



# LBA ASSOCIATES

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## MEMORANDUM

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**TO:** Megan Lane

**COMPANY:** Denver Solid Waste Management

**DATE:** June 18, 2019

**RE:** 2019 ICI Waste Composition Findings

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LBA Associates (LBA) is pleased to submit to Denver Solid Waste Management (DSWM) this summary of waste composition findings from two 2019 studies of Denver's institutional, commercial and industrial (ICI) waste streams. This work included:

- ✚ Physical Sort - of representative ICI samples in March at the city's Cherry Creek Transfer Station
- ✚ Visual Audit - of mixed business waste generated throughout Denver's commercial districts in April

Prior to this work, DSWM had limited data on the city's solid waste stream composition beyond its own residential collections<sup>1</sup>, which included 223,100 tons in 2018 or 14% of the city's total waste. Conversely, the ICI stream was 593,400 tons or nearly 37% of the total<sup>2,3</sup>. Only 23% of the ICI stream was diverted last year; the need to understand the composition and opportunities in this sector is pivotal to improving waste diversion in the future. Figure 1 (on the next page) illustrates the relative breakdown of the currently reported waste stream by weight.

### PHYSICAL SORT

This study involved manual sorting of 82 total samples (60 trash and 22 recycling) over a two-week period and in accordance with the sort methodology detailed in the "Denver ICI Sector Trash & Recyclables Composition Study" protocol<sup>4</sup>. The sample collection and analysis evaluated three specific waste generation sectors. The sort site is shown in Figure 2 (next page).

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<sup>1</sup> Includes single-family to 7-unit homes, Denver Public Schools and city government buildings

<sup>2</sup> Based on private hauler reports (DSWM, April 2019) – this value may underestimate actual ICI waste generation

<sup>3</sup> The construction/ demolition debris stream makes up the remainder and will be audited during the second quarter of 2019

<sup>4</sup> Prepared by LBA Associates, March 2019

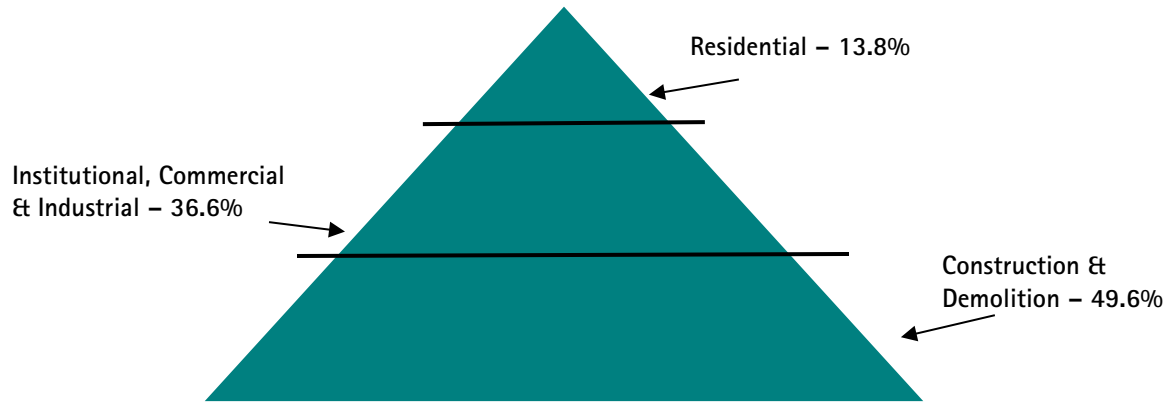


FIGURE 1 – RECORDED SOLID WASTE COLLECTIONS (BY WEIGHT)

The waste generation sectors included:

- Multi-family residential units (MFUs) – defined as having more than 8 units
- Business (including institutional) – this non-residential commercial waste stream can be extremely varied due to generation by a wide range of sources including retail, restaurants, lodging operations, grocery stores, offices, public venues, schools and medical facilities
- Industrial (trash samples only) – these non-hazardous wastes are also varied but typically generated in larger quantities by fewer sources such as brewery/distillery operations, cannabis facilities, building product manufacturers, utilities and others (for the purpose of this work these samples generally excluded C&D materials)
- Mixed loads – these include a combination of primarily MFU and business waste collected from routes that mis generator sectors



FIGURE 2 – TRASH & RECYCLING SORT SITE

## Sample Selection

ICI waste collection in Denver is conducted by private haulers. The four hauling companies that collected most ICI materials (more than 90% of tons collected<sup>2</sup>) collaborated on the sort by providing loads targeted by DSWM. The primary targets were loads from Dumpster collection routes that provided reasonable representation of individual sectors and overall waste (some roll-offs of industrial waste were also included). As shown in Table 1, however, actual loads delivered for sorting varied from targets. This was due to several uncontrollable variables:

- Inability by haulers to provide all loads from isolated generator types - many routes cross sectors and yield mixed loads
- Hauler routing changes - such as last-minute changes to accommodate driver substitutions and to choose routes closer to the city's transfer station
- Lack of precise data on waste in each load - LBA staff surveyed drivers to estimate relative MFU, business and industrial content, but information provided was more qualitative than quantitative

| Generator Sector     | Trash          |              | Recyclables    |              |
|----------------------|----------------|--------------|----------------|--------------|
|                      | Targeted Loads | Actual Loads | Targeted Loads | Actual Loads |
| Multi-Family         | 24-27          | 14           | 9-10           | 0            |
| Business             | 28-31          | 20           | 10-11          | 10           |
| Industrial (non-C&D) | 6              | 3            | 0              | 0            |
| Mixed                | 0              | 23           | 0              | 12           |
| Total                | 60             | 60           | 20             | 22           |

TABLE 1 – TARGETED VERSUS ACTUAL LOADS

## ICI TRASH COMPOSITION

The trash portion of the study focused on measuring potentially divertible recyclables and organics. During the study, 60 loads of ICI trash were sampled, and more than 13,600 pounds sorted into 39 materials spread over six primary categories<sup>5</sup>. A full set of results for every material in each sample and a statistical analysis of the results are provided in Appendix A. All values are weighted averages<sup>6</sup> and are expressed as percent by weight.

### Aggregated Trash Results

This analysis includes sort results from all generation sectors. Figure 3 (next page) shows the results for each primary material category:

- Not all materials captured in the organics, paper, plastics, metal and glass categories are recyclable - each includes some wastes that are not accepted in local diversion programs
- Other materials included composites (items consisting of more than one type of material), C&D debris, and special and hazardous waste

<sup>5</sup> The average trash sample size was 227 pounds, which met the objective of the study protocol

<sup>6</sup> Each sample value has been adjusted to reflect that sample's load weight relative to the load weight of all trash samples measured

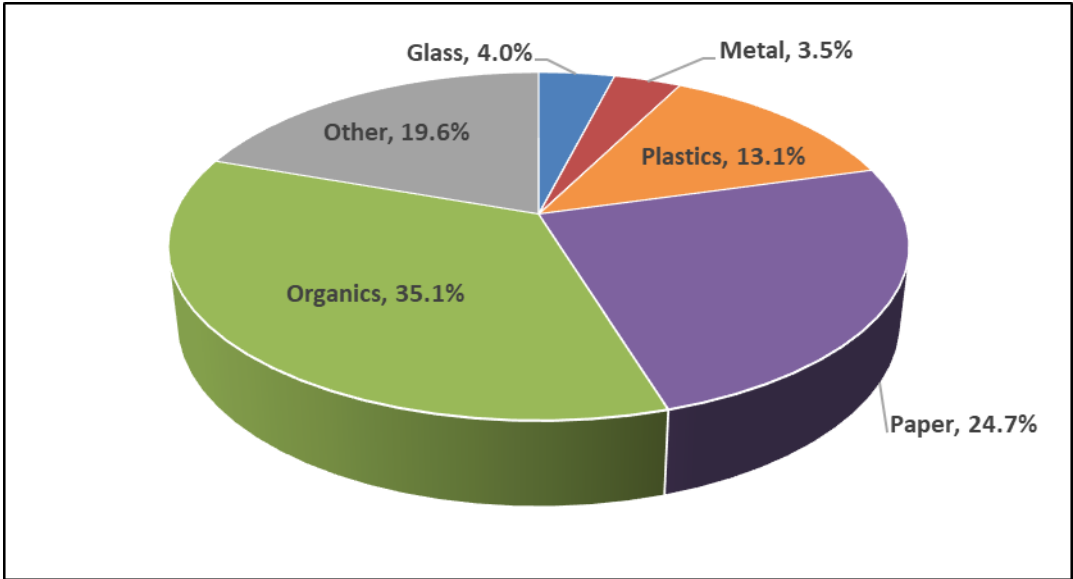


FIGURE 3 – AGGREGATED TRASH COMPOSITION BY MATERIAL CATEGORIES

As a general observation, Denver’s ICI composition appears to be generally consistent with that of other urban governments that have also characterized this waste stream. Appendix B includes a tabulation of these data sets.

Most Common Materials - Figure 4 identifies the ten most common materials in the ICI samples, which made up 75% of the overall composition. Food waste was clearly the predominant material across all sectors.

