructing new/expanded waste transfer stations as long-haul transfer options for disposal out of the city; and
   D. Other waste processing technologies such as mixed waste processing, mechanical-biological treatment, or gasification.
2. Building on promising options, identify specific facilities and programs to assist with budgetary planning for future waste disposal needs based on high-level information regarding:
   A. Costs and timelines for facility/program development, implementation, and performance;
   B. Siting requirements (e.g., whether existing facilities could be expanded or whether new sites would be needed in or around Baltimore);
   C. Environmental benefits achieved, measured in terms of lifecycle greenhouse gas (GHG) emission reductions of WTE as compared to landfilling;
   D. Other benefits (e.g., job creation potential within the public and private sectors); and
   E. Potential operational and financial challenges.

Review of potential options should also consider contingency planning for unexpected events that could temporarily or permanently interrupt the use of one of the City's main recycling or transfer/disposal locations. Contingencies for disruption to transfer/disposal facilities are best addressed through adopting a decentralized approach that provides redundancy, that is:

1. Developing multiple smaller facilities rather than relying on one centralized facility; and
2. Ensuring the sum total capacity of decentralized facilities exceeds the total capacity requirement (e.g., if three facilities are developed, each should offer more capacity than simply a third of the total required).

This is a key focus of the analysis in Task 7.

Adoption of the diversified options for waste diversion and recycling assessed in Task 5 will reduce the City's reliance on centralized disposal infrastructure and thus help build resilience to climate change or other disruptions. Contingency measures for temporary/permanent disruption to a composting or other recycling facility essentially mean disposing of materials that can no longer be processed. Therefore, assumptions for disposal tonnages and the sizing of all processing and transfer facilities in Task 7 are based on handling total waste quantities under the 2017 status quo (i.e., assuming that additional diversion rates achieved in the future may be lost temporarily or permanently).

1.3 Relevant Legislation and Existing Plans

Baltimore Clean Air Act (BCAA)

The Baltimore Clean Air Act (BCAA), introduced as Council Bill 18-0306, was approved by the City Council on 11 February 2019 and signed by then Mayor Pugh on 7 March 2019. The BCAA requires commercial solid waste incinerators in Baltimore to conduct continuous monitoring of multiple pollutants, including dioxins, furans, nitrogen oxides (NOx), sulfur dioxides (SOx), particulate matter, polycyclic aromatic hydrocarbons, and several heavy metals. It also establishes significantly stricter emission limits for mercury, NOx, SOx, and dioxins/furans than are required under Maryland regulations. As written, compliance with the BCAA is required starting in September 2020 or January 2022, depending on the specific emission control and/or monitoring system in question.

Consideration of the BCAA had significant impact on the analyses performed in Task 7. If BRESCO could not economically comply with the BCAA, it would be forced to close in 2022, adding urgency to the need for achieving significant diversion of waste from disposal. In the short term, additional disposal at QRL and/or contingency transfer of waste to other disposal facilities will be needed until more long-term options can be developed.

The status of the BCAA has been extremely fluid during development of the LWBB Plan. When the project commenced in September 2018, the BCAA had not yet been enacted. On 30 April 2019, Wheelabrator in conjunction with other plaintiffs sued the City in Federal Count over the legality of the BCAA. On 29 January 2020, at the request of the Court, the City agreed to stay implementation of the BCAA pending resolution of the motions. Soon thereafter, on 27 March 2020 the Court found that the BCAA conflicts with federal and state law, is preempted by such laws, and therefore is invalid. This effectively ruled in Wheelabrator's favor for their continued operation of BRESCO. At the time of writing this Task 7 Report, it is not known whether the City will appeal the Court's ruling. In addition, it is not known whether the City will renew its contract for disposal at BRESCO after December 2021. For the purposes of this Task 7 Report, therefore, analyses of options for disposal of what's left are centered on various scenarios in which BRESCO may or may not be available for waste disposal starting in 2022.

Baltimore Sustainability Plan (BSP)

The Baltimore Sustainability Plan was developed by the Baltimore Office of Sustainability (BOS) and adopted by the City Council in 2019. The BSP presents three major strategies for improving waste management and recycling in Baltimore with associated action items:

1. Increase the amount of trash that is diverted from the landfill and incinerator to recycling programs. Specific action items include providing free recycling bins to all residents and increasing commercial recycling; launching an anti-litter, pro-recycling campaign; and creating a plan to achieve zero waste, meaning the City "are working toward or diverting over 90% of our discards from landfilling or incineration."
2. Expand the City's Waste to Wealth Initiative. Specific action items include implementing the Baltimore Food Waste and Recovery Strategy (BFWRS), siting a local compost facility, and revising building codes and/or creating ordinances to eliminate waste and encourage reuse of deconstructed building materials.

3. Pursue legislative and policy changes to reduce the waste stream. Specific action items include imposing a fee for plastic bags, creating a procurement committee to incentivize source reduction, and developing a "save as you throw" (SAYT) program.

A more detailed description of strategies outlined under the BSP, as well as a review of the City's BFWRS and Waste to Wealth Initiative, was provided in the Task 5 Report.

Other Plans

Two other City plans with relevance to the analyses in Task 7 are:

1. The Climate Action Plan, which was developed in November 2012 to reduce Baltimore's GHG emissions by 15% below 2010 levels by 2020 through a range of strategies targeted at reducing consumption of fossil fuels. In the BSP, this goal was updated to 25% reduction by 2020 and 30% by 2025 (relative to 2007).
2. The Disaster Preparedness and Planning Project, which was created in an effort to address existing hazards while simultaneously preparing for predicted hazards due to climate change. An update to the DP3 was adopted by the City in December 2018.

The CAP and DP3 were reviewed in more detail in the Task 5 Report.

2. METHODOLOGY AND BASELINE

This Report focuses on managing "what's left" in the solid waste stream after waste reduction and diversion programs have been implemented (see the LWBB Task 5 report for details on waste reduction and diversion options). Therefore, a foundational assumption for this Report is that the materials remaining in the waste stream have little to no potential for recovery because the majority of recoverable and/or divertible materials (e.g., cardboard, plastics, metals, compostable organics, etc.) have been removed under the City's reduction and diversion measures (which will increase over time as the Task 5 options are implemented). As a result, this Report will focus on waste processing and disposal options available to manage the residual solid waste stream following implementation of the reduction and diversion strategies outlined in the Task 5 report.

The methods used in this Report to objectively assess waste processing and disposal options are presented below:

1. Estimate the expected solid waste mass and composition through 2040. This will be used as the baseline for assessing future processing and disposal options;
2. Review existing solid waste management facilities in and around Baltimore to determine what, if any, additional processing and disposal capacity will be required to manage the expected future solid waste stream;
3. Select processing and disposal options to be analyzed in this Report to meet future solid waste management needs;
4. Choose metrics by which each option will be assessed;
5. Analyze each option using these metrics to select the most effective and feasible waste processing and disposal options; and
6. Perform a scenario analysis to determine when selected solid waste processing and disposal options will be required to manage Baltimore's solid waste stream.

This Report focuses on waste processing and disposal options that can be sustained – that is, options that are robust, affordable, practical, and enforceable such that residents and businesses support them. Where appropriate, opportunities for collaboration and partnership between the public and private sectors are discussed in relation to each option.

2.1 Establishing the Baseline for Analysis

Citywide Overview of the Disposed Waste Stream

As part of the Task 5 Report, a detailed mass balance was performed on the composition of the current solid waste stream. Specifically, the composition of disposed waste was analyzed to determine the diversion potential, costs, benefits, and challenges for the various waste reduction and diversion options presented as part of the Task 5 Report. A summary of the solid waste streams in the city, including waste generation, sources and destinations of disposed waste, and disposed waste composition, is given below (based on 2017 data).

Summary of Solid Waste Generation

The waste stream in Baltimore is composed of residential and commercial waste. Residential waste is collected by DPW and includes waste generated by single family homes and government buildings. Commercial waste is collected by private haulers and includes waste generated by businesses, industries, and institutions as well as from private multi-family dwellings. In 2017, approximately 548,800 tons of residential waste and 1,093,000 tons of commercial waste were generated in the City (1,641,800 tons in total). Of the total waste generated, approximately 747,000 tons (45%) was recycled (this value includes the roughly 8,400 tons of backend scrap metal recovered from BRESCO, included in the commercial recycled scrap metal category, and the 189,400 tons of recycled soil used as daily and intermediate cover material at QRL), 78,700 tons (5%) was composted, 229,800 tons (14%) was incinerated at BRESCO (this value does not include the approximately 8,400 tons of recovered backed scrap or the 140,000 tons of ash landfilled at QRL, 292,200 tons (18%) was landfilled at QRL (including 140,300 tons of ash from BRESCO, and 279,900 tons (17%) was disposed by commercial haulers in the private system (presumed to be C&D waste).

Sources and Destinations of Disposed Waste

In total, 816,100 tons of waste generated in Baltimore were disposed in 2017. This includes 319,450 tons of disposed residential waste and 496,650 tons of disposed commercial waste. Residential disposed waste consisted predominantly of curbside residential MSW (306,550 tons) and waste collected at DPW's residents' drop-off facilities (12,900 tons) and was disposed at QRL (162,500 tons) and BRESCO (156,900 tons). Commercial disposed waste consisted predominantly of commercial MSW (201,300 tons), commercial C&D waste (279,900 tons), and waste collected by small haulers (13,200 tons) and was disposed at BRESCO (213,200 tons), QRL (3,550 tons), and private C&D disposal facilities (279,900 tons).

Expected Composition of Disposed Waste

The composition of the disposal waste stream was determined using a combination of data from the Task 0 summer and winter waste sorts and published sources. A summary of expected disposed waste composition is given in the table opposite.

Summary of Disposed Waste Composition in Baltimore in 2017 (tons)

Category	Sub-Category	Residential Waste	Commercial Waste	Total
Organics (163,200)	Food Waste	65,450	44,050	109,500
	Yard Waste	36,250	15,150	51,400
	Mixed Organics	0	2,300	2,300
Traditional Recyclables (240,700)	Cardboard	24,600	32,350	56,950
	Mixed Paper	18,700	17,600	36,300
	HDPE/PET	12,700	7,550	20,250
	Mixed Plastic	55,150	29,800	84,950
	Aluminum Cans	4,000	2,500	6,500
	Steel Cans	7,650	9,000	16,650
	Mixed Metals	250	300	550
	Glass	9,350	9,200	18,550
C&D (288,700)	Lumber	2,400	22,000	24,400
	Clay Bricks	0	6,350	6,350
	Concrete	2,050	199,300	201,350
	Asphalt Concrete	0	40,200	40,200
	Asphalt Shingles	0	7,150	7,150
	Soil	150	150	300
	Drywall	900	8,050	8,950
Non-Traditional Recyclables (5,600)	Bulk	2,500	2,500	5,000
	Textiles/Carpet	250	250	500
	Other	50	50	100
Unclassified (117,900)	-	77,050	40,850	117,900
TOTAL	-	319,450	496,650	816,100

For consistency in later analyses, waste composition categories in the table were chosen to be consistent with U.S. EPA's WARM software. A summary of the methods used to determine disposed waste composition was included in the Task 5 Report.

In summary, it is estimated that about 816,100 tons of waste were disposed in Baltimore in 2017. This included about:

1. 163,200 tons of compostable organics (including food, yard waste, and mixed organics);
2. 288,700 tons of C&D waste (including concrete, lumber, asphalt, and drywall);
3. 240,700 tons of traditional recyclables (including paper, plastics, metals, and glass);
4. 5,600 tons of non-traditional recyclables (including bulky waste and carpet); and
5. 117,900 tons of unclassified, hard-to-recycle material (including non-compostable organics, medical waste, composite materials, diapers, etc.).

Citywide "What's Left" Waste Stream

The size and composition of the future disposed waste stream (i.e. the "what's left" waste stream) were estimated using the composition of the current waste stream (detailed above), projections for waste growth in the City (detailed in the Task 3 Report), and projections for waste reduction and diversion (detailed in the Task 5 Report). A full analysis of the size and composition of the "what's left" waste stream is included in Appendix 1. A summary of the process used to determine the characteristics of the "what's left" waste stream is provided below.

Summary of the Maximum Diversion Potential

Of the waste reduction and diversion options outlined in the Task 5 Report, there is a combination of mutually exclusive options which results in achieving the Maximum Diversion Potential (MDP) and thus minimizes the residual mass of waste for disposal. As shown in the table below, the MDP sums to a total of 552,900 tons of waste per year (assuming 2017 waste tonnages and composition).

Expected Maximum Diversion Potential and Performance Timeframes for Task 5 Options

Diversion Option	Additional Diversion Potential (tons)	Expected Performance Timeframe (years)
Food Waste Reduction	72,400	20
Residential Organics Diversion	42,800	20
Commercial Organics Diversion	35,500	20
Improved Recycling Collection	84,200	10
Expanded Recycling Collection	69,300	10
C&D Reuse and Reduction	28,400	10
C&D Diversion	200,100	20
Bulk Waste Diversion	4,100	10
Drop-Off Center Improvements	16,100	5
TOTAL	**552,900**	-

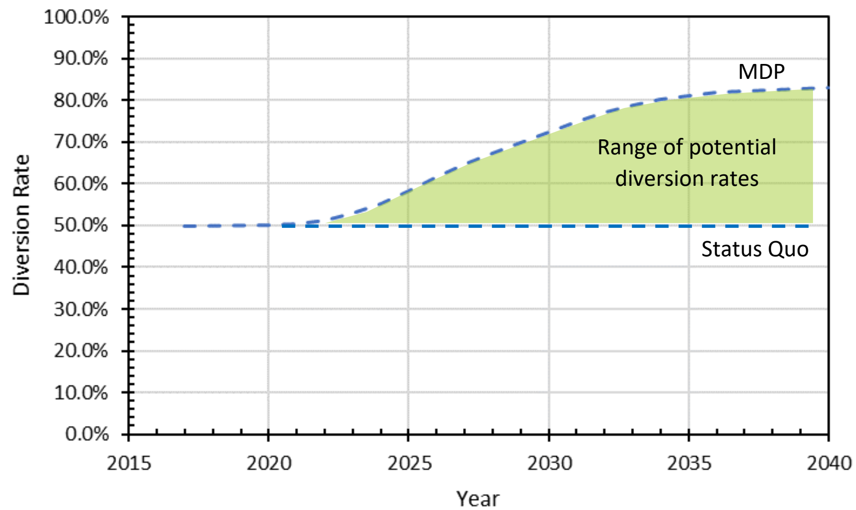
When considered in combination with the current diversion rate (747,000 tons currently recycled including soil at QRL, plus a further

78,600 tons currently composted), achieving the MDP would increase the overall diversion rate for all waste in Baltimore from 50% to about 83%.

To estimate the changing composition of the waste stream over time as waste diversion increases, it is necessary to assign an expected performance timeframe to each of the nine options comprising the MDP. The performance timeframe for each option is summarized in the table above. This timeframe represents the total time expected after implementation of an option for diversion to achieve maximum performance levels in accordance with an S-curve participation rate (as described in the Task 5 Report). Larger, more complex options have longer performance timeframes. The figure below shows the overall expected diversion rate over time assuming full implementation of all recycling/diversion options to achieve the MDP.

It should be noted that these performance timeframes are conservative estimates, which is appropriate for estimating long-term waste disposal needs in this Task 7 Report. The City could choose to decrease the performance timeframe for one or more options by phasing options in faster than assumed herein and/or by increasing funding to education and outreach and other efforts to stimulate participation. It is also important to emphasize that the timeframes shown in the table are end-points. Thus, for example, a 20-year performance timeframe means that it is expected that 100% of the MDP will be achieved within 20 years. However, this option would need only 10 years to get to 50% of the MDP and 15 years to get to 95% of the MDP (see S-curve calculation details in Appendix 1).

As shown in the figure opposite, it is expected that the overall diversion rate achieved may vary between the status quo (i.e. maintaining a 50% diversion rate consistent with performance in 2017) and implementing the MDP options to their utmost extent (resulting in 83% diversion by 2040). The actual diversion rate achieved will be dependent on multiple factors, including when each option is implemented, the level of funding provided to each option, and the level of response and participation by residents and businesses.

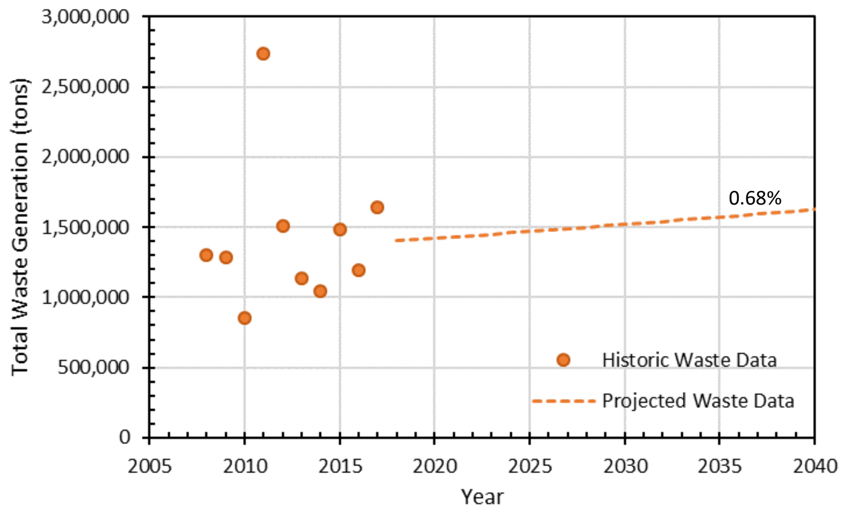


Range of Diversion Rates over Time between the Status Quo or after Implementing the MDP Options

Waste Growth Projections

To project the tonnages of waste for disposal over time, it is necessary to model the overall growth in waste generation. As described in the Task 3 Report, it is anticipated that the City's total waste stream will grow at an average annualized rate of 0.68% per year, based on historical waste generation data and projected population growth in the city. This assumption was used to estimate the total amount of waste generated in

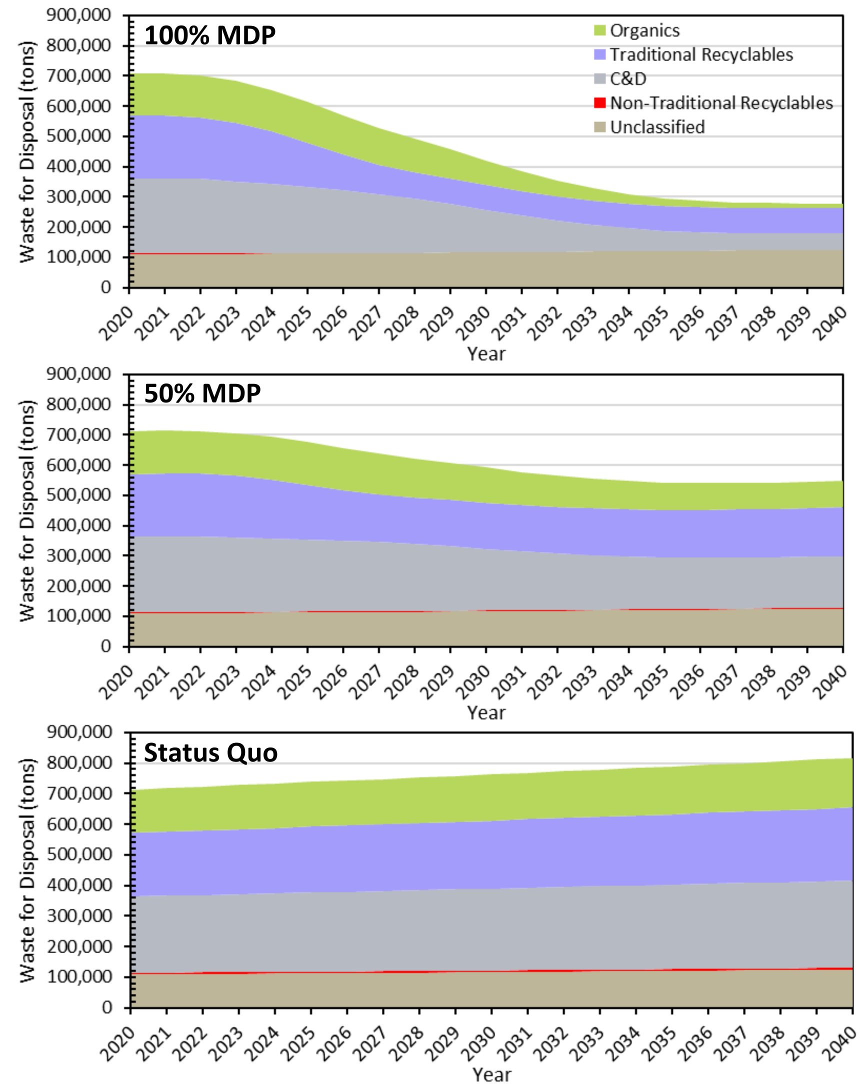
Baltimore between 2017 (the last year for which data are available based on MDE's Annual MRA Reports) and 2040 (when all of the options composing the MDP are assumed to have been fully implemented within their respective timeframes). The estimated total waste generation in the City through 2040 is indicated in the figure below.



