RHODE ISLAND RESOURCE RECOVERY CORPORATION

ANALYSIS OF STATEWIDE MUNICIPAL FOOD WASTE COLLECTION ALTERNATIVES

FINAL REPORT I MARCH 2022

DSM ENVIRONMENTAL SERVICES, INC.

Resource Economists
Environmental Scientists

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EXECUTIVE SUMMARY

DSM Environmental Services, Inc. (DSM) was contracted by the Rhode Island Resource Recovery Corporation (RIRRC) to develop a model to estimate the collection costs associated with diverting food waste generated by Rhode Island households from disposal. DSM developed the model by first establishing the collection methods and cost estimates of the current residential refuse and recycling collection system in each Rhode Island municipality (Base Case). Once the Base Case was completed DSM modeled five alternative residential food waste collection scenarios to develop estimates of costs, miles traveled and associated greenhouse gas emissions for each alternative.

DSM's scope of work excluded the costs to manage the food waste at RIRRC. This is important because the true cost of separately managing food waste includes both the collection and the cost to process the food waste at the RIRRC facility.

This analysis focuses only on municipal waste delivered to RIRRC, which excludes some residential subscription collection and multi-family dwellings and condominiums. Costs to manage special wastes (e.g., construction wastes, bulky wastes, electronics) are also excluded.

Limitations

It is important to understand that this analysis is an economic model only. DSM encountered significant difficulties in accurately estimating current collection costs for refuse and recycling for the base case despite data provided to RIRRC by municipalities and additional research independently conducted by DSM. This is because costs for collection of residential refuse and recycling often include separate yard waste collection which needed to be excluded from the base case. And, in some cases additional services are included in reported collection costs including separate bulky waste collection, education and enforcement, and provision of special collection days. As such, base case refuse and recycling collection costs may not compare with data provided by municipalities to RIRRC.

Just as importantly, modeling of the alternative collection scenarios involved a whole series of assumptions concerning collection times, set-out rates for separate food waste, and truck costs. This is especially the case at the individual municipality level of analysis. Therefore, this analysis should be compared at the state-wide level; and even in that case the comparison of alternatives to the base case should be considered a rough, order of magnitude comparison.

Alternative Food Waste Collection Scenarios

Curbside Collection

There were five alternatives analyzed for municipalities with curbside collection of refuse and recycling. These are outlined below.

Scenario 1: Collect Food Waste Separate from Refuse and Recycling, assumes that separate food waste collection will be added to all municipal collection programs in Rhode Island with no change to the existing service or programs.

Scenario 2: Split Truck Collection, Refuse and Recycling Every Other Week, Food Waste Each Week, assumes that municipalities and private haulers under contract to municipalities will switch to operating split trucks, with food waste collected each week and refuse and recycling collected on alternating weeks in the other compartment of the split truck.

Scenario 3: Every Other Week Refuse and Recycling, Food Waste Weekly, No Split Trucks, was designed to lower costs by using existing trucks where feasible but adding new trucks where there was insufficient capacity to separately collect food waste. This scenario also assumes (as in Scenario 2) alternating week collection of MSW and recyclables in all municipalities. Weekly separate food waste collection was added using the same truck type as for refuse.

Scenario 4: Baseline Collection with Bagged Food Waste in Refuse, was created to address the high cost of adding trucks to collect food waste weekly and instead assumes that residents are provided with special, colored bags which they can place food waste in and commingle in their refuse cart. The added costs in Rhode Island would be the cost of the bags as all other collection costs remain the same, with the majority of the costs incurred at RIRRC (which is not analyzed as part of this project) where specialized optical sorting equipment with associated conveyors would be necessary to sort out the colored bags.

Scenario 5: All Refuse, Recycling and Food Waste Mixed Together in Single Collection, analyzes the change in collection requirements and costs where all refuse and recyclables are collected commingled in a single truck, under the assumption that RIRRC would construct a processing system at RIRRC to separate out recyclables and organics with landfilling of the residue.

Drop-Off Collection

For all drop off facilities, food waste collection is assumed to be added by offering a separate container(s) to store the food waste collected. Program costs at these drop-offs include the capital cost of adding new containers and some minor additional labor, as well as some additional transport cost to RIRRC. While the same amount (tons) of material will have to be transported, the addition of food waste may necessitate additional hauling during warmer months even though containers will not be full.

Food Waste Diversion

Food waste diversion was estimated at 72 percent (High Diversion), based roughly on current diversion rates for recyclables, and 50 percent (Low Diversion) based on diversion rates DSM had observed in a food waste diversion pilot study for ecomaine.

Comparison of System-Wide Collection Costs

Table E.1 (on the next page) compares the collection cost for each of the five alternative collection scenarios against the Base Case (current Baseline) costs for household refuse and recycling collection in Rhode Island. Table E.1 also shows the per unit performance metric results for each scenario.

Table E.1 - Comparison of Alternative Household Food Waste Collection Scenarios Against Current Baseline Costs for Refuse and Recycling Collection, Rhode Island

METRIC	Baseline	Scenario #1 - Collect Food Waste Separate - High Recovery	Scenario #1 - Collect Food Waste Separate - Low Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - High Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - Low Recovery	Scenario #5 - Mixed Solid Waste Collection (1)
Annual Costs										
Cart Costs (2)	$0	$1,322,975	$1,322,975	$1,322,975	$1,322,975	$1,322,975	$1,322,975	$0	$0	$0
Cart Liner Costs or Bag Costs (3)	$0	$1,639,140	$1,138,292	$1,639,140	$1,138,292	$1,639,140	$1,138,292	$2,026,982	$1,407,627	$0
Collection Costs (4)	$46,726,390	$67,460,901	$63,686,428	$66,999,042	$74,467,673	$57,342,573	$53,923,505	$46,726,390	$46,726,390	$37,709,176
Estimated Food Waste Collection Cost	*$0*	*$20,734,511*	*$16,960,038*	*$26,799,617*	*$29,787,069*	*$20,734,511*	*$16,960,038*	*$0*	*$0*	*$0*
Total Cost (3):	$46,726,390	$70,423,016	$66,147,695	$69,961,156	$76,928,940	$60,304,687	$56,384,771	$48,753,373	$48,134,017	$37,709,176
Change from Baseline (%):		***51%***	***42%***	***50%***	***65%***	***29%***	***21%***	***4%***	***3%***	***-19%***
Cost Per Unit										
Cost Per Ton (Refuse, Recycling and Food Waste)	$118	$178	$167	$177	$194	$152	$142	$123	$122	$95
Cost Per Household (Refuse, Recycling and Food Waste)	$129	$195	$183	$194	$213	$167	$156	$135	$133	$104
Cost Per Ton (Food Waste Only)	$0	$575	$679	$722	$1,127	$575	$679	$49	$49	

(1) Food waste diversion for Scenario 5 depends on processing method. Cost per ton are based on assumptions used in all other scenarios and does not account for any processing residues.
(2) Annual toter costs are shown assuming 4% interest over 10 years.
(3) Bag liners are assumed to be used in 72% of weekly set outs 90% of the weeks of the year. Bag costs for Scenario 4 assumed at 22 cents per bag
(4) Excluding yard waste collection and processing, and MSW disposal tip fees.

As illustrated by Table E.1, *separate* collection of household food waste increases collection system costs ranging from a low of 21 percent to a high of 65 percent, or roughly $24 to $76 per household per year.

The lowest cost alternative for separate weekly food waste collection appears to be Scenario 3 with alternating weeks of refuse and recycling collection, however, this represents a reduction in service for most curbside households who currently receive weekly refuse collection. Maintaining current service levels increases costs, as illustrated in Scenario 1.

The high cost of separate collection of household food waste can be significantly reduced by asking households to put their separated food waste in a small (8 or 13 gallon) heavy mill, colored plastic bag and place it out with the refuse (in most cases in the refuse cart) on the refuse collection day. This would require RIRRC to construct a facility at the landfill where the refuse could be run through a conveyor with optical sorters used to separate the colored food waste bags from the refuse. The bagged food waste could then be run through a food depackaging machine to remove the plastic waste, with the food waste then processed either aerobically or anaerobically. Because DSM's analysis only estimates costs for collection, the bagged food waste collection method is an incomplete analysis of the true cost of collecting the food waste since it relies on additional costs at RIRRC before the food waste can be processed.

Eliminating recycling collection and collecting all material together, Scenario 5, appears to significantly reduce collection costs even when compared to the Base Case. However, DSM's scope of work didn't include an analysis of processing of food waste, or in this case processing of mixed waste. And since a primary goal of this analysis is to evaluate the cost to increase landfill life by reducing disposal of material that can be diverted, it is important consider that the few operational mixed waste processing facilities that DSM is aware of have very low reported overall recovery rates of roughly 15 percent for recyclables and organics.[1]

Impact on Greenhouse Gas Emissions (GHG)

Table E.2 below presents the estimated annual change in GHG emissions associated with the five scenarios analyzed. Typically, GHG emissions associated with the collection and transport of solid waste are relatively insignificant compared to either materials recycling or landfill disposal GHG emissions.