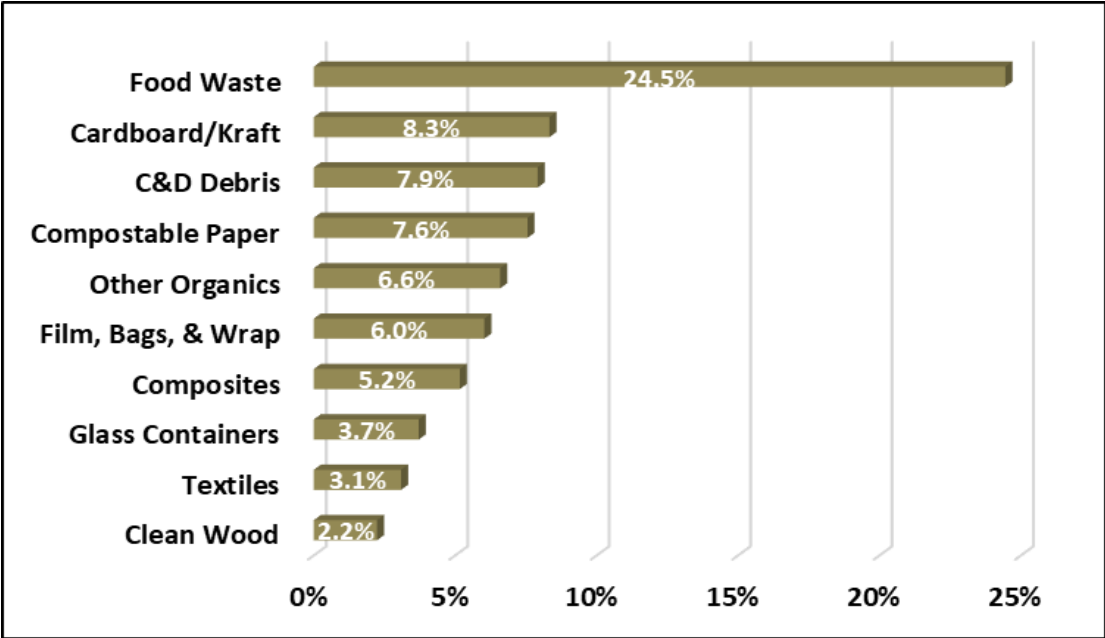


FIGURE 4 – MOST COMMON MATERIALS

Diversion Potential – To assess the maximum diversion potential achievable with full recovery and no contamination, sort results were broken into the three groups below that correspond with how materials are currently recovered in

Denver. While 100% materials recovery is improbable and these potential values likely over-estimate diversion, they provide a useful "end goal" and indication of opportunity.

- Single-Stream Recyclables – materials that can be diverted through single-stream collections and are currently accepted by local markets (this group includes cardboard, which may also be source-separated by larger generators)
- Other Recyclables or Source-Separated Recyclables – materials that can be diverted locally as a source-separated stream (i.e., electronic waste and HHW collections) or by others in the Denver metro area (these materials include paint, tires, textiles, film, Styrofoam and bulky rigids<sup>7</sup>)<sup>8</sup>
- Compostables – organics that can be diverted at regional Class III compost facilities (including food and yard waste, compostable paper and clean wood)

Other materials (i.e., textiles, carpet, some C&D and composite materials) are accepted for reuse and repurposing in small quantities in the metro area but are not specifically considered in this report

Figure 5 (and Appendix A) shows that the diversion potential for trash samples was 74%<sup>9</sup>. This potential represents nearly 337,000 annual tons that could have been diverted instead of landfilled (based on reported 2018 ICI quantities).

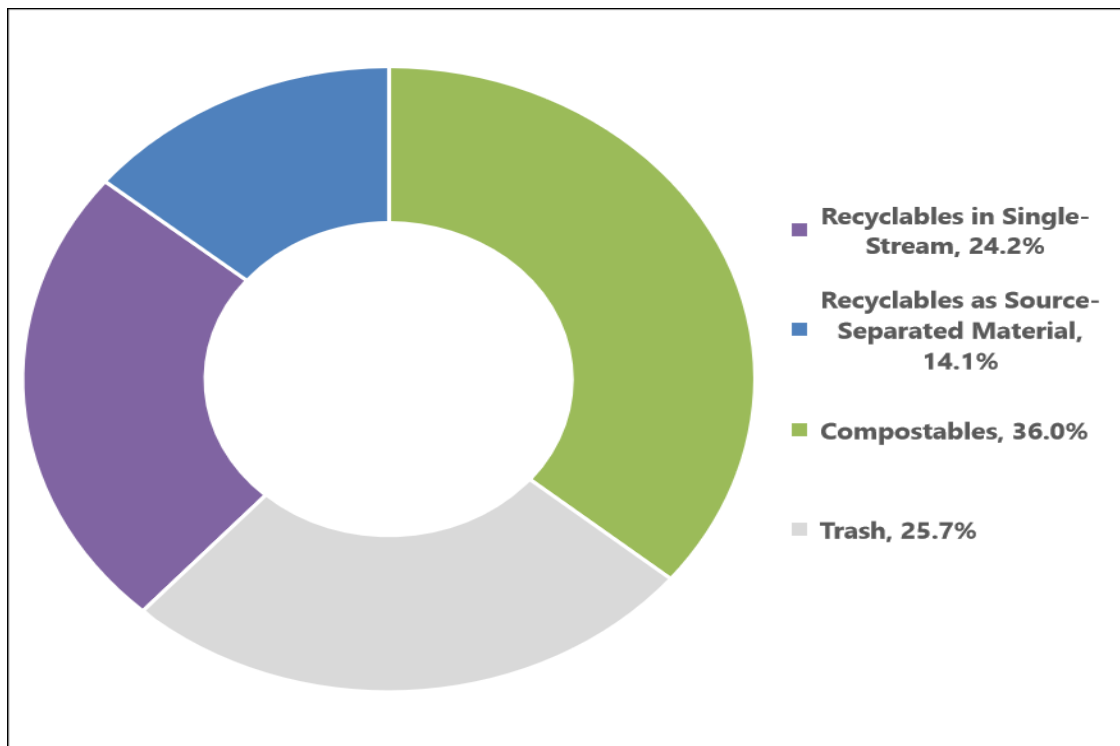


FIGURE 5 – POTENTIAL FOR DIVERSION THROUGH EXISTING PROGRAMS

<sup>7</sup> Plastic containers >3 gallons, toys, furniture and other bulky rigids are not accepted in Single-Stream Recyclable collections

<sup>8</sup> Not all materials are currently accepted by all haulers or processors or from all waste generators

<sup>9</sup> This value is slightly higher than the 69% diversion potential measured for residential trash in a 2016/2017 Denver sort (Trash & Recycling Composition Results, prepared by LBA Associates, May 2017)

## Trash Results by Generation Sector

Figure 6 compares sector-specific waste composition results. Appendix C includes a breakdown of each sector by material weight.

