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MRF MATERIAL FLOW STUDY

FINAL REPORT | APRIL 2015

COMISSIONED BY

Carton Council RecycleCartons.com · American Chemistry Council · NAPCOR · APR · FPI Foodservice Packaging Institute

PREPARED BY RRS IN CONJUNCTION WITH:

Reclay StewardEdge Product Stewardship Solutions · MOORE Recycling Associates Inc.

INTRODUCTION

The famous Greek philosopher Heraclitus captured the essence of the recycling industry over 2,500 years ago when he penned the phrase, "Nothing endures but change." The march of packaging innovation and technology, and the persistently changing habits of consumers continue to dictate the changing mix of materials that enters a material recovery facility (MRF). Over the past decade, there has been a continual decline in the once dominant materials including newspaper, glass and metal cans. At the same time, a host of other packaging types have emerged, presenting new recovery opportunities. Recycling programs throughout the country have responded by expanding the list of materials accepted for recycling, notably including a wide range of plastics and cartons. For the MRFs that receive the material, it is not always easy to keep sorting technologies and techniques on pace with this expanding mix.

STUDY OVERVIEW

Packaging companies have an interest in ensuring that the packages they produce or sell their products in have the opportunity to be recycled. The ability to recycle the package can be a consumer's deciding factor in the purchase of a particular product. This, and the desire to minimalize environmental footprints, are the drivers behind the recently completed MRF Material Flow Study.

MRFs are the intersection between consumers, residents and the industrial infrastructure that creates the products and packaging we use every day. To better understand the recyclability of their packaging, five diverse associations – the Carton Council, Foodservice Packaging Institute (FPI), American Chemistry Council (ACC), National Association for PET Container Resources (NAPCOR) and the Association of Postconsumer Plastics Reprocessors (APR) – joined together to study how numerous materials flowed through the MRF. They contracted with RRS, Reclay StewardEdge (RSE) and Moore Recycling Associates to develop a standard methodology and execute it at five MRFs.

KEY CONCLUSIONS

In studying the performance of specific materials through different MRF environments, a number of general takeaways became clear. These conclusions could help to serve as guidelines to improve recovery across the recovery value chain – from residents and municipalities to packaging designers and MRF operators and engineers, and everyone else in between.

AUDIENCE	KEY TAKEAWAYS
Packaging Designers	• Form, material and rigidity have a significant effect on a product's "sortability" in the MRF • Light-weighting of plastics can decrease recovery in a single stream MRF due to loss to the paper streams
MRF Operators	• More equipment steps (disc screen decks or other separation equipment) can improve accuracy of splitting two-dimensional from three-dimensional materials • Properly maintaining the disc screens (cleaning and replacing discs) can significantly reduce loss of containers to the paper stream • Minimizing compaction to maintain the form/shape of incoming material improves separation • Continually training sorters to recognize a wide range of acceptable packaging is of growing importance
MRF Equipment Designers	• Further research and development is needed to improve consistency of behavior of non-bottle plastics in the MRF • Further testing and refining of optical sorter programming is needed to effectively optically sort a wider range of packaging
Municipalities	• Regular communications with local MRFs is critical to understanding behavior of materials currently accepted and identifying additional materials that could be added • As the list of acceptable materials grows, continual education for residents is essential to keeping contamination to a minimum • For single stream programs, education to the consumer to not crush materials can improve their recovery
Recycling Industry	• Continually evaluate and match MRF product quality and end market capabilities to ensure true recovery

ABOUT THIS REPORT

This study examined the behavior of numerous individual products in the MRF, yielding data on cups, clamshells, containers, domes/trays, bottles, tubs, lids, gable-top and aseptic cartons, and other materials. Funders of this study have gained a greater awareness of the opportunities and obstacles regarding the recovery of each of these materials and will apply this new knowledge to increase recovery.

While the detailed data on each material are not presented within this report, key findings regarding material flows, sorting technologies, and other sorting and design related considerations are explained, along with the study's methodology.

