
MEMORANDUM

WMPSC-C 41-2021

Subject: Every-Other-Week Garbage Collection Diversion Impact – Full Year Analysis

Date: Monday, December 13, 2021

To: Waste Management Planning Steering Committee

From: Alison Powell, Business Support Analyst, Waste Management Services

Purpose

The purpose of this memorandum is to provide Waste Management Planning Steering Committee (WMPSC) with a one (1) year update on the waste diversion impact resulting from the change to every-other-week (EOW) garbage collection.

A six (6) month update was provided in PWC-C 19-2021.

Background

On October 17, 2019, Council approved implementation of EOW garbage collection. Changing the frequency of garbage collection encourages residents to divert waste through the use of the Blue/Grey Box and Green Bin, both of which are still collected weekly.

EOW garbage collection pertains to all residential properties, including Multi-Residential (MR) properties, and for those Industrial, Commercial & Institutional (IC&I) and Mixed-Use (MU) properties located outside Designated Business Areas (DBAs) that are using Niagara Region's curbside collection service.

On October 19, 2020, EOW garbage collection commenced with the start of the new waste collection contracts. Green for Life (GFL) Environmental Inc. services Collection Area One (1) and Miller Waste Systems Inc. (Miller) services Collection Area Two (2).

- Collection Area One (1) – the Town of Grimsby, the Town of Lincoln, the Town of Pelham, the City of Thorold, the Township of Wainfleet, and the Township of West Lincoln.
- Collection Area Two (2) – the Town of Fort Erie, the City of Niagara Falls, the Town of Niagara-on-the-Lake, the City of Port Colborne, the City of St. Catharines, and the City of Welland.

Curbside Tonnage Analysis

To determine the impact EOW garbage collection has had on the amount of waste collected from the curb, a one (1) year review of tonnage data from October 19, 2020 through October 15, 2021 was done, identified as 'After EOW' in this memorandum. This data has been compared with data from the same timeframe in 2019 and 2020 (October 21, 2019, through October 16, 2020), identified as 'Before EOW' in this memorandum.

It is important to note that the data presented in this memorandum pertains to all curbside collected waste from residential properties, MR properties (not including those with front-end garbage collection as an enhanced service), IC&I, and MU properties throughout Niagara region, including those IC&I and MU with weekly collection inside DBAs. However, the majority of the waste is generated by the residential sector through the EOW curbside collection service.

IC&I and MU properties inside the DBA receive enhanced service collection, paid for by local area municipalities, in which garbage is collected at minimum one (1) day per week, sometimes more depending on the DBA. In addition to increased frequency of garbage collection, certain DBAs also have increased garbage container (can/bag) limits allowed at the curb for collection. Waste collected inside DBAs is not collected separately from waste outside the DBA; therefore, this tonnage data is not tracked separately and is included in the tonnages reported in this memorandum.

After one (1) year of EOW garbage collection, the combined amount of curbside collected garbage, organics and recycling has decreased 1.2 per cent from almost 141,000 tonnes to 139,000 tonnes in total waste collected at the curb.

Additionally, since EOW garbage collection began, the amount of curbside collected organics and recycling has increased from 49 per cent to 58 per cent of all waste collected at the curb, resulting in significantly reduced demand on the landfill sites.

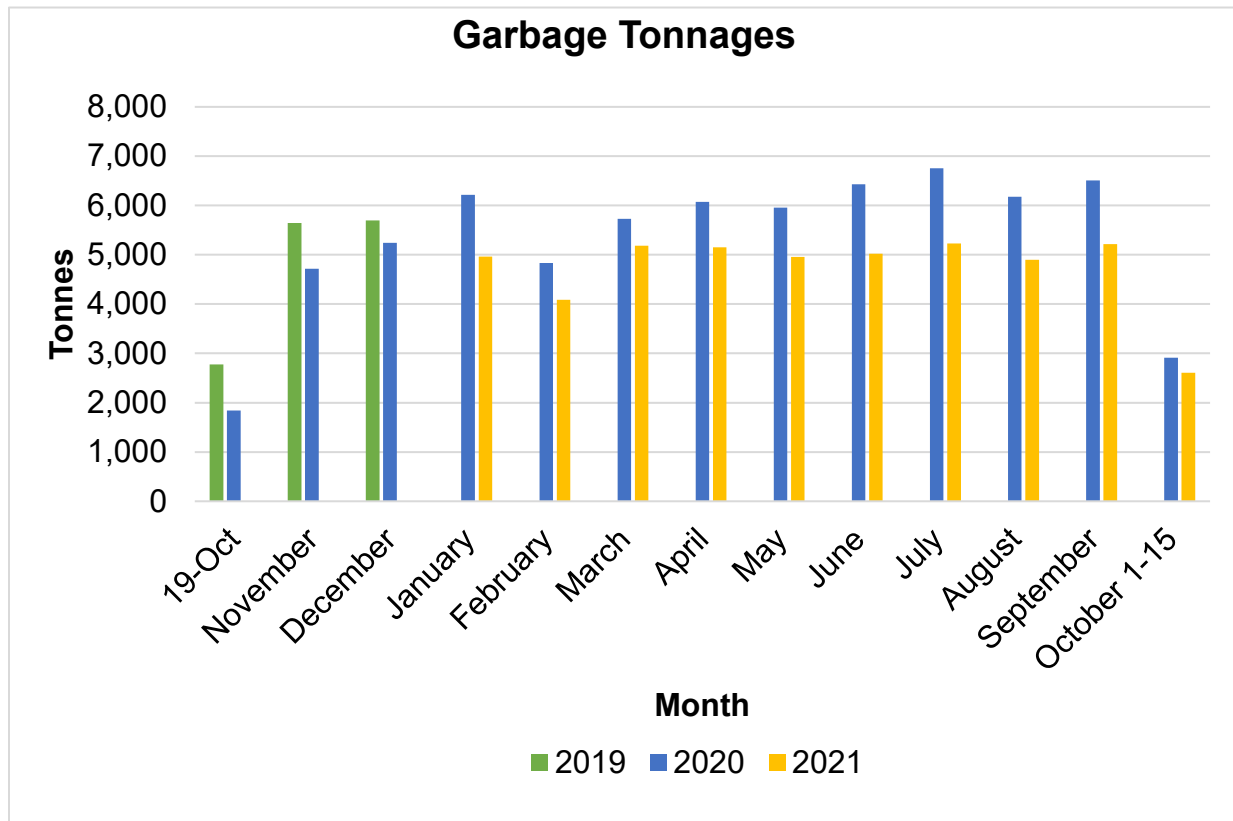
1. Curbside Garbage Tonnages

Curbside collected garbage tonnages have decreased since the start of EOW garbage collection. After one (1) year, the amount of curbside collected garbage has decreased by almost 18 per cent compared to the same time period in 2019 and 2020. Table 1 and Figure 1 provide a monthly breakdown of garbage tonnages.

Table 1: Curbside Garbage Tonnages

Month	Before EOW (Tonnes)	After EOW (Tonnes)	Difference
October 2020 (last two weeks)	2,779	1,844	-33.6%
November	5,647	4,717	-16.5%
December	5,696	5,244	-7.9%
January	6,215	4,961	-20.2%
February	4,835	4,090	-15.4%
March	5,726	5,182	-9.5%
April	6,074	5,151	-15.2%
May	5,958	4,954	-16.8%
June	6,432	5,019	-22.0%
July	6,751	5,232	-22.5%
August	6,176	4,900	-20.7%
September	6,509	5,214	-19.9%
October 2021 (first two weeks)	2,910	2,606	-10.5%
Total	71,708	59,114	-17.6%

Figure 1: Curbside Garbage Tonnages



This decrease can be attributed to residents diverting their waste through organics and recycling, as these diversion programs have seen considerable increases in tonnages collected at the curb in one (1) year.