Reductions in GHG emissions when compared to the Baseline associated with Scenarios 2 and 5 are the result of significant reductions in total collection trucks assumed to be required under these two scenarios.

Conclusion

It is DSM's opinion that the high cost associated with the alternative collection scenarios when compared to the relatively low impact on landfill volume (in the range of 5 to 7 percent after degradation and compaction) and GHG emissions makes implementation of these scenarios a relatively unattractive alternative for RIRRC or Rhode Island municipalities and households.

If RIRRC were to move forward, further investigation of Scenarios 4 and 5 for collection with the refuse would appear to make the most sense from an economic perspective.

Table E.2 - Comparison of Collection and Transport GHG Emissions, Scenarios 1 – 5

METRIC	Baseline	Scenario #1 - Collect Food Waste Separate - High Recovery	Scenario #1 - Collect Food Waste Separate - Low Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - High Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - Low Recovery	Scenario #5 - Mixed Solid Waste Collection (1)
Total MTCO2 Equivalent:	6111	8560	8386	5618	5637	7548	7316	6111	6111	5644
Change from Baseline		2449	2275	-493	-474	1436	1205	0	0	-468

[1] According to an article in Resource Recycling Magazine (2019) the Montgomery, Alabama mixed waste processing facility achieves a 15 percent recovery rate for recyclables. This is consistent with a large mixed waste processing facility operating in Cancun, Mexico which DSM toured in 2019, which despite over 200 sorters, achieves less than a 15 percent recovery rate for recyclables and organics.

I. INTRODUCTION

DSM Environmental Services, Inc. (DSM) was contracted by the Rhode Island Resource Recovery Corporation (RIRRC) to develop a model to estimate the collection costs associated with diverting food waste generated by Rhode Island households from disposal. DSM developed the model by first establishing the collection methods and cost estimates of the current residential refuse and recycling collection system in each Rhode Island municipality (Base Case). Once the Base Case was completed DSM modeled five alternative residential food waste collection scenarios to develop estimates of costs, miles traveled and associated greenhouse gas emissions for each alternative.

DSM's scope of work excluded the costs to manage the separated food waste at RIRRC. This is important because the true cost of separately managing food waste includes both separate collection and the cost to process the separated food waste at the RIRRC facility.

This analysis focuses only on municipal waste delivered to RIRRC, which excludes some residential subscription collection and most multi-family dwellings and condominiums. Costs to manage special wastes are also excluded.

In addition to estimating costs for each alternative collection scenario, DSM (in conjunction with RIRRC) developed a set of performance metrics that would be used to compare each scenario against the Base Case. These ***Performance Measures*** (for collection only – not total system costs) include:

- Total collection system costs;
- The change in total collection system costs when compared to the Base Case costs;
- Per unit costs including the cost per ton of collection (including separate food waste collection), and the annul collection cost per household for refuse, recycling and food waste;
- Miles driven including annual on-route collection miles and off-route transport miles to RIRRC; and,
- Associated greenhouse gas emissions from the collection and transport miles.

Limitations

It is important to understand that this analysis is an economic model only. DSM encountered significant difficulties in accurately estimating current collection costs for refuse and recycling for the base case despite data provided to RIRRC by municipalities and additional research independently conducted by DSM. This is because costs for collection of residential refuse and recycling often include separate yard waste collection as well as, in some cases, collection of bulky wastes which DSM attempted to exclude from the base case.

In addition, in some cases optional services are included in reported collection costs including education and enforcement, and provision of special collection days. As such, as described in more detail below, base case refuse and recycling collection costs may not compare with data provided by municipalities to RIRRC.

Just as importantly, modeling of the alternative collection scenarios involved a whole series of assumptions concerning collection times (including the time to collect each set out and the amount of time spent on route collecting each day), set-out rates for separate food waste, and truck costs. This is especially the case at the individual municipality level of analysis. Therefore, this analysis, while reporting on a municipal-by-municipal basis should be compared at the state-wide level; and even in that case the comparison of alternatives to the base case should be considered a rough, order of magnitude comparison.

II. BACKGROUND

In 2015 the RIRRC completed a waste characterization study that highlighted the large contribution of organics to the total amount of waste disposed at the Central Landfill. Subsequently, in 2018 RIRRC's Resource Recovery's Long Term Solid Waste Alternatives Study identified several alternative approaches to managing organics other than landfill disposal. These included approaches such as outdoor windrow, static pile and in-vessel composting as well as wet and dry batch anaerobic digestion. Although similar to one another, these processing approaches have somewhat differing feedstock considerations and there are differing collection alternatives that need to be taken into account when choosing which if any of the processing approaches to pursue.

Recognizing that collection costs are a significant portion of overall system costs, RIRRC issued an RFP to solicit a detailed analysis of the costs and Greenhouse Gas Emission (GHG) impacts associated with collection of organics. RIRRC identified 13 potentially viable collection scenarios that could be pursued for the organics processing technologies identified in 2018.

Subsequent to award of the RFP, DSM proposed to concentrate the analysis on five alternative collection scenarios that fairly represented the expanded 13 alternatives identified by RIRRC. In addition, based on DSM's extensive experience conducting similar analyses for Delaware, Vermont, and ecomaine (Portland, ME), DSM recommended that the analysis focus on food waste only, ignoring co-collection of yard waste and wastepaper, which most facilities in the Northeast do not accept. A detailed discussion of these recommendations is provided later in this report.

Finally, the scope of work outlined in the RFP assumed that the selected contractor would model existing collection costs rather than develop a detailed analysis of existing (base case) collection costs by municipality. DSM recommended, and RIRRC agreed, that the comparison of alternative collection scenarios to the base case (current collection system) would be more accurate if DSM attempted to estimate actual refuse and recycling collection costs, and collection and transport miles, by municipality.

A detailed description of the current collection system (Base Case) and each alternative collection scenario is presented below; as well as a description of the collection model developed and the key assumptions utilized in the model.

A summary of results is then presented with observations and conclusions about the most cost-effective collection alternative to divert municipal food waste from disposal for Rhode Island.

III. BASE CASE MUNICIPAL COLLECTION SYSTEM

Details on the residential collection system in each Rhode Island municipality were initially provided by RIRRC. This included the following:

- the average annual volumes of organic waste generated by each of the State's 39 municipalities;
- a validated count of municipally served households by service type for each municipality;
- whether the materials collected were direct hauled or transferred to RIRRC; and,
- the length of roadway miles found in each municipality.

DSM then conducted additional research for many of the municipalities to develop a more accurate and complete data set on all 39 municipalities to model how refuse and recycling are currently collected, and what the costs are in each municipality (CY 2019 – 2020). DSM's research included review of municipal websites and municipal budgets, and telephone calls to knowledgeable municipal officials in cases where there were questions based on DSM initial review.

Costs were finalized after isolating as many variables as possible, outside of collection, which influence costs and quantities for residential generators only. For example, costs for education and enforcement were excluded to the extent DSM could identify them, as well as any separate costs for bulky and special waste collections. Refuse disposal costs were also excluded.

Table 1 below summarizes the initial data set developed for each municipal refuse, recycling, and yard waste collection system. These data were incorporated into the final Excel model under two Tabs – "Tons and Truck Costs" and "Baseline" as described in more detail below.

Table 1 - Base Case Data Set

Data Type	Unit/Description
Route Distance	Miles of roadway in municipality
Distance to RIRRC	Miles from municipal center to RIRRC facility
Number of Households Served	Housing units receiving collection service
Density Per Route Mile	Households Per Mile Alone Route (Calculated)
Cost Information	Either Total Cost or Cost per Service Type: MSW, Recycling and Yard Waste
MSW Collection Characteristics	
Refuse Collection Method	Truck Type (Automated or Rearload), Assumed Capacity and Contract of Municipal
Annual Volume Collected	Tons
Collection Days	Days per Week and Weeks Per Year
Number of Trucks Used	Number of Trucks on route each collection day
Recycling Collection Characteristics	
Recycling Collection Method	Truck Type (Automated or Rearload), Assumed Capacity and Contract of Municipal
Annual Volume Collected	Tons
Collection Days	Days per Week and Weeks Per Year
Number of Trucks Used	Number of Trucks on route each collection day
Yard Waste Collection Details	
Collection Method	Bagged or Containerized
Annual Volume Collected	Tons
Weeks of Collection Provided	Weeks Per Year of Service

In summary, a total of 25 municipalities contract for, or provide, curbside collection service to all or most of the households in their municipality. An additional 10 municipalities do not contract for or provide organized collection services. In these cases, residents rely on a municipal drop-off center or pay for a subscription collection service for their refuse, recycling, and yard waste. Only those subscription households whose wastes are tipped at RIRRC under the municipal cap have been included in this analysis. (Therefore, subscription households in many drop-off communities are excluded from the analysis.)