Historical and Projected Waste Generation in Baltimore

"What's Left" Waste Stream

Combining waste growth projections with the overall waste diversion rates provided by the MDP, the characteristics of the citywide "what's left" waste stream can be determined. The figures opposite show the expected tonnage and composition of the total disposed waste in Baltimore (i.e., combined residential and commercial waste) assuming that the City achieves the full MDP, 50% of the MDP, or 0% of the MDP (i.e. the status quo).

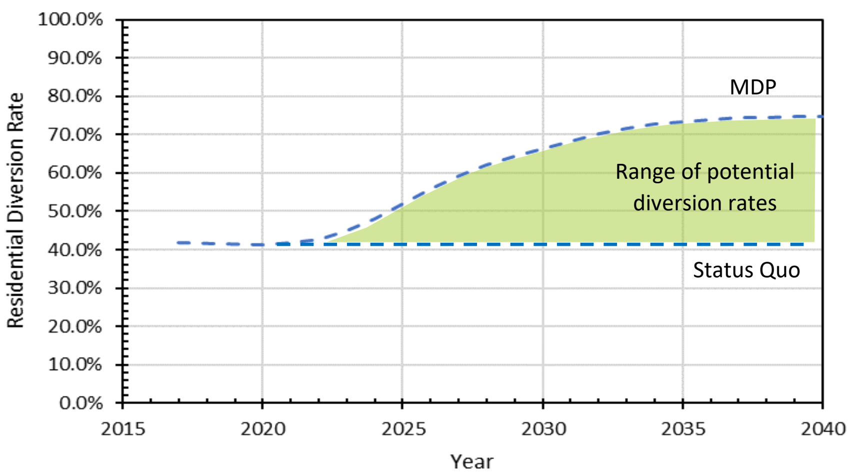


Expected Change in Mass and Composition of Citywide Disposed Waste over Time after Implementing the MDP Options

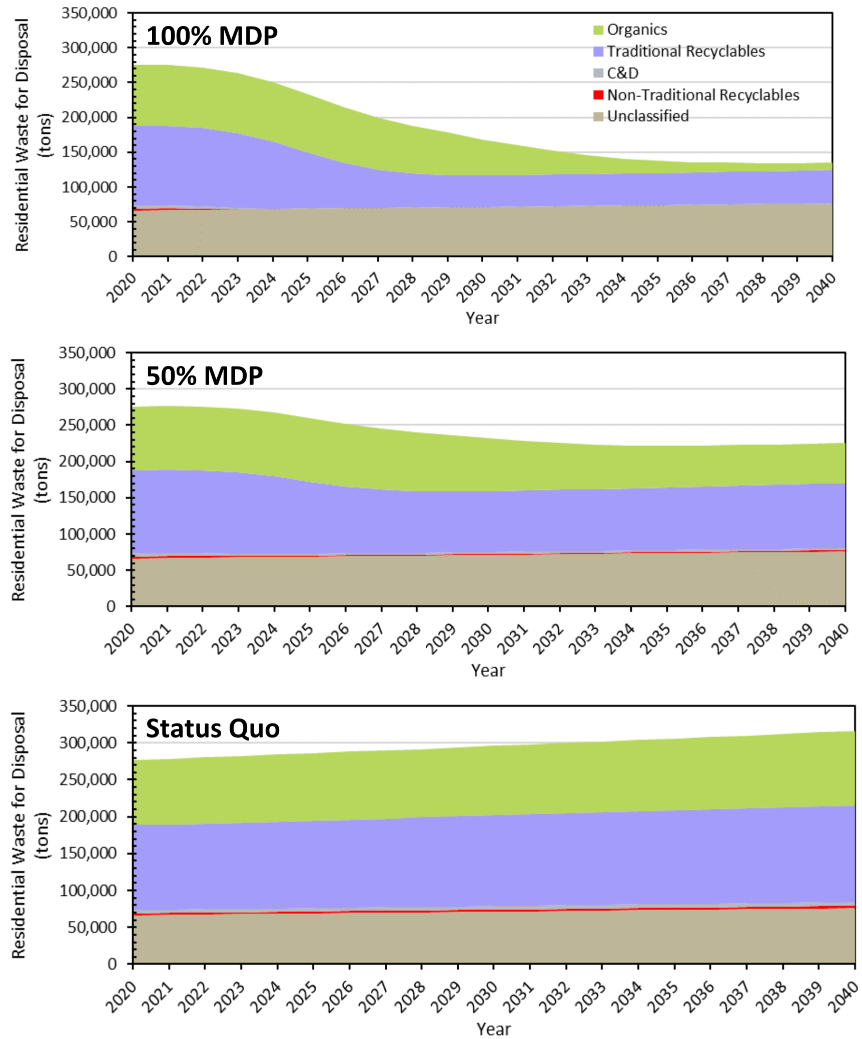
Residential and commercial waste streams are managed separately and thus will be impacted differently under the future development scenarios analyzed in this Report. Therefore, separate analyses of the residential and commercial waste streams were conducted as discussed next.

Residential "What's Left" Waste Stream

The residential waste stream comprises all waste managed by DPW, which mainly includes waste collected from single family homes (SFH) and public housing, government offices, some Downtown businesses, and residents' drop-off centers. The residential diversion rate in 2017 was approximately 42%, with 229,300 tons diverted and 319,500 tons disposed (see Appendix 1 for details). The figure below shows the expected residential diversion rate under the status quo (42%) or implementation of the MDP options to their utmost extent (resulting in 75% diversion by 2040).



Range of Residential Diversion Rates over Time between the Status Quo or after Implementing the MDP Options



Expected Change in Mass and Composition of Residential Disposed Waste over Time after Implementing the MDP Options

The figures on the previous page show the expected tonnage and composition of the residential waste stream for disposal assuming the City achieves the full MDP, 50% of the MDP, or 0% of the MDP (i.e. the status quo). The status quo and MDP diversion rates are lower for the residential waste stream than for the citywide or commercial waste stream as this includes very little C&D waste, which has a high diversion potential.

In further analysis, MSW and C&D waste in the residential waste stream are considered separately because different disposal options will be considered for each waste type (e.g., incineration is a feasible disposal option for MSW but not for C&D waste).

Expected Quantities of Residential Municipal Solid Waste

The table below shows the expected mass (in tons) of disposed residential MSW over time assuming that the City achieves different fractions of the MDP.

Expected Residential MSW Disposal Tonnages over Time as a Percentage of the MDP (0% represents Status Quo)

MDP	2020	2025	2030	2035	2040
0%	271,700	281,000	290,700	300,700	311,000
50%	270,900	257,000	229,400	219,000	222,800
100%	270,100	233,000	168,100	137,200	134,600

If the City achieves 100% of the MDP by 2040 the total tonnage of residential MSW for disposal is expected to decline from 270,100 tons in 2020 to 134,600 tons in 2040. However, under the status quo scenario (0% of the MDP), the total tonnage of residential MSW for disposal is expected to increase from 271,700 tons in 2020 to 311,000 tons in 2040.

These values are the assumed quantities of waste that will be used in analysis of management and disposal options for the residential sector in the remaining sections of this Report.

Expected Quantities of Residential C&D Waste

The table below shows the expected mass (in tons) of disposed residential C&D waste over time assuming that the City achieves different fractions of the MDP.

Expected Residential C&D Disposal Tonnages over Time as a Percentage of the MDP (0% represents Status Quo)

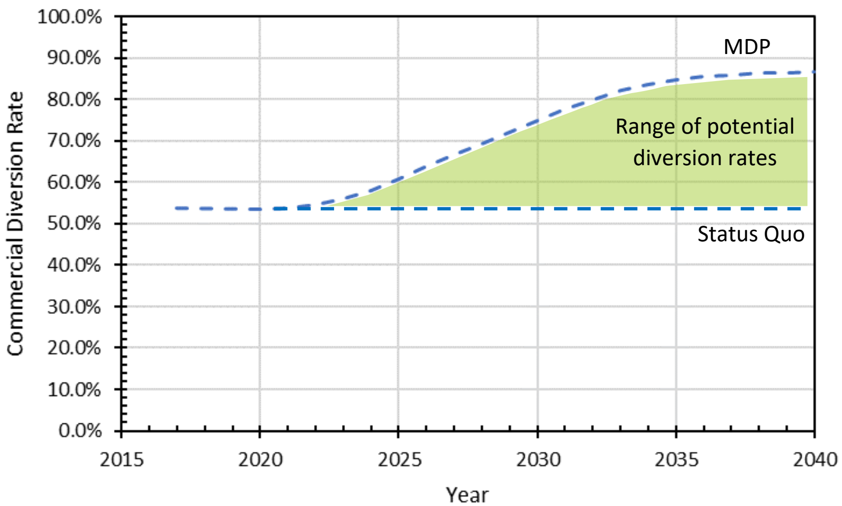
MDP	2020	2025	2030	2035	2040
0%	4,700	4,900	5,100	5,200	5,400
50%	4,700	2,700	2,800	2,900	3,000
100%	4,700	500	500	500	500

The amount of residential C&D waste generated in Baltimore (currently sent to QRL for final disposal) is expected to be *de minimis*, regardless of the fraction of the MDP that is attained. As such, disposal options for residential C&D waste will not be included further in this Report.

Commercial "What's Left" Waste Stream

The commercial waste stream comprises all waste managed by the private sector and includes waste collected from City businesses, industries, and multi-family dwellings not served by DPW's curbside collection program.

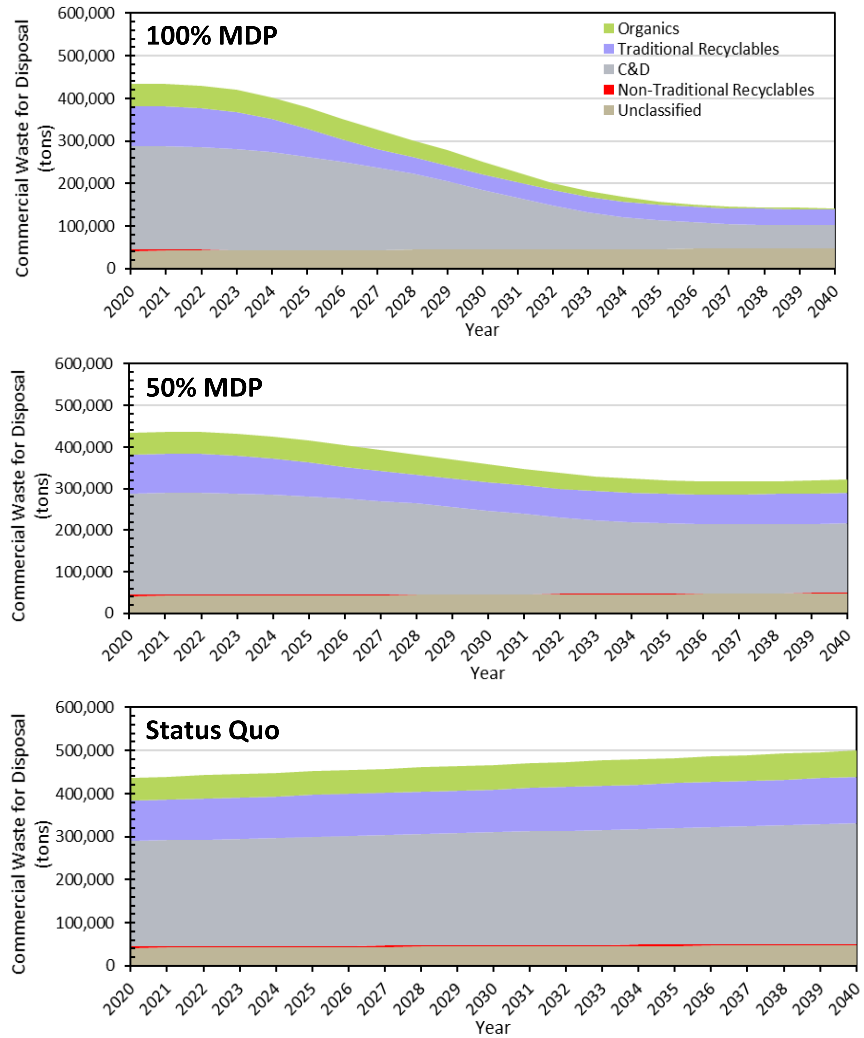
The commercial diversion rate in 2017 was approximately 54%, with 587,900 tons diverted and 496,700 tons disposed (see Appendix 1 for detailed analysis). As shown in the figure below, it is expected that the commercial diversion rate may vary between the status quo (i.e., maintaining a 54% diversion rate) and implementing the MDP options to their utmost extent (resulting in 87% diversion by 2040).



Range of Commercial Diversion Rates over Time between the Status Quo or after Implementing the MDP Options

The figures opposite show the expected tonnage and composition of the commercial disposed waste assuming that the City achieves the full MDP, 50% of the MDP, or 0% of the MDP (i.e. the status quo).

In further analysis, MSW and C&D waste are again considered separately because different disposal options will be considered for each waste type (e.g., incineration is a feasible disposal option for MSW but not C&D waste).



Expected Change in Mass and Composition of Commercial Disposed Waste over Time after Implementing the MDP Options

Expected Quantities of Commercial Municipal Solid Waste

The table below shows the expected mass (in tons) of disposed commercial MSW over time assuming that the City achieves different fractions of the MDP.

Expected Commercial MSW Disposal Tonnages over Time as a Percentage of the MDP (0% represents Status Quo)

MDP	2020	2025	2030	2035	2040
0%	191,500	198,000	204,900	211,900	219,200
50%	190,900	178,600	157,800	151,300	154,200
100%	190,300	159,200	110,800	90,800	89,200

As shown in the table, if the City achieves 100% of the MDP by 2040 the total tonnage of commercial MSW for disposal is expected to decline from 190,300 tons in 2020 to 89,200 tons in 2040. However, under the status quo scenario (0% of the MDP), the total tonnage of commercial MSW for disposal is expected to increase from 191,500 tons in 2020 to 219,200 tons in 2040.

These values are the assumed quantities of waste that will be used in analysis of management and disposal options for the commercial sector in remaining sections of this Report.

Expected Quantities of Commercial C&D Waste

The table opposite shows the expected mass (in tons) of disposed commercial C&D waste over time assuming that the City achieves different fractions of the MDP.

Expected Commercial C&D Disposal Tonnages over Time as a Percentage of the MDP (0% represents Status Quo)

MDP	2020	2025	2030	2035	2040
0%	245,100	253,500	262,200	271,200	280,500
50%	244,000	236,700	201,400	169,100	166,900
100%	243,000	220,000	140,700	67,200	53,400

As shown in the table, if the City achieves 100% of the MDP by 2040 the total tonnage of commercial C&D waste for disposal is expected to decline from 243,000 tons in 2020 to 53,400 tons in 2040. However, under the status quo scenario (0% of the MDP), the total tonnage of commercial C&D waste for disposal is expected to increase from 245,100 tons in 2020 to 280,500 tons in 2040.

As commercial C&D waste is currently disposed almost exclusively at out-of-City C&D landfills (i.e., ignoring the small quantity of C&D waste currently disposed at QRL), C&D waste disposal is not expected to significantly affect the outcome of analyses in the Task 7 Report. In other words, it is expected that the overall size of the C&D waste stream will decrease over time as Task 5 reuse/diversion options are implemented, with the remaining waste stream for disposal continuing to find its way to local C&D landfills around Baltimore. Therefore, commercial C&D waste disposal will not be considered further in this Report.

2.2 Metrics for Objective Assessment

Five metrics were used to objectively compare each potential waste processing and disposal option considered in this Report using the projected characteristics of the city's future waste stream (waste mass and composition) established in Section 2.1.

Timeline

The implementation timelines associated with each option are estimated based on Geosyntec's professional experience, online research, or other publicly available information. Timelines are assessed in terms of the short term (within the next 1-3 years), medium term (the next 5 years), long term (the next 10 years), or very long term (up to 20 years). Implementation timelines are mostly affected by the time needed to raise funds; design, permit, and construct new facilities; procure equipment; and/or allocate resources to operate new programs/systems. Performance timelines account for the expected time lag between program/system implementation and seeing noticeable improvements as a result of the affected population/businesses responding and adapting to it.

Benefits (or Drawbacks)

The benefits associated with any waste management and disposal option include revenues (e.g. from sale of recovered recyclables or from sale of energy); environmental benefits, for which reductions in greenhouse gas (GHG) emissions are used as the primary surrogate; potential increases in local employment associated with job creation; and landfill disposal airspace savings. Indirect benefits, such as synergistic interactions with other system components or options are also qualitatively assessed. Revenues from each option were estimated using unit rates obtained from Geosyntec experience, online research, or publicly available information.

GHG reductions associated with each option are calculated using the U.S. EPA Waste Reduction Model (WARM). For all WARM analyses, waste is modeled as "Mixed Organics," "Mixed Recyclables," or "Mixed MSW" because technologies included in this Report are designed to process and dispose of mixed wastes. GHG emissions are calculated over the life of the facility (i.e. on a total, not an annual basis). GHG reductions are compared against an "all landfill" baseline condition to account for the potential scenario in which BRESCO becomes unavailable (e.g. due to the City not renewing their disposal contract in December 2021) after which all un-diverted waste would likely go to QRL for final disposal. The baseline condition assumes a waste haul distance of 20 miles one way.

GHG reductions can be compared with the goals of the Baltimore Climate Action Plan (CAP) as updated by the BSP, which outlines how the City aims to reduce GHG emissions by 25% by 2020 and 30% by 2025 (relative to 2007). Baltimore's GHG emissions in 2014 were estimated at 7,230,859 metric tons (tonnes) of carbon dioxide equivalents (MTCO2E). The CAP and BSP report that transportation (30%) and disposal of waste (1%) are significant contributors to the city's overall GHG emissions.

In some cases, benefits are negative (i.e., drawbacks). For example, changes in GHG emissions are reported relative to a baseline, meaning that negative values represent expected emission reductions relative to that baseline while positive values represent expected increases in GHG emissions. For options where this occurs, this represents a drawback rather than a benefit. Similarly, implementation of some options may result in elimination of jobs rather than job creation.

It should be noted that all benefits and drawbacks, including GHG offsets, are conceptual level estimates only and that additional data collection and research is required to obtain more accurate estimates.

Costs

The cost of any waste management and disposal option includes capital costs, operating and maintenance (O&M) costs, wages, and staffing. Cost estimates for each option are based on best estimates and unit prices gathered via Geosyntec's professional experience, online research, and publicly available information. For many options considered, costs may vary widely based on implementation strategies. The costs presented herein are therefore conceptual level estimates only. All cost estimates need to be confirmed via more extensive research and data gathering prior to implementation of any option.

Challenges to Implementation

Potential challenges to implementing any given waste management option include land or infrastructure requirements and the staffing burden and potential training requirements for new or existing staff. Additionally, negative or competing impacts on other waste reduction options are considered.

Experience

The experience category highlights the similarities between the options proposed herein and existing programs run by DPW or other City departments and offices. The similarities highlighted may include educational and outreach programs, inspection programs, incentive programs, billing mechanisms, new staffing requirements and/or overlap with existing positions, and any other potentially useful experience that the City may have with respect to the options presented here. Local/regional experience within the industrial, commercial, and institutional (ICI) sectors is also important.

2.3 Assessment of Options

The remaining chapters of this Report outline the City's solid waste needs, analyze disposal and processing options to meet those needs, and analyze potential scenarios to determine when different options should be considered and constructed. The remaining sections of the report are as follows:

- Chapter 3 – Assess the existing solid waste facilities in and around Baltimore and estimate the city's needs in order to continue providing solid waste disposal in the future;
- Chapter 4 – Identify and analyze potential solid waste processing, transfer, disposal options that could help meet the city's needs;
- Chapter 5 – Scenario analyses to determine when different solid waste transfer and disposal options should be considered and constructed;
- Chapter 6 – Conceptual layout of a waste transfer operation; and
- Chapter 7 – Summary of major findings.