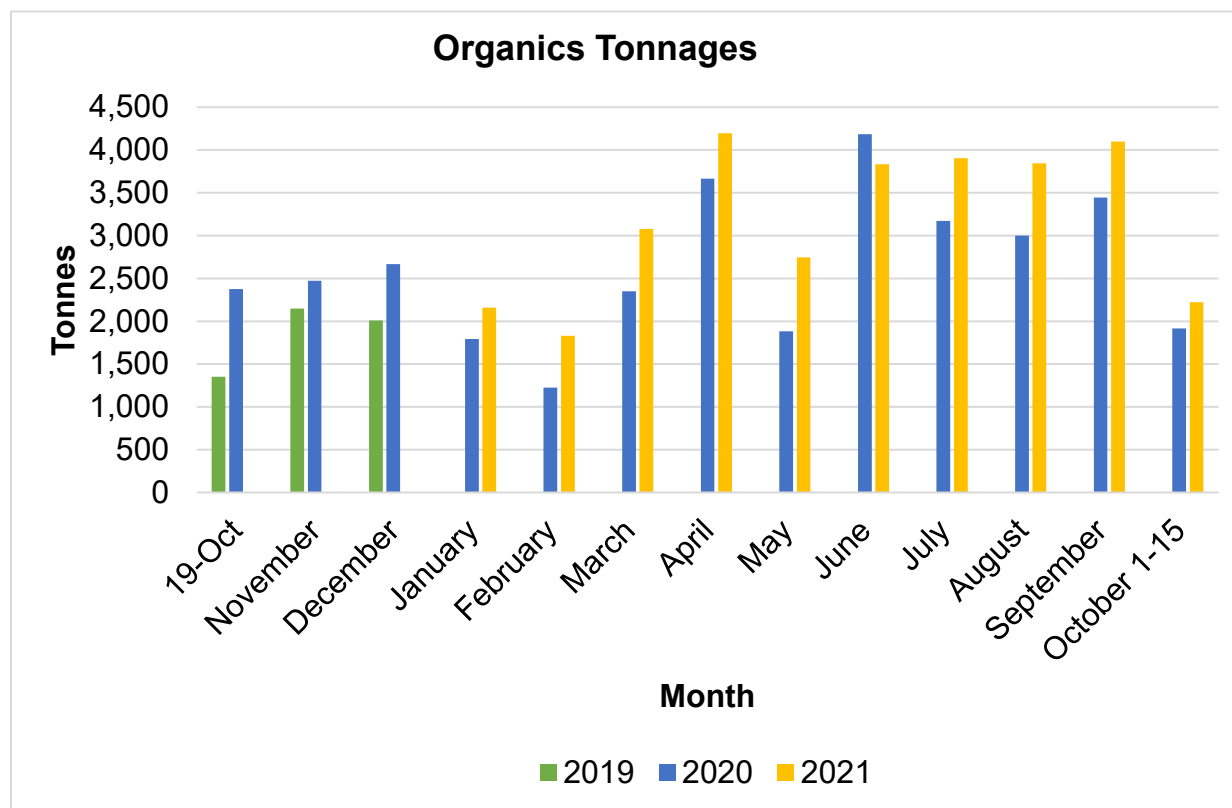
2. Curbside Organics Tonnages

Tonnages for curbside collected organics have increased 23 per cent since the start of EOW garbage collection compared to the same time period in 2019 and 2020. Table 2 and Figure 2 provide a monthly breakdown of organics tonnages.

Table 2: Curbside Organics Tonnages

Month	Before EOW (Tonnes)	After EOW (Tonnes)	Difference
October 2020 (last two weeks)	1,352	2,374	75.6%
November	2,146	2,474	15.3%
December	2,009	2,668	32.8%
January	1,794	2,157	20.2%
February	1,223	1,828	49.5%
March	2,350	3,079	31.0%
April	3,664	4,196	14.5%
May	1,882	2,746	45.9%
June	4,186	3,834	-8.4%
July	3,170	3,903	23.1%
August	3,000	3,846	28.2%
September	3,444	4,099	19.0%
October 2021 (first two weeks)	1,917	2,221	15.9%
Total	32,137	39,425	22.7%

Figure 2: Curbside Organics Tonnages



Organics collection includes food waste collected in the Green Bin and co-collected leaf and yard waste, with the exception of dedicated leaf and yard waste collection in the spring and fall in urban areas. The increase in organics can be attributed to increased participation in the Green Bin program, and co-collected leaf and yard waste.

In preparation for EOW garbage collection and the expected increase in Green Bin tonnages, staff began to deliver additional supply of Green Bins to distribution centres throughout the region, providing residents the opportunity to purchase additional containers. In 2020, staff delivered 12,077 Green Bins to distribution centres, a near 60 per cent increase over the 7,569 Green Bins delivered in 2019. In 2021, staff delivered 8,903 number Green Bins to distribution centres.

3. Curbside Recycling Tonnages

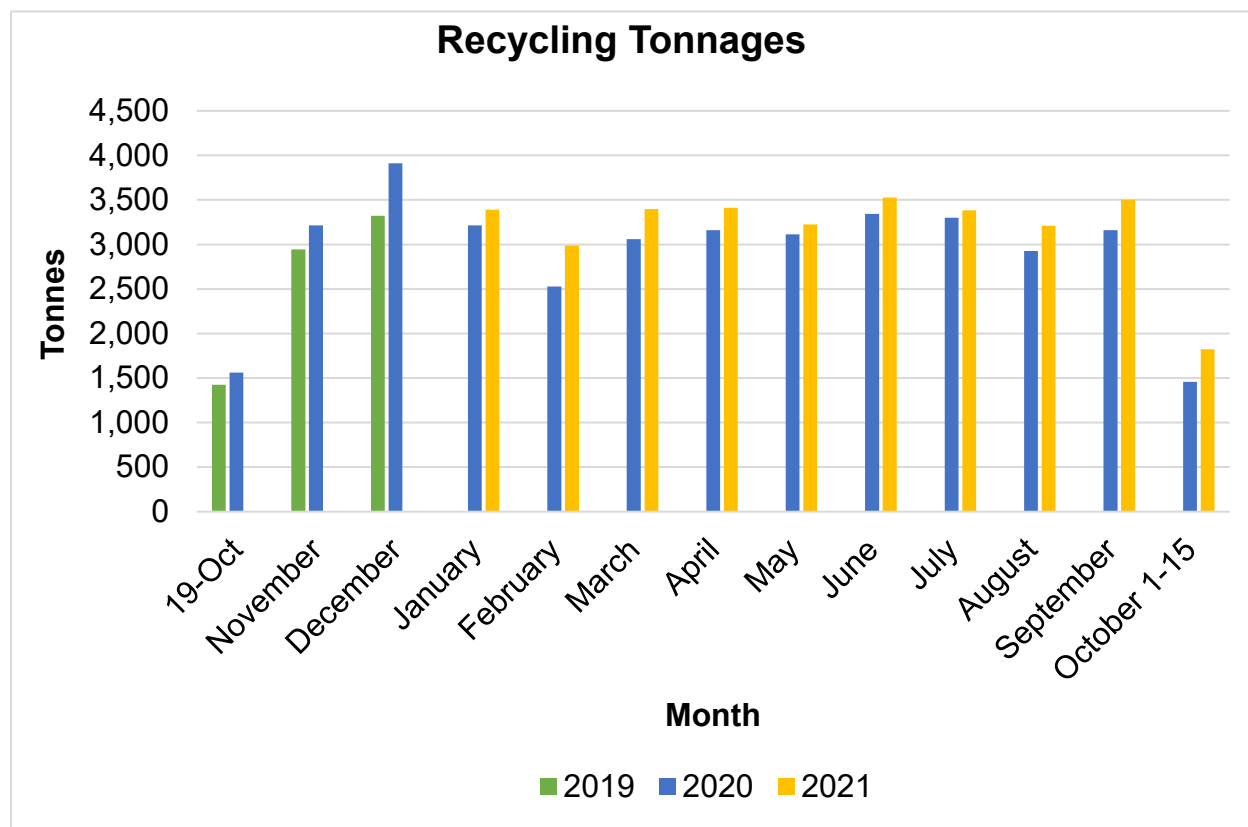
Curbside recycling tonnages have increased 9.7 per cent since the start of EOW garbage collection compared to the same time period in 2019 and 2020. Table 3 and Figure 3 provide a monthly comparison. The tonnages include all recycling collected in

Blue/Grey Boxes, Blue/Grey Carts, bundled cardboard and front-end cardboard collection from downtown St. Catharines.