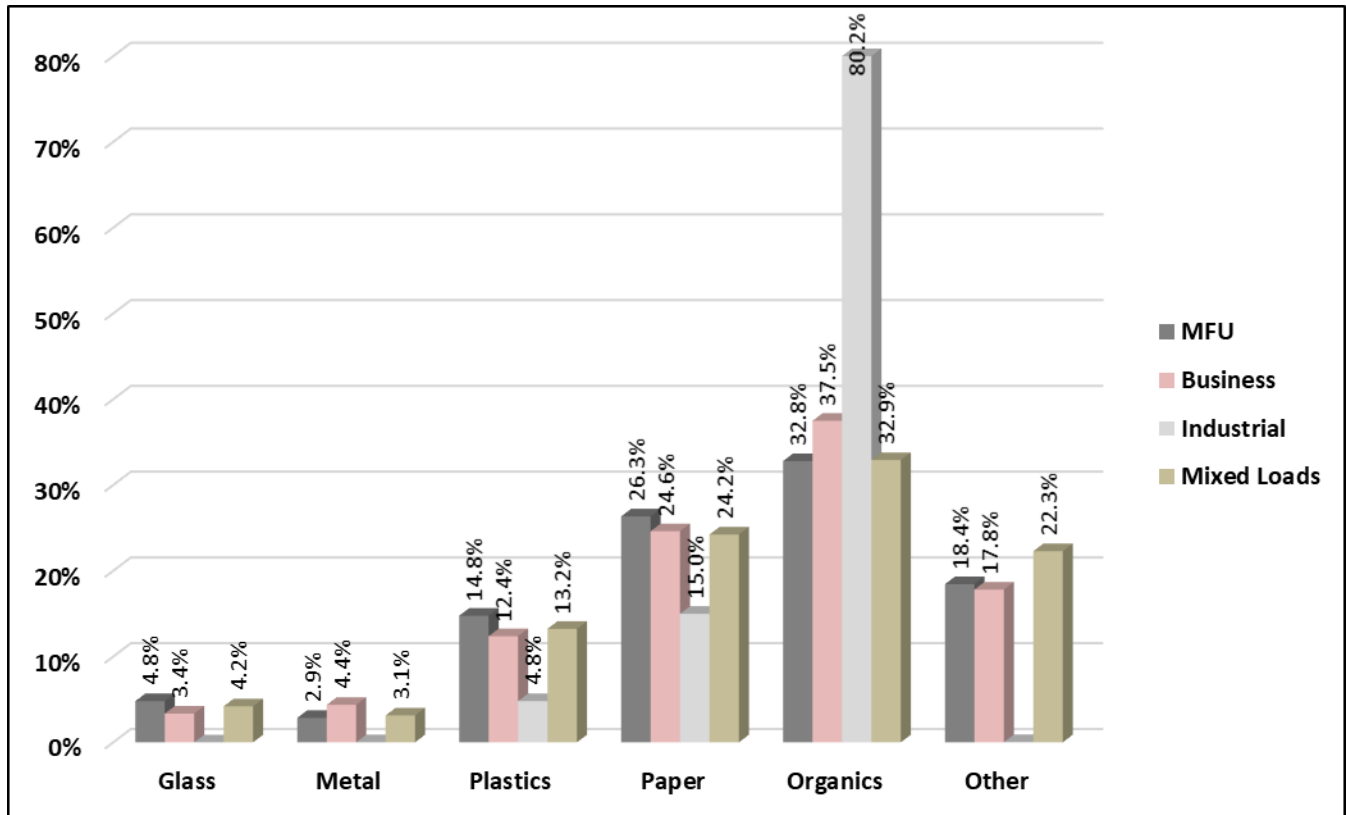


FIGURE 6 – TRASH COMPOSITION BY WASTE GENERATION SECTOR

Industrial sector characterization was limited to three industry-only samples – two were from cannabis operations and one from a site with some construction. Therefore, these results should be used with caution. As shown, the industry-only samples were notable in terms of high organics content (mostly cannabis-related materials) and clean wood (mostly pallets).

MFU sample findings were consistent with residential results obtained previously by DSWM (see Table 3 on page 8). They included comparatively higher percentages of glass, plastics and paper than the other sectors. Alternatively, business samples exhibited the highest levels of metal and organics (aside from industrial), which is consistent with restaurant and grocery waste (steel cans and food waste).

Most Common Materials - Table 2 (next page) provides a comparison of the most common materials in each of the sectors evaluated. The following materials were prevalent in MFU and business samples:

- Food waste – 20 to 30%
- Cardboard – 8 to 10%
- Compostable paper – 7 to 9%
- C&D – 7 to 9%
- Plastic film – 3 to 7%
- Textiles – 4 to 5% (a relative newcomer to the top-ten list)
- Glass containers – 3 to 5%

| MFU Samples         |       | Business Samples    |       | Industrial Samples |       | Mixed Samples       |       |
|---------------------|-------|---------------------|-------|--------------------|-------|---------------------|-------|
| Material            | %     | Material            | %     | Material           | %     | Material            | %     |
| Food Waste          | 20.5% | Food Waste          | 30.0% | Other Organics     | 39.1% | Food Waste          | 22.1% |
| Cardboard           | 9.6%  | Cardboard           | 8.5%  | Clean Wood         | 31.2% | C&D Debris          | 9.2%  |
| Compostable Paper   | 8.6%  | Compostable Paper   | 7.2%  | Other Paper        | 12.6% | Other Organics      | 8.4%  |
| Other Organics      | 8.2%  | C&D Debris          | 7.2%  | Cannabis Waste     | 9.9%  | Cardboard           | 7.7%  |
| C&D Debris          | 7.1%  | Film, Bags & Wrap   | 6.1%  | Film, Bags & Wrap  | 3.0%  | Compostable Paper   | 7.6%  |
| Composite Materials | 5.2%  | Composite Materials | 6.0%  | Cardboard          | 1.8%  | Film, Bags & Wrap   | 6.6%  |
| Film, Bags & Wrap   | 4.9%  | Other Metals        | 3.3%  | #1-7 Containers    | 1.6%  | Composite Materials | 4.5%  |
| Glass Containers    | 4.6%  | Glass Containers    | 3.1%  | Compostable Paper  | 0.5%  | Glass Containers    | 3.9%  |
| Bulky Rigid         | 3.6%  | Yard Waste          | 3.0%  | #2 HDPE Bottles    | 0.1%  | Carpet & Padding    | 3.8%  |
| Textiles            | 2.9%  | Textiles            | 2.8%  | Other Plastics     | 0.1%  | Textiles            | 3.5%  |
|                     | 75.3% |                     | 77.2% |                    | 99.8% |                     | 77.3% |

TABLE 2 – COMPARISON OF MOST PREVALENT MATERIALS IN TRASH SAMPLES BY GENERATION SECTOR

Diversion Potential - Figure 7 illustrates diversion potential in trash samples by sector (see the description of group materials on page 5)<sup>10</sup>. This figure underscores the finding that organics - most notably food waste and compostable paper for MFUs and businesses - have the greatest diversion potential in the ICI stream (wood waste was also observed in high quantities in one of three industrial loads but the limited number of samples makes this an unreliable observation without further evaluation).

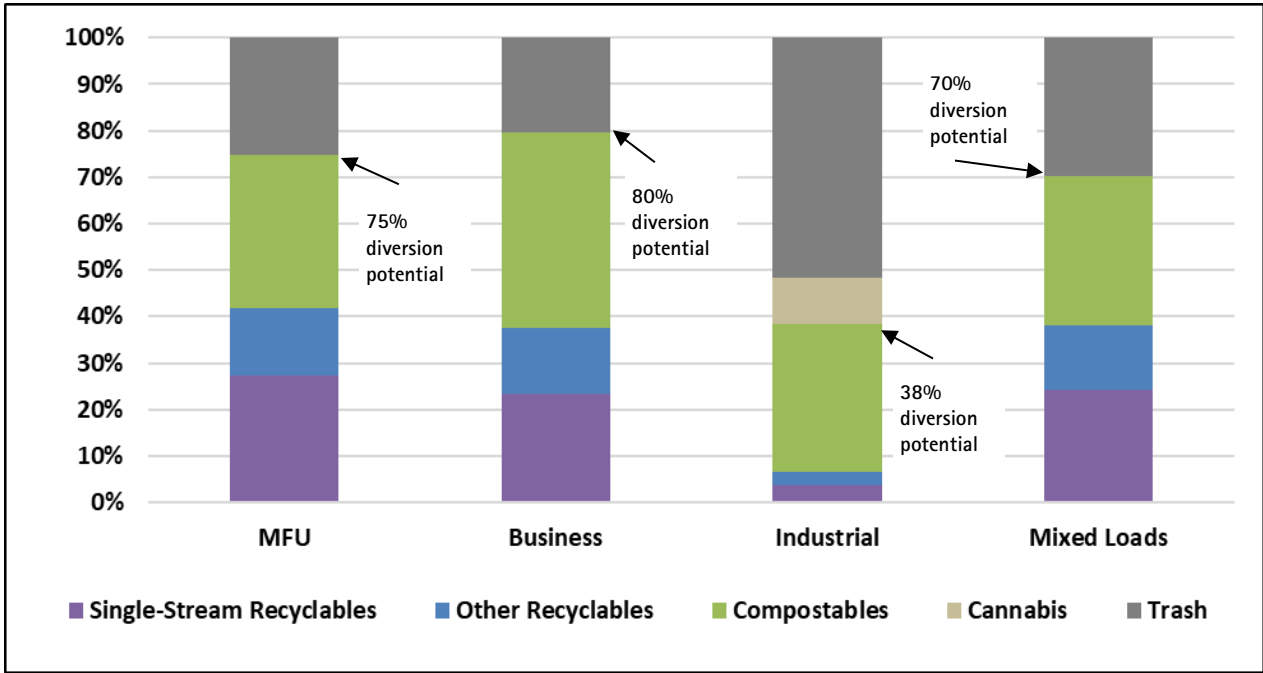


FIGURE 7 – COMPARISON OF DIVERSION POTENTIAL BY GENERATION SECTOR

Figure 7 confirms that Single-Stream Recyclables (especially cardboard and glass in MFU and business samples) has high diversion potential. Other Recyclables (primarily film) is also an important target going forward.

<sup>10</sup> Correlation between diversion potential percent and annual tons is not possible for individual sectors as hauler ICI data is currently collected as an aggregate only

Cannabis-Related Materials - Cannabis was only significant in two industrial samples and appeared to be mostly from grow facilities (i.e., root balls, plant stocks, leaves and stems were observed). Because so few industrial loads were available for sampling the results will help to inform DSWM about cannabis waste but do not necessarily represent the overall industrial waste stream.

### Comparison of MFU & Small Residential Trash Composition

DSWM has conducted multiple waste composition studies of its residential collections (the most recent was the 2016/2017 sort previously referenced). The comparative results shown in Table 3 shows the similarity between residential and MFU sample composition.