Subsequent to this Report, the Draft and Final Master Plans to be developed in Tasks 8 and 9 of the LWBB project will serve to prioritize options for implementation.

3. REVIEW OF EXISTING FACILITIES

Currently, the City manages residential waste by direct hauling collection vehicles to either the Northwest Transfer Station (NWTS), QRL, or BRESCO. In order to manage what's left following waste diversion from disposal, the City must determine how and where to transport its remaining waste. Commercial haulers face similar questions. Routed collection vehicles can reasonably travel about 15 miles one way from their route to discharge their loads. Longer distances are cost-prohibitive because of labor and equipment inefficiencies. Based on the practical limit of a 15-mile, one-way drive for collection vehicles from their route to their final destination, there are four existing transfer facilities, one WTE facility (BRESCO) and one existing landfill (QRL) that could potentially accept waste from DPW and commercial collection vehicles from Baltimore. Other disposal facilities exist within a three-hour truckshed.

The remainder of this section will discuss existing transfer and disposal facilities that are available for managing what's left.

3.1 Transfer Facilities

Northwest Transfer Station

NWTS is currently operated by DPW as a transfer station to consolidate mixed refuse and single-stream recycling (SSR) loads collected curbside by DPW's load-packer trucks into larger truckloads. It also serves as a drop-off point for the small hauler program and operates a residents' drop-off center. Mixed recyclables are sent from NWTS to the WMRA materials recovery facility while trash is sent to QRL and BRESCO. NWTS has a permitted capacity of 150,000 tons per year; however, in 2017, only about 20,400 tons of recyclables and 45,900 tons of mixed refuse were handled at the facility. One reason for this lower throughput has been the success of the small hauler program at NWTS, which has limited the volume of loadpacker trucks that the site can easily accommodate. Currently the facility is used solely for transfer of recyclables due to a shortage of transfer truck drivers.

Expansion of NWTS is constrained by the location and size of the property and existing infrastructure. In order to process the permitted capacity of 150,000 tons per year, NWTS would have to expand operation to include more shifts and/or longer working hours (which may require a permit amendment from MDE). The small hauler program would also have to be significantly cut back or relocated to another drop-off center. In order to accommodate the small hauler program, any other drop-off center would not only need significant physical changes (i.e., more space, installation of truck scales and a scale house, etc.), it would also need to be permitted by MDE as a transfer station). Extending operating hours at NWTS and relocating the small hauler program are likely to be unpopular with local residents and small haulers.

Western Acceptance Facility

The Western Acceptance Facility (WAF) is a waste transfer station that is owned and operated by Baltimore County, located in Halethorpe just outside the city limits. The facility is permitted to handle 376,626 tons annually (MSW plus single stream recycling and yard waste). In the past, WAF has processed almost 300,000 tons with extended hours of operation; however, current tonnages are significantly lower since Republic Services migrated their commercial MSW tonnage out of WAF. In light of this, Baltimore County has indicated they could potentially process up to 2,500 tons per day at WAF if BRESCO closed, and could offer significant unused throughput capacity to the City to provide short/medium term bridging capacity while the City develops its own transfer options. However, no firm offer has been made and major capital upgrades to WAF would be needed. To significantly increase waste transfer through the facility, WAF would also likely have to expand operation to include more shifts and/or longer working hours.

All waste currently received at WAF is transported off-site via tractor trailers. Similar to NWTS, WAF is constrained by the location and size of the property and the existing infrastructure. However, WAF is near existing freight rail lines and Baltimore County is reportedly exploring the option of extending a rail spur into the facility.

Curtis Creek Recovery Transfer Station

The Curtis Creek Recovery Transfer Station (CCR) is a waste transfer station that is owned and operated by Waste Management, Inc. and is located in Curtis Bay just outside the city limits. The facility manages about 280,000 tons of waste annually. Based on the size of the processing building, additional throughput capacity exists, however, the facility is constrained by a very short entrance driveway that would result in trucks queuing on public roads should substantially more waste be accepted at the facility. This would potentially be unpopular with local residents.

All waste received at CCR is transported off-site via tractor trailers.

Waste Management Quad Avenue Transfer Station

The Quad Avenue Transfer Station is operated by Waste Management, Inc. and is located in the eastern part of the city. This relatively small facility is used for transfer of recyclables only; however, the permitted throughput capacity and average annual tonnages are not known.

All waste received is transported off-site via tractor trailers.

3.2 Waste Disposal Facilities

Quarantine Road Landfill

QRL is the primary City-owned disposal facility for remaining wastes and residues. Based on records maintained by DPW, as of January 2019, QRL had approximately 3.5 million cubic yards (CY) of remaining permitted disposal capacity (of which only 3.0 million CY were considered usable). Current landfill operations consume approximately 315,600 CY per year of the remaining disposal space. As a result, assuming current disposal rates continue, the landfill will run out of disposal space in 2028.

DPW is currently pursuing an expansion of QRL in order to permit additional disposal capacity. If permitted, draft expansion plans as currently envisioned would add another 5.9 million CY of disposal space, bringing the potential total of remaining usable disposal capacity to 8.9 million CY as of the end of 2019. At current disposal rates, this expansion capacity would be fully consumed around 2048.

If the City achieves a high percentage of the MDP from implementing Task 5 reduction/diversion measures, and QRL is used for future disposal of residual waste, it is likely that the facility will be significantly impacted by the changing waste stream. Specifically, landfill gas (LFG) production at QRL will likely diminish and leachate quality will improve as organics are removed from the disposed waste stream. As LFG production decreases, the potential for harnessing that LFG for energy production also decreases. This could have minor cost implications for the facility in the future.

BRESCO Waste-to-Energy Facility

BRESCO is owned and operated by Wheelabrator Technologies, Inc. (Wheelabrator) and manages both residential and commercial waste from Baltimore as well as surrounding counties, in particular Baltimore County. The facility is permitted to process 2,250 tons of waste per day (approximately 750,000 tons per year). In 2017, approximately 156,900 tons of residential waste and 221,700 tons of commercial waste from the city was directed to BRESCO. In the same year, BRESCO managed roughly 330,000 tons of additional out-of-city waste for a total of 708,600 tons processed.

During preparation of this Task 7 Report, Wheelabrator was in litigation with the City regarding the emissions requirements imposed by the BCAA. In order to meet these requirements, BRESCO needed to make significant improvements to its emissions control features. To assess BRESCO's ability to meet the requirements of the BCAA (and other regulations), Geosyntec retained a specialty subconsultant Deltaway Energy, Inc. (Deltaway) to perform a comprehensive review of the facility. Deltaway's WTE expert inspected the facility and provided a summary report of findings in December 2019, which is included as Appendix 2 to this Report. As concluded in Deltaway's report:

1. Assuming Wheelabrator continues to maintain the boilers and plant auxiliary equipment at BRESCO in accordance with historical spending (and projected spending over the next several years), there is no reason why the plant cannot be operated through 2040 from a mechanical perspective.
2. There are significant issues related to the change-in-law provisions that will require Wheelabrator to increase capital spending significantly and quickly. Wheelabrator has already installed or committed the capital improvements needed to meet the new Maryland NOx emission limits effective May 2019 and May 2020. However, Deltaway estimates that Wheelabrator would need to invest in excess of $95 million in additional capital improvements to meet the BCAA emissions limits. These improvements include installing baghouse technology and selective catalytic reduction (SCR) technology. These are long lead time modifications that include complex engineering, permitting, procurement, and installation. Deltaway concluded these modifications may not be achievable by January 2022 if not started quickly.
3. Given the magnitude of the investment required to meet the BCAA, Wheelabrator may not be able to install the new technology without a long-term contract renewal commitment by the City. The minimum contract term that would be requested by Wheelabrator is not known.

As of April 2020, Wheelabrator has successfully challenged the BCAA such that BRESCO may remain in operation as is without complying with the new emission and monitoring standards. In this Report, BRESCO's ongoing operation is considered when analyzing the future disposal options available to the City. If BRESCO voluntarily elects to meet the BCAA requirements (or makes some alternative improvements that are agreeable to the City), it is assumed the facility would remain a reliable disposal option for the City. If not, the City may elect not to renew their disposal contract in December 2021 and will thus seek alternative options for disposal of residential waste. In this case, given the loss of one of their largest customers and loss of their primary ash disposal option (QRL), it is assumed BRESCO may close, ceasing to function as a disposal option for any waste generator in the city. Alternatively, BRESCO will remain in operation by making up for the loss of the City's contract in other ways. In this case, private haulers collecting waste from within city limits would likely continue to dispose of commercial waste at BRESCO. Similarly, out-of-city customers, including public entities such as Baltimore County, would likely continue to utilize BRESCO.

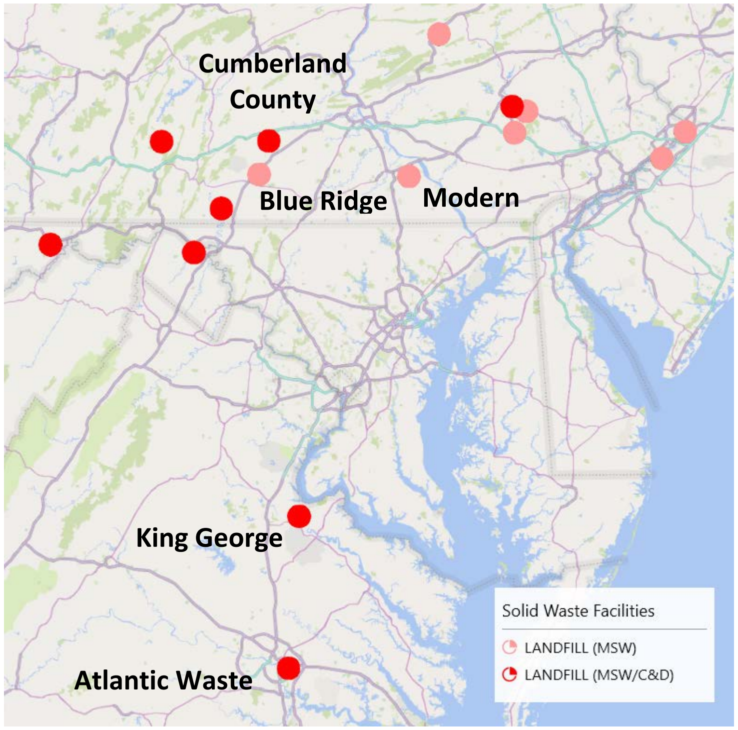
Other Private Landfills

As previously highlighted in the Task 3 Report, there are a number of private landfills within a three-hour truckshed of Baltimore (see map overleaf). All of these facilities are located more than 50 miles from the city, thereby necessitating transfer by rail or tractor trailer.

A brief overview of the regional landfills that have sufficient available capacity to accept waste from Baltimore is provided next. Many of these landfills already serve other Maryland communities. Note that tipping fees at private landfills tend to be negotiated individually with each client (depending on factors such as the daily quantity, composition, and expected variability in the client's waste stream) and are not typically posted publicly like at public landfills.

Atlantic Waste Landfill, Virginia (Waste Management, Inc.)

The Atlantic Waste Landfill in Waverly, VA is a regional landfill that currently receives more than 3,500 tons per day of waste from a large portion of the east coast, include the greater New York City area. In addition to a truck scale, the facility is equipped with rail unloading facilities for intermodal containers and is serviced by Norfolk Southern Rail, a Class 1 rail provider. Based on 2018 records from VDEQ, the facility has more than 70 years of remaining disposal life at current waste receipts.



Private Landfills within a Three-hour Truckshed of the City

Blue Ridge Landfill, Pennsylvania (Waste Connections, Inc.)

The Blue Ridge Landfill in Chambersburg, PA is a regional landfill that currently receives more than 2,500 tons per day of waste from Maryland and Pennsylvania. All waste is received by truck, as rail unloading capacity is not available. Based on 2016 records from PADEP, the facility has approximately four years of permitted disposal capacity remaining at current waste receipts; however, it is assumed that an expansion permit will be granted.

Cumberland County Landfill, Pennsylvania (Advanced Disposal Services, Inc.)

The Cumberland County Landfill in Newburg, PA is a regional landfill that currently receives more than 2,000 tons per day of waste from Maryland and Pennsylvania. All waste is received by truck, as rail unloading capacity is not available. Based on 2016 records from PADEP, the facility has approximately six years of permitted disposal capacity remaining at current waste receipts; however, it is assumed that an expansion permit will be granted.

King George Landfill, Virginia (Waste Management, Inc.)

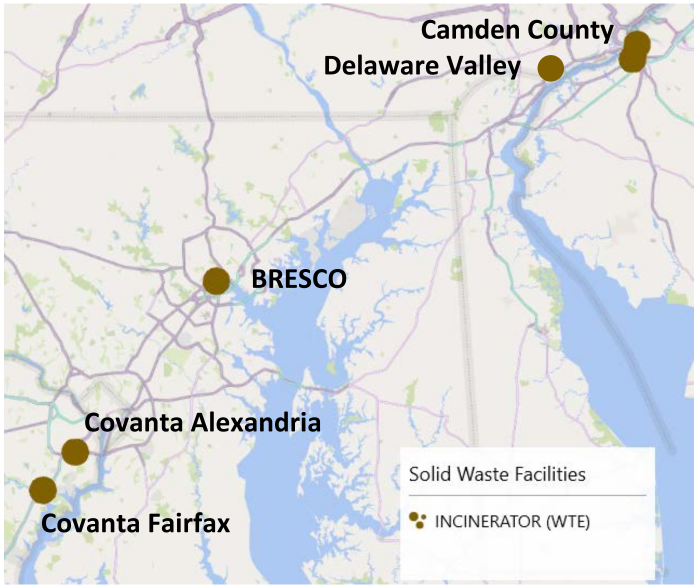
The King George Landfill in King George, VA is a regional landfill that currently receives more than 5,000 tons per day of waste from a number of mid-Atlantic public entities, including Anne Arundel County and Howard County. In addition to a truck scale, the facility is equipped with rail unloading facilities for gondola cars and is serviced by CSX Transportation, a Class 1 rail provider. Based on 2018 records from the Virginia Department of Environmental Quality (VDEQ), the facility has more than 30 years of remaining disposal life at current waste receipts.

Modern Landfill, Pennsylvania (Republic Services, Inc.)

The Modern Landfill in York, PA is a regional landfill that currently receives more than 4,000 tons per day of waste from eastern Pennsylvania, Maryland, and New Jersey. All waste is received by truck, as rail unloading capacity is not available. Based on 2016 records from Pennsylvania Department of Environmental Protection (PADEP), the facility has approximately 10 years of permitted disposal capacity remaining at current waste receipts; however, it is assumed that an expansion permit will be granted.

Other Private Waste-to-Energy Facilities

In addition to landfills, there are a number of private WTE facilities within a three-hour truckshed of Baltimore (see map below). However, all of these facilities are located more than 50 miles from the city and will therefore require transfer by rail or tractor trailer. A brief overview of the WTE facilities identified on the map is provided overleaf.



Private WTE Facilities within a Three-hour Truckshed of the City

Camden County Resource Recovery Facility, New Jersey

The Camden County Resource Recovery Facility in Camden, NJ is owned and operated by Covanta and serves Camden County and southern New Jersey. It was opened in 1991 and has a processing capacity of 1,050 tons of MSW per day.

Covanta Alexandria/Arlington Waste to Energy Facility, Virginia

The Covanta Alexandria/Arlington Waste to Energy Facility in Alexandria, VA is owned by the City of Alexandria and Arlington County but operated by Covanta. It currently serves the City of Alexandria and Arlington County. It began operations in 1990 and has a processing capacity of 3,000 tons of MSW per day.

Covanta Fairfax Incorporated, Virginia

The Covanta Fairfax Incorporated facility in Lorton, VA is owned and operated by Covanta and primarily serves Fairfax County. It began operations in 1990 and has a processing capacity of 3,000 tons of MSW per day.

Delaware Valley Resource Recovery Facility, Pennsylvania

The Delaware Valley Resource Recovery Facility in Chester, PA is owned and operated by Covanta and serves Delaware County and the surrounding area. It was opened in 1992 and has a processing capacity of 3,500 tons of MSW per day.

3.3 Summary and Assessment of Needs

The City currently depends heavily on BRESCO and QRL to dispose of its waste. However, BRESCO may cease to be a feasible waste disposal option from 2022. In this case, the City would have few options except to send its waste to QRL for final disposal, rapidly consuming remaining airspace at the landfill. Commercial haulers would also have to redirect their waste to QRL or other regional facilities.

Few transfer options are currently available to the City, although NWTS does have the capacity to manage a large portion of the City's current waste stream if it can be operated to permitted capacity and if waste can be sent to a regional landfill. Another option would be for the City to buy or contract with a private transfer operation to manage its waste stream (although local facilities are currently operated at or near capacity and service commercial clients in and around Baltimore).

Due to the lack of disposal and transfer options currently available, the City may wish to consider the following options to economically manage waste moving forward:

1. Reduce Waste Volume: Mixed waste processing can be used to sort disposed waste and remove recyclables and organics for further processing.
2. Continued Disposal within the City: This may require contracting with BRESCO over the long term or constructing new disposal capacity in Baltimore (either by further expanding QRL or constructing a new landfill in the City).
3. Disposal of Waste Outside of City: This would require construction of truck, rail, or barge transfer facilities to move waste to one of the regional landfills or WTE facilities located in Virginia, Pennsylvania, or New Jersey. After some consideration, barging was not investigated in detail as a transfer option. There would likely be a lot of pushback against using waterfront property for waste transfer. Also, a key requirement for the transfer operation is for it to be robust to impacts and provide a

reliable means of waste management in the event of a natural disaster, whereas a waterfront facility would be vulnerable to storm impacts and flooding. There are also fewer unloading options with barging compared to rail.

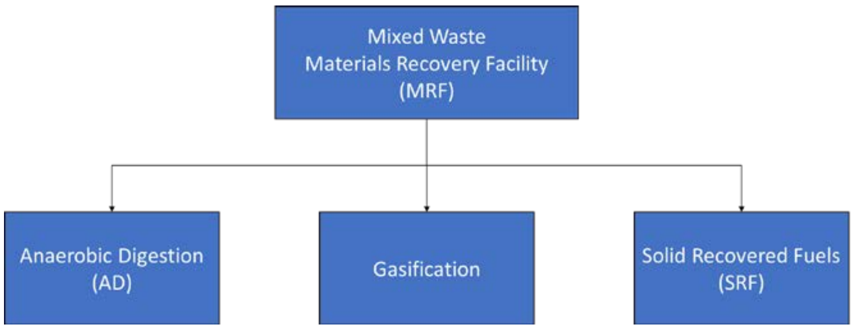
In the next section of this Report, each of these options will be reviewed in detail for their ability to help the City to economically dispose of its waste in the future.

4. ASSESSMENT OF OPTIONS

Long-term waste disposal needs were summarized in Section 3.3. In Chapter 4, the ability of different options to meet these needs is analyzed in terms of costs, benefits, challenges, and timelines.

4.1 Mixed Waste Processing (MWP)

To reduce future disposal needs, the City may consider constructing a mixed waste processing (MWP) facility. MWP facilities are complex operations that employ a multi-stage approach to sort and process the incoming mixed waste stream. A simplified depiction of MWP is shown in the figure below.



Typical Components of Mixed Waste Processing

It is noted that a MWP facility may not include all of these technologies, or may employ different technologies in alternative configurations. However, the main goals of MWP are to generate energy, recover recyclables, create reusable products, and reduce the final quantity of waste that requires disposal.

The first stage of MWP typically involves constructing a materials recovery facility (MRF) to recover recyclables and separate out undesirable materials prior to processing. Unlike the MRFs discussed in the Task 5 Report, which process source separated recyclables and are thus often referred to as "clean MRFs," a MRF at a MWP facility is used to pre-sort the full mixed waste stream. As such, MRFs operated as a component of a MWP facility are often referred to as "dirty MRFs."

After the separation stage, remaining components of the remaining waste stream are sent for processing. Organics, plastics, and other high calorific materials can be converted to energy and base products using gasification or pyrolysis technology or converted to solid recovered fuels (SRF). Although organics can be composted, they are more commonly processed at anaerobic digestion (AD) plants with biogas conversion to energy. MRFs, AD, gasification, and SRF are described more fully later in this section.