Two municipalities (North Kingstown and Jamestown) provide contracted curbside recycling collection services only, leaving households the option to drop-off residential refuse at a drop-off facility or subscribe for refuse collection. The estimated number of households receiving subscription refuse services that tip against the cap for these two communities was provided to DSM by RIRRC and are included in the base case of the model.

Details on the characteristics of collection services by municipality and the sources of these data are included in Table 2, and are further outlined below, together with a description of the manipulation of the data provided by RIRRC that was performed by DSM to more accurately represent the Base Case that was modeled.

Types and Sources of Data Used

Tons Collected

A key piece of data are the estimated annual tons of refuse and recycling collected and disposed or recycled by each municipality at RIRRC. The data used in this analysis are based on a five-year average of tons delivered to RIRRC, as provided to DSM by RIRRC from compiled scale house data. DSM calculated the pounds collected per household for each material stream to identify and address any potential outliers in the data.

It should also be noted that in some municipalities refuse and recycling collected from schools and/or municipal buildings are included in the residential tons reported. This results in slightly higher residential tonnages. No attempt has been made to eliminate this material from the annual residential tons.

Number of Households Served

An accurate count of the number of households served is a critical component of the model to predict changes in collection costs associated with separate food waste collection. The number of households served by current refuse, recycling, and yard waste collection programs in each municipality was provided to DSM by RIRRC. This data is collected by RIRRC as part of the Annual Municipal Survey but adjusted by RIRRC in some cases.

Collection System Type

There are five different types of municipal collection systems currently utilized in Rhode Island: curbside direct; curbside transfer; split direct haul; split transfer; and drop off, as described below.

> *Curbside Direct* – Refuse and recyclables are collected curbside and hauled directly to RIRRC. These materials are then tipped against a municipal account.

Curbside Transfer –Refuse and recycling are collected curbside and tipped at a known transfer station before being transported to RIRRC and tipped against a municipal account.

Split Direct Haul – Residents have access to both curbside and drop-off refuse and recycling collection and may use different service types for each stream (e.g., curbside recycling and drop-off refuse). All material collected curbside or at drop-off is hauled directly to RIRRC and tipped against a municipal account.

Split Transfer - Split transfer municipalities offer both curbside and drop-off refuse and recycling collection, but the material collected is transferred through a known transfer station and tipped against a municipal account at RIRRC.

Drop Off – Residents can drop-off refuse, recycling, and yard waste at a known drop off site. This material is then hauled directly to RIRRC and tipped against a municipal account. Residents in these municipalities may opt to instead pay for subscription curbside collection service.

Each service type impacts both the overall cost and transportation requirements for municipal refuse, recycling, and yard waste programs. The service type data was provided by RIRRC and in some cases verified or modified through DSM research.

Curbside Collection Service Characteristics

In addition to the data sets listed above, there are several key components of curbside collection programs that impact costs. These are presented below.

Provider

Curbside collection (when available) is provided by a contracted hauler or the municipality, or through a subscription (where the household contracts directly with a hauler for service). The method used impacts the overall cost of collection in a municipality and is an important factor when evaluating the alternative collection scenarios. Data on the collection provider was obtained from the Annual Municipal Surveys and supplemented through DSM's research which included reviewing information from municipal websites and making phone calls to municipalities and their contractors.

Collection Method

Different types of refuse (and recycling) collection trucks are used to reduce labor costs and improve collection efficiency. DSM labeled collection trucks as either:

- Automated (A) – where a single driver can be assigned to a truck since they typically do not need to leave the cab to collect material from (in most cases) a uniform cart or container; or,
- Rear Loader (RL) - where material (or a cart) must be moved by hand from the curb to be emptied into the rear of a truck (note that the truck may or may not have a cart tipper which removes the need for the worker to lift and then empty the cart into the truck's hopper).

DSM assumed that Side-Loader trucks were automated (A), whereas Semi-Automated trucks were assumed to be Rear Loaders (RL)[2]. Because municipalities may use an assortment of different trucks

[2] Note that is some cases a side loader may be a semi-automated truck where the driver must get out and roll the cart to the truck and attach it to a cart tipper.

depending on the routes and street lay out, DSM recorded the most frequently used truck type in the Collection Method column when modeling collection in that municipality.

Provision of Carts

Uniform refuse (and recycling) carts are provided to households in many municipalities either through the municipality or the collection contractor. This information was obtained from the Annual Municipal Surveys to RIRRC or from municipal websites. If data were not available, DSM assumed that all automated routes included carts.

Collection Frequency

Curbside refuse collection is provided weekly in all Rhode Island municipalities[3] whereas some curbside recycling collection services are offered every-other-week. The Annual Municipal Survey data was supplemented by searching municipal websites and making some phone calls to confirm these data.

Truck Counts and Collection Route Size

DSM also researched the number of days per week the refuse and recycling collection vehicles were operating in each municipality and the number of trucks used each collection day. The number of Households Served could then be divided by the truck count in each municipality to determine the number of households on each collection route.

In a few cases where the truck count was low compared against the number of households served, DSM verified data and adjusted to ensure route sizes were realistic. Truck counts and route sizes are important to estimate with accuracy to determine the opportunity for collection cost savings on refuse routes when food waste is removed.

Daily Tons Per Route

For each collection route, DSM calculated the daily tons of refuse (and recycling) collected. DSM then used scale data from RIRRC to calculate average truck weights when tipping refuse (and recycling) by dividing the daily tons by the number of trucks. Using these truck weights, the model calculates the number of times a truck would have to tip per route day.

Development of Base Case Cost Data

The cost estimates used in the model are limited to the collection costs and exclude the costs of disposal or any recycling processing as well as the overhead, administrative, and education costs that a municipality incurs associated with provision of the service (or managing the collection contract). By disaggregating these overhead and administrative costs (or contract management costs), it was possible to estimate an annual cost per truck operating in each municipality, as well as a cost per ton collected. These estimates were necessary to determine both the increase in truck needs (and costs) or any reductions when food waste is removed from refuse and collected separately.

Curbside Costs

For those municipalities where there was little or no cost data available, DSM reviewed cost data from Rhode Island municipalities with similar collection program characteristics (number of households

[3] There may be some subscription providers offering every other week refuse collection service, but these were not included in the model.

served, density, and collection method) to develop an estimate of truck costs. Using both the number of households and the number of trucks on route in that municipality, DSM estimated an annual cost to provide weekly refuse collection and to provide recycling collection (based on frequency). Together the 25 municipalities providing curbside refuse service spend roughly $20.7 million on refuse collection and transfer to RIRRC; and the 27 municipalities providing curbside recycling spend an estimated $15.6 million on this service as well. Note that disposal costs are in addition to these collection and transfer costs.

Transfer and Drop-off Facility Costs

Transfer costs are incurred in those municipalities that utilize a transfer station to consolidate and then transport refuse and/or recycling from curbside vehicles. Transfer costs include the cost to handle refuse (and/or recycling) from curbside vehicles plus the cost to transfer the material to RIRRC for disposal (or processing).

When available DSM used data from Annual Municipal Surveys, supplemented by phone calls and municipal websites, to estimate the cost per ton to process and transfer the material to RIRRC. When data were unavailable DSM used a cost per ton for handling material plus a cost per mile estimate utilizing the distance to RIRRC and the capacity of a 100-yard container (assumed to be used in Warren, Newport, Pawtucket and South Kingston) or a 40-yard compactor (used in Bristol) for the smaller transfer stations. However, in some cases the costs to transfer refuse and/or recycling was included in the curbside collection contract costs and therefore is incorporated into the truck costs.

For drop-off facilities serving households, DSM also used data from the Annual Municipal Surveys and municipal websites (such as detailed budgets and operation contracts) to estimate annual costs and the cost per ton to operate the facility. For those municipal drop-offs with no cost data, DSM applied an estimate of $100 per ton for refuse and $50 per ton for recycling. Note that these estimates are fully allocated costs (not marginal costs) but may include some (but not all) of the costs to collect special wastes (or hard to handle) materials at the facility. In addition to operating costs, a transfer cost was estimated based on the use of 40- or 100-yard containers and the distance to RIRRC. These costs are included in the current costs but may change under different collection scenarios that include food waste.

Disposal Costs

In all cases DSM removed disposal costs from the collection costs to ensure Base Case costs reflects only the collection and transfer costs and exclude any disposal costs.

Base Case Yard Waste Collection

Making an estimate of the yard waste collection costs were necessary in some cases to disaggregate yard waste costs from the refuse and recycling collection costs. For example, curbside yard waste collection costs are frequently bundled in the contract cost of refuse (and recycling) collection because they are required on a less frequent basis and trucks can then be shared between refuse and yard waste collection during yard waste collection periods.