Table 3: Curbside Recycling Tonnages

Month	Before EOW (Tonnes)	After EOW (Tonnes)	Difference
October (last two weeks)	1,424	1,563	9.8%
November	2,945	3,213	9.1%
December	3,321	3,912	17.8%
January	3,213	3,390	5.5%
February	2,527	2,987	18.2%
March	3,058	3,399	11.2%
April	3,162	3,412	7.9%
May	3,114	3,226	3.6%
June	3,342	3,526	5.5%
July	3,299	3,382	2.5%
August	2,927	3,210	9.7%
September	3,160	3,502	10.8%
October (first two weeks)	1,456	1,822	25.1%
Total	36,948	40,544	9.7%

Figure 3: Curbside Recycling Tonnages



Similar to the Green Bins, additional Blue and Grey Boxes were delivered to distribution facilities for resident purchase. In 2020, staff delivered 25,464 Blue/Grey Boxes to distribution centres, a 20.5 per cent increase over the 21,131 Blue/Grey Boxes delivered in 2019. As of October 21, 2021, staff delivered 21,146 Blue/Grey Boxes to distribution centres this year.

Further to the EOW analysis above, Niagara Region completed a waste composition study and environmental benefits analysis to further review the impact of EOW garbage collection.

Waste Composition Study

As part of the EOW garbage collection analysis, the Region completed a waste composition study. The 2020-2021 four (4)-season average curbside waste diversion rate is 60 per cent, an increase of 14.3 per cent from the 2015-2016 diversion rate of 45.7 per cent. This can be attributed to the implementation of EOW garbage collection, which resulted in residents decreasing their disposal of garbage, and increasing their

diversion of recycling and organics. The results of this waste composition study were presented at the October 18, 2021 WMPSC meeting, and can be found in the memorandum, WMPSC-C 34-2021.

Environmental Benefits Analysis

Niagara Region retained Sound Resource Management Group, Inc. (SRMG) to evaluate and quantify the environmental benefits over the first year following the Region's switch to EOW curbside garbage collection. SRMG was to: Evaluate the garbage collection decreases, organics collection increases and recycling collection increases during this first year of EOW curbside garbage collection;

- Estimate the environmental impacts of these changes in waste diversion and disposal; and
- Estimate the economic value of the changes in environmental impacts.

The report completed by SRMG can be found in Appendix 1. SRMG analyzed the curbside tonnages as well as the combined curbside and drop-off depot tonnages.

1. Curbside Collection Tonnages

SRMG analyzed the curbside collection tonnages both before and after EOW garbage collection; however, a marginally different time period was reviewed than in the analysis completed by the Region. SRMG analyzed data from October 26, 2020 through October 22, 2021. The first week of EOW garbage collection (week of October 19, 2020) was not included in the analysis as Collection Area One (1) had received garbage collection the previous week; therefore, the amount of garbage placed at the curb would likely have been lower than what is expected for the EOW garbage collection frequency.

An additional difference between the analysis completed by staff and that of SRMG is that SRMG included dedicated leaf and yard waste and brush in the organics total. The Region's analysis of organics did not include dedicated leaf and yard waste and brush as the focus was on Green Bin organics tonnages. Combining this data with dedicated leaf and yard waste could potentially over or understate the impact of EOW garbage collection on the organics program, depending on the amount collected.

Table 4 breaks down the curbside tonnages, which have been adjusted to account for processing residues.

Table 4: SRMG Analysis of Curbside Collected Tonnages

Waste Stream	Before EOW (Tonnes)	After EOW (Tonnes)	Difference
Garbage	80,939	70,238	-13.2%
Recycling	33,153	35,809	8.0%
Organics (including leaf and yard waste)	38,140	45,620	19.6%

Decreases in curbside collected garbage tonnages suggest diversion increases in the recycling and organics waste streams are a direct result of the change to EOW garbage collection.

2. Curbside Collection and Self-Haul Diversion

In addition to curbside collection, residents and businesses are able to self-haul their waste to depots. SRMG compared combined annual totals for both before and after EOW for curbside collection and self-haul deliveries. Table 5 provides a breakdown of tonnages, which have been adjusted to account for processing residues.

Table 5: SRMG Analysis of Curbside and Self-Haul Tonnages

Waste Stream	Before EOW (Tonnes)	After EOW (Tonnes)	Difference
Garbage	117,128	111,702	-4.6%
Recycling	34,549	37,349	8.1%
Organics (including leaf and yard waste)	51,005	59,948	17.5%

The combined curbside and self-haul data shows only a 4.6 per cent decrease for garbage diverted when compared to just curbside collection, which saw a reduction of 13.2 per cent in the analysis by SRMG.

It is possible that residents will have used the drop-off depot to supplement EOW garbage collection. However, the change to EOW from weekly curbside garbage collection was not the only major occurrence during 2020-2021 that could have altered solid waste disposal and diversion behaviors. Other potential drivers of change include, but are not limited to, the COVID-19 pandemic, in which travel restrictions or shutdowns

forced people to stay home, and in many cases work from home, and economic growth in spring 2021.

3. Environmental Impacts and Economic Value of EOW Garbage Collection

SRMG relied on its proprietary Measuring Environmental Benefits Calculator (MEBCalc) to evaluate nine (9) environmental impacts of switching from weekly to EOW curbside garbage collection. The environmental benefits of these disposal reductions and diversion increases are substantial, including the following annual tonnes of pollution decreases:

- 18,400 tonnes in climate changing carbon dioxide equivalent (CO_2e or eCO_2) emissions;
- 4.7 tonnes in fine particle emissions ($\text{ePM}_{2.5}$) that cause respiratory cancers and asthmas;
- 1,375 tonnes in non-carcinogenic and carcinogenic toxic chemical pollutants;
- 93 tonnes in nitrogen equivalent (eN) emissions that cause waterways eutrophication; and
- 350 tonnes in ozone equivalent (eO_3) emissions that cause ground level smog formation.

The tonnage totals for these pollution reductions are different quantitatively, so it can be difficult to prioritize trade-offs between public health and environmental impacts. One solution is to monetize these impacts into economic cost and benefit dollar values so that they can be compared and summed up into overall totals. It is estimated that the pollution reductions associated with disposal tonnage decreases and diversion tonnage increases amount to \$13.2 million CAD, or \$1,300 CAD per average metric tonne of additional curbside diversion.

Illegal Dumping

Based on comments received from municipal comparators who have implemented EOW garbage collection, Niagara Region expected this change in garbage collection frequency to influence illegal dumping for a short term; however, other municipalities experienced a leveling off back to normal levels in the long term. In 2020, there were 678 incidents of illegal dumping investigated by Niagara Region. This is a small increase over the 677 incidents that were investigated in 2019. EOW garbage collection did not appear to have a large impact on the number of reported incidents of illegal dumping in 2020.

In 2021, Waste Management staff have continued to respond to reports of illegal dumping, as well as proactively monitored hotspots and public space litter bins. The number of reported incidents can be highly influenced by the amount of proactive monitoring undertaken by Regional staff. This is especially true for illegal dumping that occurs in or around public space litter bins. As of October 15, 2021, 630 incidents of illegal dumping have been investigated in 2021. An update on illegal dumping in 2021 will be provided next year.

Next Steps

The goal for reducing the frequency of garbage collection to EOW was to encourage residents to divert waste through use of the Blue/Grey Box and Green Bin, both of which are still collected weekly. A one (1)-year review of this change has shown a decrease in garbage collected from the curb, and increases in the recycling and organics programs. Participation in diversion programs has increased based on the number of containers distributed and an improved curbside diversion rate, as determined by the Waste Composition Study. The benefits of EOW garbage collection were not only seen at the curb, but also in terms of environmental benefits, such as decreases in pollution.

Staff will continue to monitor the diversion impact of the change to EOW garbage collection.

Respectfully submitted and signed by

Alison Powell,
Waste Management Business Support Analyst

Appendices

Appendix 1 Environmental Benefits Analysis Report

Niagara Region EOW Garbage Collection Environmental Benefits Analysis

Prepared by Dr. Jeffrey Morris, Sound Resource Management Group, Inc.

I. Summary and Conclusions

Niagara Region's implementation of every-other-week (EOW) curbside garbage collection in October 2020 resulted in an increased amount of diverted waste collected at the curb. Pre-EOW, 46.8% of waste collected at the curb was diverted from landfill using the organics and recycling programs. After EOW, 53.7% of curbside collected waste was diverted from landfill, an increase of 6.9%.

At the same time EOW garbage collection reduced annual disposal amounts by 10,700 metric tons (MT). These results are based on comparing curbside garbage collection customer disposal and diversion tonnages for the year following Niagara Region's implementation of curbside garbage EOW collection frequency against the year prior to EOW implementation when curbside garbage was collected weekly.