Existing MWP Facilities

There are currently no operational facilities in or near Baltimore that are fully capable of processing MSW to remove and divert the recyclable and organic fractions of the waste stream. While there are some facilities that could potentially be used as part of a processing option for source separated organics (e.g., the anaerobic digestors at BRWWTP), there are currently no fully operational processing facilities identified by Geosyntec that could realistically be retooled to handle bulk MSW.

Proposed MWP Facilities

The City has been approached by some potential partners to develop MWP technology in Baltimore. One interesting example is a consortium headed by Trilogy Financial Group, with technology partners Clark

Technology and Evergreen Energy, who have proposed an MWP facility that would comprise a MRF combined with a gasifier or pyrolysis plant (for non-recyclable plastics) and an AD facility (for organics) to process the City's MSW stream. The gasifier and AD facilities would be used to generate energy (as electricity, heat, and/or renewable natural gas), as well as fertilizer and secondary products for reuse in the plastics industry. According to Trilogy, the facility could reduce the final mass of waste requiring disposed by up to 95%, assuming optimal conditions for gasification and AD and the availability of end markets for energy, secondary products, fertilizer, and recovered glass, metals, and recyclable plastics. Trilogy has proposed to self-finance the project if the City provides the land for siting a facility (about 40 acres, preferably at/adjacent to a transfer station), a guaranteed supply of MSW for at least 15 years, and cost-free disposal of all unsalable products generated at the facility. The financial viability of the facility would also be dependent on Trilogy securing commitments to purchase renewable energy from the facility. The consortium has pilot operations in the U.S. and experience with bulk MSW processing in Europe.

Mechanical-Biological Treatment (MBT)

Mechanical-biological treatment (MBT) involves co-locating a mixed waste MRF with an organics processing facility (typically an AD plant) such that organics separated from the disposed waste stream can be processed onsite. MBT is widely employed in Europe (there were 330 operational MBT facilities in the EU in 2012) although the technology is not common in the U.S. One reason may be the ability of AD systems at European MBT facilities to handle mixed waste, whereas AD facilities in the US have typically been used to process relatively clean, often single stream, organics. That is changing, with a number of U.S. technologies now offering mixed waste processing capabilities. A specific MBT technology to consider is the Maximum Yield Technology by ZAK, a German company that successfully operates MBT facilities in France and Germany. ZAK is currently constructing a 300,000 ton/year facility in Bangkok, Thailand.

As MBT represents a combination of other MWP technologies, MBT is not evaluated separately in this Report.

Evaluation of MWP Technologies

In the remainder of Section 4.1, the separate technologies that may comprise a MWP facility are evaluated sequentially in the context of their development to process the City's residential waste stream. A MWP facility could be constructed and operated by the City or through a public-private partnership (PPP) with a private entity (as proposed by Trilogy). Construction of MWP capacity would allow the City to continue to leverage existing disposal options in the long-term (i.e., QRL and/or BRESCO). It may also help the City to minimize the use of QRL and preserve airspace in the case that BRESCO ceases operation.

For the analyses presented herein, it is assumed that only residential MSW (i.e., the portion of the waste stream collected and handled by DPW) would be processed. However, if Task 5 reduction/diversion programs are successful at achieving a large fraction of the maximum diversion potential (MDP), the size of the waste stream for disposal will reduce over time, with the result that the MWP facility may have significant excess capacity in the medium to long term. In this case, the City may elect to open the facility to commercial customers at some point in the future to utilize redundant capacity.

Materials Recovery Facility (MRF)

For this analysis, it is assumed that a MRF would be constructed as part of any MWP facility developed in the city, with the aim of recovering traditional recyclables and separating out organics from the residual waste stream for further processing.

Timeline

It is assumed that approval, land acquisition, design/permitting, and construction of the MRF could be fast-tracked such that it could begin operation within five years (this expedited schedule reflects the urgency of potentially responding to non-availability of BRESCO from 2022). As such, for this analysis it is anticipated that the MRF could be operational by 2025 and would remain in service from 2025 through 2040 and beyond.

Processing Requirements

The estimated capacity, costs, and benefits of the MRF were evaluated under the following assumptions:

1. Feedstock: The MRF would need to process 100% of all residential MSW collected in Baltimore between 2025 and 2040.
2. Capacity: The capacity of the MRF was estimated to be 120% of the maximum annual feedstock to provide contingent capacity and account for fluctuations in the waste stream.
3. Expected Recovery: It is expected that the MRF will be capable of recovering 50% of the traditional recyclables and 50% of the organics in the incoming feedstock.
4. Variable MDP Attainment: The expected throughput, costs, and benefits of the MRF were estimated assuming the City is able to attain 100%, 50%, and 0% of the MDP.

The required capacity of the MRF under these assumptions is summarized in the table below.

Required Capacity of MRF as a Percentage of the MDP (0% represents Status Quo)

MDP Attainment	Maximum Incoming Waste (tons/year)	Design Capacity (tons/year)	Maximum Expected Recovery (tons/year)	Maximum Residual Waste for Disposal (tons/year)
100%	233,000	279,600	82,000	151,000
50%	257,000	308,400	93,400	163,600
0%	311,000	373,200	116,000	195,000

Estimated Costs

The capital expenditure (CAPEX) and operating expenses (OPEX) for constructing and operating a MRF were calculated using the following assumptions:

1. Estimated CAPEX of $200 per ton of capacity: This value is based on recently constructed MRF in San Leandro, CA. The facility was built to separate traditional recyclables and organics from a mixed waste stream with a capacity of 100 tons per hour and a total CAPEX of $120 million.

2. Estimated operating costs of $75 per ton of incoming waste: This value was chosen based on Geosyntec experience with other recent projects.
3. Estimated disposal costs of $67.50 per ton for residuals, based on the current tip fee at QRL.

The estimated costs for the MRF facility assuming variable attainment of the MDP are summarized in the table below.

Estimated Cost of MRF as a Percentage of the MDP

MDP Attainment	CAPEX	Annual OPEX
100%	$ 55,900,000	$ 27,700,000
50%	$ 61,700,000	$ 30,300,000
0%	$ 74,700,000	$ 36,500,000

Potential Benefits

The benefits of constructing a MRF include job creation, direct revenue from the sale of recyclables, and GHG emissions reductions (as a component of a MWP facility in comparison to landfilling and WTE). Job creation and direct revenue associated with operation of a MRF were calculated using the following assumptions:

1. Expected recovery rate of 50% for traditional recyclables;
2. A rejection rate of 15% for traditional recyclables;
3. A unit commodity price of $26 per ton for traditional recyclables; and
4. An employment rate of 0.03 people per ton per day processed at the facility with one additional supervisor.

The landfill disposal airspace savings were calculated as the cumulative tonnages of traditional recyclables diverted from disposal between 2025 and 2040. GHG reductions were calculated by comparing with an "all landfill" baseline condition. The estimated benefits of the MRF are summarized in the table below assuming variable attainment of the MDP.

Estimated Benefits of MRF as a Percentage of the MDP

MDP Attainment	Annual Gross Revenue	Job Creation	GHG Reduction (MTCO2E)	Airspace Savings (tons)
100%	$ 900,000	28	-1,000,000	340,300
50%	$ 1,100,000	31	-1,747,000	594,400
0%	$ 1,500,000	37	-2,415,000	848,600

Challenges to Implementation

The major challenges associated with constructing a mixed waste MRF are summarized below:

1. Land acquisition: It is estimated that the facility would require as much as 25 acres of land. It may be difficult to acquire a contiguous 25-acre parcel in or around Baltimore.
2. Public perception and opposition: Mixed waste MRFs are generally not well received by environmentalists and zero waste advocacy groups. It is likely that the City would face significant public opposition if it chose to move to mixed waste processing.
3. Public antipathy toward recycling: Mixed waste MRFs do not encourage consumers to think about recycling, waste reduction, or composting. This could have negative impacts on the City's upstream diversion efforts detailed in the Task 5 Report.

4. Contamination: Based on historical performance data from U.S.-based facilities, mixed waste MRFs tend to be very inefficient at separating and removing recyclables and organics. Recyclables that end up in disposal tend to become contaminated with food scraps and other degradable waste. Also, processing of organics separated at a mixed waste MRF can be problematic because high levels of inorganic contaminants can affect the composting/digestion process and residues in the finished compost (e.g., glass chips, plastic shreds, etc.) prevent it from being marketable. It is noted, however, that new generation technology used in Europe has reportedly overcome many of these issues.
5. Upstream diversion efforts: Since this process is expected to be performed while upstream diversion efforts (detailed in the Task 5 Report) are being implemented, the expected volume of targeted recyclables and organics in the disposed waste stream is expected to diminish over time. This could lead to overdesign and underperformance issues.

Experience

The City has very little experience with MRFs or similar facilities. There are also no other operating mixed waste MRFs in the Baltimore region. This lack of local experience may make it difficult to operate a mixed waste MRF efficiently.

Anaerobic Digestion (AD)

For this analysis, it is assumed that a mixed waste MRF and an AD facility would be co-located to remove and process organic material from the disposed waste stream. Details regarding the costs, benefits and challenges associated with a mixed waste MRF are given above, so this discussion will focus on the construction and operation of an AD facility.

A good example of an AD technology that may be applicable to Baltimore was developed by a Belgian company, OWS. The technology provided by OWS combines a MRF to concentrate the organic fraction of MSW followed by a dual-stage AD process with dry digestion followed by wet separation of the digestate. Products are energy (biomethane) and compost, with recovery of recyclables. Based in Belgium, OWS has operating facilities processing mixed MSW at several sites in Europe.

Timeline

For this analysis, it is again assumed that approval, land acquisition, permitting, and construction of the AD facility could be fast-tracked such that the facility could be operable within five years (i.e. by 2025). It is anticipated that the AD facility would operate through 2040 and beyond.

Processing Requirements

For this analysis, the waste stream of interest is the organic fraction of the residential waste stream recovered at the MRF. To estimate the mass of organic material to be processed at the AD facility, the following assumptions were made:

1. Feedstock: The AD facility would process 100% of organic material recovered from the MRF between 2025 and 2040.
2. Capacity: The capacity of the AD facility would be 120% of the expected maximum annual tonnage of separated organics between 2025 and 2040 to provide contingent capacity and account for fluctuations in the waste stream.

3. Estimated Recovery: It is estimated that contamination would represent 20% of the incoming organics mass (Cecchi et al., 2011) and residual biosolids would represent 30% of incoming organics mass (NREL, 2013), meaning that 50% of the mass of incoming organics could be recovered for energy production.
4. Variable MDP Attainment: The expected throughput, costs, and benefits of the AD facility were estimated assuming the City is able to attain 100%, 50%, and 0% of the MDP.

The required capacity of the AD facility is summarized in the table below.

Required Capacity of AD Facility as a Percentage of the MDP

MDP Attainment	Maximum Organics from MRF (tons/year)	Design Capacity (tons/year)	Maximum Expected Recovery (tons/year)	Maximum Residual Waste for Disposal (tons/year)
100%	41,700	50,000	20,900	20,800
50%	43,600	52,300	21,800	21,800
0%	50,400	60,500	25,300	25,200

Estimated Costs and Revenues

The costs of constructing and operating an AD facility were estimated using the following assumptions:

1. Unit CAPEX would be $600 per annual ton of capacity (NREL, 2013).
2. Unit OPEX would be $70 per ton of annual throughput (Olivard, 2017).
3. Inorganic contamination would represent 20% of incoming organics mass (Cecchi et al., 2011) and residual digestate (non-digestible organics) would represent 30% of incoming organics mass (NREL, 2013). While digestate can sometimes be composted and sold as a soil amendment, for this analysis it is assumed that both contaminants and digestate would need to be landfilled at a cost of $67.50 per ton, the current tip fee at QRL.

The estimated CAPEX and OPEX for an AD facility assuming variable attainment of the MDP are summarized in the table below.

Estimated Cost of AD facility as a Percentage of the MDP

MDP Attainment	CAPEX	Annual OPEX
100%	$ 30,015,000	$ 4,325,000
50%	$ 31,395,000	$ 4,524,000
0%	$ 36,271,000	$ 5,227,000

Potential Benefits

The benefits of constructing an AD facility include job creation, direct revenue from the sale of electricity (produced from biogas), GHG emissions reductions, and landfill disposal airspace savings. Job creation and direct revenue associated with operation of an AD facility were calculated using the following assumptions:

1. Energy production would be 220 kWh per ton of incoming material (NREL, 2013).
2. The price of electricity generated would be $0.05 per kWh generated, a conservative estimate assumed to be about twice

the current wholesale price in the Mid-Atlantic (PJM West) market (EIA, 2020) to account for renewable energy credits. It is noted that electricity pricing is highly variable and difficult to predict accurately; therefore, assessment of long-term financial performance of an AD facility needs to be cognizant of pricing risks.

3. Personnel requirements at an AD facility would include one full time supervisor and 0.1 workers per ton of organics processed per day (Olivard, 2017), from which it is estimated that a total of 16 workers would be needed for an AD facility with a capacity of 140 tons per day).

Landfill disposal airspace savings were calculated as the cumulative tonnage of organic waste diverted from disposal between 2025 and 2040. GHG reductions were calculated assuming AD as a component of a MWP facility by comparing with an "all landfill" baseline condition. The estimated benefits for the AD facility are summarized in the table below assuming variable attainment of the MDP.

Estimated Benefits of AD Facility as a Percentage of the MDP

MDP Attainment	Annual Gross Revenue from Energy Sales	Job Creation	GHG Reduction (MTCO2E)	Airspace Savings (tons)
100%	$ 458,600	15	-43,000	155,900
50%	$ 479,600	16	-74,000	269,600
0%	$ 554,100	18	-105,000	383,300

Challenges to Implementation

The major challenges associated with constructing an AD facility in the City are summarized below:

1. Land acquisition: It is estimated that a MWP facility with an AD facility would require as much as 40 acres of land (25 for MRF and 15 for AD). It may be difficult to acquire a contiguous 40-acre parcel.
2. Contamination: Mixed waste MRFs tend not to be very efficient at separating organics from the disposed waste stream. Processing of organics separated at a mixed waste MRF can thus be problematic because high levels of inorganic contaminants can affect the digestion process and residues in the finished compost product (e.g., glass chips, plastic shreds, etc.) prevent it from being marketable.
3. Upstream diversion efforts: Since the AD facility is expected to be constructed while upstream diversion efforts (detailed in the Task 5 Report) are being implemented, the expected volume of organics in the disposed waste stream is expected to diminish over time. This could lead to overdesign and/or underperformance of the AD facility.

Experience

DPW operates an AD facility at the Back River Wastewater Treatment Plant (BRWWTP); however, the City does not currently operate any MSW-based AD facilities. This lack of experience may make it difficult for the City to operate an AD facility efficiently.

Gasification

Gasification is a process whereby carbon-rich organics (both biogenic and fossil-based materials) are converted into syngas (a mixture of carbon monoxide, carbon dioxide, and hydrogen) by reacting the material at high temperatures without combustion. The resulting syngas can then be combusted and used to generate electricity. In this analysis, the targeted fraction of the mixed waste includes organics (food scraps and yard waste), mixed plastics with no/little recycle value, and mixed paper and cardboard. Gasification requires pre-sorting of MSW (either source separation via a curbside organics collection program or post-collection at a mixed waste MRF) to provide feedstock. In the context of this analysis, however, gasification is considered as a technology to process the above waste components following separation at a MRF.

Geosyntec is not aware of any commercial scale MSW gasification project currently in operation in the U.S. It is not a mature technology and thus analyses presented in this section are based on extrapolation from pilot projects that may not be scalable or projects currently under construction (which are unproven). This adds an extra dimension of uncertainty to the findings discussed here. Of the projects analyzed, the Sierra BioFuels Plant, currently under construction near Reno, NV and owned by Fulcrum BioEnergy, is the nearest to completion (it is expected to be fully operable in 2020). Cost data from this project will thus be used to benchmark this section. The project uses gasifier technology developed by a Baltimore-based company ThermoChem Recovery International (TRI).

Timeline

For this analysis, similar to AD technology it is assumed that approval, land acquisition, permitting, and construction of the gasifier could be fast-tracked such that the facility could be operable within five years (i.e. by 2025). It is anticipated that the facility would operate through 2040 and beyond. It is assumed the gasifier would be co-located with the MRF.

Processing Requirements

For this analysis, the waste stream of interest is the organics, mixed plastics, and mixed paper and cardboard in residential MSW. To estimate the mass of targeted material to be processed at the gasifier, it was assumed that 50% of targeted materials could be recovered at the MRF. The capacity of the facility was estimated to be 120% of the expected maximum annual feedstock tonnage between 2025 and 2040 to account for fluctuations in the waste stream.

The expected throughput, costs, and benefits of the gasifier were estimated assuming the City is able to attain 100%, 50%, and 0% of the MDP as summarized in the table below.

Required Capacity of Gasifier as a Percentage of the MDP

MDP Attainment	Maximum Input from MRF (tons/year)	Design Capacity (tons/year)	Maximum Expected Recovery (tons/year)	Maximum Residual Waste for Disposal (tons/year)
100%	67,200	80,600	32,500	9,200
50%	72,900	87,500	34,000	9,600
0%	87,000	104,400	39,300	11,100

Estimated Costs

The costs of constructing and operating a gasifier were estimated using the following assumptions:

1. 78% of the mass of incoming materials would be converted to syngas. The remainder would be rejected upon initial screening at the gasifier (20%) or would be converted to char (2%) (Vakalis et al. 2014).
2. Syngas density of 6.8 pounds per gallon (based on jet fuel density)
3. CAPEX of $14 per gallon of syngas generation capacity. This was estimated using the capacity at the Sierra Biofuels Plant (10.5 million gallons) and an estimated CAPEX for the gasifier of $145 million (the total CAPEX for the Sierra Biofuels Plant is $180 million but this includes the associated MRF, which is estimated to cost $35 million using a $200 per ton unit CAPEX and a throughput of 175,000 tons per year).
4. OPEX of $0.75 per gallon of syngas generated (Lane, 2012).
5. Disposal costs of $67.50 per ton of residual (includes 20% rejected material and 2% char) based on the current tip fee at QRL.

A summary of the expected costs associated with constructing and operating a gasifier assuming variable attainment of the MDP is shown in the table opposite.

Estimated Cost of Gasifier as a Percentage of the MDP

MDP Attainment	CAPEX	Annual OPEX
100%	$ 255,486,000	$ 12,561,000
50%	$ 277,116,000	$ 13,624,000
0%	$ 330,623,000	$ 16,255,000

Estimated Benefits

The benefits of constructing a gasifier include job creation, direct revenue from the sale of syngas, GHG emissions reductions, and landfill disposal airspace savings. Job creation and direct revenue associated with operation of a gasifier were calculated using the following assumptions:

1. Syngas sale price of $1.40 per gallon (based on the 50-day moving average price of ethanol through December 2021).
2. Employment of 0.0019 people per cubic yard of syngas produced. This value was estimated based on an estimated 98 permanent employees at the gasifier at the Sierra Biofuels Plant (permanent employment is reported as 120 people, but it is estimated that 22 of these people are employed at the co-located MRF assuming one supervisor and 0.03 people per ton per day).

Airspace savings were calculated as the cumulative organic waste diversion between 2025 and 2040. GHG reductions were calculated by comparing with an "all landfill" baseline condition. The estimated benefits for the gasifier are summarized in the table overleaf assuming variable attainment of the MDP.

Estimated Benefits of Gasifier as a Percentage of the MDP

MDP Attainment	Annual Gross Revenue	Job Creation	GHG Reduction (MTCO2E)	Airspace Savings (tons)
100%	$ 21,893,000	144	-67,000	491,300
50%	$ 23,746,000	156	-115,000	761,800
0%	$ 28,331,000	186	-164,000	1,032,200

Challenges to Implementation

The major challenges associated with constructing a gasifier in Baltimore are summarized below:

1. Land acquisition: It is estimated that a MWP facility using a gasifier would require as much as 35 acres of land (25 for MRF and 10 for gasifier). It may be difficult to acquire a continuous 35-acre parcel in the Baltimore area.
2. Upstream diversion efforts: Since the gasifier is expected to be constructed while upstream diversion efforts (detailed in the Task 5 Report) are being implemented, the expected volume of targeted materials in the disposed waste stream is expected to diminish over time. This could lead to overdesign or performance issues with the gasifier.
3. Permitting and acceptance: Gasification is an emerging and untested technology for waste processing in the U.S. As such, it may be difficult to permit and build such a facility. Further, government agencies and the public may be skeptical of the benefits of gasification.