In addition, some municipal contracts are bid out as a combined price to provide refuse, recycling, and yard waste collection services in the municipality. Therefore, the municipality has no idea what the additional cost is for the yard waste collection service.

In addition, RIRRC does not have accurate yard waste disposal data for some municipalities because they do not all use the RIRRC facility for yard waste processing and not all of the other facilities accepting yard waste from Rhode Island municipalities have scales. Therefore, some municipalities have little or no data on yard waste quantities collected in their municipality.

Finally, DSM used data provided and researched municipal websites to determine how may weeks of yard waste collection were provided in each community.

Based on limited data available, DSM then made the following assumptions:

- When a single cost estimate was provided for refuse collection that included yard waste collection service in a municipality, yard waste collection was assumed to represent 20% of the total annual collection cost, with refuse collection representing the remaining 80% of the cost.
- When refuse, recycling, and yard waste collection were bid as one cost, yard waste collection was assumed to be 12% of the total collection cost and removed from the cost of refuse and recycling collection.
- Where no cost data were available, DSM created an average cost per service week per household based on available cost data from other municipalities.

To create the average costs, DSM separated communities based on density using the weekly cost to serve populations above, or below, that density (set at 3,500 persons per square mile). DSM then applied the appropriate average per household cost to municipalities with no cost data to develop the annual yard waste collection cost for that municipality. DSM estimated the average cost per week of service to be $0.49 and $0.85 per household in municipalities with populations above and below 3,500 per square mile respectively.

Incorporation of Yard Waste Data in Scenarios

DSM recommended, and RIRRC ultimately agreed, that yard waste collection would not be incorporated into the food waste collection scenarios for the following reasons.

First, yard waste and food waste are co-collected in west coast municipalities for composting but only because of the more temperate year-round climate that requires year round yard waste collection. In contrast, Rhode Island has significant swings in both quantities and the composition of yard waste, with heavy leaf fall in late fall (high carbon), virtually no yard waste in the winter season, grass clippings in the spring and early summer (high nitrogen), converting to brush in late summer (primarily carbon). This makes it much more difficult to successfully incorporate yard waste into a food waste composting facility (where food waste is much more consistent across the seasons) as well as difficult to size containers and offer joint collection programs.

Second, and equally important, large scale food waste composting facilities in the Northeast have not been very cost effective. Instead, the trend has been to incorporate food waste into anaerobic digesters. Anaerobic digesters do not need significant amounts of carbon because of their low energy value when anaerobically digested. As such, most anaerobic digesters do not accept yard waste, and it is likely that

RIRRC will find anaerobic digestion to be a more feasible processing alternative for residential food waste.

Third, the available cost data for yard waste collection programs in Rhode Island are significantly less robust than data on recycling and refuse collection costs.

For these reasons, yard waste is not included in total baseline costs, or in comparing the costs of alternative collection scenarios.

Base Case Greenhouse Gas Emission Estimates

Greenhouse gas emissions were estimated on a Metric Ton Carbon Dioxide Equivalent (MTCO2e) basis for the Base Case Collection System. This estimate was developed solely on the estimated current municipal collection and transport system emissions from refuse and recycling collection activity for comparison against how this system would change when food waste was collected and managed under the proposed scenarios.

Two transport components make up this estimate: on-route refuse and recycling collection vehicle miles; and the mileage from the route or the transfer or drop-off facility to deliver full trucks or containers of refuse or recycling to RIRRC.

Distances Traveled on Route

The number of road miles in each municipality that would be covered by municipal collection trucks were provided by RIRRC. To estimate the total mileage driven each year by the collection vehicles, it was assumed that side loading and automated trucks only collect on the right side of the street/road, therefore doubling the mileage on each route. In contrast rear load trucks can collect on both sides of some streets so route mileage was multiplied by 1.5 to account for some cross street collection. Each municipality was assumed to have the entire town (road miles) covered each week by refuse collection vehicles, and the number of trucks operating were ignored. For recycling vehicles, the collection frequency was used to estimate route mileage since some municipalities offer every other week collection service but the type of collection – rear load or automated – was also used to develop the recycling collection route mileage.

Distance to RIRRC

The road miles from each municipality to RIRRC is based on data calculated through *Google Maps* utilizing the center of each municipality and RIRRC's physical address. DSM recognizes that there are multiple routes from each municipality to RIRRC, however, for this study DSM selected the route that took the least amount of time (instead of the least miles).

Total mileage to RIRRC was based on the mileage from the center of the municipality times the number of trips required based on the number of trucks used, the truck capacity and the tons collected (indicating whether a truck tipped once or twice per day). In each case round trip mileage was used.

For transfer stations and drop-off facilities the physical address of the facility was used to calculate round trip mileage. The number of trips were determined by dividing the annual refuse or recycling tonnage by the container capacity (100 or 40 yard) for that material (refuse or recycling). The annual number of trips multiplied by round trip mileages generated the total miles for these facilities.

Total miles driven for collection and transfer was then multiplied by a per mile emission factor for Carbon Dioxide and Nitrous Oxides (for diesel engines)[4], with the Nitrous Oxide emissions multiplied by 280 to represent Carbon Dioxide Equivalent emissions.

An estimated annual 6,111 MTCO2e were emitted from the Base Case municipal refuse and recycling collection and transport in Rhode Island. It should be emphasized here that while collection and transport GHG emissions are significant, they are a relatively small part of total state-wide GHG emissions, or GHG associated with management of refuse and recycling savings associated with substituting recycled materials for production of virgin materials.

For example, refuse and recycling collection and transport GHG emission of 6,111 MTCO2e can be compared against 4.6 MTCO2e per year for a typical passenger car (US EPA); and annual savings of an estimated 260,000 MTCO2e (rounded) from municipal recycling of close to 90,000 tons.[5]

[4] US EPA, Office of Transportation and Air Quality, *Average In-Use Emissions from Heavy-Duty Trucks,* 2008

[5] Calculated using the US EPA WARM Model for average single stream materials.

IV. DESCRIPTION OF MODEL AND KEY ASSUMPTIONS

The scope of work described in the RFP for this project included a detailed description of the nature of the model and the collection scenarios RIRRC wanted incorporated in the analysis. DSM reviewed the preliminary scenarios defined in the RFP and proposed revisions to the RIRRC scenarios. DSM also considered important model assumptions and variables and made recommendations to these elements as well. These are described below.

Recommended Changes to Proposed Model Elements

Elimination of Compostable Paper

DSM recommended that co-collection (and diversion of) compostable paper with food waste be eliminated from the model because, based on DSM's experience, neither composting facilities nor anaerobic digestion (AD) facilities can utilize compostable paper, although for different reasons. For composting facilities compostable paper (while physically compostable) represents a contaminant that significantly reduces the marketability of the resulting finished compost. For example, incorporation of food packaging, grease resistant fast-food containers/wrappers and microwave popcorn bags increases polyfluoroalkyl (PFAS) contamination since food service grade containers contain PFAS as a grease inhibitor. The result is PFAS contamination of the compost eliminating the ability to market organic compost, which typically cuts the value of the compost by almost 50 percent.

Similarly, a certain percent of paper plates and paper cups incorporate a polyethylene layer, also as a grease inhibitor or to keep the paper cup or plate from soaking through as quickly. This introduces plastic as a contaminant to the compost, reducing the value of the resulting compost.

For AD facilities, compostable paper does not have sufficient energy value to incorporate into the digester. Therefore, the operators of AD facilities do not want compostable paper incorporated into the energy rich food waste.

Finally, in both cases the inclusion of compostable paper in a residential organics collection program will invite significantly greater levels of contamination of the desirable food waste.

Elimination of Yard Waste

As discussed above, inclusion of yard waste in the alternative collection scenarios is problematic because of the variations in both yard waste generation rates and collection methods offered over the course of the year in the Northeast. While yard waste is typically co-collected with food waste in many western coastal programs (i.e., Seattle, Portland, and San Francisco), yard waste generation and collection in the wetter and warmer coastal cities is typically year-round, and food waste was simply added to many of these collection programs.

Conversely, yard waste generation is both seasonal in the Northeast, and quite variable with respect to composition and quantities. In addition, and similar to dirty paper, yard waste, with the possible exception of grass clippings has a very low energy value in an AD facility and therefore is not desirable as an input.

As such DSM eliminated the co-collection of yard waste with food waste from the model.

Critical Model Assumptions

Food Waste Recovery Rate

DSM believes that the assumption of a recovery rate (participation rate times the percent captured from each participant) of 72 percent for food waste is optimistic – even in a fully developed program. For example, DSM measured a capture rate of 45 percent for a recent ecomaine analysis based on pilot food waste collection programs in two ecomaine communities. As such DSM ran the model at two rates - 50 percent (assuming mandatory food waste separation requirements which were not in place at ecomaine) and the 72 percent recovery rate specified by RIRRC. In both cases it is likely that the limiting factor will be route size (and time collecting) and not the truck capacity given the small amounts of food waste that will be collected from participating households on a weekly basis under either recovery rate.