The only notable difference was yard waste, which was predictably larger for small homes/small complexes where waste generators more commonly mow and garden (the earlier sort also covered heavy fall leaf/spring clean-up periods, while the 2019 sort was conducted when landscape activities were probably more limited).

| Material Category       | 2016/2017 Sort<br>Single-Family to 7-Unit<br>Homes <sup>11</sup> | 2019 Sort<br>Multi-Family Homes<br>(>7 units) |
|-------------------------|--|---|
| Glass                   | 5%   | 5%  |
| Metal                   | 2%   | 3%  |
| Plastics                | 13%  | 15%   |
| Paper                   | 21%  | 26%   |
| Organics                | 48%  | 33%   |
| <i>Food Waste</i>       | <i>Food Waste 19%</i>  | <i>Food Waste 21%</i>                         |
| <i>Yard Waste</i>       | <i>Yard Waste 17%</i>  | <i>Yard Waste 2%</i>                          |
| Hazardous/Special Waste | 11%  | 18%   |

TABLE 3 – COMPARISON OF SMALL & LARGE RESIDENTIAL TRASH COMPOSITION

### Small Business Trash Composition

As many of Denver’s smaller businesses share Dumpsters - or are collected in mixed loads - it can be difficult to characterize this portion of the waste stream. To provide additional small business data, a visual audit was conducted on 56 trash Dumpsters in ten different commercial districts across the city. Volumetric observations were converted to weight-based estimates for better comparison to the ICI sort results<sup>12</sup> - all values are expressed as percent by weight. Additional details on the small business audit are provided in Appendix D.

Dumpster selection within business districts was not rigorously tied to business type or size, but more to container accessibility during the audit. As a result, audit observations only approximate Dumpster content and the overall commercial stream; they do, however, yield additional insight into commercial waste patterns and diversion potential.

<sup>11</sup> 2016/2017 Trash & Recycling Composition Results (LBA Associates, 2017)

<sup>12</sup> Based on USEPA conversion factors



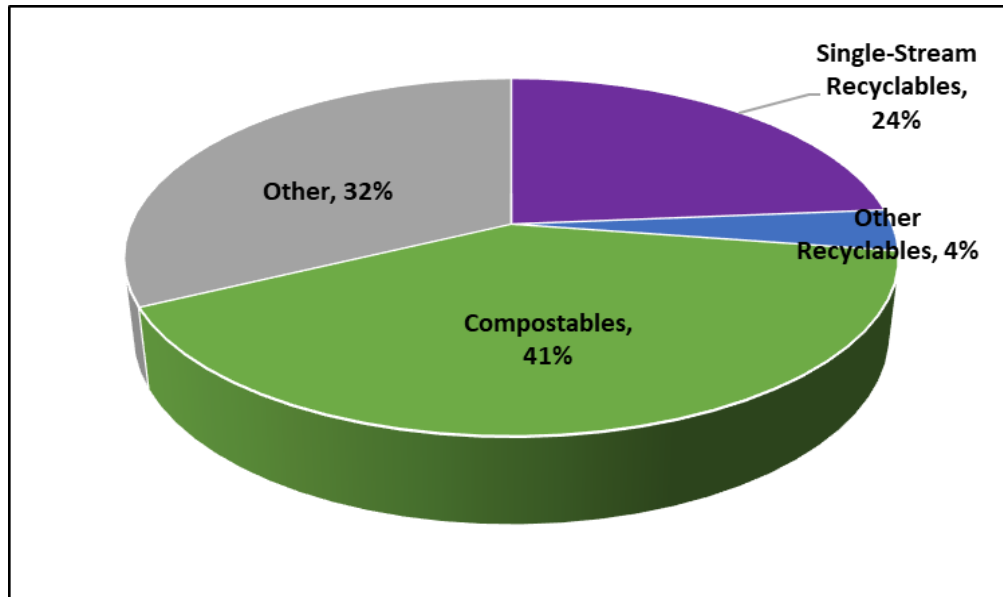


FIGURE 9 – OBSERVATIONS OF DUMPSTER TRASH COMPOSITION FROM SMALL BUSINESSES BY MATERIAL CATEGORIES

As shown in Figure 9, more than two-thirds of audited Dumpster trash contents appeared to be divertible through local programs. Organics (notably food waste) was the most prevalent material observed; nearly half of Dumpsters audited served one or more restaurants. Other observations included:

- Single-Stream Recyclables (primarily cardboard) was the second most common material
- Recyclable materials included small quantities of both non-cardboard Single-Stream and Other Recyclables
- The other category included trash and materials that could not be identified in a visual audit (and which may under-estimate the quantity of divertible materials).

These results are similar to the physical sort of all business sizes (see Figure 7 on page 7) – especially for Single-Stream Recyclables and Compostables. This may show that small businesses don't generate as many Other Recyclables as larger businesses.

### ICI RECYCLABLES COMPOSITION

The recyclables portion of the study focused on measuring contamination in MFU and business recyclable samples. During the study, 22 loads of ICI commingled recyclables were sampled, and more than 3,663 pounds sorted into 17 materials spread over five primary categories<sup>13</sup>. A full set of results for every material in each sample and a statistical analysis of the results are provided in Appendix E. All values are weighted averages<sup>14</sup> and are expressed as percent by weight.

<sup>13</sup> The average recyclables sample size was 167 pounds, which met the objective of the study protocol

<sup>14</sup> Each sample value has been adjusted to reflect that sample's load weight relative to the load weight of all recyclable samples measured.

### Aggregated Recyclables Results

This analysis includes sort results from business and mixed MFU/business recyclable samples, and reflects materials accepted as Single-Stream Recyclables. Figure 10 illustrates the percentage in each primary material category. As shown, nearly 20% of recyclables diverted by ICI generators were contaminants (including grit collected as sample residue)<sup>15</sup>. This value is more than double the contamination level measured in Denver residential recyclables (9.1%) in the 2016/2017 sort.

Figure 11 (on the next page) provides the composition of all materials measured. Single-Stream Recyclables made up 79% of the total (see the sample picture at right), with limited Other Recyclables (1%) and contaminants.

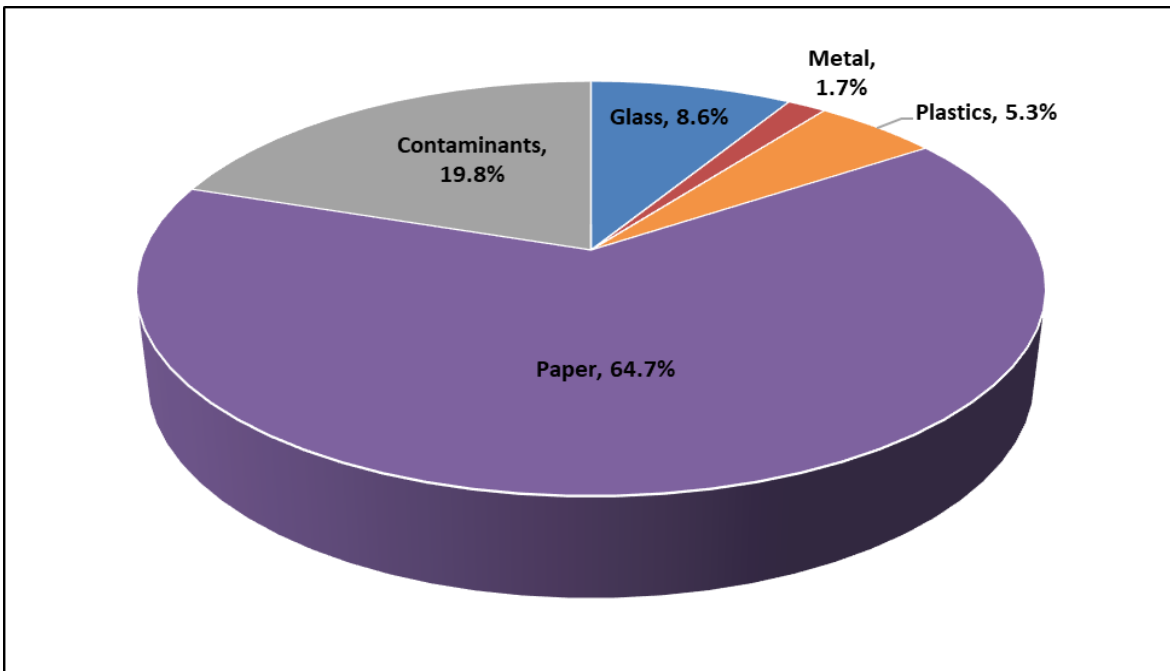


FIGURE 10 – AGGREGATED RECYCLABLES COMPOSITION BY MATERIAL CATEGORIES

### Recyclable Results by Generation Sector

No MFU-only or industrial recyclables samples were collected during the audit, although MFU recyclables were included in mixed loads. Appendix F includes a breakdown of each sector by material weight and a statistical analysis of the results.

While MFU-specific sample results are not available, it is expected that recyclables composition would be similar to residential results obtained by DSWM in 2016/2017. For comparative purposes, these results have been included in Figure 12 (bottom of the next page), which shows composition by generation sector.