Experience

As stated previously, gasification is a relatively new and untested technology in the U.S. As such, there are very few working examples from which the City could draw inspiration or seek advice.

Solid Recovered Fuels (SRF)

SRF involves recovering the combustible fraction of the residual waste stream (e.g. cardboard, paper, plastics, wood, organics, etc.), shredding it, and pelletizing it to create a substitute for other fuels such as coal. This technology inherently requires a MRF in order to segregate the combustible fraction of the waste stream.

SRF is commonly used in Europe but is relatively new to the U.S. In March 2019, Entsorga West Virginia opened its first facility in Martinsburg, WV that converts biomass, plastic, and other carbon-based materials into SRF for use as a replacement for coal at a local cement plant (note that Entsorga refers to this facility as an MBT facility, but it is not referred to as such in this Report because it functions as an SRF facility). Another recently constructed SRF facility was opened by RePower South in South Carolina in April 2019. SRF material from this facility is sold to industry, cement kilns, and utility companies to replace coal. In addition to these two facilities, other U.S.-based companies, such as National Energy and Accordant Energy, market SRF technology in the U.S.

Timeline

For this analysis, it is assumed that the SRF processing facility would be constructed at the same time as other components of the MRF, which would be co-located. As such, it is anticipated that the SRF processing facility could be fully operable by 2025 and would operate through 2040 and beyond.

Processing Requirements

In this analysis, SRF technology is analyzed as an alternative to landfilling the material that is rejected from the other components of the MWP facility (i.e., combustible materials screened out at the MRF plus those rejected at either the AD facility or gasifier) as well as carpets, textiles, and other combustible waste items collected at residents' drop-off centers. The amount of material available for SRF processing was estimated using the following assumptions:

1. 90% of disposed residential bulky waste and carpet can be captured for SRF processing. The majority of this material is processed at residential drop-off centers, making it easy to segregate.
2. 15% of traditional recyclables recovered at the MRF are rejected and sent for SRF processing.
3. 20% of the material sent for AD or gasification is rejected and sent for SRF processing.
4. The capacity of the facility would be 120% of the expected maximum annual feedstock tonnage between 2025 and 2040 to account for fluctuations in the waste stream.

Under these assumptions, the amount of material available for SRF processing, assuming varying attainment of the MDP, is shown in the table opposite.

Required SRF Processing Capacity as a Percentage of the MDP

MDP Attainment	Maximum Expected Throughput (tons/year)	Design Capacity (tons/year)
100%	14,400	17,300
50%	17,400	20,900
0%	22,400	26,900

Estimated Costs

The costs of constructing and operating an SRF processing facility were estimated using the following assumptions:

1. SRF processing machinery and equipment would be placed inside of the MWP facility, so no additional land acquisition would be required to process SRF material.
2. CAPEX would be $200 per ton of material processing capacity. This value was selected based on the total cost of the Entsorga West Virginia facility ($33 million), the assumed cost for MRF facility at Entsorga (estimated as $22 million using $200 per ton per year and 110,000 tons per year capacity), and the mass of SRF generated (55,000 tons per year).
3. OPEX would be $75 per ton (this was assumed to be similar to the operating costs for the MRF).

Under these assumptions, the cost of SRF processing was estimated assuming variable attainment of the MDP as shown in the table overleaf.

Estimated Cost of SRF Processing as a Percentage of the MDP

MDP Attainment	CAPEX	Annual OPEX
100%	$ 3,458,000	$ 1,080,000
50%	$ 4,183,000	$ 1,307,000
0%	$ 5,370,000	$ 1,678,000

Estimated Benefits

The benefits of constructing an SRF facility include job creation, direct revenue from the sale of SRF, GHG emissions reductions, and landfill disposal airspace savings. Job creation and direct revenue associated with operation of a gasifier were calculated using the following assumptions:

1. Labor requirements of 0.03 people per ton of material processed annually (Dubanowitz 2000).
2. SRF material can be sold for $20 per ton (Dondur et al. 2015).

Airspace savings were calculated by calculating the cumulative expected diversion to the SRF facility from 2025 through 2040. GHG reductions were calculated by comparing with an "all landfill" baseline condition. Under these assumptions, the estimated benefits of SRF processing are summarized in the table opposite assuming variable attainment of the MDP.

Challenges to Implementation

The primary drawback of SRF technology is that fuel purchasers typically have specified windows for energy content and moisture that are difficult to meet. This is because the energy content of the SRF is dependent upon the moisture content and types of materials that are recovered, which can vary widely. In the past 10 years, there have been multiple failed attempts to develop SRF plants in the U.S. using MSW as feedstock and there are currently a handful still in development. Additionally, no facility in the United States has a proven record of commercial success, likely due to several challenges, including lower throughput efficiency than anticipated, inability to consistently meet minimum fuel specifications for prospective purchasers of SRF, lack of market for recovered recyclables, and lack of long-term markets for the SRF. As a result, SRF technology has not been considered further in this Report, since it is considered too speculative for planning purposes.

Experience

DPW has no experience with SRF. As stated previously, no SRF plants have been successful long-term in the U.S. As such, this technology will not be considered further in this Report.

Estimated Benefits of SRF processing as a Percentage of the MDP

MDP Attainment	Annual Gross Revenue	Job Creation	GHG Reduction (MTCO2E)	Airspace Savings (tons)
100%	$ 288,000	2	-61,000	122,700
50%	$ 349,000	3	-116,000	231,600
0%	$ 447,000	3	-170,000	340,400

4.2 Continued Disposal within the City

As a more practical and cost-effective alternative to constructing mixed waste processing capacity, the City may consider leveraging in-city disposal options to meet future disposal needs. Current disposal options available include BRESCO and QRL.

BRESCO

In 2017, BRESCO handled approximately 156,900 tons of residential waste (approximately 49% of the disposed residential waste stream) and 221,700 tons of commercial waste (approximately 44% of the disposed commercial waste stream).

To review the viability of continued use of BRESCO, Geosyntec retained Deltaway to perform a review of the facility and, specifically, its ability to meet emission limits under the BCAA (see discussion in Section 3.2 and Deltaway Report in Appendix 2). Wheelabrator would need to invest in excess of $95 million in capital improvements to meet the BCAA emission limits. In this analysis, it is assumed that BRESCO makes this investment such that the City continues to contract with Wheelabrator for disposal of residential MSW. Conditions under which BRESCO does not make this investment are discussed in terms of their impact on operations at QRL in the next subsection.

Timeline

Notwithstanding Deltaway's opinion that Wheelabrator would likely need to secure a long-term contract with the City prior to making substantial capital investments, for this analysis, short-term (five year), medium-term (ten year), and long-term (20 year) contract extensions were all assessed. This helps understand the impact on unit pricing (i.e., the tip fee at BRESCO) that the City should expect under different contract terms. All contract extensions are assumed to begin in 2022, as the City's current contract with BRESCO expires in December 2021.

Costs

It is assumed that Wheelabrator would pass on the cost of the capital investments at BRESCO (approximately $95 million) to the City and its other customers by increasing its tip fee. For simplicity, it is assumed the fee increase to all customers would be amortized over the period of the contract extension signed by the City. This is reasonable given that the City is one of BRESCO's largest customers. The approximate yearly cost to be passed on to customers of BRESCO, as well as the approximate per ton cost assuming that the BRESCO continues to process roughly 700,000 tons per year is shown in the table below.

BRESCO Annualized Capital Improvement Cost

Contract Period (years)	Annualized Cost of Capital Improvements	Annualized Cost per ton ($/ton)
5	$ 19,000,000	$27
10	$ 9,500,000	$14
20	$ 4,750,000	$7

According to the existing contract between the City and BRESCO, the tip fee is expected to rise to $57 per ton by 2021. However, between 2012 and 2017, the City actually paid an effective tip fee to BRESCO of $47 per ton on average. Nonetheless, it is reasonable to assume that the BRESCO tip fee would start at $57 per ton in 2022. Adding the base tip fee of $57 per ton to the annualized cost per ton for capital improvements, the expected future tip fee is calculated in the table below for 5-year, 10-year, and 2-year contract periods.

BRESCO Expected Tip Fee

Contract Period (years)	Expected Tip Fee ($/ton)
5	$84
10	$71
20	$64

Benefits

The financial benefits to the City of continuing to contract with BRESCO include revenues, airspace savings at QRL, electricity (sold to the City at negotiated rates), and steam used to heat some downtown businesses and City offices. Changes in GHG emissions were not quantified for this option because this option represents a continuation of the current method for waste disposal in the city (i.e. BRESCO is already used to dispose of much of the city's waste)

Revenues include the tip fees for disposal of BRESCO ash at QRL (approximately $19 per ton of ash disposed at QRL between 2012 and 2017) as well as Host fees currently paid by BRESCO to the City (i.e., community fee and city surcharge, approximately $15 per ton of waste disposed at BRESCO between 2012 and 2017). BRESCO also pays property taxes and site lease payments to the City, but these were not considered as revenue for this analysis. In 2017, revenues totaled approximately $4,100,000. Over the period 2012 through 2017, BRESCO payments to the City averaged $34 per ton of residential waste disposed at the facility. If the City continues to contract with BRESCO, it is expected that these revenues will continue at the average rate of $34 per ton.

Airspace savings were calculated as the cumulative waste disposed at BRESCO (assumed to be 150,000 tons per year per the City's current contract) over a 5-, 10-, and 20-year contract as shown in the table below. This represents waste that will not be disposed at QRL over the same period (minus a small portion that will be landfilled as ash) but does not account for commercial waste.

BRESCO Expected Airspace Savings

Contract Period (years)	Expected Airspace Savings (tons)
5	750,000
10	1,500,000
20	3,000,000

Challenges

Some of the challenges associated with continued disposal at BRESCO include:

1. Public opposition: BRESCO has been the target of numerous public campaigns from residents and other stakeholders who feel that BRESCO is not only an eyesore for the city (its location next to I-95 makes it highly visible to visitors) but also a public health hazard due to air emissions. BRESCO also faces environmental justice objections as these air emissions are seen as impacting predominantly low income and minority neighborhoods. Such opposition may persist even if Wheelabrator were to implement the emissions control systems needed to comply with the BCAA.

2. Age: BRESCO was constructed in 1985 and is nearing 35 years of age. Although Deltaway reported that the facility is well managed and maintained and could reasonably operate through 2040, BRESCO is an older facility that will likely require increasingly frequent and expensive maintenance and repair as it ages.
3. Contract uncertainty: Notwithstanding that Wheelabrator has won its lawsuit such that BRESCO can continue operation without meeting the BCAA emission limits, the City may nonetheless end its contract with BRESCO in December 2021 and find an alternative option for residential MSW disposal. Assuming BRESCO remains operational, the commercial sector would likely continue use of BRESCO. However, if Wheelabrator loses the City's contract, they may choose to cease operations at BRESCO. The City's willingness to sign a long-term contract may also factor into Wheelabrator's risk-benefit assessment for investing heavily in installing additional emission controls.

Experience

The City has established experience with this option as it has been sending waste to BRESCO since its construction in 1985. This represents the "status quo" option for waste disposal.

Quarantine Road Landfill

In 2017, the City disposed of approximately 149,600 tons of residential waste (approximately 47% of the disposed residential waste stream), 2,300 tons of commercial waste (approximately 0.5% of the disposed commercial waste stream), and 140,300 tons of BRESCO ash at QRL. Additionally, the City beneficially used roughly 189,400 tons of soil as approved cover material at QRL and recycled 3,500 tons of asphaltic concrete.

As discussed in Section 3, the remaining permitted capacity at QRL as of January 2019 was 3.45 million CY. Under the proposed lateral expansion over the adjacent Millennium Landfill, the capacity would increase to 8.9 million CY. For future development of QRL, it is recommended to maintain significant residual capacity in the landfill for two reasons: leverage when negotiating contracts with private disposal facilities, and contingency capacity for disaster debris management. The U.S. Environmental Protection Agency reports that major hurricanes have resulted in significant generation of disaster debris (5 million CY after Hurricane Iniki in 1992, 2 million CY following Hurricane Hugo in 1989). As such, it is recommended to maintain approximately 4 million CY of capacity at QRL in case of a natural disaster.

In this section, multiple options for the continued future use of QRL are considered, including status quo operation of QRL (including under the proposed lateral expansion, design and permitting of which is well advanced), a further vertical expansion of QRL, privatization of the landfill, landfill mining, and landfill rapid filling.

Options and Strategies

Continued Operation of QRL

Continued operation of QRL would involve accepting all residential waste not sent to BRESCO as well as ash from BRESCO (the quantity of commercial waste that currently makes its way to QRL is negligible). The landfill would be filled to final permitted grades. In 2017, this resulted in the landfilling of approximately 481,600 tons, which occupied approximately 370,500 CY of airspace (including soil used as daily and intermediate cover). However, the size of the disposed waste mass at QRL has the potential to change depending on the fate of BRESCO and the City's attainment of the MDP. Three outcomes are considered:

1. City renews contract with BRESCO: If BRESCO invests in BCAA-compliant emission controls, or makes other improvements to the satisfaction of the City, it is assumed the City will renew their contract to send residential MSW to BRESCO after December 2021. In this case, the current system does not change significantly beyond 2022, with QRL continuing to accept roughly half of the residential waste stream as well as ash from BRESCO and a negligible quantity of the City's commercial waste.
2. City does not renew contract with BRESCO: Under this outcome, it is assumed contract renewal terms between the City and BRESCO cannot be agreed. The City will initially send all of residential MSW to QRL (commercial waste is expected to continue to go primarily to BRESCO). In this case, the City would not accept BRESCO ash or commercial waste at QRL.
3. BRESCO ceases operations: If BRESCO closes in 2022, the City will be forced to send all of its waste to QRL (at least in the short term). In this case, the commercial sector will also need to find new disposal options and may turn to QRL for final disposal.

It is assumed that DPW would continue to operate QRL directly; however, a PPP contract in which a private company or a state agency such as MES takes over operation could be considered.

Vertical Expansion of QRL

This option would involve the construction of a mechanically stabilized earth (MSE) wall along the perimeter of the existing QRL to allow additional vertical landfill capacity. Based upon existing geotechnical information, an MSE wall could be constructed with a base width of 40 feet and some waste relocation from the landfill perimeter to another area of the landfill. However, additional geotechnical investigation and evaluation would be required to confirm the suitability of this approach and the associated design details and construction costs. Overall, Geosyntec understands that a vertical expansion of QRL is not considered to be feasible by DPW at this point and thus is not considered further in this Report. The City could conduct a feasibility study in the future if this option is needed after the horizontal expansion is fully utilized.

Privatization of QRL

Privatization of QRL would involve sale of QRL to a private waste disposal company such as Waste Management or Republic Services. This could be considered in order for the City to gain immediate revenue for exploring other long-term waste management options. However, this option is inadvisable because private companies generally seek to fill landfills as quickly as possible (likely with predominantly commercial waste). If this were to occur at QRL, it would leave the City with fewer disposal options in the future. It is recognized that a privatization contract could include provisions to limit annual tonnages and/or preserve airspace for the City at a set (discounted) tipping fee with appropriate penalties for failing to meet agreed performance metrics. Overall, however, keeping QRL in the possession of the City provides more leverage in negotiating tip fees with BRESCO or other private disposal entities. As such, privatization is not considered further in this Report.

Landfill Mining at QRL

Landfill mining would involve the excavation of waste at QRL and the processing of that waste onsite to recover recyclables. This option would reclaim disposal airspace while potentially providing the City with a revenue stream from the sale of recyclables.

While it may have some benefits, landfill mining at QRL is considered inadvisable, as the process has had little economic success. While multiple pilot tests of this technology have been conducted, and the technology itself was deemed feasible, few full scale landfill mining operations have ever been attempted in the U.S. due to poor economic returns (Karidis 2019). As such, this technology is not considered feasible for QRL and is not considered further in this Report.

Rapid Filling at QRL

Rapid filling at QRL has been tentatively considered as a way for the City to generate revenue quickly (via tip fees) to pay for the various diversion options discussed in the Task 5 Report. However, this option would leave the City with limited future disposal capacity and leave the City dependent on private waste disposal facilities. This option would also make it more difficult to negotiate competitive rates with private disposal companies. As such, this option is not considered further.

Disposal Potential

This analysis assumes continued operation of QRL by DPW as the most feasible option considered above. The expected annual waste tonnage sent to QRL under this option is included in Appendix 1. Under this option, there are three different scenarios which were used to determine the future tonnage of waste to be disposed at QRL.

Scenario 1: City Renews Contract with BRESCO

Under this scenario, it is assumed that the City continues to contract with BRESCO and send 150,000 tons per year of residential MSW to BRESCO each year (pursuant to their current contract terms) with the remainder of residential MSW disposed at QRL. Using the current soil utilization rate at QRL (approximately 40% soil by mass), the current ratio of BRESCO ash to MSW disposed at QRL (approximately 0.92 tons of ash for every ton of MSW disposed), and the average in-place waste density at QRL (approximately 1.3 tons per CY), the volume of disposed waste at QRL was estimated over time assuming variable attainment of the MDP. The anticipated year in which QRL will reach capacity under the current permitted grade and the proposed lateral expansion is shown in the table below.

Estimated Year in Which QRL Reaches Capacity – Scenario 1

MDP Attainment	Year in Which QRL Capacity is Reached: Permitted Grade	Year in Which QRL Capacity is Reached: Lateral Expansion
100%	2078	After 2100
50%	2030	2059
0%	2028	2044

Scenario 2: City Does Not Renew Contract with BRESCO

For this scenario, it is assumed that the City discontinues its contract with BRESCO beginning in January 2022 and sends all of its residential MSW to QRL. No BRESCO ash is expected to be sent to QRL after 2021. Using the current soil utilization rate at QRL (approximately 40% soil by mass), the current ratio of BRESCO ash to MSW disposed at QRL (approximately 0.92 tons of ash for every ton of MSW disposed), and the average in-place waste density at QRL (approximately 1.3 tons per CY with ash, estimated as 1.15 tons per CY without ash), the volume of disposed waste at QRL was estimated over time assuming variable attainment of the MDP. The anticipated year in which QRL will reach capacity under the current permitted grade and the proposed vertical expansion is shown in the table below.

Estimated Year in Which QRL Reaches Capacity – Scenario 2

MDP Attainment	Year in Which QRL Capacity is Reached: Permitted Grade	Year in Which QRL Capacity is Reached: Lateral Expansion
100%	2028	2055
50%	2027	2045
0%	2027	2040

Scenario 3: BRESCO Ceases Operation

For this scenario, it is assumed that BRESCO ceases operation beginning in January 2022 and the City sends all of its residential MSW to QRL. No BRESCO ash is expected to be sent to QRL after 2021 and all commercial MSW collected in Baltimore is also anticipated to be sent to QRL. Using the current soil utilization rate at QRL (approximately 40% soil by mass), the current ratio of BRESCO ash to MSW disposed at QRL (approximately 0.92 tons of ash for every ton of MSW disposed), and the average in-place waste density at QRL (approximately 1.3 tons per CY with ash, estimated as 1.15 tons per CY without ash), the volume of disposed waste at QRL was estimated over time assuming variable attainment of the MDP.

The anticipated year in which QRL will reach capacity under the current permitted grades and the proposed vertical expansion is shown in the table opposite.

Estimated Year in Which QRL Reaches Capacity – Scenario 3

MDP Attainment	Year in Which QRL Capacity is Reached: Permitted Grades	Year in Which QRL Capacity is Reached: Lateral Expansion
100%	2025	2040
50%	2025	2035
0%	2025	2033

Costs

The following cost assumptions were made for continued use of QRL:

1. OPEX of $21 per ton estimated using expenditures for QRL operations in 2017 ($5,206,600) and expenditures on the QRL closure/post-closure fund in 2017 ($865,521) and the total mass of waste landfilled at QRL in 2017 (292,200 tons).
2. CAPEX of $5 per ton per year for small projects estimated using expenditures for QRL capital projects in 2017 ($1,560,600) and the total mass of waste landfilled at QRL in 2017 (292,200 tons).
3. CAPEX of $68 million for the proposed lateral expansion of the QRL (EA Engineering, 2019).