In addition, DSM has assumed that food waste separation will be mandatory – similar to recycling collection. That is, all households will be provided the collection service and appropriate container and not have the option of opting out of the program. Some level of education and enforcement will be assumed to reach the 50-72 percent recovery rate level.

Static Analysis

Typically, implementation of a state-wide food waste collection program would occur over a several year period, with recovery rates increasing over a longer time period as households get used to separating food waste.

Just as with implementation of the mandatory recyclables program, it would be necessary to purchase and distribute carts to all households and begin an educational program to introduce households to the requirement to separate food waste. In addition, municipalities with refuse and recycling contracts would have to bid out, or renegotiate their collection programs, and municipalities that operate their own programs would have to purchase new trucks and adjust their operations to incorporate the new collection material.

Finally, during implementation there would be a need for an increase in both education and enforcement budgets to monitor participation and contamination rates. Taking these issues all into consideration it is safe to say that fully ramping up separate residential food waste collection could take a minimum of five years before the program was fully operational and recovery rates began to plateau.

While it is possible to build a more complex model over a ten-year period that illustrates phased in costs and volumes from an organics collection program, given the complexities of the model and the large number of scenarios, DSM has chosen to assume that costs and recovered volumes are based on a fully developed program – that is it is a static, single year analysis. This one-year cost model includes amortized capital costs and average organics recovery. The results of this can be used to estimate costs over ten years if necessary – as in the end, the results are unlikely to differ much from a fully modeled ten-year phased in program.

Model Design

The Model was built in Excel with each sheet representing a different collection scenario. There are six collection scenarios in total, the Base Case and five alternatives. Assumptions for both the Base Case and the alternative collection scenarios are presented in a separate sheet for reference, and more importantly to allow the user to vary key assumptions to assess the impact of those assumptions.

State-wide results from each scenario are shown in a separate sheet entitled "Performance" and summarized in Table 4, below.

Base Case

The Base Case represents current conditions in Rhode Island for refuse, recycling, and yard waste collection including drop-off collection and transfer requirements. The Base Case is used to compare against the alternative food waste collection scenarios. As described above, the Base Case was populated using data RIRRC supplied, and DSM verified to account for missing data through telephone calls, e-mail correspondence, and internet research on a municipality-by-municipality basis.

Alternative Food Waste Collection Scenarios

The five alternative food waste collection scenarios modeled are described below.

Scenario 1, Collect Food Waste Separate from Refuse and Recycling, assumes that separate food waste collection will be added to all municipal collection programs in Rhode Island with no change to the existing collection programs or service. The type of collection occurring in each municipality was mirrored for separate food waste collection, with the addition of new trucks to separately collect food waste once per week from all participating households.

Scenario 2, Split Truck Collection, Refuse and Recycling Every Other Week, Food Waste Each Week, assumes that municipalities and private haulers under contract to municipalities will switch to the use of split trucks, with food waste collected each week and refuse and recycling collected on alternating weeks in the other compartment of the split truck. Split trucks were assumed to be automated side loaders with a low loading height so they could function as semi-automated trucks with cart tippers for areas where there was insufficient room to operate a fully automated truck. The truck was assumed to be split horizontally 60/40 with food waste collected in the smaller compartment.

Scenario 3, Every Other Week Refuse and Recycling, Food Waste Weekly, No Split Trucks, was designed to lower costs by using existing trucks where feasible but adding new trucks where there was insufficient capacity to separately collect food waste. This scenario also assumes (as in Scenario 2) alternating week collection of MSW and recyclables in all municipalities. Weekly separate food waste collection was added using the same truck type as for refuse.

Scenario 4, Baseline Collection with Bagged Food Waste in Refuse, was created to address the high cost of adding trucks to collect food waste weekly and instead assumes that residents are provided special, colored bags which they can place food waste in and commingle in their refuse cart.[6] The added costs in Rhode Island would be the cost of the bags as all other collection costs remain the same, with the majority of the costs incurred at RIRRC (which is not analyzed as part of this project) where

[6] DSM tested this concept for ecomaine and also looked at the cost of optically sorting the bags at the ecomaine facility in the ecomaine analysis.

specialized optical sorting equipment with associated conveyors would be necessary to sort the colored bags.

Scenario 5, All Refuse, Recycling and Food Waste Mixed Together in Single Collection, analyzes the change in collection requirements and costs where all refuse and recyclables are collected commingled in a single truck, under the assumption that RIRRC would construct a processing system at RIRRC to separate out recyclables and organics with landfilling of the residue.

For all drop off facilities, food waste collection is assumed to be added by offering a separate container(s) for food waste collection available to residents. Program costs at these drop-offs include the capital cost of adding new containers (or renting them) and some minor additional labor, as well as some additional transport cost to RIRRC. While the same amount (tons) of material will have to be transported, the addition of food waste may necessitate additional hauling during warmer months even though containers will not be full.

Additional Containers and Bags Used

For Scenarios 1, 2 and 3 DSM assumes that a new 30-gallon food waste cart will be provided to all curbside households. The cart cost was amortized over ten years, and an assumed 10 percent replacement cost was added to the existing annual capitalization. In addition, cart liners similar to small plastic kitchen waste bags are assumed to be used by households to place food waste in so that the food waste carts remain fairly clean, and the food waste can be emptied even on the coldest days when the food waste would freeze to the side of the cart without the bags.[7]

Key Collection Model Variables

The number of trucks required to be on route each day drives the cost of the system and contributes to the GHG emission estimates. Truck requirements and miles driven are impacted by several variables including:

- The density of the route – the higher the density, the greater the number of households that can be served per hour – although in some cases parked cars and traffic can negate the higher number of potential stops per hour.
- The collection truck type, with rear loading trucks assumed to cover 1.5 times the route miles and side loading/automated collection assumed to cover 2 times the route miles to account for right side collection only.
- The participation rate – especially for food waste where DSM expects a significantly reduced number of households setting out food waste (especially at a 50 percent capture/recovery rate) when compared to refuse and recycling.[8]

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[7] It is assumed that whatever processing system RIRRC implemented to manage the separated food waste would include de-packaging equipment designed to remove the food waste from the bags at the front end of the process.
[8] DSM typically observes 90 percent set-outs for refuse, and 75 to 85 percent set-outs for recycling – that is the number of households setting out refuse or recycling on the collection day, with every-other-week recycling set-out rates at the higher end of the set-out rates. Conversely, food waste capture rates of 72 and 50 percent (especially) will result in set-out rates that are significantly less; therefore, DSM has increased the number of households that can be served by the food waste truck to account for the number of non-participating households.

- The distance and drive time to and from the disposal/transfer/processing site as opposed to the on-route productive collection time.
- The time required to tip the refuse/recyclables/food waste at RIRRC (and the number of tips made each collection day). (Note that DSM has assumed that the food waste processing facility would be adjacent to the landfill.)
- The collection route distances and whether collection occurs only on the right side of the road – as is required on side load automated vehicles. Therefore, DSM has assumed that the use of side loading trucks dictates right-side loading only, which doubles the route miles and has assumed that for safety reasons, rear-loading trucks only collect on both sides of the street or road one-half the time, so route miles are multiplied by 1.5 times.
- The capacity of the refuse or recycling truck (in tons) when it is fully loaded.

Performance Metrics

The model results are summarized in the Performance Tab (sheet) and shown as several different performance measures including costs, tons diverted and greenhouse gas emissions.

The ***primary performance metric*** is the change in the total collection system costs compared against the baseline system cost under each alternative scenario to collect food waste. While costs are presented separately for drop-off and curbside collection systems; and by municipality, total system costs are presented as:

- State-wide total costs for each alternative scenario, and for the Base Case;
- The percent change in costs of each alternative compared to the Base Case;
- The costs per household served calculated by dividing total system costs (of the Base Case and each scenario) by the total households served; and,
- Cost per ton collected (for all materials combined), and for the separate food waste collection.

The ***second performance metric*** is the change in miles driven and the associated greenhouse gas emissions from collection and transport based on these additional (or reduced) miles. This is compared to the base case GHG emissions calculated from the estimate of current trucks on routes (and miles driven) in each municipality for all types of collection. GHG emissions are estimated from assumed annual diesel fuel consumption from each truck.[9]

The ***third performance metric*** is the estimated annualized increase in capital costs associated with new food waste carts depending on the scenario; as well as the increased cost of kitchen garbage bags for Scenarios 1 through 3 and specially colored heavy mill bags for Scenario 4. (Note that the capital costs associated with truck use are incorporated into the total collection system costs.)