The environmental benefits of these disposal reductions and diversion increases are substantial, including the following annual metric tons of pollution decreases:

- 18,400 MT climate changing carbon dioxide equivalent (CO_2e or eCO_2) emissions,
- 4.7 MT in fine particle emissions ($\text{ePM}_{2.5}$) that cause respiratory cancers and asthmas,
- 1,375 MT decrease in non-carcinogenic and carcinogenic toxic chemical pollutants,
- 93 MT in nitrogen equivalent (eN) emissions that cause waterways eutrophication, and,
- 350 MT in ozone equivalent (eO_3) emissions that cause ground level smog formation.

Because the tonnage totals for these pollution reductions are so different quantitatively, decision makers may have difficulty prioritizing trade-offs between public health and environmental impacts that differ so widely in magnitude. One solution is to monetize these impacts into economic cost and benefit dollar values so that they can be compared and also summed up into overall totals. Using this technique, we estimate that the pollution reductions associated with disposal tonnage decreases and diversion tonnage increases discussed in this report amount to \$13.2 million (in 2020 Canadian \$), or \$1,300 per average metric ton of additional curbside diversion.

Climate change accounts for the largest portion of this estimate at 40.3% of the total, or \$5.3 million. Perhaps surprisingly, given the small number of metric tons in decreased pollution of fine particulates listed just above, human health respiratory pollutant reductions account for the second largest portion of total monetized environmental benefits at 29.6% of total and \$3.9 million in environmental economic value. Eutrophication comes in third at 24.0% of total environmental economic value and \$3.2 million of the overall EOW pollution reduction benefit.

The report below also details the lower environmental benefits when taking into account the pre-EOW versus post-EOW depot tonnage changes. As discussed below in this report in more detail regarding this result, there is reason to posit that some EOW curbside garbage collection customers may have used the depot drop-off facilities to handle garbage (and perhaps some recyclable and/or compostable materials) during their week's in-between EOW garbage collections.

However, there was no change in recyclable or organic material collection frequencies when EOW garbage collection was implemented. Furthermore, the 5,275 MT increase in depot garbage for the EOW first year versus the last year for weekly curbside garbage collection is quite large. If entirely due to EOW curbside customers self-hauling garbage to depots during weeks between their EOW collections, this depot garbage tonnage increase would have entailed hundreds of thousands of depot visits annually. In fact, the number of residential depot trips increased by 56,000. In addition, the curbside and drop-off depot tonnage changes after introduction of EOW curbside garbage collection were likely influenced by other factors such as the Covid-19 pandemic, population growth, economic activity levels, weather differences, and changing purchasing patterns. Effects of such additional factors were not assessed for this report.

Despite these many unknown effects and uncertainties, the curbside customers' tonnage only results detailed above and discussed throughout the report appear to be better estimates for the benefits of EOW curbside garbage collection than the curbside plus depot tonnage results. Nevertheless, curbside plus depot tonnage comparisons for EOW versus pre-EOW are reported throughout the report alongside the curbside customer only results. This provides an indication of the extent to which increased use of drop-off depots by EOW curbside garbage customers could reduce EOW environmental benefits. In our judgement, the benefits of EOW seem more likely to be much nearer to the curbside only results summarized above.

II. Introduction

Niagara Region engaged Sound Resource Management Group, Inc. (SRMG) to evaluate and quantify the environmental benefits over the first year following the Region's switch to every-other-week (EOW) curbside garbage collection. The switch from weekly to EOW was implemented October 19, 2020. SRMG's endeavor required:

1. Evaluating garbage disposal decreases, organics collection increases and recycling collection increases during this first year of EOW curbside garbage collection,
2. Estimating the environmental impacts of these changes in disposal and waste diversion, and,
3. Estimating the environmental economic value (EEV) of the changes in environmental impacts.

SRMG relied on curbside collection and depot drop-off tonnage data, residential drop-off depot trip counts, and precipitation data supplied by the Region to evaluate changes in diversion and disposal associated with the change to EOW curbside garbage collection. SRMG used both curbside collection tonnages as well as curbside plus drop-off depot tonnages to provide a range of estimates for the disposal and diversion impacts of the switch to EOW curbside garbage collection. SRMG then used the tonnage data and its proprietary Measuring Environmental Benefits Calculator (MEBCalc) to evaluate nine environmental impacts of switching from weekly to EOW curbside garbage collection:

- ***Climate Change*** – the potential increase in greenhouse effects due to anthropogenic emissions. Carbon dioxide (CO₂) originating from human activities that burn fossil fuels is the most common source of greenhouse gases (GHGs). Methane from anaerobic decomposition of organic material is a GHG and also a large source of climate change impacts. The reference substance for climate change potential is CO₂.
- ***Human Respiratory Disease and Death from Particulates*** – potential human health impacts from anthropogenic releases of coarse particles known to aggravate respiratory conditions such as asthma, releases of fine particles that can lead to more serious respiratory symptoms and disease, and releases of particulate precursors such as nitrogen oxides and sulfur oxides. The reference substance for human respiratory disease potential is particulate matter no larger than 2.5 microns, PM_{2.5}.
- ***Human Disease and Death from Toxics*** – potential human health impacts (other than respiratory and carcinogenic effects) from releases of chemicals that are toxic to humans. There are many chemical and heavy metal pollutants that are toxic to

humans, including 2,4-D, benzene, DDT, formaldehyde, permethrin, toluene, chromium, copper, lead, mercury, silver, and zinc. The reference substance for human toxicity potential used in MEBCalc is toluene, T.

- **Human Disease and Death from Carcinogens** – potential human health impacts from releases of chemicals that are carcinogenic to humans. Many chemical and heavy metal pollutants are carcinogenic to humans, including 2,4-D, benzene, dichlorodiphenyltrichloroethane (the pesticide commonly known as DDT), formaldehyde, kepone, permethrin, chromium, and lead. The reference substance for human carcinogenic potential used in MEBCalc is benzene, B.
- **Eutrophication** – potential environmental impacts from addition of mineral nutrients to the soil or water resulting from emissions of eutrophying pollutants to air, soil or water. The addition to soil or water of mineral nutrients, such as nitrogen and phosphorous, can yield generally undesirable shifts in the number of species in ecosystems and a reduction in ecological diversity. In water, nutrient additions tend to increase algae growth, which can lead to reductions in oxygen and death of fish and other species. The reference substance for waterways eutrophication potential is nitrogen, N.
- **Acidification** – potential environmental impacts from anthropogenic releases of acidifying compounds, principally from fossil fuel and biomass combustion, which affect trees, soil, buildings, animals and humans. The main pollutants involved in acidification are sulfur, nitrogen and hydrogen compounds – e.g., sulfur oxides, sulfuric acid, nitrogen oxides, hydrochloric acid, and ammonia. The reference substance for acidification potential is sulfur dioxide, SO₂.
- **Aquatic Ecosystems Toxicity** – the relative potential for chemicals released into the environment to harm aquatic ecosystems, including wildlife. There are many chemical and heavy metal pollutants that are toxic to aquatic ecosystems, including 2,4-Dichlorophenoxyacetic acid (an herbicide commonly referred to as 2,4-D), benzene, DDT, ethyl benzene, formaldehyde, kepone, permethrin, toluene, chromium, copper, lead, silver, and zinc. The reference substance for aquatic ecotoxicity potential used in MEBCalc is 2,4-D.
- **Ozone Depletion** – the relative potential for chemical compounds released into the atmosphere to cause degradation of the Earth's ozone layer. The reference substance for ozone depletion potential (ODP) is trichlorofluoromethane, CFC-11, where CFC is the acronym for chlorofluorocarbon. CFC-11 is sometimes called R-11, and is also called carbon tetrachloride.
- **Ground Level Smog Formation** – the relative potential for chemical compounds released into the atmosphere to react with sunlight, heat and fine particles to form ozone (O₃). For example, nitrogen oxides (NO_x) and volatile organic compounds (VOCs) released during fuel combustion are some of the chemical compounds that

contribute to ground level smog formation. The reference substance for smog formation is ozone, O₃.¹

MEBCalc uses estimates of pollutant releases associated with waste collections, processing, disposal and diversion to recycling and/or composting, as well as pollution releases from manufacturing products from diverted waste materials versus the same products manufactured from virgin raw materials extracted from Earth's ecosystems. Based on these pollution release profiles, MEBCalc calculates quantitative estimates for the nine environmental impacts.