<sup>15</sup> This rate indicates that as many as 27,000 annual tons of material collected as ICI recyclables were contaminants and not ultimately diverted from the waste stream (based on reported 2018 quantities)

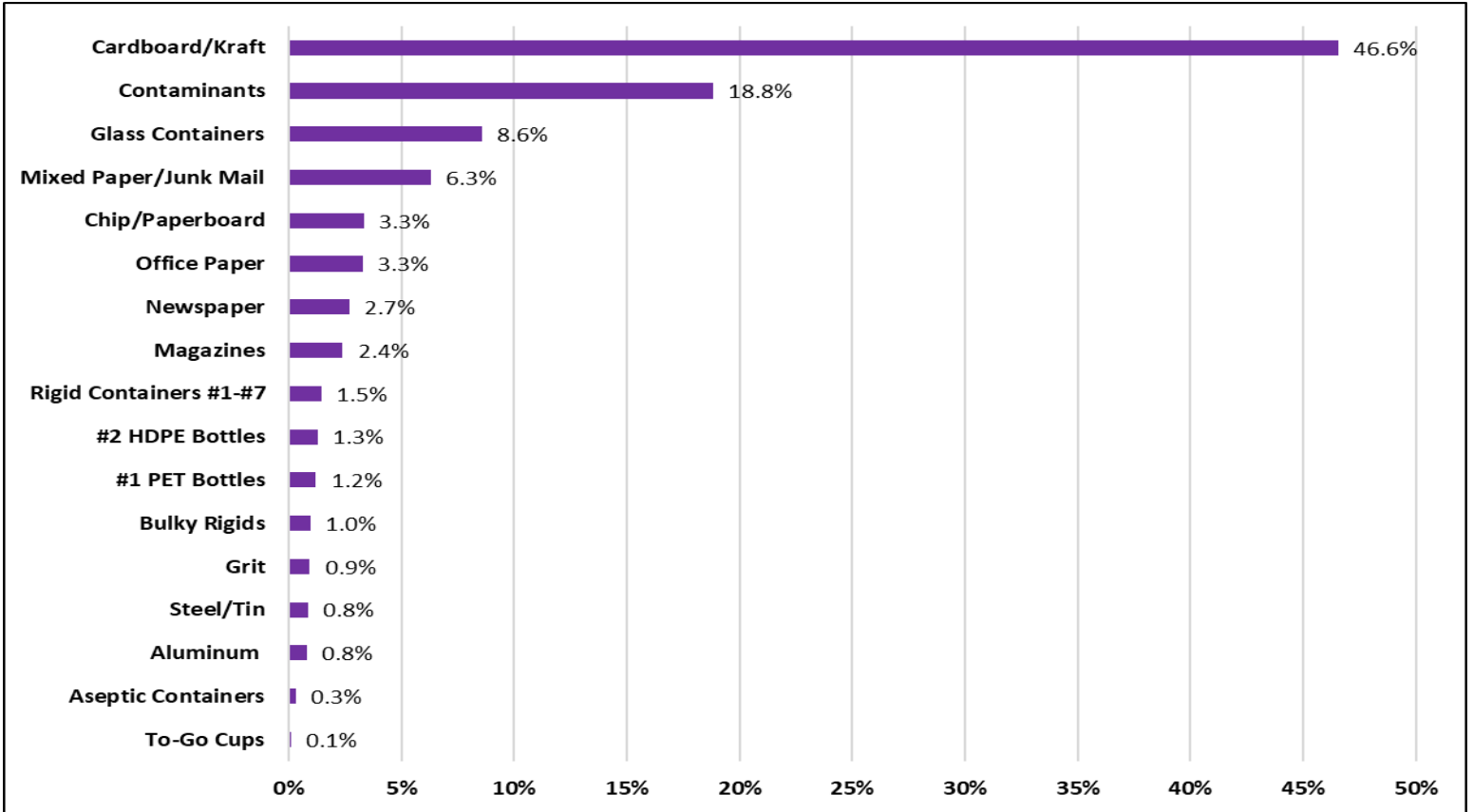


FIGURE 11 – RECYCLABLES COMPOSITION BY MATERIAL

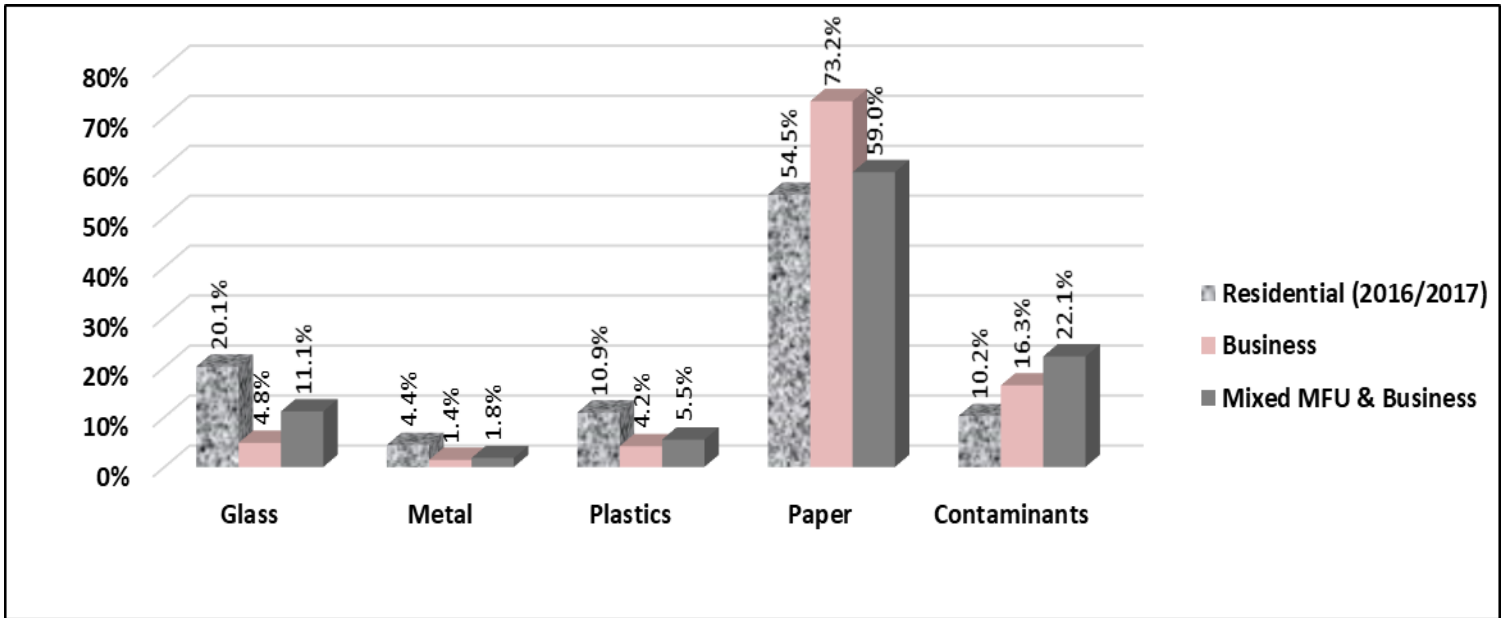


FIGURE 12 – RECYCLABLES COMPOSITION BY WASTE GENERATION SECTOR



FIGURE 13 – PHOTO OF RECYCLING LOAD WITH MOSTLY CARDBOARD

Business samples exhibited higher levels of paper than residential. As demonstrated in Figure 13 (above), cardboard was 51% of business recyclable samples (see detail in Appendix F). The predominance of paper (cardboard) recycling by sector is consistent with the overall ICI results illustrated in Figure 10 (on page 10).

### Small Business Recyclables Composition

A visual audit was conducted on 22 recyclable Dumpsters in ten different commercial districts across the city. Visual volumetric observations were converted to estimates of weight-based composition values for better comparison to the ICI sort results<sup>14</sup>.

Additional details on the small business audit are provided in Appendix G. Dumpster selection within business districts was not rigorously tied to business type or size, but more to container accessibility during the audit. As a result, audit observations only approximately represent Dumpster content and the overall commercial stream and yield some additional insight into commercial waste patterns and diversion potential.

As shown in Figure 14 (on the next page), 90% of audited Dumpster content appeared to be Single-Stream Recyclables. Most of this fraction was cardboard (46%) and glass containers (33%). Other materials included food waste, contaminants, and materials that could not be identified in a visual audit (which may have slightly over-estimated the contamination levels). The results reflect slightly more Single-Stream Recyclables and notably less contaminants (i.e., about 7% in the visual Dumpster audit) than were measured in the physical recyclables sort.