[9] DSM recognizes that in some cases the collection trucks run on natural gas and that emissions may be reduced, but no data on the mix of trucks used in RI was available

V. COLLECTION SCENARIO ASSUMPTIONS

The model developed is divided into three main collection methods. These are:

- Organized curbside collection where everyone receives the same collection service in a municipality at their place of residence either by the municipality, or by a private hauler contracted by the municipality;
- Subscription collection where households must independently contract for collection service by a private hauler; and,
- Drop-off collection (where households must deliver their refuse, and in most cases recycling, to a facility where it is consolidated for delivery to the RIRRC landfill or MRF).

Most Rhode Island households are served by the first - organized, curbside collection – and this method represents the vast majority of costs.

In addition, five municipalities have a transfer station where curbside collection providers tip refuse and recycling for consolidation and transfer to RIRRC.

For each of the five alternative collection scenarios a series of assumptions were made to model the logistics and associated costs of collection. These are outlined below.

An important assumption that applies to most of the scenarios is the capacity of trucks used. Table 2 presents the assumed capacity of the different trucks used for each material type, and for the split truck assuming refuse and recycling occupy the larger compartment (See Scenario 2).

Table 2 - Truck Types and Assumed Capacity by Material Type Collected

Truck Type	Symbol	Truck Capacity (Yds)	Refuse (Tons)	Recycling (Tons)	Food Waste (Tons)
Rearload - Contract	RL - C	36	11.7	7.2	16.2
Rearload - Municipal	RL - M	36	11.7	7.2	16.2
Automated Side Load - Contract	A - C	36	11.7	7.2	16.2
Automated Side Load - Municipal	A - M	36	11.7	7.2	16.2
Side Load Split (1)	A - SP	30 (60/40 Split)	5.85	3.6	5.4
Food Waste Specific	FW	20 - 27			10.6
Pounds Per Cubic Yard (compacted):			*650*	*400*	*900*

(1) Available in 28 and 32 yd3, so 30 yd3 was used.

Scenario 1: *Addition of Separate Food Waste Collection with No Change to Existing Collection System for Refuse and Recyclables*

Scenario 1 assumes that the existing refuse and recycling collection system in each municipality will not change but that separate food waste collected will be offered to all households. For curbside households, this means that weekly collection of food waste will be added to the existing curbside collection service using the same type of truck at the same cost per truck as the one collecting refuse in each municipality. For drop-off customers, this means that a separate food waste collection container(s) will be available at the drop-off facility.

Organized Curbside Service

Under Scenario 1 municipalities that provide curbside refuse collection to households would add a separate weekly curbside food waste collection, making no change to the existing refuse and recycling collection programs. This means that additional trucks must be used in each program to separately collect the food waste; and as noted above it will be necessary to collect food waste every week given the nature of food waste.

The food waste collection route sizes (the number of households served) are assumed to be larger than the refuse routes because the set-out rates of food waste are assumed to be lower than those for refuse. For high capture, or 72% food waste recovery, the routes are assumed to be 120% of the refuse route. For lower capture, or 50% food waste recovery, the routes are assumed to be 140% of the refuse route due to the large number of households who do not set out food waste for collection (and the greater number of drive-byes). This reduces the number of trucks needed each week for food waste collection when compared to those used for weekly refuse collection.

It should be noted here that the number of households served by each truck can only be roughly estimated, especially in the more densely populated urban areas. This is because a single location or stop may represent several households using several carts, or sharing carts both for refuse and recycling, and with the new service, for food waste.

Second, another key assumption is that costs are calculated for partial trucks, and not rounded to whole numbers. In other words, if the route size in a municipality is assumed to require 1.7 trucks each week, then truck costs are multiplied by 1.7 instead of rounding up to 2 trucks. This assumption recognizes that if Rhode Island were to mandate food waste separation and new collection contracts were negotiated, there likely would be some truck (and route) sharing between municipalities to minimize collection costs. Because weekly household food waste generation is relatively low compared to refuse and even single stream recycling, truck payloads will be low with the limiting factor for the route size each collection day being collection time, not the payload. Contract haulers may end up with long collection days to reduce costs and are likely to share trucks with nearby municipalities where they also have a contract.

The third major assumption is the cost of the food waste collection trucks used. Truck costs are assumed to be the same as the average refuse collection truck cost in each municipality.

Finally, DSM investigated the possibility of cost savings associated with refuse collection due to the removal of food waste. As shown in the model, the impact of removing food waste from refuse trucks was calculated in each municipality to compute the average reduction in tons collected per day in each refuse truck. This was used to determine whether the lower payload eliminated a second trip to RIRRC to tip refuse in cases where trucks typically tip more than once daily.

In addition, DSM considered the impact of a reduced number of households setting out refuse each week due to the elimination of rotting food waste on the remaining primarily dry refuse, thus encouraging some households to refrain from setting out their refuse container as frequently. For example, it is plausible that the set-out rates of refuse might be reduced by 10% (say, from a 95 percent weekly set-out rate to 85 percent, rounded) due to the removal of food from the refuse (with households setting out food waste containers weekly but sometimes not their refuse containers.[10] This reduction would not shorten the routes size significantly enough to eliminate a truck from the collection fleet in any municipality but shortens collection time, which is incorporated in the model.

Food Waste Transfer

In the five municipalities that utilize transfer stations for refuse and recycling, food waste transfer would be added. We appreciate that there may be space limitations at some transfer stations making it difficult to add another container but assume for modeling purposes that this could be addressed. Costs to transfer the food waste were estimated based on adding containers to consolidate food waste and then transferring them at least weekly (whether full or not) to RIRRC.[11] The model also adjusts for savings in refuse transfer costs realized by freeing up some refuse container capacity and therefore reducing the number of pulls of refuse (to RIRRC) each year.

Note here that DSM has only calculated the ***change in transfer station costs***, not the entire transfer costs for each scenario for comparison against the base case.[12]

Subscription Curbside Service

In those municipalities where multiple haulers offer subscription service, haulers would now have to provide additional weekly food waste collection and would do so in a separate truck under Scenario 1. Because of the multiple haulers, and longer distances between stops, route sizes are typically smaller than organized municipal service.

DSM investigated pricing for subscription food waste collection in the Northeast and identified a wide range depending on the demographics, housing density, and any mandatory service requirements. Given the number of haulers operating in Rhode Island subscription communities, a cost of $15 per household per month was assumed to reflect additional hauler pricing associated with providing the additional weekly food waste collection service. This cost per month is similar to what DSM has observed haulers in Vermont proposing to charge for separate food waste collection and is one of the key reasons that separate collection of food waste for subscription haulers in Vermont has not occurred to any significant degree.

In all cases separate food waste collection is assumed to be provided by the subscription haulers using a separate truck.

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[10] Note that in municipalities where DSM has measured participation and set-out rates for recycling it is typical for to see set-out rates ranging from 75 to 85 percent depending on participation rates.

[11] DSM has assumed that for the transfer stations it is likely that 15-yard roll-offs would be necessary. The problem is that these roll-offs would need to be cleaned fairly frequently to avoid odors and maggots – which could also freeze in the winter preventing some portion of the food waste from being emptied.

[12] The Base Case includes best estimate of the current transfer costs (and does not include the total costs of operating each transfer station for all materials but only the costs to handle the refuse and recycling tons in the model), and therefore only the change in drop-off or transfer costs is included in the alternative collection scenarios.

Drop-off Collection Service

In municipalities that provide drop-off refuse and recycling, separate food waste containers would be added to each facility. These containers would range from 48 to 64-gallon toters to 8-yard dumpsters. In all cases the containers are assumed to be emptied weekly. In reality, in the summer months, twice weekly may be required due to odors. And during some winter periods weekly collection may also not be enough due to freezing.[13]

The assumed container capacities and associated weights are shown below in Table 3. As shown in Table 3, the compaction ratios for containers are lower than those achieved in trucks. The primary reason for higher compaction ratios in trucks (as opposed to in stationary compactors) is that trucks achieve better compaction because the waste (or recyclable material) is pushed against a moving back wall, while stationary compactors only push against all the garbage (or recyclables) in the entire container, reducing compaction.

Table 3 - Container Sizes Used at Transfer Stations and Drop-offs and Associated Weights

Facilities	Container Capacity (yds)	**Refuse (Tons)**	**Recycling (Tons)**	**Food Waste (Tons)**
Transfer Station - Large	100	22.5	13.75	15
Transfer Station - Small	40	9	5.5	15
Transfer Station - Small	8			3
Transfer Station - Small (Toter)	0.48			0.18
Pounds Per Cubic Yard (compacted)		*450*	*275*	*750*

The cost for adding and managing containers on-site for food waste is assumed to be $30 per ton, exclusive of the collection and hauling costs. The costs to collect or empty containers are estimated based on a cost per ton handled. In this case DSM has assumed that the collection and hauling would be priced similar to commercial collection of refuse or recycling based on an all-in cost for container rental and periodic emptying and hauling. In cases where 8-yard containers or toters are used, routes are assumed to be consolidated with similar containers at other near-by drop-offs.