MEBCalc relies on the U.S. Environmental Protection Agency's TRACI (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts) to provide characterization factors for pollutants that cause each of these nine environmental impacts.² Readers are probably familiar with characterization factors for the climate change impact of GHGs. Each GHG release is multiplied by its global warming potential (GWP) relative to carbon dioxide. These GWPs are the TRACI characterization factors for the GHGs causing climate change. A GWP weight converts each GHG's emissions into a carbon dioxide equivalent (CO₂e or eCO₂). This allows total GHG pollutant emissions to be characterized by a single number -- their carbon dioxide equivalent emissions amount.

In addition to climate change, TRACI codifies characterization factors for each of 3,944 chemical and other environmental pollutants for each of the other eight environmental impacts evaluated by MEBCalc. Like the GWPs for climate change, characterization factors for the other environmental impacts are based on scientific research and consensus on the impact severity of each pollutant relative to the reference substance for each of these other eight environmental impacts.

¹ Genesis, Methodology & Sources for MEBCalc, available via email by request to info@srmginc.com.

² Jane C. Bare, *Developing a Consistent Decision-Making Framework by Using the U.S. EPA's TRACI*, U.S. Environmental Protection Agency, Cincinnati, OH, 2002; Jane C. Bare, Gregory A. Norris, David W. Pennington and Thomas McKone, TRACI: The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts. *Journal of Industrial Ecology* 2003, 6(3-4): 49-78; and Jane C. Bare, TRACI 2.0: the tool for the reduction and assessment of chemical and other environmental Impacts 2.0. *Clean Technologies and Environmental Policy*, 2011, 13(5) 687-696, provide expositions on the original and more recent versions of the TRACI model.

Finally, MEBCalc estimates the economic value or cost of decreases or increases in each of the nine environmental impacts. The latest cost estimates for pollutant releases amounting to one metric ton (MT) for each environmental impact are (in 2020 Canadian dollars)³:

- Climate Change -- \$289 per MT eCO₂.
- Human Health Respiratory Effects -- \$824,336 per MT ePM_{2.5}.
- Human Health Non-Carcinogenic Effects -- \$466 per MT eT.
- Human Health Carcinogenic Effects -- \$3,328 per MT eB.
- Waterways Eutrophication -- \$33,901 per MT eN.
- Acidification -- \$559 per MT SO₂.
- Aquatic Ecosystems Toxicity -- \$5,681 per MT 2,4-D.
- Ozone Layer Depletion -- \$77,246 per MT CFC-11.
- Ground Level Smog Formation -- \$332 per MT O₃.

The following three sections discuss results for disposal and diversion tonnage changes associated with the switch to EOW curbside garbage collection in the Niagara Region, the environmental benefits (or costs) of those collection tonnage changes, and the monetized value of all nine environmental impact benefits resulting from EOW garbage collection.

III. Tonnage Impacts of EOW Garbage Collections and Self-Hauling to Depots

Curbside Collection Impacts

Tables 1 and 2 show annual curbside garbage, recycling and organics (including leaf and yard wastes) collection quantities for the Niagara region for October 26, 2020, thru October 22, 2021. These are the second through 53rd weeks of curbside EOW garbage collection. The first week of EOW implementation (the week of October 19, 2020) is not included because half of curbside garbage customers received garbage collection the previous week. As a result, their garbage generation for collection in that first week is lower than normal for EOW collection frequency.

³ Morris, J., *Economic Damage Costs for Nine Human Health and Environmental Impacts*, Prepared by SRMG for Oregon Department of Environmental Quality and Oregon Metro, Portland, OR, July 2020. Available via email by request to info@srmginc.com.

Tables 1 and 2 also show collection quantities for the 52 weeks preceding October 19, 2020. Comparisons between these two sets of annual curbside collection data provides one basis for evaluating diversion and disposal tonnage impacts of EOW curbside garbage collection. According to the data reported in Table 1, total curbside waste generation during the two years is very similar at 151,667 MTs for the EOW analysis year and 152,231 for the pre-EOW year. Total curbside waste generation decreased by 564 MTs, or 0.4%, following EOW implementation.

Table 1 Disposal Reductions and Diversion Increases for the First Year of EOW Curbside Garbage Collection

Material Stream	Annual Tonnes EOW	Annual Tonnes Pre-EOW	Difference	Per Cent Increase or Decrease
Garbage	64,364	75,640	-11,275	-14.9%
Recycling	40,140	37,162	2,977	8.0%
Organics (including leaf and yard waste)	47,162	39,429	7,734	19.6%

Table 2 Disposal Reductions and Diversion Increases for First Year of EOW Curbside Garbage Collection Adjusted for Processing Residues

Material Stream	Annual Tonnes EOW	Annual Tonnes Pre-EOW	Difference	Per Cent Increase or Decrease
Garbage	70,238	80,939	-10,701	-13.2%
Recycling	35,809	33,153	2,656	8.0%
Organics (including leaf and yard waste)	45,620	38,140	7,481	19.6%

Annual EOW quantities include weeks two thru 53 following EOW implementation October 19, 2020, to adjust for the fact that half of EOW collection entities received garbage collection the week prior to EOW week 1.

The 564 MT decrease in total curbside waste generation following curbside EOW garbage collection implementation, as well as disposal decreases and diversion increases, may have been influenced by drivers other than just the decrease in garbage collection frequency. For example:

- Weather patterns -- precipitation in the Region during the first nine months of 2021 was up 19%, with most of that increase occurring during July thru September. This would tend to increase post-EOW waste generation due to increases in plant and turfgrass growth.
- COVID-19 pandemic effects. Some of the effects of the pandemic included business shutdowns, more employees working at home, increased online purchasing and home meal preparation with associated decreases of in-store shopping and meals at restaurants and fast-food outlets, and increased purchases of durable goods and reduced purchases of services. Whether these effects tended to increase or decrease pre-EOW versus post-EOW waste generation is not known.
- Economic activity levels. The aggregate demand effects from shutdowns and lockdowns of 2020 versus pent-up demand surges of mid-2021 also had unknown impacts on pre- and post-EOW curbside waste generation.
- Population growth. This driver would tend to increase waste generation post-EOW.

More important, and certainly of much greater magnitude, than the 0.4% decrease in curbside customer overall waste generation post-EOW is the rather dramatic shift in garbage and diversion quantity proportions of total waste generation following EOW curbside garbage collection implementation. As indicated in Table 1, the first full year of EOW curbside garbage collection effects differs from the last year of weekly curbside garbage collection, as follows:

- 11,275 MT lower garbage, a 7.3 percentage points lower proportion of waste generation going to garbage collection,
- 7,734 MT additional organics collections (including leaf & yard wastes), a 5.2 percentage points higher organics collection proportion, and,
- 2,977 MT additional recycling, a 2.1 percentage point higher recycling collection proportion.
- Pre-EOW garbage collections accounted for 49.7% of total annual curbside waste generation, organics collections 25.9%, and recycling collections made up 24.4% of total waste collected curbside in the Niagara Region. By contrast, following EOW curbside garbage collections implementation, garbage accounted for 42.4% of curbside waste generation, organics collections 31.1%, and recycling collections 26.5% of curbside collected wastes.

In other words, instead of following the waste generation disposal and diversion proportions associated with the final year of weekly curbside garbage collections, EOW curbside garbage customers in 2020-2021 lowered garbage collection by 11,275 MTs, a 14.9% reduction. This was accomplished by increasing organics collection by 19.6%

and recycling 8.0%. The diversion rate based on collections, thus, went up to 57.6 % for EOW curbside garbage collection versus 50.3% for weekly garbage, a 7.3 percentage point diversion rate increase.

Yet, this is not quite the end of the story for disposal and diversion tonnage changes associated with the switch to EOW curbside garbage collection. Customers for curbside collections may place non-recyclable materials in their recycling containers or include non-compostable materials in their set outs for organics or leaf & yard waste collections. Material recovery facilities for collected recyclables and composting facilities for organics and leaf & yard wastes have to sort out and dispose of these non-acceptable materials. In addition, sorting of the acceptable commingled collected recyclable or compostable materials into separate material types for marketing by material recovery and composting facilities is itself not typically 100% efficient and accurate.