Benefits

The expected benefits for continued use of QRL include revenues from tip fees (commercial waste only) and leverage for bargaining tip fees with private disposal facilities (because the City continues to have the option of sending all of its waste to QRL rather than to a private disposal facility). Revenues were estimated as

$67.50 per ton of commercial waste accepted at QRL as this is the current tip fee charged at the facility.

Challenges

The main challenge associated with continued use of QRL is that airspace would be quickly consumed under Scenario 2 and 3 (i.e., if BRESCO ceases operation or the City discontinues using BRESCO). This could be a problem for the City as it tries to find another place to send its waste for disposal.

Experience

The City has established experience with this option as DPW has been operating QRL for decades. This represents the "status quo" option for waste disposal.

Timeline

The expected timeline for continued use of QRL is established in the disposal potential section above. Under different scenarios, it is anticipated that QRL will deplete its remaining capacity at different times.

Development of a New Landfill in the City

While development of a new landfill in Baltimore is a theoretical option, the City has not performed any preliminary siting work to date to identify a potential site and the City's zoning code does not allow any new landfills. Siting, design, permitting, and construction of a new landfill in Maryland is expected to take at least ten years based on Geosyntec's experience. Further, it would likely be impractical to construct a new landfill in the Baltimore area as it would require an undeveloped or brownfield area of up to 1,000 acres. Overall, this option is not considered practical and is not discussed further in this Report.

4.3 Transfer Facilities for Out-of-City Disposal

In addition to constructing post-processing facilities and leveraging in-city disposal options (e.g. QRL and BRESCO), the City may consider constructing additional transfer capacity to meet future disposal needs by transferring waste for out-of-city disposal. The urgency of this option is pressing assuming BRESCO is no longer available beginning in 2022. Currently, the City operates NWTS as an intra-City truck transfer facility where waste collected from the northern parts of the City can be transferred from smaller load-packer trucks to larger roll-off trucks for transport to BRESCO or QRL. Currently, NWTS is only used as a drop-off facility for small haulers and residents (waste sent to BRESCO) and transfer of recyclables to WMRA in Elkridge, MD.

If needed, NWTS could be used to transfer waste to out-of-city disposal facilities. However, the current permitted capacity of NWTS is 150,000 tons per year, considerably less than the total disposed residential waste stream (319,500 tons in 2017) and the disposed commercial MSW waste stream (221,900 tons in 2017) in the City. Further, NWTS has only ever been operated at a maximum of 67,000 tons per year and would require significant staffing and equipment upgrades to reach its permitted capacity. As such, the City would quickly require a second, larger transfer facility to handle additional waste transfers for out-of-city disposal. In the longer-term, the most sustainable and cost-effective transfer mechanism would be to develop a large transfer facility with both rail and truck transfer capabilities.

Based on the above, three options are considered for developing transfer capacity:

1. Configuring NWTS to operate at its maximum permitted capacity for out-of-city disposal;
2. Construction of an additional truck transfer facility in the city; and
3. Construction of a large rail transfer facility.

Similar to the MWP options reviewed in Section 4.1, for the analyses presented herein, it is assumed that only residential MSW (i.e., the portion of the waste stream collected and handled by DPW) would be transferred using the first two truck transfer facilities (these are mainly intended to provide the City with fast-track transfer capacity in the event of BRESCO shutting down in 2022). However, if Task 5 reduction/ diversion programs are successful at achieving a large fraction of the maximum diversion potential (MDP), the size of the waste stream for transfer will reduce over time, with the result that the City's transfer operation(s) may have significant excess capacity in the medium to long term. In this case, the City may elect to open their facilities to commercial customers at some point in the future to utilize redundant capacity. The large rail transfer facility is intended as a citywide solution that would be open to the commercial sector.

Utilize Permitted Capacity at Northwest Transfer Facility

Timeline

For this analysis, it is assumed that DPW could relatively quickly configure NWTS to operate at its permitted capacity and begin transferring waste to out-of-city landfills for final disposal. It is estimated that the only changes that would have to be made would be adding additional shifts and equipment to keep the facility open for longer (potentially 24 hours a day, six days a week, depending on permit conditions and local neighborhood concerns). As such, it is anticipated NWTS could be operating at 150,000 tons per year by early 2023.

Processing Requirements

For this analysis, it is assumed that NWTS would be reconfigured to operate at its permitted capacity of 150,000 tons per year.

Estimated Costs

The costs of configuring NWTS to process 150,000 tons per year and transfer waste to out-of-city landfills were calculated using the following assumptions:

1. CAPEX assumed to be negligible. NWTS has recently undergone capital improvements and only minor purchases (e.g. equipment) are expected to be needed to upgrade the facility further.
2. Estimated processing OPEX of $21 per ton. This value is based on DPW's currently unit cost for operation of NWTS ($1,708,119 in 2017) and the mass of waste handled at NWTS in 2017 (79,500 tons, including small hauler waste).
3. Estimated transfer OPEX of $19 per ton. This value is based on current contracts for waste transportation and disposal between NMWDA and two Maryland counties.
4. Estimated tip fee of $30 per ton at out-of-city landfills. This value is based on current contracts for waste transportation and disposal between NMWDA and two Maryland counties.

Based on the above, the estimated OPEX for using NWTS for out-of-city waste transfer and disposal is $10,577,000 per year. However, it is important to note that costs were estimated based on current contracts in place, while closure of BRESCO would invariably have upward pressure on pricing.

Potential Benefits/Drawbacks

Additional benefits of maximizing use of NWTS for waste transfer include job creation and landfill disposal airspace savings at QRL. However, GHG emissions will increase if waste is hauled out of the city, especially if it is landfilled compared to WTE. Job creation was calculated by assuming an employment rate of 0.02 people per ton of waste transferred at the facility each day, with one additional supervisor. GHG emissions were calculated using the U.S. EPA's WARM software and increasing the haul distance from 20 miles (for status quo) to 180 miles. These benefits are summarized in the table below assuming variable attainment of the MDP. As shown, trucking waste to out-of-city landfill disposal would result in an overall increase in GHG emissions relative to the baseline status quo.

Estimated Benefits/Drawbacks of Using NWTS as an Out-of-City Truck Transfer Facility as a Percentage of the MDP

MDP Attainment	Job Creation	GHG Reduction* (MTCO2E)	Airspace Savings (tons)
100%	13	68,200	2,595,200
50%	13	70,900	2,700,000
0%	13	70,900	2,700,000

*Positive values represent an increase in GHG emissions

Challenges to Implementation

The major challenges associated with upgrading NWTS are summarized below:

1. Space restrictions: Because of the tight layout at NWTS, operating at full capacity would likely require operating 24 hours a day, six days a week. The number of load-packers accessing the site would mean that lines of small-haulers and residents accessing the drop-off center could not be accommodated. Therefore, the small hauler program, which is very popular, would have to be limited to weekends and/or transferred to another drop-off center (which would have to be quickly upgraded/expanded to accommodate increased use and would require a transfer station permit from MDE). This will likely prove very unpopular with small haulers and local residents.
2. Public perception: Hauling waste to disposal options that are located more than three hours' drive time outside of Baltimore is not a sustainable method of waste disposal and the City should expect pushback from environmental and zero waste advocacy groups if this option is chosen. As shown by the increased GHG emissions for this option, constructing a truck transfer station will result in higher GHG emissions than the current system.
3. Additional traffic at NWTS: Increasing waste transfer at NWTS will result in additional traffic for incoming collection vehicles as well as outgoing transfer trailers. This will result in additional road wear, local congestion, and noise, including impacts outside of typical business hours as the facility must expand to operating two shifts.

Experience

DPW has years of experience operating NWTS although they have never operated a full-blown waste transfer operation. However, it is not expected that DPW would encounter any significant issues in expanding operations at NWTS.

Construct New Truck Transfer Facility

Currently, NWTS acts as an intra-city truck transfer facility. NWTS is ideally located to service northern and, potentially, western parts of the city. If all waste is to be transferred for out-of-city disposal, additional transfer capacity would be required to serve other parts of the City. Although sized to help handle the residential waste stream, over time the new transfer facility could also service commercial MSW haulers and may include a residents' drop-off facility and a small hauler area. Potential options for locating such a facility include expanding Eastern Sanitation Yard (Bowleys Lane), expanding Western Sanitation Yard (Reedbird Avenue), buying and expanding Waste Management's Quad Avenue facility, and/or building a transfer station at QRL.

Timeline

For this analysis, it is assumed that the City could acquire land and design, permit, and construct a truck transfer facility within five years. As such, it is anticipated that the transfer facility could be fully operable by 2025.

Processing Requirements

The required capacity of the new transfer facility is estimated under the following assumptions:

1. Maximum capacity: The transfer facility would process all residential MSW collected in the City with the exception of the waste handled by NWTS (assumed as 150,000 tons per year for this analysis). The capacity of the facility is estimated to be 120% of the maximum remaining incoming waste tonnage between 2025 and 2040 to provide redundancy and account for annual fluctuations in the waste stream.
2. Variable MDP attainment: The throughput, costs, and benefits of the facility are dependent on the waste tonnages for transfer, which will vary depending on how successful the Task 5 recycling/diversion options are. The required transfer capacity depending on whether the City attains 100%, 50 %, or 0% of the MDP is presented in the table below. Zero percent represents the status quo.

Required Capacity of Truck Transfer Facility as a Percentage of the MDP

MDP Attainment	Maximum Incoming Waste (tons/year)	Design Capacity (tons/year)
100%	83,000	100,000
50%	107,000	128,400
0%	161,000	193,200

Estimated Costs

The costs of constructing and operating truck transfer facility in the City were calculated using the following assumptions:

1. Estimated CAPEX of $80 per ton of capacity. This value is based on the estimated amortized capital cost of $2-$3 per ton for a

500 ton per day facility with an assumed service life of 20 years (Dempsey 2004).

2. Estimated OPEX of $21 per ton of incoming waste for the transfer facility. This value is based on DPW's current unit cost for operation of NWTS.
3. Estimated transfer OPEX of $19 per ton. This value is based on current contracts for waste transportation and disposal between NMWDA and two Maryland counties.
4. Estimated tip fee of $30 per ton at out-of-city landfills. This value is based on current contracts for waste transportation and disposal between NMWDA and two Maryland counties.

Estimated costs for the truck transfer facility assuming variable attainment of the MDP are summarized in the table below. Again, OPEX for out-of-city transfer and disposal were estimated based on current contracts in place; however, closure of BRESCO would invariably have upward pressure on pricing.

Estimated Cost of Truck Transfer Facility as a Percentage of the MDP

MDP Attainment	CAPEX	Annual OPEX
100%	$ 8,000,000	$ 5,800,000
50%	$ 10,300,000	$ 7,500,000
0%	$ 15,500,000	$ 11,400,000

Estimated Benefits/Drawbacks

The estimated benefits for the truck transfer facility are summarized in the table opposite assuming variable attainment of the MDP. Additional benefits of constructing a truck transfer facility include job creation and landfill disposal airspace savings at QRL. Job creation was calculated by assuming an employment rate of 0.02 people per ton of waste transferred at the facility each day, with one additional supervisor. GHG emissions were calculated using WARM and increasing the haul distance from 20 miles (for status quo) to 180 miles. As shown, trucking waste to out-of-city landfill disposal would result in an overall increase in GHG emissions relative to the baseline status quo.

Estimated Benefits/Drawbacks of Truck Transfer Facility as a Percentage of the MDP

MDP Attainment	Job Creation	GHG Reduction* (MTCO2E)	Airspace Savings (tons)
100%	8	7,600	290,500
50%	10	33,100	1,259,200
0%	14	61,300	2,332,800

*Positive values represent an increase in GHG emissions

Challenges to Implementation

The major challenges associated with constructing a truck transfer facility in the city are summarized below:

1. Land acquisition: Using information for NWTS, it is estimated that a truck transfer facility would require at least 10 acres of land (NWTS has a design capacity of 150,000 tons per year and sits on an approximately 7.5-acre site). It may be difficult for the City to find a suitable site in the City with this much land available for development.

2. Public perception: Hauling waste to disposal options that are located more than three hours' drive outside of the city is not the most sustainable method of waste disposal and the City should expect pushback from environmental and zero waste advocacy groups if this option is chosen. As shown by the increased GHG emissions for this option, constructing a truck transfer station will result in higher GHG emissions than the current system.
3. Added traffic in the vicinity of the transfer station: The development of a truck transfer station will result in additional traffic for incoming collection vehicles as well as outgoing transfer trailers in the vicinity of the facility. This will result in additional road wear, local traffic congestion, and noise.

Experience

DPW has plenty of experience operating NWTS but has never operated a transfer facility that would transport waste out of the city (except for local recyclable material transfer to Elkridge, MD). However, it is expected that DPW can easily use its experience with NWTS to operate a new truck transfer facility.

Construct Large Rail Transfer Facility

In addition to constructing a truck transfer station to complement NWTS, the City should also consider constructing a large transfer station where operations can be consolidated and provided more efficiently. Such a facility would be constructed so it could be operated as a truck transfer station, but would be built along a rail spur to allow for containerization and rail shipment to suitable out-of-city landfills as the primary transfer mechanism. Rail would be the preferred method of transfer with trucking capabilities providing a backup. This option would provide a more efficient, cost-effective, and environmentally friendly service than a truck transfer facility and would allow the City to send waste to regional landfills or even more distant facilities as needed.

Likely locations for a large rail transfer facility are QRL (rail lines currently run around the northern property boundary) or the Western Acceptance Facility in Baltimore County. If the Western Acceptance Facility is chosen for development, it will require a collaborative agreement with Baltimore County to construct the facility. Adding a rail spur at Western Acceptance Facility will likely be more challenging than at QRL.

Timeline

For this analysis, it is assumed that ten years would be required to acquire land and right-of-way rights; design, permit, and construct the transfer facility; and complete the associated rail spur. As such, it is anticipated that the transfer facility could be fully operable by 2030 at the earliest. For this analysis, it is assumed that the transfer facility would operate from 2030 through 2040, although the facility would remain in service long after 2040.

Processing Requirements

For this analysis, it is assumed that both residential and commercial MSW would be routed to the rail transfer facility. Developing a rail transfer station would be a capital intensive project; therefore, this analysis assumes that it would require waste from the commercial as well as residential sectors in Baltimore (and potentially surrounding counties) to help make it economically viable.

The estimated capacity, costs, and benefits of the rail transfer facility are determined under the following assumptions:

1. Capacity: The transfer facility would process all residential and commercial MSW collected in the City between 2030 and 2040. It is assumed that if the City constructs a rail transfer facility, NWTS would be used to send waste to the new facility, rather than to out-of-City landfills. The capacity of the facility is estimated to be 120% of the maximum incoming waste tonnage between 2030 and 2040 to account for annual fluctuations in the waste stream.
2. Variable MDP attainment. The size, costs, and benefits of the facility are estimated assuming the City can attain 100%, 50 %, and 0% of the MDP. Zero percent is the status quo.

The required capacity of the transfer facility is summarized in the table below.

Required Capacity of Rail Transfer Facility as a Percentage of the MDP

MDP Attainment	Maximum Incoming Waste (tons/year)	Design Capacity (tons/year)
100%	278,900	334,700
50%	387,200	464,700
0%	530,200	636,200

Estimated Costs

The costs of constructing and operating a large rail transfer facility were calculated using the following assumptions:

1. Estimated CAPEX of $95 per ton of capacity. This value is based on the estimated cost to construct a 425 ton per day capacity rail transfer facility in Alexandria, Virginia (HDR, 2018) .
2. Estimated OPEX of $10 per ton of incoming waste for the transfer facility. This value is based on DPW's current unit cost for operation of NWTS but assuming economies of scale would decrease unit operating costs significantly for a large rail facility.
3. Estimated OPEX of $7 per ton of disposed waste for transfer activities. This value is based on an assumed operation cost of $0.04 per ton-mile and a 180 mile rail journey to out-of-city landfills (likely either in Pennsylvania or Virginia) (AAR 2018).
4. Estimated tip fee of $30 per ton at out-of-city landfills. This value is based on current contracts for waste transportation and disposal between NMWDA and two Maryland counties.

The estimated costs for the rail transfer facility assuming variable attainment of the MDP are summarized in the table below. However, as noted previously, OPEX for out-of-city transfer and disposal were estimated based on current contracts in place, while closure of BRESCO would invariably have upward pressure on pricing.

Estimated Cost of Rail Transfer Facility as a Percentage of the MDP

MDP Attainment	CAPEX	Annual OPEX
100%	$ 31,800,000	$ 13,200,000
50%	$ 44,100,000	$ 18,400,000
0%	$ 60,400,000	$ 25,100,000

Potential Benefits/Drawbacks

Relative to the assumed all-landfill baseline condition (where all waste is assumed to be sent to QRL for final disposal), the benefits of constructing a rail transfer facility mostly involve job creation. In addition, the City would gain significant redundant capacity (available for contingency operations during emergencies) and increased options for long-haul waste disposal. GHG emissions are likely to increase slightly if waste is hauled out of the City by rail, although rail transfer would be roughly four times more fuel efficient than using trucks. GHG emissions from rail transportation are very low, which means that changes in overall GHG emissions are negligible based on WARM analysis. Job creation was calculated by assuming an employment rate of 0.02 people per ton of waste transferred each day, plus one additional supervisor.

The estimated benefits for the rail transfer facility are summarized in the table below assuming variable attainment of the MDP.

Estimated Benefits of Rail Transfer Facility as a Percentage of the MDP

MDP Attainment	Job Creation	GHG Reduction (MTCO2E)	Airspace Savings (tons)
100%	23	Negligible	2,614,100
50%	31	Negligible	4,126,900
0%	42	Negligible	5,639,800

Challenges to Implementation

The major challenge associated with constructing a large rail transfer facility are summarized below:

1. Land acquisition and rail spur construction: A large rail transfer facility will require many acres of land to operate. Further, the site chosen for the facility will have to be easily connected to existing freight rail tracks. As such, there are very few locations where such a facility could be constructed. As noted, the City may have to partner with Baltimore County to construct a facility.
2. Public perception: Transferring waste for out-of-city disposal, albeit by rail, may not be considered a sustainable method of waste disposal and the City may encounter pushback from environmental groups if this option is chosen.

Experience

DPW has considerable experience operating NWTS and large waste handling operations at QRL, but has never operated a rail transfer facility. However, it is expected that DPW can use its experience at QRL and NWTS to its advantage when constructing and operating a large rail transfer facility. Further, the City could contract out operations of the facility to an experienced private entity.

4.4 Summary and Selection of Options

A summary of the costs, benefits, and assumed implementation timeline for each option at varying MDP attainment levels are given in Tables 4.1 through 4.3 on the following pages. The columns on the far right of the tables provide unit CAPEX and OPEX normalized over the airspace savings for each option (i.e., assuming that, in the absence of the option in question, the equivalent quantity of waste would be landfilled at QRL at $67.50/ton). This is a representation of costs in terms of avoided landfill disposal, and provides an objective comparison of costs between the options summarized in the tables, which are markedly different. The timing of CAPEX and OPEX can be inferred with reference to the assumed implementation timeline. For example, for an option shown as medium term (5 years), it is fair to assume that CAPEX will be incurred by 2025, with annual OPEX incurred from 2025 onwards.

TABLE 4.1 – Comparison of Options Assuming 100% MDP Attainment

Report Section	Description	Assumed Timeline	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Cumulative Airspace Savings (tons)	Jobs	CAPEX / Airspace Saved ($/ton)	Net OPEX / Airspace Saved ($/ton)
4.1	**MRF + AD**	Medium (5 years)	$ 85,926,000	$ 21,797,000	$ 1,349,000	$ 20,448,000	496,200	43	**$ 173**	**$ 41.21**
	MRF + AD + SRF	Medium (5 years)	$ 89,384,000	$ 22,878,000	$ 1,638,000	$ 21,240,000	618,900	45	**$ 144**	**$ 34.32**
	MRF + Gasification	Medium (5 years)	$ 311,397,000	$ 30,033,000	$ 22,219,000	$ 7,814,000	561,200	172	**$ 555**	**$ 13.92**
	MRF + Gasifier + SRF	Medium (5 years)	$314,855,000	$ 31,114,000	$ 22,508,000	$ 8,606,000	683,900	174	**$ 460**	**$ 12.58**
4.2	**BRESCO***	Medium (5 years)	$ 0	$ 12,621,000	$ 5,100,000	$ 7,521,000	750,000	0	**$ 0**	**$ 10.03**
		Long (10 years)	$ 0	$ 10,586,000	$ 5,100,000	$ 5,486,000	1,500,000	0	**$ 0**	**$ 3.66**
		V. Long (20 years)	$ 0	$ 9,568,000	$ 5,100,000	$ 4,468,000	3,000,000	0	**$ 0**	**$ 1.49**
	QRL	Existing	$ 88,861,000	$ 3,865,000	$ 0	$ 3,865,000	N/A	0	**N/A**	**N/A**
4.3	**Upgrade NWTS**	Short (1-3 years)	Negligible	$10,577,000	$ 0	$ 10,577,000	2,595,200	13	**$ 0**	**$ 4.08**
	Truck Transfer	Medium (5 years)	$ 7,965,000	$ 5,850,000	$ 0	$ 5,850,000	290,500	8	**$ 27**	**$ 20.14**
	Rail Transfer	Long (10 years)	$ 31,798,000	$ 13,228,000	$7,480,000	$ 5,748,000	2,614,100	23	**$ 12**	**$ 2.20**

* Note: Assumed timeframe for continued use of BRESCO starts in 2022 when current contract expires.