To estimate transport miles, several assumptions were made.

First, because toters are used at smaller drop-offs, it is assumed that the collection truck is on an organized route and therefore the drop-off is assigned only part of the mileage to RIRRC. An assumption is made that 1/5 of a round trip is assigned to that transfer station weekly.

Second, in the case of 8-yard containers, it is assumed these are tipped into a rear loader also on an organized route. In this case, it is assumed that ¼ of a round trip is assigned to that transfer station weekly.

[13] Note that the majority of drop-off separate food waste collection in Vermont is provided by 48 to 64-gallon toters.

Finally, because the drop offs are all assumed to have 40-yard compactors for refuse that are serviced at least weekly there is not an assumption of route milage savings because that container would remain on a weekly pull schedule.

Scenario 2: *Split Truck Collection, Every Week Food Waste, Alternating Weeks Refuse and Recycling*

In this scenario all curbside customers with weekly refuse and weekly recycling would now have every other week collection for both materials. And because no municipalities in Rhode Island currently use a split truck for service, all new trucks would be needed. For drop-offs there would be no change in service as there are no efficiencies in splitting transfer containers between two materials.

Organized Curbside Collection

DSM has assumed that the "all in" truck cost would be $400,000 annually for the new split trucks, including amortization over a ten-year period of the capital cost. This "all in" cost includes capitalization of the truck, all operating costs, including fuel and maintenance, labor costs, and in the case of collection under contract to private companies, typical profit margins. Because this all-in cost per truck is greater than the estimated all-in cost for the existing baseline[14], DSM has chosen to not round truck counts up for calculation of total costs. Ultimately this Scenario did not end up being cost competitive in any case, so the impact of this assumption is somewhat academic.

This is the case because unfortunately, a 60/40 split, while the standard in the industry, is not ideal for food waste collection because of the small amount of food waste set out each week. This means that the refuse or recycling side of the truck prematurely fills up before the food waste side is full, forcing the truck off the route to tip more frequently.

Key assumptions associated with this Scenario include:

- All trucks are purchased new since no one is currently using split trucks. This has a large impact on total costs because purchasing new trucks is significantly more costly than using existing trucks, especially given new Tier 4 emission standards required of new trucks.
- The 30-yard trucks are assumed to be fully automated, side loaders, with a low loading height. This allows them to be used as semi-automated trucks with a cart tipper in tight neighborhoods.
- The truck is split horizontally 60/40 with the 40 percent side used for food waste and the 60 percent side used for refuse one week and recycling the next.
- The number of trucks required per municipality is based on the lower of the number of households which can be collected on the refuse or recycling route (before the truck must tip). The key is the assumption related to refuse and recycling densities. As shown in Table 2, DSM has assumed 650 and 400 pounds per compacted cubic yard respectively for refuse and recycling. It is possible, although DSM does not have data to justify it, that removal of food waste could lower the density for refuse; which the model user can change on the Assumptions Tab of the model.

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[14] Note that DSM assumes that the baseline truck costs include shared trucks in some cases which is one of the reasons the costs are lower than would be estimated if the baseline were simply modeled.

- As can be seen from the model, the lack of capacity on the refuse/recycling side requires the truck to go off-route to dump at RIRRC after between 125 and 440 stops (depending on waste generation in that municipality).
- To determine if there is sufficient time during the day to return to the route and collect a second load, DSM has assumed a range of stop times based loosely around timing data for automated side loaders DSM timed in Columbus, OH. The data are old but probably relatively accurate for this analysis. Stop times for rear loaders and automated side loaders are adjusted based on household densities ranging from under 50 households per mile to over 150 per mile in 50 per mile increments.
- We assume that the truck travels to and from RIRRC at an average rate of speed of 35 mph, with the round-trip mileage based on a Google Maps search from the center of the municipality to RIRRC and weighs and unloads both compartments in 30 minutes.[15]
- All households are provided a 30-yard cart for food waste. This cart is larger than necessary for food waste but is the smallest cart that can be grabbed by the automated arm used to collect 64 or 92-gallon refuse or recycling carts.
- We assume that the Newport, Bristol and Warren transfer stations have the capacity to add food waste transfer trailers/roll-offs. We assume that the Pawtucket transfer station uses the same trailer for refuse but direct hauls recycling and food waste on the recycling week; but stores the food waste on the tip floor and then transfers it with the refuse trailer at some point during the week on the refuse week. Note that recycling is assumed to be direct hauled from Pawtucket in all of the scenarios.
- Finally, as discussed above, costs for Scenario 2 are based on partial trucks. We do not round up to whole trucks.

Subscription Collection

For subscription households, households are assumed to keep their refuse hauler and that the municipality requires collection of both recycling and food waste for all subscribers. For Narragansett/South Kingstown we assume that the 10,581 households that subscribe would now have service every other week for refuse and recycling.

In Jamestown and North Kingstown, where the municipality offers curbside recycling, it is assumed that separate food waste collection would be added to the recycling collection.

Drop-off Collection

The drop-off costs associated with Scenario 1 apply for all households for Scenarios 2 and 3 so we simply carry that information from Scenario 1.

Scenario 3: *Existing Trucks, Every Other Week Recycle and Refuse Collection*

In this scenario the existing refuse and recycling trucks would be used but everyone would receive every other week refuse collection and every other week recycling collection, as opposed to Scenario 1 where refuse is collected weekly and where most recycling is collected weekly. In essence, this represents a

[15] Without knowing what RIRRC would use to process the separated food waste DSM has assumed that the food waste side of the truck can be tipped adjacent to where the refuse or recycling is tipped. Note that travel and tip time are relatively irrelevant to the total cost of the system when compared to truck requirements.

reduction in service to many curbside households when compared to the Baseline or Scenario 1. To change the service frequency and add separate food waste collection several assumptions were made as outlined below.

Organized Curbside Collection

The baseline refuse truck costs were used to estimate truck costs (instead of the baseline recycling truck costs because the food waste collection will not be capacity limited and therefore the longer refuse routes are the logical choice). Note that some baseline refuse truck costs are the same as the baseline recycling truck costs while some are higher, with overall average refuse truck costs higher than recycling. Overall, use of the baseline truck costs reduces the cost of this Scenario when compared to Scenario 2 where all new trucks (at an all-in cost of $400,000 per truck) are required.

As with Scenario 2 the number of trucks required is based on the higher truck count, whether that is for recycling or for refuse. In this case the shared truck count is calculated by comparing the number of refuse trucks required and the number of recycling trucks required and then using the greater number to generate the required truck count.

Because the higher truck count is used, and a full eight hours of collection are not required, a partial truck count is used to estimate costs. In other words, shared truck counts are ***not*** rounded up to a whole number for use in calculating costs. This represents a better comparison with baseline costs.

Scenario 4: *Baseline Collection with Addition of Specially Colored Bags for Food Waste*

This is the easiest Scenario to run because the only change to the Baseline is that households only have to place their food waste in a specially colored bag and then place that bag in with the refuse. This can be done by all households whether they are served by organized or subscription curbside collection or use a drop-off facility.[16]

DSM has calculated the cost associated with purchase of these bags[17], but the real cost is incurred by RIRRC which would have to install a front-end system to optically sort out those bags from the refuse before transferring the remaining refuse to the landfill face. Estimating costs to RIRRC are not included in this analysis and are outside of DSM's scope of work.

Scenario 5: *Recyclables and Refuse Collected Commingled for Processing to Separate Recyclables and Food Waste at RIRRC*

Scenario 5 assumes that Rhode Island eliminates the requirement for households to keep recyclables separate from refuse and therefore recyclables and refuse (including food waste) are collected

[16] It should be noted based on limited testing at ecomaine that some of these special-colored bags break in the refuse truck and therefore the food waste is not recovered. Given the ease associated with participation associated with Alternative 4, DSM would expect higher participation, which would offset losses associated with broken bag.

[17] Data on costs of a heavy mill, 8-gallon bag, plus administrative costs to supply bags has been provided by Waste Zero to DSM for estimation purposes only, November 2021.

commingled on the truck. This scenario is likely to be the least cost alternative (as it eliminates all separate recycling collection and does not add separate food waste collection).

Organized (and Subscription) Curbside Collection

Key assumptions associated with the curbside collection system under Scenario 5 include:

- The same mix of refuse trucks currently in use under the Base Case would be used to collect the commingled refuse and recycling;
- Compaction rates for comingled refuse and recycling result in a lower density due to the lighter-weight recyclables mixed in, with the density in each municipality calculated in the model based on the ratio of refuse and recycling currently separately collected;
- It is assumed that the current carts for refuse and recycling could be used for comingled refuse and recycling; and,
- Subscription refuse collection would also change to mixed waste collection, at a lower price per household.