STUDY METHODOLOGY

There were three stated goals of the study:

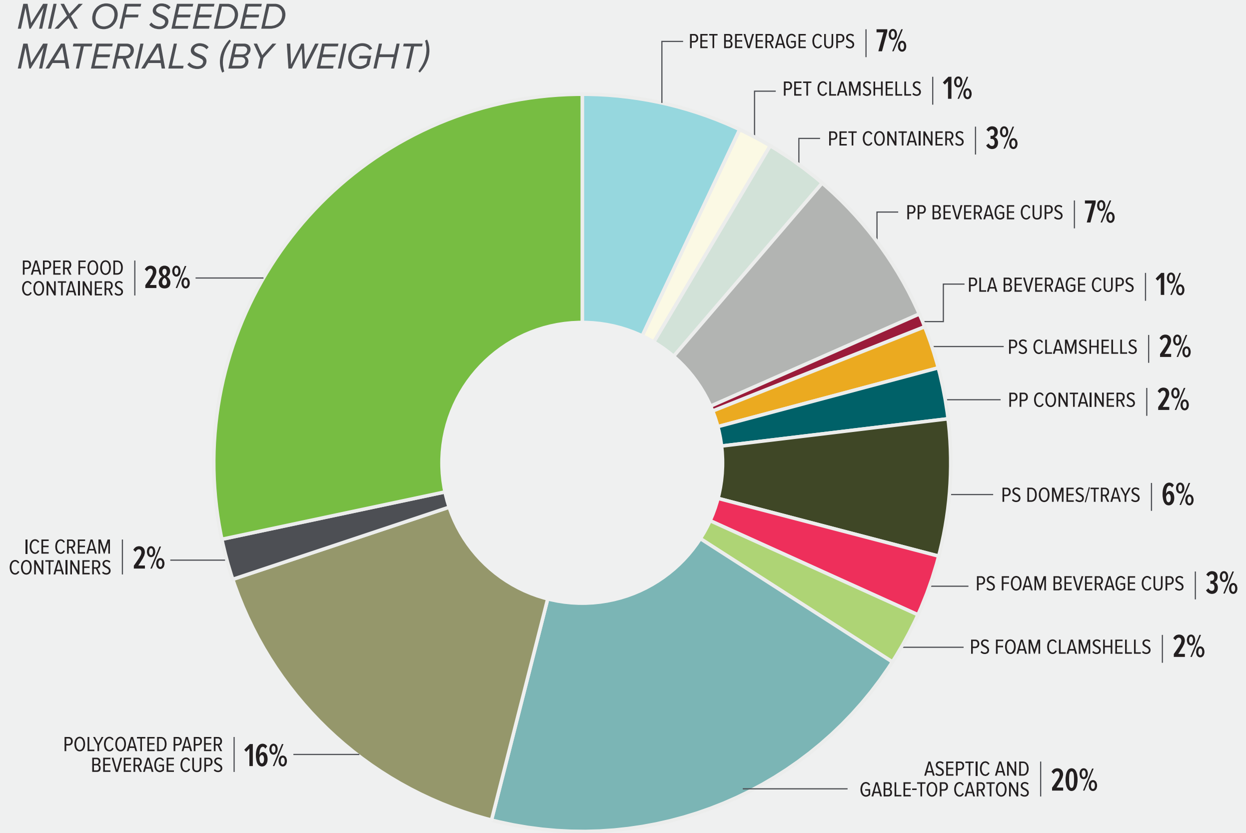
1. Learn how materials similar to the test samples and other study materials would flow through typical MRF environments;
2. Determine which of the study materials, not currently accepted by MRFs, could potentially be recycled using existing MRF infrastructure; and
3. Start to develop an understanding of what sort processes could be modified to allow effective recovery of sample materials

The study focused on a broad range of materials, many that are currently widely accepted and some that are very rarely included in recycling programs. Materials that are not commonly accepted for recycling were brought in and added, or "seeded", to the normal stream received by the MRF. To simulate a realistic recovery scenario, care was taken to add materials at levels that corresponded to their relative prevalence in the marketplace. In other words, more common materials were seeded in larger amounts (by weight) than less common ones.

The plastic materials studied included cups, clamshells, domes/trays, bottles, tubs, lids and other containers. Each was classified by resin identification code and in some categories including containers and tubs, by size as well. The paper products studied included cups, ice cream containers, gable-top and aseptic cartons, and take-out food containers. Figure 1 shows the representative mix of materials that was seeded.

FIGURE 1

MIX OF SEEDED MATERIALS (BY WEIGHT)



In each of the five MRFs that served as test sites for this study, a standard methodology was applied to analyze the flow of materials. This methodology was, in essence, quite simple and could be replicated for other materials or repeated in other MRFs.