TABLE 4.2 – Comparison of Options Assuming 50% MDP Attainment

Report Section	Description	Assumed Timeline	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Cumulative Airspace Savings (tons)	Jobs	CAPEX / Airspace Saved ($/ton)	Net OPEX / Airspace Saved ($/ton)
4.1	**MRF + AD**	Medium (5 years)	$ 93,075,000	$ 23,799,000	$ 1,580,000	$ 22,219,000	864,000	47	**$ 108**	**$ 25.72**
	MRF + AD + SRF	Medium (5 years)	$ 97,258,000	$ 25,106,000	$ 1,929,000	$ 23,178,000	1,095,600	50	**$ 89**	**$ 21.15**
	MRF + Gasification	Medium (5 years)	$ 338,796,000	$ 32,899,000	$ 24,199,000	$ 8,700,000	984,400	187	**$ 344**	**$ 8.84**
	MRF + Gasifier + SRF	Medium (5 years)	$ 342,979,000	$ 34,207,000	$ 24,548,000	$ 9,659,000	1,215,900	1909	**$ 282**	**$ 7.94**
4.2	**BRESCO***	Medium (5 years)	$ 0	$ 12,621,000	$ 5,100,000	$ 7,521,000	750,000	0	**$ 0**	**$ 10.03**
		Long (10 years)	$ 0	$ 10,586,000	$ 5,100,000	$ 5,486,000	1,500,000	0	**$ 0**	**$ 3.66**
		V. Long (20 years)	$ 0	$ 9,568,000	$ 5,100,000	$ 4,468,000	3,000,000	0	**$ 0**	**$ 1.49**
	QRL	Existing	$ 94,746,000	$ 4,955,000	$ 0	$ 4,955,000	N/A	0	**N/A**	**N/A**
4.3	**Upgrade NWTS**	Short (1-3 years)	Negligible	$ 10,577,000	$ 0	$ 10,577,000	2,700,000	13	**$ 0**	**$ 3.92**
	Truck Transfer	Medium (5 years)	$ 10,272,000	$ 7,545,000	$ 0	$ 7,545,000	1,259,200	10	**$ 8**	**$ 5.99**
	Rail Transfer	Long (10 years)	$ 44,145,000	$ 18,365,000	$ 10,654,000	$ 7,711,000	4,126,900	31	**$ 11**	**$ 1.87**

* Note: Assumed timeframe for continued use of BRESCO starts in 2022 when current contract expires.

TABLE 4.3 – Comparison of Options Assuming 0% MDP Attainment

Report Section	Description	Assumed Timeline	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Cumulative Airspace Savings (tons)	Jobs	CAPEX / Airspace Saved ($/ton)	Net OPEX / Airspace Saved ($/ton)
4.1	MRF + AD	Medium (5 years)	$ 110,918,000	$ 28,554,000	$ 2,004,000	$ 26,550,000	1,231,900	55	**$ 90**	**$ 21.55**
	MRF + SRF	Medium (5 years)	$ 116,288,000	$ 30,232,000	$ 2,452,000	$ 27,780,000	1,572,300	58	**$ 74**	**$ 17.67**
	MRF + Gasification	Medium (5 years)	$ 405,270,000	$ 39,582,000	$ 28,972,000	$ 10,610,000	1,407,500	223	**$ 288**	**$ 7.54**
	MRF + Gasifier + SRF	Medium (5 years)	$ 410,640,000	$ 41,260,000	$ 29,420,000	$ 11,840,000	1,748,000	226	**$ 235**	**$ 6.77**
4.2	BRESCO*	Medium (5-years)	$ 0	$ 12,621,000	$ 5,100,000	$ 7,521,000	750,000	0	**$ 0**	**$ 10.03**
		Long (10 years)	$ 0	$ 10,586,000	$ 5,100,000	$ 5,486,000	1,500,000	0	**$ 0**	**$ 3.66**
		V. Long (20 years)	$ 0	$ 9,568,000	$ 5,100,000	$ 4,468,000	3,000,000	0	**$ 0**	**$ 1.49**
	QRL	Existing	$ 100,631,000	$ 6,046,000	$ 0	$ 6,046,000	N/A	0	**N/A**	**N/A**
4.3	Upgrade NWTS	Short (1-3 years)	Negligible	$ 10,577,000	$ 0	$ 10,577,000	2,700,000	13	**$ 0**	**$ 3.92**
	Truck Transfer	Medium (5 years)	$ 15,459,000	$ 11,354,000	$ 0	$ 11,354,000	2,332,800	14	**$ 7**	**$ 4.87**
	Rail Transfer	Long (10 years)	$ 60,444,000	$ 25,145,000	$ 14,795,000	$ 10,351,000	5,639,800	42	**$ 11**	**$ 1.84**

* Note: Assumed timeframe for continued use of BRESCO starts in 2022 when current contract expires.

A summary of the major observations and conclusions from Chapter 4 is given below.

1. MWP options (AD, gasification, or SRF) tend to be the most expensive of the options considered (both in terms of capital costs and operating costs). Many of these technologies are also largely unproven in the U.S. and they generally work counter to reduction/diversion measures implemented in Task 5 (i.e., they become more expensive on a per ton basis at higher attainment of the MDP). More realistically, MWP technologies effectively compete with many Task 5 recycling/diversion options for feedstock (i.e., the City would not implement a source separated organics collection and composting program if a MWP facility that includes AD is available). As such, in many cases the city would need to choose MWP or increased recycling/diversion programs, not both. Nonetheless, significant opportunities for MWP development under a PPP contract appear to be available to the City. As such, although these MWP options will not be considered further in the scenario analyses presented in Chapter 5 (which looks predominantly at disposal options), they will be considered further in the Master Plan (Task 8) as alternatives to recycling/diversion programs and transfer operations.
2. Continued use of QRL will incur significant capital costs in the medium to long-term once the lateral expansion is constructed. Therefore, the City may want to consider options that reduce reliance on QRL such that construction of the lateral expansion can be delayed. That being said, it is recommended that the City continue to pursue the permit for the lateral expansion of QRL as quickly as possible as this permitted disposal capacity can be used as leverage when negotiating with private disposal facilities. It will also allow the landfill to quickly expand to accommodate waste should a natural disaster occur.
3. Of the short-term options available to the City, the most competitive would be to continue to contract with BRESCO for residential MSW disposal and upgrading NWTS for out-of-city waste transfer by truck. These options result in airspace preservation at QRL and minimal annual net CAPEX and OPEX for the City. These options also facilitate the orderly and gradual implementation of the waste diversion options presented in the Task 5 Report.
4. Of the medium-term options available to the City, the most cost-competitive is again to continue to contract with BRESCO. However, if this is not an option, the City should consider constructing a second truck transfer facility to ship waste out of the city. This facility would supplement NWTS. While this option would result in an increase in GHG emissions compared to WTE, it also increases employment and generally results in the lowest costs over the medium term (particularly at lower rates of MDP attainment).
5. In the long-term, the most cost-competitive option is again to continue to contract with BRESCO. Even if this is an option, however, due to its age the City should be prepared that BRESCO will not remain a viable option much beyond 2040. Therefore, the City needs to consider constructing and operating a rail transfer station to send waste out of the city for disposal. While this option has relatively high initial CAPEX, it is both cheaper to operate and more environmentally friendly than truck transfer.

With regard to the medium- and long-term options, it must be remembered that acquiring funding, siting, design, permitting, and construction will likely require long lead times of 5 to 10 years for all options except for continued use of BRESCO. If these options are chosen, therefore, it is important that the City commence with their development as soon as possible. All analyses presented in Chapter 4 assumed commencement with planning and financing in 2020.

Finally, it should be remembered that all options in Tables 4.1 to 4.3 are presented in terms of MDP attainment. Capacity requirements, CAPEX, and OPEX are lower when the fraction of the MDP attained is higher (i.e., when Task 5 reduction/diversion options are more successful). However, achieving higher MDP fractions has its own cost burden as was presented in the Task 5 Report.

5. SCENARIO ANALYSES

In this chapter, a scenario analysis is performed to demonstrate an optimal course of action for the City under the three main scenarios that drive the evaluations in Task 7, particularly with regard to timing:

1. City renews contract with BRESCO: Depending on contract negotiations, the City may choose to continue to utilize BRESCO for short, intermediate, and long-term waste disposal. In this scenario, it is assumed that Wheelabrator voluntarily upgrades the emission controls at BRESCO to comply with the BCAA, or some equivalent agreed by the City. Costs for these upgrades would be passed on to customers, including the City.
2. City does not renew contract with BRESCO: If contract renewal terms cannot be agreed, the City may allow its current contract with BRESCO to expire at the end of 2021; and
3. BRESCO ceases operations in 2022: If BRESCO closes because the City does not renew its contract, the City as well as commercial entities in the city (many of which currently send their MSW to BRESCO) would be forced to find a new destination for their waste.

For each of the above scenarios, combinations of options that are feasible and that will meet City's short, intermediate, and long-term disposal needs are assembled and analyzed for their combined costs and benefits. Appendix 1 contains the full analysis for each scenario.

This scenario analysis is focused on ensuring the City has sufficient disposal capacity to meet its needs, and thus does not include MWP technologies discussed in Section 4.1. As shown below, each of the scenarios presented results in significant residual capacity at QRL. Maintaining this residual capacity is important for a variety of reasons, including leverage when negotiating contracts with private disposal facilities and providing emergency capacity for disaster management. As discussed previously, it is recommended to maintain approximately 4 million CY of capacity at QRL in case a natural disaster, such as a hurricane, strikes the city.

As was outlined in Section 4.4, it should be remembered that the performance of all options is dependent on MDP attainment, with higher MDP attainment resulting in lower disposal quantities and costs. However, achieving higher MDP fractions has its own cost burden as was presented in the Task 5 Report. This Task 7 Report only addresses wastes that are left after reduction/diversion measures to reduce what is sent for disposal. Therefore, the scenarios discussed in this section should not be considered as stand-alone recommendations for the City moving forward but must be considered in conjunction with options outlined in the Task 5 Report.

5.1 City Renews Contract with BRESCO

Under this scenario, the City chooses to renew its contract with BRESCO, as this option will result in airspace savings at QRL and relatively low costs to the City (see Section 4.4). In this section, two analyses are performed assuming that the City chooses a short-term or long-term contract with BRESCO.

Scenario 5.1.1: Long-Term Contract with BRESCO

Under this scenario, it is assumed that the City will sign a 10-year contract with BRESCO, which would cover its waste disposal needs through 2032.

Concurrently, the City should commence with developing a rail transfer facility to send both residential and commercial waste to out-of-city landfills following termination of the BRESCO contract. It is expected the rail transfer facility will take 10 years to develop. A summary of the timeline considered for this scenario is given below:

- **Short/medium-Term**: Status quo disposal at BRESCO and QRL. The City may consider sending more than the presumptive 150,000 tons of waste to BRESCO to save airspace at QRL (although depending on the City's level of attainment of the MDP this may not be necessary).
- **Long-term**: Permit and construct a rail transfer station for residential and commercial MSW. The rail transfer station would be available to begin operations when the City's contract with BRESCO expires in 2032. This will give the City a long-term solution to its waste disposal needs. This is assuming that the City confirms there will be no alternate WTE facility constructed in BRESCO's place or elsewhere in the City at the end of its life.

A summary of the costs and benefits associated with this scenario is given in Tables 5.1 through 5.3.

Scenario 5.1.2: Short-Term Contract with BRESCO

Under this scenario, it is assumed that the City chooses to sign a 5-year contract with BRESCO to give the City time to transition to a different form of waste disposal. A summary of the timeline considered for this scenario is presented below:

- **Short-term**: Same as Scenario 5.1.1.
- **Medium-term**: Upgrade NWTS for out-of-city disposal and permit and construct an additional truck transfer facility (TS2) to begin sending residential waste to an out-of-city landfill within a three hour drive for final disposal (5-year timeframe, fully operable by 2025). This option will be cost effective while also allowing the City to conserve airspace at QRL. However, it will result in increased GHG emissions compared to the status quo.
- **Long-term**: Permit and construct a rail transfer station. The City should consider constructing a rail transfer station for more efficient and environmentally friendly transfer of both residential and commercial waste in the long-term (10-year timeframe, fully operable by 2030). When the rail transfer facility is constructed, the truck transfer facilities in the City (NWTS and TS2) would be used as intermediate facilities to send waste to the rail transfer station.

A summary of the costs and benefits associated with this scenario is given in Tables 5.1 through 5.3.

5.2 City Does Not Renew BRESCO Contract

Under this scenario, it is assumed the City will choose not to renew its contract with BRESCO, meaning that beginning in 2022 the City will need to find an alternative destination for its residential waste (commercial waste will likely continue to go to BRESCO). In this section, two analyses are performed assuming that NWTS is upgraded immediately, or in 2025 when an additional truck transfer facility can become fully operable.

Scenario 5.2.1: Second Truck Transfer Facility Built

Assuming that the contract with BRESCO expires at the end of 2021, the most likely option for the City would be to upgrade NWTS as quickly as possible for out-of-city disposal and operation at full capacity and to landfill all of its remaining waste at QRL until another option becomes available (i.e. it permits and constructs an additional truck transfer facility). A summary of the timeline considered for this scenario is given below:

- **Short-term**: Contingency use of QRL for residential waste. Under this scenario, the City will need to use capacity at QRL to manage all its residential waste after the contract with BRESCO expires and until NWTS is operational for out-of-city waste transfer (estimated at 1-3 years, depending mainly on time needed to relocate small hauler program). However, the City will also likely stop accepting ash from BRESCO under this scenario, so airspace usage at QRL will not increase substantially.
- **Medium-term**: Upgrade NWTS and construct an additional truck transfer facility (TS2). Operation as per short term, until TS2 can be permitted and constructed (5-year timeframe, fully operable by 2025). This option will be cost effective while also allowing the City to save airspace at QRL. However, it will result in increased GHG emissions compared to the status quo.
- **Long-term**: Same as Scenario 5.1.2.

A summary of the costs and benefits associated with this scenario is given in Tables 5.1 through 5.3.

Scenario 5.2.2: Second Truck Transfer Facility Not Built

To eliminate the need for a second truck transfer facility, the City may choose to begin using NWTS for out-of-city transfer immediately (at its current capacity of 70,000 tons per year) and dispose of remaining residential waste at QRL until such a time that a rail transfer facility can be constructed. A summary of the timeline considered for this scenario is given below:

- **Short/medium-term**: Contingency use of QRL for residential waste with NWTS operating for out-of-city transfer. NWTS can be used immediately so long as it is not operated at full capacity (operating at full capacity would result in significant interference with the small hauler program). During this time, QRL could be used for contingency disposal of remaining residential waste. While this will result in faster consumption of airspace at QRL, it will allow the City to focus its efforts on construction of a rail transfer facility.
- **Long-term**: Same as Scenario 5.1.2.

A summary of the costs and benefits associated with this scenario is given in Tables 5.1 through 5.3.

5.3 BRESCO Ceases Operation

If BRESCO ceases operations in 2022, both the City's residential and commercial MSW waste streams will need to be sent to an alternative facility. In this case, the City would likely begin accepting commercial waste at its facilities once BRESCO ceases operations (as a contingency gesture to help ease the commercial sector's inevitable short-term trash crisis). In this case, airspace at QRL will be consumed quickly, accelerating the need for alternative disposal options.

Scenario 5.3.1: Second Truck Transfer Facility Built

Assuming that the City upgrades NWTS immediately, it is likely that QRL and/or NWTS could accept both residential and commercial waste. To conserve airspace at QRL, the City may choose to construct an additional truck transfer facility to handle the combined residential and commercial waste streams. In the long-term, a rail transfer facility should be considered to avoid long-term reliance on truck transfer. A summary of the proposed timeline for this scenario is given below:

- **Short-term**: Same as Scenario 5.2.1 but with commercial waste accepted at QRL after BRESCO ceases operations.
- **Medium-term**: Same as Scenario 5.2.1 but with commercial waste accepted at NWTS and TS2 but no longer at QRL once both transfer facilities are operable.
- **Long-term**: Same as Scenario 5.1.2

A summary of the costs and benefits associated with this scenario is given in Tables 5.1 through 5.3.

Scenario 5.3.2: Second Truck Transfer Facility Not Built

To eliminate the need for a second truck transfer facility, the City may choose to begin using NWTS for out-of-city transfer immediately (at its current capacity of 70,000 tons per year) and dispose of remaining residential and commercial waste at QRL until such a time that a rail transfer facility can be constructed. A summary of the proposed timeline for this scenario is given below:

- **Short/medium Term**: Same as Scenario 5.2.2 but with commercial waste accepted at QRL and NWTS.
- **Long-term**: Same as Scenario 5.1.2.

A summary of the costs and benefits associated with this scenario is given in Tables 5.1 through 5.3.