Niagara Region staff provided estimates for the year 2020 of disposal residues from processing recyclables, organics, and leaf & yard waste materials collected from single-family residential customers. According to these data 10.79% of materials collected for curbside recycling end up in material recovery facility processing residues for disposal. The similar estimate for organics and leaf & yard waste composting facility processing residue disposal amounts to 3.27% of collection tonnages for composting.⁴

Table 2 reflects tonnage adjustments to account for processing residues. Taking into account processing residues that end up as garbage, the first full year of EOW curbside garbage collection differs from the last year of weekly curbside garbage collection, as follows:

- 10,701 MT less garbage, a 6.9 percentage points lower proportion of waste generation going to garbage disposal,
- 7,481 MT additional organics diverted (including leaf & yard wastes), a 5.0 percentage points higher organics diversion generation, and,
- 2,656 MT additional recycling, a 1.9 percentage point increase in recycling diversion.

⁴ There are multi-family apartment building households and IC&I customers using curbside collections. We assume that single-family processing residue estimates for 2020 are reasonable numbers to use for recycling and organics processing residues for collection quantities from multi-family and IC&I curbside collection customers. Because single-family customers account for most curbside collection customers, any differences in processing residues for these two categories of customers hopefully do not substantially change the overall weighted average processing residue rates for collected recyclables or organics.

- Pre-EOW garbage collections accounted for 53.2% of total annual curbside customers' waste generation, organics generation 25.0%, and recyclables generation made up 21.8% of total waste collected curbside in the Niagara Region. By contrast, following EOW curbside garbage collections implementation, garbage accounted for 46.3% of curbside customers' waste generation, organics generation 30.1%, and recycling generation amounted to 23.6% of curbside collected wastes.

In other words, instead of following the waste generation disposal and diversion proportions associated with the final year of weekly curbside garbage collections, EOW curbside garbage customers in 2020-2021 lowered garbage generation by 10,701 MTs, a 13.2% reduction. This was accomplished by increasing organics diversion by 19.6% and recycling diversion 8.0%. The diversion rate based on materials actually recycled or composted, thus, went up to 53.7% for EOW curbside garbage collection versus 46.8% for weekly garbage, an increase in the disposal diversion rate for organics and recyclables of 6.9 percentage points. Recyclable materials collected, processed, and sold to recycled-content product manufacturing markets increased by 2,656 MT as a result of EOW curbside garbage implementation. Organics materials composted increased by 7,481 MT.

Curbside plus Self-Haul Disposal and Diversion Impacts

Because residential households and industrial, commercial and institutional (ICI) entities can self-haul their wastes to depots as well as having them collected curbside, SRMG also compared annual totals for pre-EOW and post-EOW years for curbside collections plus self-haul deliveries to depots for garbage, organics and recyclables. Table 3, Curbside & Self-Haul Disposal Reductions and Diversion Increases for First Year of EOW Curbside Garbage Collection, displays that comparison.

Table 3 shows annual curbside collection plus depot drop-off garbage, recycling and organics (including leaf and yard wastes and brush) collection quantities for the Niagara Region for October 26, 2020, thru October 22, 2021. These are the second through 53rd weeks of curbside EOW garbage collection. As explained regarding the data in Tables 1 and 2, the first week of EOW implementation (October 19, 2020) is not included in Table 3. Table 3 also shows curbside collection plus depot self-haul quantities for the 52 weeks preceding October 19, 2020.

Depot self-haul garbage and organics collection quantities included in Table 3 are adjusted for organics processing residues that go to garbage disposal rather than being processed into compost products. It is assumed that self-haul recycling materials do not

generate processing residues because they are source sorted for drop off into depot bins segregated for individually marketed recycled materials.

Table 3 Curbside and Self-Haul Disposal Reductions and Diversion Increases for First Year of EOW Curbside Garbage Collection

Material Stream	Annual Tonnes EOW	Annual Tonnes Pre-EOW	Difference	Per Cent Increase or Decrease
Garbage	111,702	117,128	-5,426	-4.6%
Recycling	37,349	34,549	2,800	8.1%
Organics (including leaf and yard waste)	59,948	51,005	8,944	17.5%

Annual EOW quantities include weeks 2 thru 53 following EOW implementation October 19, 2020, to adjust for the fact that half of EOW collection entities received garbage collection the week prior to EOW week 1.

Table 3 data combining curbside and depot tonnages adjusted for processing residues show a substantial 49% lower decrease for garbage disposal impacts of EOW garbage collection than Table 1 does for curbside alone. This is because annual self-haul garbage tonnage increased substantially by 5,275 MT following implementation of curbside EOW garbage collection. This suggests that some EOW curbside garbage collection households and ICI curbside garbage customers may have diverted some of their garbage to self-haul during the in-between weeks of their EOW curbside garbage collections. In doing so, they could also have brought along recyclables and/or organics for drop off at the same time. Table 2 displays increases in diversion to recycling and organics.

The mandatory switch to EOW from weekly curbside garbage collection in Niagara Region was not the only major occurrence during 2020-2021 that might be expected to have altered solid waste disposal and diversion behaviors. Other potential factors driving changes in curbside collection and depot drop off disposal and diversion quantities include:

- Responses to the worldwide COVID pandemic, such as school, business and institutional shutdowns, as well as travel restrictions that became widespread in spring 2020, continuing throughout the remainder of that year and into 2021.
- Employees shifting to working remotely at home during the same time period.

- The spring 2021 surge in economic activity from pent up demand and population relief at being able to get out and about once many thought the pandemic was tamed.

Whatever may have been the cause of collection versus self-haul delivery tonnage impact differences, one approach to estimating the impact of EOW curbside garbage collection would be to use the tonnage impacts shown in the two tables as lower and upper bounds. In other words, EOW curbside garbage collection annual impacts resulted in a disposal decrease (after accounting for disposal of processing contaminants and rejects) between 5,426 and 10,701 MT. The respective diversion increases were between 7,481 and 8,944 MTs of increased composting and between 2,656 and 2,800 MTs of increased sales of recycled materials to manufacturers of recycled content products.

The corresponding diversion increase falls somewhere in the interval between 4.4 and 6.9 percentage points as a result of the switch to EOW curbside garbage collection. The curbside diversion percentage for EOW is 53.7% versus 46.8% pre-EOW. Curbside plus depot diversion percentage is 46.6% versus 42.2% pre-EOW.

There is reason to suspect that the depot annual disposal and diversion increases for EOW versus pre-EOW are not all the result of curbside garbage customers flocking to drop-off depots in the weeks between their EOW garbage pickups. For one thing EOW curbside garbage customers did not have any change in their organics or leaf & yard waste collection frequencies or capabilities.

More importantly, the additional 5,275 MT going to landfill disposal from depot drop-off garbage increases during the first year of EOW most likely could not have come entirely from EOW curbside garbage collection customers. Even at the very high rate of 25 kilograms of garbage per trip self-hauled by EOW customers to a depot during off weeks for garbage collection, it would entail an additional 211,000 depot visits in total, or 4,060 per week, during the first year of EOW garbage collection by EOW curbside garbage collection customers in order to increase depot garbage quantities by 5,275 MT.

In fact, residential drop-off depot traffic counts increased by 56,000 trips post-EOW versus pre-EOW, only a little more than 25% of the 211,000 depot visits increment derived above. Thus, the disposal and diversion changes shown in Table 1 rather than those shown in Table 2 are likely to be closer to the true amount of disposal and diversion tonnage changes induced by the Niagara Region switch to EOW curbside garbage collection frequency. Nevertheless, due to the uncertain and unknown impacts

of other potential drivers of disposal and diversion tonnage changes post- versus pre-EOW, we report curbside plus depot, as well as curbside only, results throughout this report.

IV. Environmental Impacts of EOW Curbside Garbage Collection

Table 4: Estimated Pollution Decrease/(Increase) Associated with EOW Garbage Collection shows estimated pollution decreases or increases associated with implementation of EOW curbside garbage collection. Decreases in pollution during the first year of EOW curbside garbage collection versus pollution during the last year of weekly curbside garbage collection are displayed as positive numbers to emphasize the environmental benefit of less pollution.