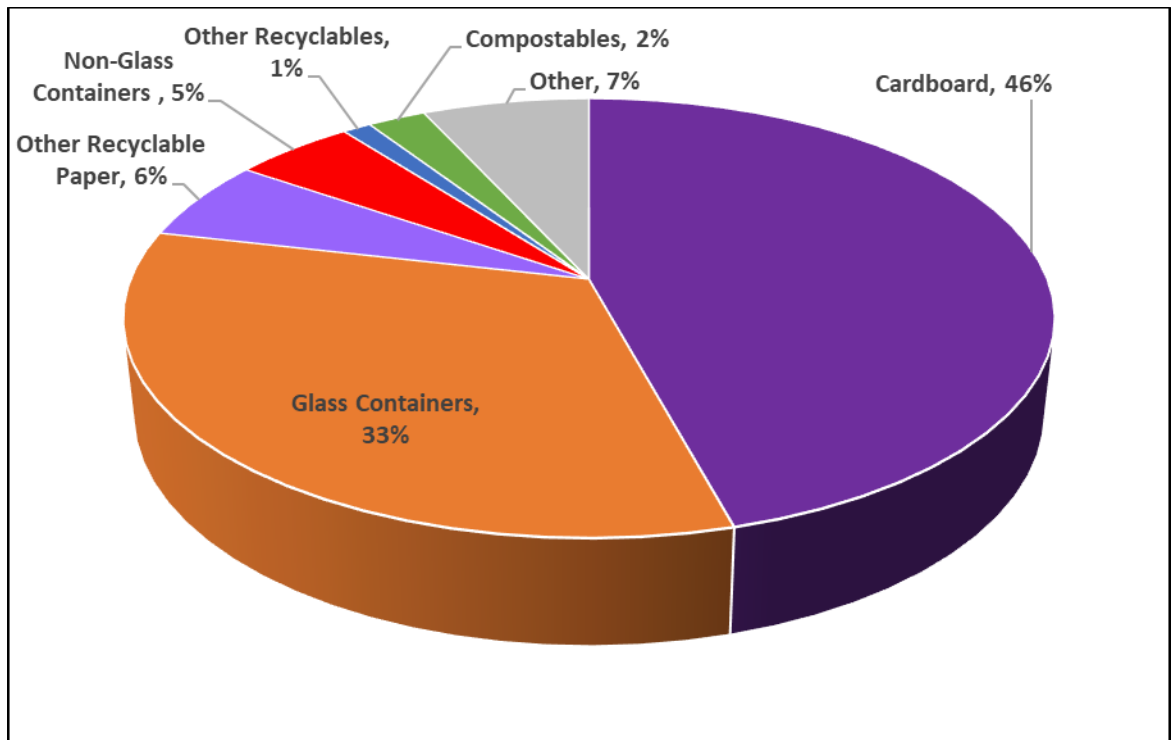


FIGURE 14 – OBSERVATIONS OF DUMPSTER RECYCLABLES COMPOSITION FROM SMALL BUSINESSES BY MATERIAL CATEGORY

## TRASH & RECYCLABLES COMPOSITION OBSERVATIONS

The following observations were made based on the ICI trash/recyclables stream studies completed this year:

- ✚ Characterizing the ICI stream composition – 37% of the city's total solid waste – is critical to city-wide waste diversion
- ✚ Diversion potential in MFU and business trash is high
  - If all divertible materials measured in the trash samples were recovered and there were no contaminants in the recyclable samples, an additional 360,000 tons could have been diverted from landfilling in 2018 (taking the diversion level from the recorded 23% as high as 80%)<sup>16</sup>
  - These findings represent a significant opportunity for improvement if DSWM can address obstacles related to private collection, large generator variability, material quality, generator access and resources
- ✚ Overall, food waste represents the greatest diversion potential – cardboard has the greatest recycling potential
- ✚ Industrial waste diversion opportunities will require further research by specific industry type
- ✚ Visual audits provide a reasonable approximation of Dumpster trash at a much lower cost

The observations listed below support early recommendations that may warrant further evaluation. Table 4 (on the next page) includes a partial list of opportunities that may be considered during development of Denver's Solid Waste Master Plan update in 2020.

<sup>16</sup> This also assumes that the audit findings for trash and recyclables samples accurately represents the overall ICI waste stream

1) MFU Waste Diversion programs – stakeholders should:

- Build on existing residential outreach and education messaging
  - MFU and residential trash is similar (except for yard debris)
  - Understand that diversion strategies will vary between residential and MFU (i.e., MFU outreach requires interaction with property owners/managers as well as with tenants)
  - Messaging should be consistent city-wide (text and graphic signals, colors, etc.)<sup>17</sup>
  - Involve haulers directly in outreach and education efforts (or require haulers to conduct)
- Utilize results from the Recycle Colorado pilot project that is currently in progress (expected to provide insight into encouraging “new” MFUs start recycling and helping “existing” MFUs improve the quality of their recyclables)
- Focus on single-stream recyclables initially (especially cardboard and glass)
- Phase in food waste recovery after recycling has been consistently established, collection is more universal and diversion costs have stabilized

|  |
|--|
| ✚ Require space for recycling & organics recovery in new or renovated construction                               |
| ✚ Require generators to use registered haulers (require haulers to provide education & outreach to customers)    |
| ✚ Require generators to have waste plans and/or some level of waste management certification                     |
| ✚ Set limits on allowable recyclables/organics in trash & trash in diverted containers                           |
| ✚ Increase number of drop-sites for MFU and business access  |
| ✚ Require haulers to collect recyclables and organics from commercial customers                                  |
| ✚ Require large food-waste generators to recover organics  |
| ✚ Require businesses to provide recycling to employees, guests & customers (and education on how implementation) |
| ✚ Require businesses with liquor licenses to recycle glass   |
| ✚ Implement disposal bans – such as cardboard, glass, plastic packaging/service ware, polystyrene, etc.          |
| ✚ Evaluate source-separated cardboard, glass & plastic film collection   |
| ✚ Evaluate feasibility of new transfer station(s) especially for organics  |
| ✚ Explore a procurement program to use recycled products & compost locally                                       |
| ✚ Expand existing Denver Water requirement to use amend soil with compost  |
| ✚ Require more detailed reporting from haulers   |
| ✚ Increase overall enforcement of current & future programs & policies   |

TABLE 4 – POSSIBLE NEW DENVER PROGRAMS, POLICIES & INFRASTRUCTURE

2) Business Waste Diversion programs:

- Implement an organics recovery program for food-waste generating businesses (including restaurants, grocers and cafeterias)
  - Phase in for increasingly smaller generators over time (similar to what was recommended in Denver’s 2010 Solid Waste Master Plan)
  - Utilize the 70+ restaurants with Certifiably Green Denver (CGD) certifications as models and champions<sup>18</sup>

<sup>17</sup> Ideally, Denver will work towards messaging consistency with other U.S. communities, using standards suggested by Recycle Across America or similar organizations

<sup>18</sup> CGD is also launching an organics recovery pilot project for restaurants in the Highlands neighborhood later this year which may yield helpful information on most effective tools

- Create tools and guidance addressing waste auditing, Dumpster selection, hauler contracting, purchasing and menu-planning strategies, recycling outlets for unique materials (especially plastic film and textiles from restaurants with kitchen/wait staff uniforms), etc.
- Messaging should be consistent city-wide (text and graphic signals, colors, etc.)<sup>19</sup>
- Implement a recycling program for all businesses that focuses on single-stream recyclables with commingled or source-separated cardboard and glass
- Work with MRF operators to establish a consistent list of accepted materials (especially important for plastics #3-#7, aseptics and Styrofoam – see the example of mixed materials in Figure 15)



FIGURE 15 – PHOTO OF MIXED PLASTICS IN TRASH SAMPLE

### 3) Organics:

- Improve collection options with access to generators of all sizes and competitive pricing
  - Facilitate lower collection costs through increased participation and greater tons
  - Consider expanding existing hauler ordinance to require trash haulers to provide organics collection to customers who generate de minimis quantities of food waste
- Work with Class III compost facilities to clarify and simplify acceptable plastic packaging and food/service ware

### 4) Recyclables:

- Consider expanding existing hauler ordinance to require trash haulers to provide recyclables collection to all generators as a core service
  - Implement a cardboard collection program with a pilot project for the source-separation of cardboard along a dedicated collection route
  - Subsequently expand to encourage source-separation by large business, institutional, and industrial generators to increase diversion and improve quality

- Evaluate the value of a glass recycling program to close the gap between landfilled glass and existing end-markets that may consider
    - Focused public outreach strategies such as the on-going TRP project that targets aluminum cans
    - Recommendations from Recycle Colorado's "non-bottle bill" container recycling task force in 2019
  - Address plastic film management in light of existing local outlets and recyclables contamination<sup>19</sup>
    - Improve awareness around the recovery of source-separated film, bags and wrap – and locations that will accept (i.e., most larger grocers and some retailers)
    - Increase outreach about the prohibition of these materials in recycling carts and Dumpsters
- 5) Industry:
- Conduct additional research to identify key industrial generators (in addition to cannabis)
  - Evaluate strategies for biggest waste generators
  - Build on successfully sustainable programs by model companies (some are certified by CGD)
- 6) Improve Quantity Data – primarily by increasing the completeness and detail of hauler-reported data:
- Improve the accuracy of data reported<sup>20</sup>
  - Increase requirements around existing code language – specifically for characterizing reported tons
    - Break down of MFU versus business Dumpster tons (both trash and recyclables)
    - Break down of C&D versus other industrial roll-off tons (both trash and recyclables)
  - Increase hauler enforcement – with more effective penalties for non-compliance
- 7) Continue trash and recyclables stream composition analysis every 3-4 years with a combination of physical sorts and visual audits to track the progress of existing and new programs and policies.