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VI. RESULTS AND OBSERVATIONS

Table 4 compares the collection cost for each of the five alternative collection scenarios against the Base Case (current Baseline) costs for household refuse and recycling collection in Rhode Island. Table 4 also shows the per unit performance metric results for each scenario.

Table 4 - Comparison of Alternative Household Food Waste Collection Scenarios Against Current Baseline Costs for Refuse and Recycling Collection, Rhode Island

METRIC	Baseline	Scenario #1 - Collect Food Waste Separate - High Recovery	Scenario #1 - Collect Food Waste Separate - Low Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - High Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - Low Recovery	Scenario #5 - Mixed Solid Waste Collection (1)
Annual Costs										
Cart Costs (2)	$0	$1,322,975	$1,322,975	$1,322,975	$1,322,975	$1,322,975	$1,322,975	$0	$0	$0
Cart Liner Costs or Bag Costs (3)	$0	$1,639,140	$1,138,292	$1,639,140	$1,138,292	$1,639,140	$1,138,292	$2,026,982	$1,407,627	$0
Collection Costs (4)	$46,726,390	$67,460,901	$63,686,428	$66,999,042	$74,467,673	$57,342,573	$53,923,505	$46,726,390	$46,726,390	$37,709,176
Estimated Food Waste Collection Cost	*$0*	*$20,734,511*	*$16,960,038*	*$26,799,617*	*$29,787,069*	*$20,734,511*	*$16,960,038*	*$0*	*$0*	*$0*
Total Cost (3):	$46,726,390	$70,423,016	$66,147,695	$69,961,156	$76,928,940	$60,304,687	$56,384,771	$48,753,373	$48,134,017	$37,709,176
Change from Baseline (%):		***51%***	***42%***	***50%***	***65%***	***29%***	***21%***	***4%***	***3%***	***-19%***
Cost Per Unit										
Cost Per Ton (Refuse, Recycling and Food Waste)	$118	$178	$167	$177	$194	$152	$142	$123	$122	$95
Cost Per Household (Refuse, Recycling and Food Waste)	$129	$195	$183	$194	$213	$167	$156	$135	$133	$104
Cost Per Ton (Food Waste Only)	$0	$575	$679	$722	$1,127	$575	$679	$49	$49	

(1) Food waste diversion for Scenario 5 depends on processing method. Cost per ton are based on assumptions used in all other scenarios and does not account for any processing residues.
(2) Annual toter costs are shown assuming 4% interest over 10 years.
(3) Bag liners are assumed to be used in 72% of weekly set outs 90% of the weeks of the year. Bag costs for Scenario 4 assumed at 22 cents per bag
(4) Excluding yard waste collection and processing, and MSW disposal tip fees.

As illustrated by Table 4, separate collection of household food waste increases collection system costs ranging from a low of 21 percent to a high of 65 percent, or roughly $24 to $76 per household per year.

The lowest cost alternative for separate weekly food waste collection appears to be Scenario 3 with alternating weeks of refuse and recycling collection. This assumes the same types of trucks currently used for refuse and recycling collection in Rhode Island municipalities (at the same costs) are used. It should be noted, however, that the lower cost also represents a significant reduction in service for most curbside households who currently receive weekly refuse collection (and in many cases weekly recycling collection). Maintaining current service levels increases costs, as illustrated in Scenario 1.

The highest cost alternative, Scenario 2, is based on the use of (new) split trucks to co-collect refuse/recyclables and food waste. The high cost is driven by the need to replace the entire fleet of refuse and recycling trucks in Rhode Island with new split body trucks. In addition, while theoretically co-collection should reduce costs, the standard division in the packer body of 60/40 is not ideal for co-collection of food waste alone because there is so little food waste potentially available each week by the average household, and therefore the food waste compartment is underutilized. In contrast, every other week refuse (or recyclables) fills the other side of the truck fairly quickly. This requires the split trucks to go off route before the food waste side is full, limiting the number of stops (households) that can be serviced before the refuse (especially) side of the truck fills up.

Note that the increase in Drop-Off costs associated with separate food waste are the same for Scenarios 1 through 3.

The high cost of separate collection of household food waste can be significantly reduced by asking households to place their separated food waste in a small (8 or 13 gallon) heavy mill, colored plastic bag and place it out with the refuse (in most cases in the refuse cart) on refuse collection day. This would require RIRRC to construct a facility at the landfill where the refuse could be run through a conveyor with optical sorters used to separate the colored food waste bags from the refuse. The bagged food waste could then be run through a food depackaging machine to remove the plastic from the food waste with the food waste then processed either aerobically or anaerobically. The remaining refuse would then need to be transferred to the working face of the landfill.

Because DSM's analysis only estimates costs for collection, the bagged food waste collection method is an incomplete analysis of the true cost of collecting the food waste since it relies on additional costs at RIRRC before the food waste can be processed.

Eliminating recycling collection and collecting all material together, Scenario 5, will significantly reduce collection costs even when compared to the Base Case. However, as stated above, DSM's scope of work does not include an analysis of the processing of food waste, or in this case the processing of mixed waste.

But it should be noted that since a primary goal of this analysis of separate food waste collection is to evaluate the cost to increase landfill life by reducing disposal of material that can be diverted, it is important to consider that the few operational mixed waste processing facilities that DSM is aware of have very low reported overall recovery rates of roughly 15 percent for recyclables and organics.[18]

Cost of Separate Collection of Food Waste When Compared to Benefit of Increased Landfill Capacity

Assuming the high diversion rate of 72 percent of household food waste, 41,000 tons of food waste would be diverted annually from the roughly 335,500 tons per year disposed at the RIRRC landfill, reducing disposal tons by roughly 14 percent. Collection costs only (exclusive of further costs to process the food waste) for Scenarios 1 and 3 (the lowest cost separate food waste collection alternatives) are estimated to be roughly $17 to $21 million annually, or $415 to $512 per ton of diverted food waste. This adds an average cost of $52 per household per year and compares against the current cost of $129 per household per year for the current refuse and recycling collection system.

The 14 percent reduction in landfilling is based on the weight of the food waste as delivered to the landfill, but the reality is that much of the food waste will be significantly reduced by anaerobic activity in the landfill, so that the volume of landfill savings will likely be less than one-half of the as delivered weight, or roughly 5 to 7 percent.

[18] According to an article in *Resource Recycling* Magazine (2019) the Montgomery, Alabama mixed waste processing facility achieves a 15 percent recovery rate for recyclables. This is consistent with a large mixed waste processing facility operating in Cancun, Mexico which DSM toured in 2019, which despite over 200 sorters, achieves less than a 15 percent recovery rate for recyclables and organics.

Collection costs to collect food waste in the refuse, either bagged, or commingled with recycling and sorted at a RIRRC facility are significantly less, but require extensive processing, which costs are not included in this analysis.

Impact on Greenhouse Gas Emissions

Table 5 presents the estimated annual change in collection and transport GHG emissions associated with the five scenarios analyzed. Typically, collection and transport GHG emissions associated with solid waste management are relatively insignificant compared to GHG emissions associated with disposal or recycling. Reductions in GHG emissions when compared to the Baseline associated with Scenarios 2 and 5 are the result of significant reductions in total collection trucks assumed to be required under these two scenarios.

Table 5 - Comparison of Collection and Transport GHG Emissions, Scenarios 1 – 5

METRIC	Baseline	Scenario #1 - Collect Food Waste Separate - High Recovery	Scenario #1 - Collect Food Waste Separate - Low Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #2 - Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - High Recovery	Scenario #3 - No Split Truck, Weekly Food Waste, EOW Collection Refuse and Recycling - Low Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - High Recovery	Scenario #4 - Food Waste Bagged In Refuse Truck - Low Recovery	Scenario #5 - Mixed Solid Waste Collection (1)
Total MTCO2 Equivalent:	6111	8560	8386	5618	5637	7548	7316	6111	6111	5644
Change from Baseline		2449	2275	-493	-474	1436	1205	0	0	-468

One potentially important consideration for collecting and processing food waste separate from refuse is the impact on methane generation from the landfill. Using the current US EPA WARM model (version 15), diversion of 41,000 tons of food waste from the Central Landfill results in a savings of 22,600 MTCO2e after accounting for the existing landfill collection system, and the increase in GHG emissions from collection and transport emissions associated with food waste collection. However, this can be compared with the GHG emissions savings associated with the current diversion in Rhode Island of roughly 90,000 tons of recyclables of 260,000 MTCO2E. That means that diversion of recyclables reduces GHG emissions by six times more than diversion of an equivalent quantity of food waste.

Conclusion

It is DSM's opinion that the high cost associated with the alternative food waste collection scenarios when compared to the relatively low impact on landfill volume and GHG emissions makes implementation of these scenarios a relatively unattractive alternative for RIRRC or Rhode Island municipalities and households.

If RIRRC were to move forward, further investigation of Scenarios 4 and 5 for collection would appear to make the most sense from a collection cost perspective.