Table 4 shows increased or decreased environmental benefits of diversion tonnage changes for EOW garbage collection customers alone, as well as for curbside customers plus depot disposal and diversion tonnage changes, during the first year of EOW curbside garbage collection in the Niagara Region⁵. Some households and ICI entities using curbside garbage collection may have increased self-hauling of garbage, as well as recyclables and organics, to depots during the in-between weeks for their garbage collection. Unfortunately, the depot tonnage data do not identify whether a depot drop-off customer is a curbside garbage collection customer. Hence, the depot tonnage changes for the first EOW year versus the last weekly curbside garbage collection year likely overestimate, perhaps substantially, any increased use of depot drop-off facilities for disposal or diversion by curbside garbage collection customers. Nevertheless, curbside plus depot tonnage changes for the EOW first year versus the weekly last year are provided in Table 4 to indicate the potential low end for pollution benefits of EOW garbage collection.

⁵ The 564 MT decrease in total curbside waste generation during the first complete post-EOW year is not included as a benefit of EOW implementation in our evaluation of the benefits of EOW compared to weekly curbside garbage collection. The additional depot garbage disposal tonnage post-EOW is counted as a decrease in environmental benefits for the curbside plus depot calculation of environmental benefits for EOW curbside garbage collection. These two methodological assumptions provide a conservative basis for both high and low estimates for the environmental benefits of EOW garbage collection.

Table 4 Estimated Pollution Decrease/Increase Associated with EOW Garbage Collection

Pollution Environmental Impact	Pollution Indicator Substance	Pollution Decrease/(Increase) (MT indicator Substance) - Curbside Only	Pollution Decrease/(Increase) (MT indicator Substance) - Curbside and Depot
Climate Change	eCO ₂	18,413.92	10,725.08
Human Health - Respiratory	ePM _{2.5}	4.73	1.14
Human Health – Non-Carcinogenic	eT	1,366.97	(1,514.32)
Human Health – Carcinogenic	eB	8.39	(10.84)
Eutrophication	eN	93.39	56.56
Acidification	eSO ₂	29.88	(8.48)
Ecosystems Toxicity	e2,4-D	0.04	(0.17)
Ozone Depletion	eCFC-11	0.05	0.03
Smog Formation	eO ₃	348.67	(142.89)

The pollutant decreases or increases for each of the nine environmental impacts are measured in terms of the indicator substance for each impact. For example, for climate change curbside only diversion tonnage increases reduced climate impacts by 18,413.9 MT eCO₂. However, for curbside plus depot disposal and diversion tonnage changes, the additional depot disposal offset the additional depot diversions, decreasing climate benefits to 10,725.1 MT eCO₂.

Table 4 also shows that the absolute quantity of pollution decreases or increases measured in terms of each environmental impact's indicator substance vary dramatically among the nine environmental impacts. Curbside EOW pollution decreases range from 18,413.9 MT eCO₂ for climate change down to less than a tenth MT e2,4-D for aquatic ecosystems toxicity reductions and eCFC-11 for ozone depletion impact reductions. These quantitative disparities present challenges for decision makers who may need to somehow compare and prioritize these environmental impact reductions.

Section V details the monetization method for comparing impact reductions. Figure 1 in this section introduces that method's economic valuations for GHG reductions along with its display of estimated GHG reduction quantities associated with EOW curbside garbage collection.

Figure 1 GHG Reductions and Environmental Economic Value (EEV) per MT Material Diverted Curbside

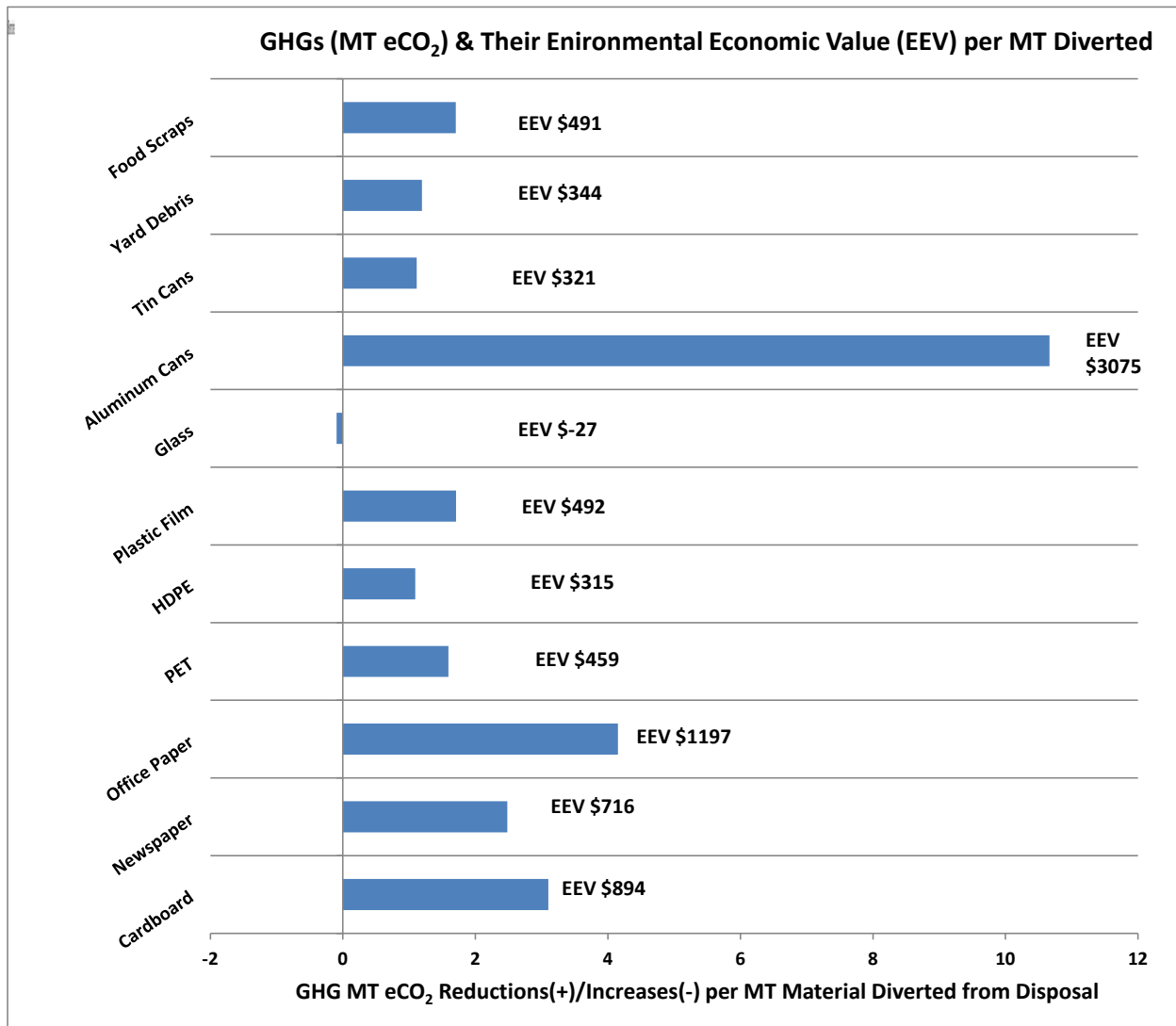


Figure 1: GHGs Reductions & Environmental Economic Value (EEV) per MT Material Diverted Curbside displays in bar graph format the GHG reductions per MT for materials collected in curbside recycling when those materials are diverted from disposal. Reductions due to recycling are shown on Figure 1 as positive numbers to emphasize the environmental benefits of diverting materials from disposal to recovery for use in manufacturing recycled-content products or composting into soil amendments.

Figure 1 text to the right of the graph's blue bars give the environmental benefit valuation for GHG changes for the different materials whose diversion was increased during the first year of EOW curbside garbage collection. For example, as indicated in Figure 1, diverting aluminum reduces climate impacting GHG emissions more than 2.5

times as much as diverting a metric ton of any of the other materials collected curbside for diversion. The GHG reductions from recycling a metric ton of aluminum have an environmental economic value (EEV) of \$3,075 per MT recycled.

Diversion of paper fiber ranks second in EEV. Food scraps, plastic film and PET rank third in terms of climate impact reductions and EEV per MT. Yard debris and HDPE come next. Glass containers diverted for use as construction aggregates rank last and slightly increase GHGs versus landfill disposal.

V. Comparison of Economic Benefits for Each Environmental Impact Pollution Reduction

It is apparent from the pollution decrease or increase estimates shown on Table 4 that the nine different environmental impacts have vastly different absolute levels of pollution reduction as measured by each impact's pollution indicator substance. This is in part due to the different scale of emissions measured by each impact's reference substance. Tables 5 and 6 show the environmental economic value for decreases in pollution emissions for each of the nine public health and environmental impact categories.