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<sup>19</sup> 2019 CDPHE survey identifies plastic bags and wrap as the most "problematic" material in operating material recovery facilities in Colorado

<sup>20</sup> In 2019, Kessler Consulting used Denver employment numbers and CalRecycle's commerce-specific waste generation rates to estimate that the Denver's 2018 ICI quantities reported by haulers were likely under-estimated



## APPENDIX A AGGREGATED TRASH COMPOSITION STUDY RESULTS & STATISTICAL ANALYSIS

|    | Material Category            | Weighted Average | 90% Confidence Interval |              |
|----|------------------------------|------------------|-------------------------|--------------|
|    |                              |                  | Lower Bounds            | Upper Bounds |
| 1  | Cardboard/Kraft              | 8.3%             | 6.8%                    | 9.8%         |
| 2  | Newspaper                    | 0.5%             | 0.3%                    | 0.6%         |
| 3  | Office Paper                 | 1.1%             | 0.7%                    | 1.4%         |
| 4  | Chip/Paperboard              | 2.2%             | 1.8%                    | 2.6%         |
| 5  | Mixed Paper/Junk Mail        | 1.6%             | 1.3%                    | 2.0%         |
| 6  | Magazines                    | 0.8%             | 0.4%                    | 1.3%         |
| 7  | To-Go Cups                   | 0.5%             | 0.4%                    | 0.7%         |
| 8  | Aseptic Containers           | 0.2%             | 0.2%                    | 0.3%         |
| 9  | Compostable Paper            | 7.6%             | 6.6%                    | 8.5%         |
| 10 | All Other Paper              | 1.8%             | 1.0%                    | 2.6%         |
|    | <b>Total Paper</b>           | <b>24.7%</b>     |                         |              |
| 11 | #1 PET Bottles               | 1.5%             | 1.3%                    | 1.7%         |
| 12 | #2 HDPE Bottles              | 0.8%             | 0.6%                    | 1.0%         |
| 13 | #1-#7 Containers             | 1.4%             | 1.2%                    | 1.6%         |
| 14 | Bulky Riqids                 | 1.4%             | 0.6%                    | 2.2%         |
| 15 | Styrofoam                    | 0.7%             | 0.5%                    | 0.8%         |
| 16 | Film, Bags, Et Wrap          | 6.0%             | 5.3%                    | 6.7%         |
| 17 | Other Plastics               | 1.3%             | 1.1%                    | 1.6%         |
|    | <b>Total Plastics</b>        | <b>13.1%</b>     |                         |              |
| 18 | Aluminum                     | 0.9%             | 0.8%                    | 1.0%         |
| 19 | Steel/Tin Cans               | 0.6%             | 0.5%                    | 0.7%         |
| 20 | Other Metals                 | 2.0%             | 1.1%                    | 3.0%         |
|    | <b>Total Metal</b>           | <b>3.5%</b>      |                         |              |
| 21 | Glass Containers             | 3.7%             | 2.9%                    | 4.5%         |
| 22 | Other Glass                  | 0.2%             | 0.1%                    | 0.3%         |
|    | <b>Total Glass</b>           | <b>4.0%</b>      |                         |              |
| 23 | Food Waste                   | 24.5%            | 21.0%                   | 27.9%        |
| 24 | Yard Waste                   | 1.7%             | 0.5%                    | 3.0%         |
| 25 | Cannabis Waste               | 0.1%             | -0.6%                   | 0.9%         |
| 26 | Clean Wood                   | 2.2%             | 0.2%                    | 4.2%         |
| 27 | Other Organics               | 6.6%             | 2.9%                    | 10.3%        |
|    | <b>Total Organics</b>        | <b>35.1%</b>     |                         |              |
| 28 | Textiles                     | 3.1%             | 2.4%                    | 3.7%         |
| 29 | Carpet Et Padding            | 2.0%             | -0.4%                   | 4.3%         |
| 30 | Recyclable E-waste           | 0.4%             | 0.2%                    | 0.7%         |
| 31 | Other E-waste                | 0.0%             | 0.0%                    | 0.1%         |
| 32 | Batteries                    | 0.1%             | 0.0%                    | 0.1%         |
| 33 | CFLs                         | 0.0%             | 0.0%                    | 0.0%         |
| 34 | Paint                        | 0.0%             | 0.0%                    | 0.1%         |
| 35 | Motor Vehicles               | 0.3%             | 0.0%                    | 0.7%         |
| 36 | C&D Debris                   | 7.9%             | 4.6%                    | 11.2%        |
| 37 | Other Haz/Special Waste      | 0.1%             | -0.2%                   | 0.4%         |
| 38 | Composites                   | 5.2%             | 3.7%                    | 6.6%         |
| 39 | Residue                      | 0.5%             | 0.2%                    | 0.7%         |
|    | <b>Total Other Materials</b> | <b>19.6%</b>     |                         |              |
|    |                              | <b>100.0%</b>    |                         |              |

The statistical analysis indicates how well samples can be expected to represent the waste stream. Standard deviations measure how widely the values for each material vary around the weighted average. A higher standard of deviation is indicative of greater variation in samples; it is not unusual to see high values for municipal solid waste materials. A 90% confidence interval was also applied to reflect the range of values within which the actual material weight is expected to fall. A narrower confidence interval is typical of a larger number of samples, although this relationship is less noticeable when the underlying waste stream is highly variable (i.e., when standard deviations are high).

## APPENDX B COMPARISON WITH OTHER NORTH AMERICAN ICI COMPOSITION RESULTS

| Material Category | Denver (2019) | Larimer County (2016) | Boulder County (2010) | Olympia, WA (2009) |            | Oxford County, Ontario (2017) |
|-------------------|---------------|-----------------------|-----------------------|--------------------|------------|-------------------------------|
|                   | ICI           | Commercial            | ICI                   | MFU                | Commercial | ICI                           |
| Glass             | 4.0%          | 2%                    | 2.9%                  | 3.6%               | 2.5%       | 2%                            |
| Metal             | 3.5%          | 5%                    | 4.7%                  | 8.7%               | 6.2%       | 4%                            |
| Plastics          | 13.1%         | 12%                   | 13.8%                 | 8.8%               | 11.6%      | 14%                           |
| Paper             | 24.7%         | 15%                   | 20.2%                 | 13.9%              | 15.6%      | 29%                           |
| Organics          | 35.1%         | 41%                   | 35.9%                 | 24.0%              | 34.8%      | 35%                           |
| Other             | 19.6%         | 25%                   | 22.6%                 | 41.0%              | 29.2%      | 16%                           |

*These data sets are not intended to match cities of equal size and demographics to Denver (ICI waste data is very limited across North America). The data also reflect many variables that cannot be addressed in this report, such as over-arching state diversion policies, local program and infrastructure, impacts of changing waste streams over time.*

## APPENDIX C TRASH COMPOSITION RESULTS BY SECTOR

|    | Material Category       | Weighted Average |          |            |        |
|----|-------------------------|------------------|----------|------------|--------|
|    |                         | Multi-Family     | Business | Industrial | Mixed  |
| 1  | Cardboard/Kraft         | 9.6%             | 8.5%     | 1.8%       | 7.7%   |
| 2  | Newspaper               | 0.5%             | 0.5%     | 0.0%       | 0.4%   |
| 3  | Office Paper            | 0.5%             | 1.1%     | 0.0%       | 1.3%   |
| 4  | Chip/Paperboard         | 2.9%             | 2.0%     | 0.0%       | 2.2%   |
| 5  | Mixed Paper/Junk Mail   | 1.6%             | 1.8%     | 0.0%       | 1.6%   |
| 6  | Magazines               | 0.7%             | 1.2%     | 0.0%       | 0.6%   |
| 7  | To-Go Cups              | 0.4%             | 0.5%     | 0.0%       | 0.7%   |
| 8  | Aseptic Containers      | 0.3%             | 0.2%     | 0.0%       | 0.2%   |
| 9  | Compostable Paper       | 8.6%             | 7.2%     | 0.5%       | 7.6%   |
| 10 | All Other Paper         | 1.3%             | 1.6%     | 12.6%      | 1.9%   |
| 11 | #1 PET Bottles          | 1.8%             | 1.3%     | 0.1%       | 1.5%   |
| 12 | #2 HDPE Bottles         | 1.2%             | 0.7%     | 0.1%       | 0.7%   |
| 13 | #1-#7 Containers        | 1.3%             | 1.2%     | 1.6%       | 1.6%   |
| 14 | Bulky Rigid             | 3.6%             | 1.0%     | 0.0%       | 0.8%   |
| 15 | Styrofoam               | 0.7%             | 0.7%     | 0.0%       | 0.6%   |
| 16 | Film, Bags, & Wrap      | 4.9%             | 6.1%     | 3.0%       | 6.6%   |
| 17 | Other Plastics          | 1.1%             | 1.4%     | 0.1%       | 1.5%   |
| 18 | Aluminum                | 1.1%             | 0.7%     | 0.0%       | 1.0%   |
| 19 | Steel/Tin Cans          | 0.8%             | 0.4%     | 0.0%       | 0.7%   |
| 20 | Other Metals            | 1.0%             | 3.3%     | 0.0%       | 1.5%   |
| 21 | Glass Containers        | 4.6%             | 3.1%     | 0.0%       | 3.9%   |
| 22 | Other Glass             | 0.2%             | 0.2%     | 0.0%       | 0.3%   |
| 23 | Food Waste              | 20.5%            | 30.0%    | 0.0%       | 22.1%  |
| 24 | Yard Waste              | 2.1%             | 3.0%     | 0.0%       | 0.5%   |
| 25 | Cannabis Waste          | 0.0%             | 0.0%     | 9.9%       | 0.0%   |
| 26 | Clean Wood              | 2.0%             | 1.8%     | 31.2%      | 1.9%   |
| 27 | Other Organics          | 8.2%             | 2.7%     | 39.1%      | 8.4%   |
| 28 | Textiles                | 2.9%             | 2.8%     | 0.0%       | 3.5%   |
| 29 | Carpet & Padding        | 0.4%             | 0.8%     | 0.0%       | 3.8%   |
| 30 | Recyclable E-waste      | 1.0%             | 0.3%     | 0.0%       | 0.3%   |
| 31 | Other E-waste           | 0.0%             | 0.1%     | 0.0%       | 0.0%   |
| 32 | Batteries               | 0.0%             | 0.1%     | 0.0%       | 0.0%   |
| 33 | CFLs                    | 0.0%             | 0.0%     | 0.0%       | 0.0%   |
| 34 | Paint                   | 0.2%             | 0.0%     | 0.0%       | 0.0%   |
| 35 | Motor Vehicles          | 0.0%             | 0.1%     | 0.0%       | 0.8%   |
| 36 | C&D Debris              | 7.1%             | 7.2%     | 0.0%       | 9.2%   |
| 37 | Other Haz/Special Waste | 0.4%             | 0.0%     | 0.0%       | 0.0%   |
| 38 | Composites              | 5.2%             | 6.0%     | 0.0%       | 4.5%   |
| 39 | Residue                 | 1.1%             | 0.5%     | 0.0%       | 0.1%   |
|    | TOTALS                  | 100.0%           | 100.0%   | 100.0%     | 100.0% |