- The MRF set aside enough inbound recyclable material to run their facility for 3 hours (between 30 and 100 tons). This represented the average material that the facility processes on a day to day basis.
- The study team worked with the MRF staff to mix the seeded packaging into the inbound material. In each facility, the seeded materials represented about 1% of the incoming stream by weight.
- Sort staff was trained on how to handle the seeded materials. In general, the materials were allowed to flow where they naturally did within the facility and sorters were instructed to not pick and dispose of the seeded materials as residue. However, each seeded package was given one or more target commodity streams and if, for example paper beverage cups flowed to the container line, the sorters were directed to positively sort them to the carton bale and if they flowed to the paper line they were allowed to stay in the mixed paper bale. Seeded materials therefore flowed to existing MRF products – new product grades were not produced for the seeded materials.
- The facility processed the material for 3 hours. During the processing, video cameras were set up to monitor the flow of materials and the actions of the sorters.
- Random samples of the main products were taken either as loose samples or from random bales. The target sample weight was about 600 pounds for each of the products and, where possible, multiple samples were taken of each product or the majority of the product was sorted.
- Each of the samples was sorted into 104 categories. The plastic sort categories were chosen to match other studies commissioned by ACC, APR, NAPCOR, and others.

Ideally, tests were run during a time that the facility was not planning to operate, so as not to hinder normal operations. MRFs operate on extremely tight timelines, and without careful scheduling a study could easily create problematic disruptions.

DATA ANALYSIS

Based on the data collected, two analyses were performed. The first was characterizations of each of the product streams. These were completed for each of the samples of a single product and then averaged to get the product characterization. Product characterizations showed how much of that stream was composed of each sort category. An example is shown in Figure 2. The product characterizations are important for end

The MRFs at which this study was conducted were chosen to represent the wide diversity of facilities that currently process recyclables nationwide. Here are some of their key descriptors and differentiators:

- 1 dual stream and 4 single stream facilities
- Throughput range (tons per hour): 10 tph – 35 tph
- Four different equipment manufacturers
- Number of optical sorters ranged from 0 – 5
- Varying combinations of disc screens and other mechanical separation equipment

PRODUCT CHARACTERIZATIONS WERE CALCULATED FOR THE FOLLOWING STREAMS:

Mixed Paper	Mixed Paper/ Newspaper[1]	cHDPE
Newspaper	PET	nHDPE
Cartons	Mixed Plastics[2]	Residue

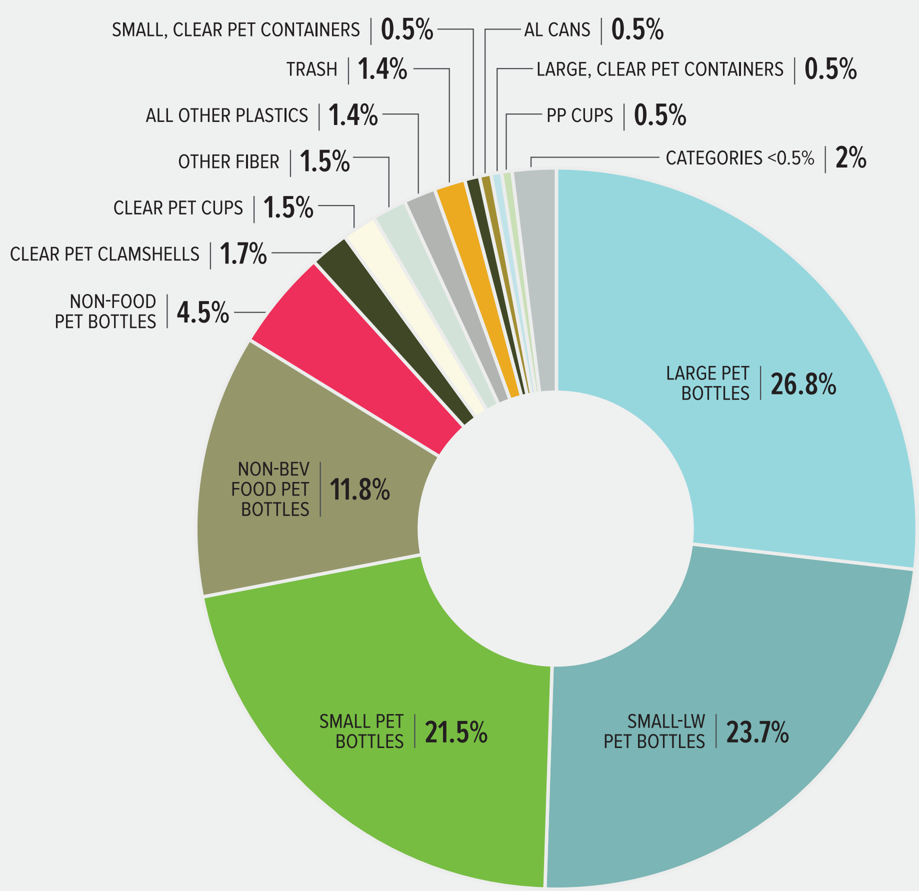
1 Some facilities only marketed one grade of paper
2 Also included a HDPE/PP Tubs and Lids grade

markets to understand the quality and composition of a MRFs products. For this study, it was important to see if the addition of seeded materials would increase contamination of existing product streams.