Table 5 Economic Value of Pollution Decreases Due to EOW Curbside Garbage Collection

Environmental Impact	Pollution Indicator Substance	Midpoint Economic Cost of Pollution per MT (CDN \$)	Curbside Only - Pollution Decreases	Curbside Only - Value of Decreases (CDN \$)	Curbside Only – Per Cent of Total Benefit
Climate Change	eCO ₂	\$288.35	18,413.92	\$5,309,772	40.3%
Human Health - Respiratory	ePM _{2.5}	\$824,335.45	4.73	\$3,902,718	29.6%
Human Health – Non-Carcinogenic	eT	\$465.81	1,366.97	\$636,746	4.8%
Human Health – Carcinogenic	eB	\$3,328.67	8.39	\$27,913	0.2%
Eutrophication	eN	\$33,900.36	93.39	\$3,165,898	24.0%
Acidification	eSO ₂	\$558.97	29.88	\$16,701	0.1%
Ecosystems Toxicity	e2,4-D	\$5,681.36	0.04	\$250	<0.1%
Ozone Depletion	eCFC-11	\$77,246.25	0.05	\$3,611	<0.1%

Environmental Impact	Pollution Indicator Substance	Midpoint Economic Cost of Pollution per MT (CDN \$)	Curbside Only - Pollution Decreases	Curbside Only - Value of Decreases (CDN \$)	Curbside Only – Per Cent of Total Benefit
Smog Formation	eO ₃	\$332.05	348.67	\$116,010	0.9%
Overall Total Benefit	N/A	N/A	N/A	\$13,179,620	100.0%

Table 6 Economic Value of Pollution Decreases Due to EOW Curbside and Depot Garbage Collection

Environmental Impact	Pollution Indicator Substance	Midpoint Economic Cost of Pollution per MT (CDN \$)	Curbside and Depot - Pollution Decreases	Curbside and Depot - Value of Decreases (CDN \$)	Curbside and Depot – Per Cent of Total Benefit
Climate Change	eCO ₂	\$288.35	10,725.08	\$3,092,645	59.9%
Human Health - Respiratory	ePM _{2.5}	\$824,335.45	1.14	\$943,350	18.3%
Human Health – Non-Carcinogenic	eT	\$465.81	-1,514.32	-\$705,378	-13.7%
Human Health – Carcinogenic	eB	\$3,328.67	-10.84	-\$36,067	-0.7%
Eutrophication	eN	\$33,900.36	56.56	\$1,917,294	37.2%
Acidification	eSO ₂	\$558.97	-8.48	-\$4,743	-0.1%
Ecosystems Toxicity	e2,4-D	\$5,681.36	-0.17	-\$968	>0.1%
Ozone Depletion	eCFC-11	\$77,246.25	0.03	\$2,051	<0.1%
Smog Formation	eO ₃	\$332.05	-142.89	-\$47,543	-0.9%
Overall Total Benefit	N/A	N/A	N/A	\$5,160,641	100.0%

Pollution environmental costs for each environmental impact are based on a recent study and literature review by SRMG for the Oregon Department of Environmental Quality and Oregon Metro. That study developed low and high estimates for the human health and environmental costs incurred from emissions of the indicator substances for each of the nine environmental impacts. For this report, the midpoint of these Oregon

study ranges in 2019 U.S. dollars was converted to 2020 Canadian dollars. These midpoints for the environmental economic cost of releases of each indicator pollutant is listed in the introduction to this report and also shown in Tables 5 and 6.

As indicated in Tables 5 and 6 the value of annual pollution decreases caused by landfill disposal decreases and diversion increases associated with the switch to EOW curbside garbage collection in the Niagara Region is between \$5.2 million and \$13.2 million. This is quite a wide range. The lower end includes the environmental cost of an additional 5,275 MT going to landfill disposal due to depot drop-off garbage increases during the first year of EOW. As indicated previously in this report, much of the tonnage changes for depots may have little to do with increased use of depot drop-off facilities by curbside garbage collection customers during the first year of EOW garbage collection. The curbside only environmental valuation of \$13.2 million, thus, may be a closer approximation to the environmental benefits induced by the switch to EOW curbside garbage.

Figure 2: Percentage Shares of Environmental Economic Value for EOW Curbside Garbage Collection Benefits provides a visualization for the distribution of total EOW environmental benefits among the nine environmental impacts. This distribution is also listed on Table 5.

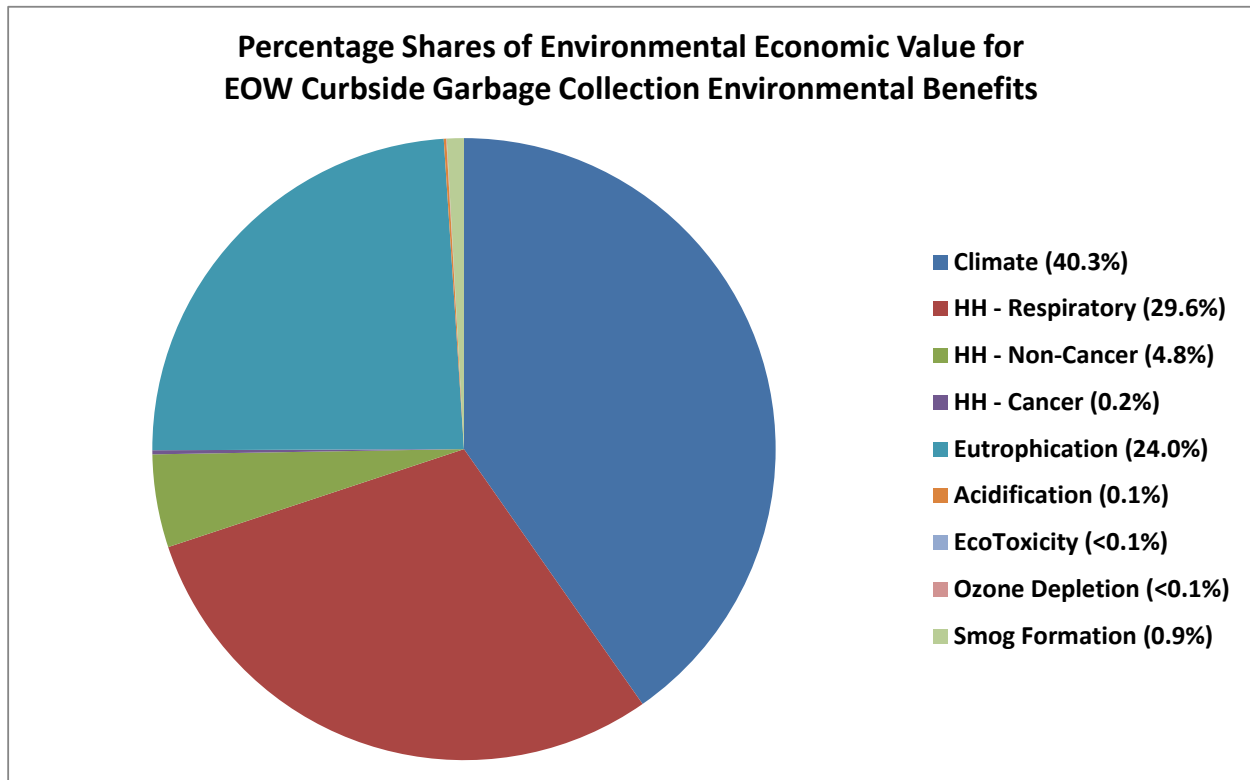
Figure 2 Percentage Shares of Environmental Economic Value

Figure 2 shows that climate benefits provide the largest total environmental economic value among the nine environmental impacts whose environmental economic value is assessed by MEBCalc. Climate changing GHG reductions induced by EOW curbside garbage collection have an economic value of \$5.3 million, 40.3% of the \$13.2 curbside only benefits. Emissions decreases due to Niagara Region's switch to EOW curbside garbage collection in pollutants that cause respiratory diseases have the second highest environmental economic value at \$3.9 million. This accounts for 29.6% of overall curbside waste disposal decrease and diversion increase benefits from EOW garbage collection. Reduced eutrophication of waterways is third at \$3.2 million, accounting for 24.0% of monetized environmental benefits for EOW garbage collection. Reductions of non-carcinogenic toxics emissions amount to 4.8% of total environmental economic benefits.