TABLE 5.1 – Comparison of Scenarios Assuming 100% MDP Attainment

Scenario	Timeframe	Option	Years	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Jobs	2040 QRL Capacity (CY)
5.1.1 Long-Term BRESCO	Short / Medium	BRESCO	2022-2031	$ 0	$ 10,586,000	$ 5,100,000	$ 5,486,000	0	**6,379,132**
		QRL	2022-2031	$ 4,591,000	$1,489,000	$ 0	$ 1,489,000	0	
	Long	Rail TS	2032+	$ 31,798,000	$ 10,914,000	$ 6,185,000	$ 4,729,000	19	
	TOTAL	-	-	**$ 36,389,000**	**$ 22,989,000**	**$ 11,285,000**	**$ 11,704,000**	**19**	
5.1.2 Short-Term BRESCO	Short	BRESCO	2022-2026	$ 0	$ 12,621,000	$ 5,100,000	$ 7,521,000	0	**6,727,387**
		QRL	2022-2026	$ 3,834,000	$2,131,000	$ 0	$ 2,131,000	0	
	Medium	NWTS	2027+	$ 0	$ 10,577,000	$ 0	$ 10,577,000	13	
		TS2	2027+	$ 4,731,000	$ 193,000	$ 0	$ 193,000	2	
	Long	Rail TS	2030+	$ 31,798,000	$ 11,270,000	$ 6,385,000	$ 4,885,000	20	
	TOTAL	-	-	**$ 40,363,000**	**$ 36,792,000**	**$ 11,485,000**	**$ 25,307,000**	**35**	
5.2.1 No BRESCO Contract Renewal, TS2 Constructed	Short	QRL	2020-2024	$ 3,848,000	$2,994,000	$ 0	$ 2,994,000	0	**7,204,209**
	Medium	NWTS	2023+	$ 0	$ 10,166,000	$ 0	$ 10,166,000	13	
		TS2	2025+	$ 7,965,000	$1,280,000	$ 0	$ 1,280,000	3	
	Long	Rail TS	2030+	$ 31,798,000	$ 11,270,000	$ 6,385,000	$ 4,885,000	20	
	TOTAL	-	-	**$ 43,611,000**	**$ 25,710,000**	**$ 6,385,000**	**$ 19,325,000**	**36**	
5.2.2 No BRESCO Contract Renewal, No TS2	Short / Medium	QRL	2020-2029	$ 7,116,000	$2,769,000	$ 0	$ 2,769,000	0	**6,458,160**
		NWTS	2020+	$ 0	$4,936,000	$ 0	$ 4,936,000	7	
	Long	Rail TS	2030+	$ 31,798,000	$ 11,270,000	$ 6,385,000	$ 4,885,000	20	
	TOTAL	-	-	**$ 38,914,000**	**$ 18,975,000**	**$ 6,385,000**	**$ 12,590,000**	**27**	

TABLE 5.1 – Comparison of Scenarios Assuming 100% MDP Attainment (continued)

Scenario	Timeframe	Option	Years	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Jobs	2040 QRL Capacity (CY)
5.3.1 BRESCO Closed, TS2 Constructed	Short	QRL	2020-2024	$ 6,754,000	$5,256,000	$ 12,243,000	$ (6,987,000)	0	**6,415,523**
	Medium	NWTS	2023+	$ 0	$ 10,166,000	$ 5,063,000	$ 5,103,000	13	
		TS2	2025+	$ 23,248,000	$8,851,000	$ 2,185,000	$ 6,666,000	11	
	Long	Rail TS	2030+	$ 31,798,000	$ 11,270,000	$ 6,385,000	$ 4,885,000	20	
	TOTAL	**-**	**-**	**$ 61,800,000**	**$ 35,543,000**	**$ 25,876,000**	**$ 9,667,000**	**44**	
5.3.2 BRESCO Closed, No TS2	Short / Medium	QRL	2020-2029	$ 23,672,000	$5,307,000	$ 0	$ 5,307,000	0	**4,687,538**
		NWTS	2020+	$ 0	$4,936,000	$ 2,138,000	$ 2,798,000	7	
	Long	Rail TS	2030+	$ 31,798,000	$ 11,270,000	$ 6,385,000	$ 4,885,000	20	
	TOTAL	**-**	**-**	**$ 55,470,000**	**$ 21,513,000**	**$ 8,523,000**	**$ 12,990,000**	**27**	

TABLE 5.2 – Comparison of Scenarios Assuming 50% MDP Attainment

Scenario	Timeframe	Option	Years	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Jobs	2040 QRL Capacity (CY)
5.1.1 Long-Term BRESCO	Short / Medium	BRESCO	2022-2031	$ 0	$ 10,586,000	$ 5,100,000	$ 5,486,000	0	**5,488,719**
		QRL	2022-2031	$ 9,335,000	$2,117,000	$ 0	$ 2,117,000	0	
	Long	Rail TS	2032+	$ 44,145,000	$ 17,696,000	$ 10,293,000	$ 7,403,000	30	
	TOTAL	**-**	**-**	**$ 53,480,000**	**$ 30,399,000**	**$ 15,393,000**	**$ 15,006,000**	**30**	
5.1.2 Short-Term BRESCO	Short	BRESCO	2022-2026	$ 0	$ 12,621,000	$ 5,100,000	$ 7,521,000	0	**6,514,778**
		QRL	2022-2026	$ 4,296,000	$2,388,000	$ 0	$ 2,388,000	0	
	Medium	NWTS	2027+	$ 0	$ 10,577,000	$ 0	$ 10,577,000	13	
		TS2	2027+	$ 8,839,000	$5,306,000	$ 0	$ 5,306,000	7	
	Long	Rail TS	2030+	$ 44,145,000	$ 17,793,000	$ 10,345,000	$ 7,448,000	30	
	TOTAL	**-**	**-**	**$ 57,280,000**	**$ 48,685,000**	**$ 15,445,000**	**$ 33,240,000**	**50**	
5.2.1 No BRESCO Contract Renewal, TS2 Constructed	Short	QRL	2020-2024	$ 3,999,000	$3,112,000	$ 0	$ 3,112,000	0	**7,160,803**
	Medium	NWTS	2023+	$ 0	$ 10,577,000	$ 0	$ 10,577,000	13	
		TS2	2025+	$ 10,272,000	$5,549,000	$ 0	$ 5,549,000	8	
	Long	Rail TS	2030+	$ 44,145,000	$ 17,793,000	$ 10,345,000	$ 7,448,000	30	
	TOTAL	**-**	**-**	**$ 58,416,000**	**$ 37,031,000**	**$ 10,345,000**	**$ 26,686,000**	**51**	
5.2.2 No BRESCO Contract Renewal, No TS2	Short / Medium	QRL	2020-2029	$ 8,369,000	$3,256,000	$ 0	$ 3,256,000	0	**6,115,867**
		NWTS	2020+	$ 0	$4,936,000	$ 0	$ 4,936,000	7	
	Long	Rail TS	2030+	$ 44,145,000	$ 17,793,000	$ 10,345,000	$ 7,448,000	30	
	TOTAL	**-**	**-**	**$ 52,514,000**	**$ 25,985,000**	**$ 10,345,000**	**$ 15,640,000**	**37**	

TABLE 5.2 – Comparison of Scenarios Assuming 50% MDP Attainment (continued)

Scenario	Timeframe	Option	Years	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Jobs	2040 QRL Capacity (CY)
5.3.1 BRESCO Closed, TS2 Constructed	Short	QRL	2020-2024	$ 7,017,000	$5,461,000	$ 12,716,000	$ (7,255,000)	0	**6,341,668**
	Medium	NWTS	2023+	$ 0	$ 10,577,000	$ 5,063,000	$ 5,514,000	13	
		TS2	2025+	$ 27,420,000	$ 16,683,000	$ 5,596,000	$ 11,087,000	20	
	Long	Rail TS	2030+	$ 44,145,000	$ 17,793,000	$ 10,345,000	$ 7,448,000	30	
	TOTAL	-	-	**$ 78,582,000**	**$ 50,514,000**	**$ 33,720,000**	**$ 16,794,000**	**63**	
5.3.2 BRESCO Closed, No TS2	Short / Medium	QRL	2020-2029	$ 31,401,000	$6,177,000	$ 0	$ 6,177,000	0	**4,078,353**
		NWTS	2020+	$ 0	$4,936,000	$ 2,138,000	$ 2,798,000	7	
	Long	Rail TS	2030+	$ 44,145,000	$ 17,793,000	$ 10,345,000	$ 7,448,000	30	
	TOTAL	-	-	**$ 75,546,000**	**$ 28,906,000**	**$ 12,483,000**	**$ 16,423,000**	**37**	

TABLE 5.3 – Comparison of Scenarios Assuming 0% MDP Attainment

Scenario	Timeframe	Option	Years	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Jobs	2040 QRL Capacity (CY)
5.1.1 Long-Term BRESCO	Short / Medium	BRESCO	2022-2031	$ 0	$ 10,586,000	$ 5,100,000	$ 5,486,000	0	**4,598,307**
		QRL	2022-2031	$ 19,300,000	$ 2,744,000	$ 0	$ 2,744,000	0	
	Long	Rail TS	2032+	$ 60,444,000	$ 24,478,000	$ 14,402,000	$ 10,076,000	41	
	TOTAL	-	-	**$ 79,744,000**	**$ 37,808,000**	**$ 19,502,000**	**$ 18,306,000**	**41**	
5.1.2 Short-Term BRESCO	Short	BRESCO	2022-2026	$ 0	$ 12,621,000	$ 5,100,000	$ 7,521,000	0	**6,302,169**
		QRL	2022-2026	$ 4,759,000	$ 2,645,000	$ 0	$ 2,645,000	0	
	Medium	NWTS	2027+	$ 0	$ 10,577,000	$ 0	$ 10,577,000	13	
		TS2	2027+	$ 15,459,000	$ 10,419,000	$ 0	$ 10,419,000	13	
	Long	Rail TS	2030+	$ 60,444,000	$ 24,315,000	$ 14,306,000	$ 10,009,000	41	
	TOTAL	-	-	**$ 80,662,000**	**$ 60,577,000**	**$ 19,406,000**	**$ 41,171,000**	**67**	
5.2.1 No BRESCO Contract Renewal, TS2 Constructed	Short	QRL	2020-2024	$ 4,150,000	$3,229,000	$ 0	$ 3,229,000	0	**7,117,398**
	Medium	NWTS	2023+	$ 0	$ 10,577,000	$ 0	$ 10,577,000	13	
		TS2	2025+	$ 15,459,000	$ 10,280,000	$ 0	$ 10,280,000	13	
	Long	Rail TS	2030+	$ 60,444,000	$ 24,315,000	$ 14,306,000	$ 10,009,000	41	
	TOTAL	-	-	**$ 80,053,000**	**$ 48,401,000**	**$ 14,306,000**	**$ 34,095,000**	**67**	
5.2.2 No BRESCO Contract Renewal, No TS2	Short / Medium	QRL	2020-2029	$ 9,859,000	$3,743,000	$ 0	$ 3,743,000	0	**5,773,574**
		NWTS	2020+	$ 0	$4,936,000	$ 0	$ 4,936,000	7	
	Long	Rail TS	2030+	$ 60,444,000	$ 24,315,000	$ 14,306,000	$ 10,009,000	41	
	TOTAL	-	-	**$ 70,303,000**	**$ 32,994,000**	**$ 14,306,000**	**$ 18,688,000**	**48**	

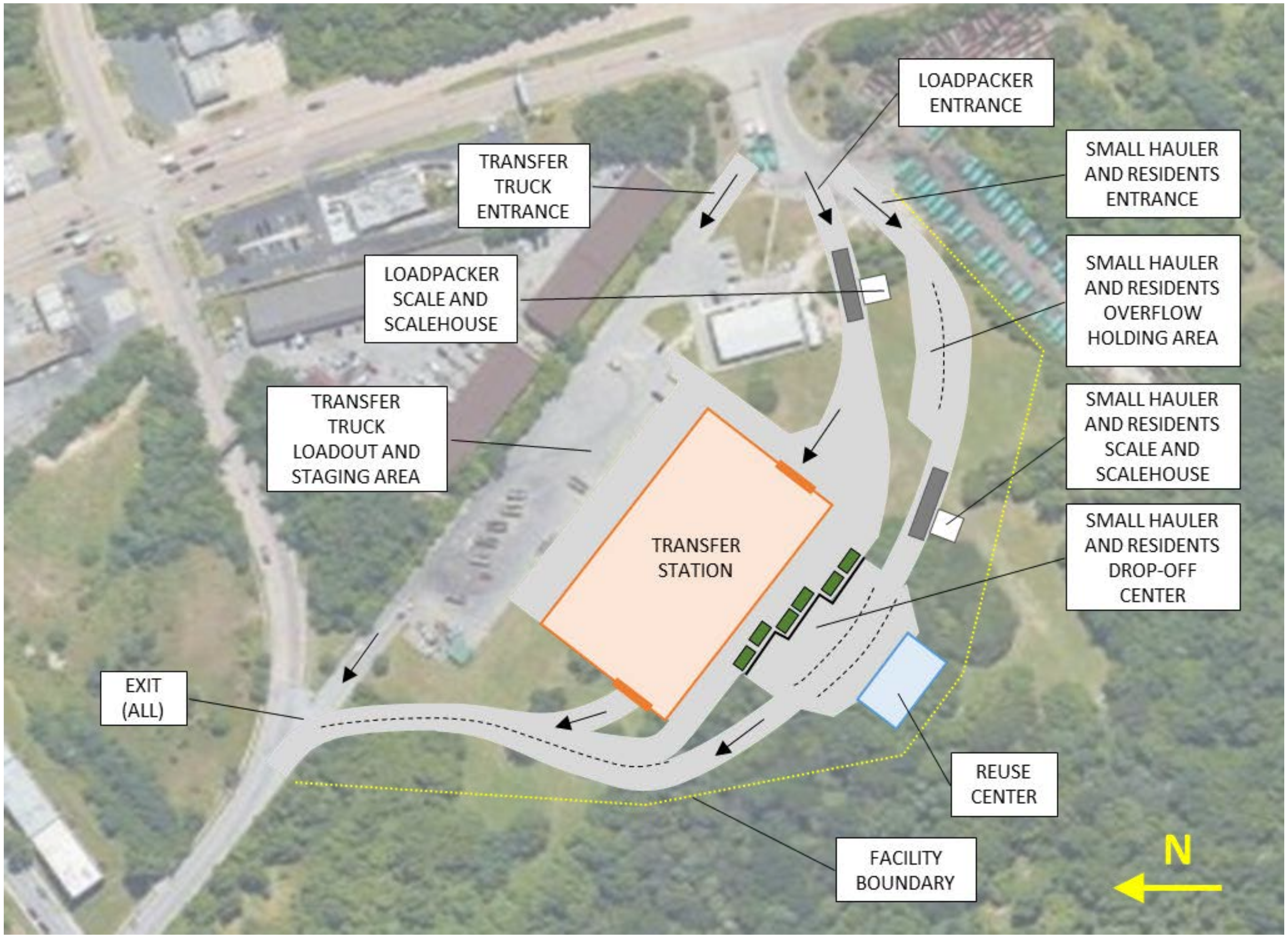
TABLE 5.3 – Comparison of Scenarios Assuming 0% MDP Attainment (continued)

Scenario	Timeframe	Option	Years	CAPEX	Annual OPEX	Annual Revenue	Annual Net OPEX	Jobs	2040 QRL Capacity (CY)
5.3.1 BRESCO Closed, TS2 Constructed	Short	QRL	2020-2024	$ 7,281,000	$5,666,000	$ 13,189,000	$ (7,523,000)	0	6,267,814
	Medium	NWTS	2023+	$ 0	$ 10,577,000	$ 5,063,000	$ 5,514,000	13	
		TS2	2025+	$ 36,500,000	$ 24,978,000	$ 9,008,000	$ 15,970,000	29	
	Long	Rail TS	2030+	$ 60,444,000	$ 24,315,000	$ 14,306,000	$ 10,009,000	41	
	TOTAL	-	-	**$ 104,225,000**	**$ 65,536,000**	**$ 41,566,000**	**$ 23,970,000**	**83**	
5.3.2 BRESCO Closed, No TS2	Short / Medium	QRL	2020-2029	$ 39,130,000	$7,047,000	$ 0	$ 7,047,000	0	3,469,168
		NWTS	2020+	$ 0	$4,936,000	$ 2,138,000	$ 2,798,000	7	
	Long	Rail TS	2030+	$ 60,444,000	$ 24,315,000	$ 14,306,000	$ 10,009,000	41	
	TOTAL	-	-	**$ 99,574,000**	**$ 36,298,000**	**$ 16,444,000**	**$ 19,854,000**	**48**	

6. CONCEPTUAL LAYOUT OF NEW TRUCK TRANSFER FACILITY

A conceptual layout of the new truck transfer facility (TS2) is provided on the figure on this page. It is assumed the TS2 facility will be developed at DPW's Bowleys Lane Residents' Drop-Off Center in the northeast of the city, although an alternative location such as the closed Monument Landfill site could be used.

As shown, in addition to transfer operations, the TS2 facility developed by expanding Bowleys Lane would provide a drop-off area for residents and small haulers (with six bays for MSW, C&D, traditional recyclables, yard waste and other organics, and non-traditional recyclables) as well as a materials reuse center. Traffic flow is isolated between loadpackers, transfer trucks, and small haulers and residents.



7. SUMMARY OF MAJOR FINDINGS

This final chapter contains a summary of the major findings from this Report. Section 7.1 summarizes the existing disposal and transfer facilities in and around Baltimore and specifically focuses on the City's future disposal needs. Section 7.2 contains a summary of the options considered to meet the needs outlined in Section 7.1, focusing on the most practical, beneficial, and cost competitive options capable of meeting the City's short-, medium- and long-term needs. Finally, Section 7.3 contains a summary of the scenario analyses performed in this Report, specifically focusing on the City's decision on whether or not to renew their contract with BRESCO.

7.1 Assessment of Future Disposal Needs

As outlined in Section 3 of this Report, the City currently sends its waste through direct haul to NWTS, QRL, and BRESCO.

A review of local transfer capacity found that, in addition to NWTS, numerous private transfer stations operate in and around Baltimore. These include Baltimore County's Western Acceptance Facility as well as the privately operated Curtis Creek Recovery Transfer Station and Quad Avenue Transfer Station. Any of these facilities could feasibly be used to transfer waste for out-of-city disposal; however, they are all constrained by space or capacity limitations. As such, if the City wishes to consider long-haul out-of-city transfer for future disposal, it will likely need to construct additional transfer capacity. Out-of-city disposal is a promising option for the City, given that multiple private landfills with available capacity, as well as a number of WTE facilities, exist within a three-hour truckshed of Baltimore.

QRL and BRESCO are currently the only waste disposal facilities available for residential and commercial MSW in the city. The City's contract for waste disposal with BRESCO is due for renewal in December 2021. Whether or not this contract is renewed has the potential to dramatically shape the City's waste disposal future in the following ways:

1. If the City renews their contract with BRESCO, the City can continue to rely on that facility for waste disposal services (e.g. it can maintain the status quo).
2. If the City does not renew its contract with BRESCO, the City will likely send its residential MSW to QRL until alternative disposal options become available via out-of-city transfer options.
3. If the City does not renew its contract for waste disposal and stops accepting ash, BRESCO may cease operations. Both residential and commercial MSW will likely be directed to QRL until alternative disposal options become available.

The lack of alternative waste disposal options for the City means that significant additional waste would be sent to QRL in the event that waste does not go to BRESCO. As such, the City may wish to consider the following options to economically manage waste moving forward:

1. Reduce Waste Volume: Mixed waste processing can be used to sort disposed waste and remove recyclables and organics for further processing.
2. Continued Disposal within the City: This effectively requires contracting with BRESCO over the long term. Although expanding QRL beyond its currently pending lateral expansion via a vertical expansion is a future possibility, once completed it would have limited capacity. Building a replacement landfill in

the Baltimore area is not considered feasible due to space and zoning restrictions.

3. Out-of-City Waste Disposal: This would require construction of truck and/or rail transfer facilities to move waste from the City to regional landfills or WTE facilities located in Virginia, Pennsylvania, or New Jersey.

7.2 Options Evaluation

To meet the future disposal needs of the City, multiple waste processing and disposal options were considered and evaluated based on their potential implementation timeline, costs, benefits, challenges, and the City's experience. Each option was evaluated in terms of attainment of the MDP (the specific upstream diversion programs that comprise the MDP and their costs are outlined in the Task 5 Report). A summary of the options considered and their potential use in the City is given below:

1. Mixed waste processing. Options considered included AD, gasification, and SRF (all of which would also incorporate an MRF). These technologies are largely unproven for use in the U.S. They also tend to be capital intensive and expensive to operate, especially when compared with other waste disposal options, such as continued use of BRESCO or constructing a transfer station. Another major drawback is that waste processing options work in opposition to reduction/diversion measures implemented in Task 5. In other words, mixed waste processing performs best when all organic and recyclable material is left in the mixed waste stream. MWP may thus be an inefficient, expensive, and highly centralized method of meeting diversion goals, which could be better achieved by implementing the more diversified options from Task 5. Nevertheless, MWP options will be considered in the Draft Master Plan (Task 8 Report) as alternatives to the options from Task 5. For this reason, waste processing options were not considered as part of the scenario analysis in Chapter 5 of this Report, which focused on ensuring the City would have sufficient long-term and contingency disposal capacity.
2. Continued Disposal within Baltimore. Options considered included continued use of BRESCO and QRL (status quo), expansion of QRL, and construction of additional landfill capacity. There are currently plans to permit a lateral expansion of QRL, which would increase the remaining capacity of QRL to 8.9 million CY (as of 2019). Although it may be feasible to further increase the capacity of QRL in the future using a vertical expansion, developing a new landfill in the Baltimore area is not feasible. As such, continued use of BRESCO (short to medium term) and the proposed lateral expansion of QRL (medium term) were deemed the most competitive options for continued disposal in the local area.
3. Disposal of Waste Outside the City. Options considered included upgrading NWTS for out-of-city transfer at full capacity, construction of an additional truck transfer facility, and construction of a rail transfer facility. Upgrading NWTS was deemed the most competitive short- to medium-term option, while construction of a rail transfer station was deemed the most competitive long-term option due to its lower operating costs and smaller carbon footprint compared with truck transfer. An additional truck transfer facility could also feasibly be

constructed in the city in the medium-term to help reduce airspace consumption at QRL.

7.3 Scenario Analysis

Section 5 of this report contains a scenario analysis to determine the City's potential actions regarding whether or not their disposal contract with BRESCO is renewed in December 2021. In all cases, it is recommended that the City pursue the construction of a rail transfer facility to enable environmentally friendly transfer of waste for out-of-City disposal in the long-term. Short- and medium-term options for each scenario were chosen to minimize airspace consumption at QRL (to facilitate cleanup following a natural disaster, but also to provide leverage when negotiating rates for out-of-City disposal) while also considering the timing requirements of permitting and constructing new facilities. A full summary of the scenarios considered was given in Tables 5.1 through 5.3.

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