## APPENDIX D SMALL BUSINESS DUMPSTER TRASH VISUAL AUDIT RESULTS

| Material Category          | Average % by Volume | Average % by Weight |
|----------------------------|---------------------|---------------------|
| Glass Containers           | 0%                  | 1%                  |
| Other Glass                | 0%                  | 0%                  |
| Recyclable Alum/Steel Cans | 2%                  | 1%                  |
| Appliances                 | 0%                  | 0%                  |
| Scrap Metal                | 0%                  | 0%                  |
| Other Metal                | 1%                  | 0%                  |
| Mixed Plastic Bottles      | 1%                  | 0%                  |
| Rigid Plastics             | 3%                  | 1%                  |
| Polystyrene Pkg/Insulation | 2%                  | 1%                  |
| Film                       | 5%                  | 1%                  |
| Other Plastic              | 2%                  | 0%                  |
| Cardboard                  | 30%                 | 16%                 |
| Shreds                     | 0%                  | 0%                  |
| Other Recyclable Paper     | 3%                  | 5%                  |
| Other Paper                | 1%                  | 1%                  |
| Food Waste                 | 11%                 | 33%                 |
| Yard Waste                 | 4%                  | 8%                  |
| Other Organics             | 2%                  | 2%                  |
| Textiles                   | 2%                  | 2%                  |
| Carpet/Padding             | 0%                  | 0%                  |
| E-Waste                    | 0%                  | 0%                  |
| C&D                        | 1%                  | 1%                  |
| HHW                        | 0%                  | 0%                  |
| Other                      | 3%                  | 2%                  |
| Bagged/Unknown Waste       | 14%                 | 14%                 |
| Trash                      | 13%                 | 14%                 |
| <b>Total</b>               | <b>100%</b>         | <b>100%</b>         |

*Volumes estimated in field through visual observation & based on average Dumpster size of 4.16 cubic yards. Volume estimates were converted to weight estimates using USEPA's April 2016 Volume-to-Weight Conversion Factors.*

*Values are approximate only and should be used judiciously in interpreting business waste generation or management patterns and practices.*

## APPENDIX E AGGREGATED RECYCLABLES COMPOSITION STUDY RESULTS & STATISTICAL ANALYSIS

|    | Material Category      | Weighted Average | 90% Confidence Interval |              |
|----|------------------------|------------------|-------------------------|--------------|
|    |                        |                  | Lower Bounds            | Upper Bounds |
| 1  | Cardboard/Kraft        | 46.6%            | 37.9%                   | 55.3%        |
| 2  | Newspaper              | 2.7%             | 1.4%                    | 3.9%         |
| 3  | Office Paper           | 3.3%             | 0.8%                    | 5.8%         |
| 4  | Chip/Paperboard        | 3.3%             | 2.4%                    | 4.3%         |
| 5  | Mixed Paper/Junk Mail  | 6.3%             | 3.3%                    | 9.4%         |
| 6  | Magazines              | 2.4%             | 0.9%                    | 3.9%         |
| 7  | To-Go Cups             | 0.1%             | 0.1%                    | 0.1%         |
| 8  | Aseptic Containers     | 0.3%             | 0.2%                    | 0.4%         |
| 9  | #1 PET Bottles         | 1.2%             | 0.8%                    | 1.6%         |
| 10 | #2 HDPE Bottles        | 1.3%             | 0.9%                    | 1.6%         |
| 11 | Rigid Containers #1-#7 | 1.5%             | 0.9%                    | 2.0%         |
| 12 | Bulky Rigids           | 1.0%             | 0.4%                    | 1.6%         |
| 13 | Aluminum               | 0.8%             | 0.5%                    | 1.1%         |
| 14 | Steel/Tin              | 0.8%             | 0.5%                    | 1.2%         |
| 15 | Glass Containers       | 8.6%             | 4.9%                    | 12.3%        |
| 16 | Contaminants           | 18.8%            | 13.8%                   | 23.9%        |
| 17 | Grit                   | 0.9%             | 0.6%                    | 1.3%         |
|    | TOTAL                  | 100.0%           |                         |              |

*The statistical analysis indicates how well samples can be expected to represent the waste stream. Standard deviations measure how widely the values for each material vary around the weighted average. A higher standard of deviation is indicative of greater variation in samples; it is not unusual to see high values for municipal solid waste materials. A 90% confidence interval was also applied to reflect the range of values within which the actual material weight is expected to fall. A narrower confidence interval is typical of a larger number of samples, although this relationship is less noticeable when the underlying waste stream is highly variable (i.e., when standard deviations are high).*

**APPENDX F**  
**RECYCLABLES COMPOSITION RESULTS BY SECTOR**

|    | Material Category      | Weighted Average |        |
|----|------------------------|------------------|--------|
|    |                        | Business         | Mixed  |
| 1  | Cardboard/Kraft        | 50.9%            | 43.7%  |
| 2  | Newspaper              | 3.1%             | 2.4%   |
| 3  | Office Paper           | 5.9%             | 1.5%   |
| 4  | Chip/Paperboard        | 3.4%             | 3.3%   |
| 5  | Mixed Paper/Junk Mail  | 7.7%             | 5.4%   |
| 6  | Magazines              | 2.0%             | 2.7%   |
| 7  | To-Go Cups             | 0.1%             | 0.1%   |
| 8  | Aseptic Containers     | 0.2%             | 0.4%   |
| 9  | #1 PET Bottles         | 0.9%             | 1.4%   |
| 10 | #2 HDPE Bottles        | 0.9%             | 1.6%   |
| 11 | Rigid Containers #1-#7 | 1.2%             | 1.6%   |
| 12 | Bulky Rigids           | 1.1%             | 0.9%   |
| 13 | Aluminum               | 0.8%             | 0.8%   |
| 14 | Steel/Tin              | 0.6%             | 1.0%   |
| 15 | Glass Containers       | 4.8%             | 11.1%  |
| 16 | Contaminants           | 15.6%            | 21.1%  |
| 17 | Grit                   | 0.7%             | 1.1%   |
|    | TOTAL                  | 100.0%           | 100.0% |

**APPENDX G**  
**SMALL BUSINESS DUMPSTER RECYCLABLES VISUAL AUDIT RESULTS**

| Materials                  | Average % by Volume | Average % by Weight |
|----------------------------|---------------------|---------------------|
| Glass Containers           | 9%                  | 33%                 |
| Other Glass                | 0%                  | 0%                  |
| Recyclable Alum/Steel Cans | 6%                  | 3%                  |
| Appliances                 | 0%                  | 0%                  |
| Scrap Metal                | 0%                  | 0%                  |
| Other Metal                | 0%                  | 0%                  |
| Mixed Plastic Bottles      | 2%                  | 1%                  |
| Rigid Plastics             | 4%                  | 1%                  |
| Polystyrene Pkg/Insulation | 0%                  | 0%                  |
| Film                       | 2%                  | 0%                  |
| Other Plastic              | 0%                  | 0%                  |
| Cardboard                  | 67%                 | 46%                 |
| Shreds                     | 0%                  | 0%                  |
| Other Recyclable Paper     | 3%                  | 6%                  |
| Other Paper                | 4%                  | 3%                  |
| Food Waste                 | 1%                  | 2%                  |
| Yard Waste                 | 0%                  | 0%                  |
| Other Organics             | 0%                  | 0%                  |
| Textiles                   | 0%                  | 0%                  |
| Carpet/Padding             | 0%                  | 0%                  |
| E-Waste                    | 0%                  | 0%                  |
| C&D                        | 0%                  | 0%                  |
| HHW                        | 0%                  | 0%                  |
| Other                      | 0%                  | 0%                  |
| Bagged/Unknown Waste       | 0%                  | 0%                  |
| Trash                      | 3%                  | 4%                  |
| <b>Total</b>               | <b>100%</b>         | <b>100%</b>         |

*Volumes estimated in field through visual observation & based on average Dumpster size of 4.39 cubic yards. Volume estimates were converted to weight estimates using USEPA's April 2016 Volume-to-Weight Conversion Factors.*

*Values are approximate only and should be used judiciously in interpreting business waste generation or management patterns and practices.*