The second analysis used the characterizations to determine the destination of each of the study materials. For example, if 10,000 paper beverage cups were introduced into the MRF, how many would end up in the mixed paper, how many in the carton bale and how many in the residue and other categories. This analysis was the key to understanding how the materials flowed in the MRF environment. Examples of this analysis are shown in the Results section.

FIGURE 2

EXAMPLE PRODUCT STREAM CHARACTERIZATION: PET, AVERAGED ACROSS ALL 5 MRFS



RESULTS

While a diverse set of MRFs was chosen for the study, the results presented here are specific to the MRFs studied, as different results can be achieved by modifying equipment layouts, operating protocols and material streams.

Key findings are grouped by type of MRF, type of sortation equipment and material form and prevalence.

DUAL STREAM SYSTEMS

Two types of MRFs were included in the study: one dual stream and four single stream. While only one MRF was dual stream, one comparison about the difference between dual and single stream systems can be made.

Dual stream systems, which are declining nationally in favor of single stream systems, require residents to separate paper materials from metal, glass and plastic containers. As will be highlighted in the next section, dual stream systems offer the advantage of reducing loss of plastics and other containers to the paper streams. On the other hand, as the material mix has expanded to new packaging types, it isn't always well understood to by residents in which stream they should be included. For MRFs, it is more difficult to sort these containers from the paper stream than it is from the container stream, making this a real obstacle.

SINGLE STREAM SYSTEMS

While single stream systems allow for easier communication to consumers about how to recycle (and simplify collection systems), the difficulty in separating the materials is passed onto the MRF. One of the key observations in this study is that there are wide variations in how effective single stream facilities are in separating paper from the containers. To accomplish this separation, single stream facilities use a series of disc screens and other equipment that all utilize the difference in shape between paper and containers. Flat materials (generally 2-dimensional) will travel to the top of the screen and to one series of conveyors, while bottles and other containers (generally 3-dimensional) will either fall through the screens or tumble to the bottom to a different series of conveyors.

There are numerous factors that affect the ability of single stream equipment to accurately separate the 2D and 3D materials. They include equipment design factors (such as screen design and angle), operation issues (such as overloading the screens, cleaning the screens, and wet material), maintenance issues (such as wear to discs) and collection issues (such as excessive compaction of the material by residents or collection vehicles). Further, the packaging design itself can also affect the flow of individual materials. All of these variables cannot be evaluated in one study, but general conclusions are possible.

BEST PRACTICES FOR ACCURATE 2D/3D SEPARATION IN SINGLE STREAM MRFS:

- Avoid loading screens past their design throughput
- Clean screens of material that are wrapped around the shafts
- Replace worn and damaged discs
- Minimize compaction of material by residents and collection trucks
- Keep material dry

SCREENS

In this study, plastics separation by screens was examined in depth and the analysis can act as a surrogate for other container material types, such as aluminum and steel. The amount of plastics (including bottles, containers, clamshells and cups) lost to the paper stream varied from 3% to 12%. The two MRFs that experienced a 12% loss of plastics to the paper stream were both medium sized single stream facilities (25-30 rated tons per hour (tph)) that had fewer screens than the larger two (35 tph). After seeing the screening effectiveness data from this study, both replaced worn discs in their disc screens and reported a significant improvement in the 2D/3D separation. The facility that experienced a 3% loss of plastic to the paper stream was a large MRF with an adequate number of screens for the incoming volume and material type (note: this facility was the top performer across the entire study). Interestingly, the facility with 8% loss was similar to the 3% facility, but it had two distinct operational issues that were not normal for their facilities: material was wetter than normal due to heavy snow storms, and space constraints on the tip floor caused by equipment failures resulted in handling of the material significantly more than normal (including driving over it with a loader). These results suggest that a well maintained facility with an adequate number of screens for the incoming volume and material mix, operating under normal conditions can achieve very low losses of containers to paper products.

Note: Both large single stream MRFs, which had better success than the medium single stream MRFs at separating the plastic containers from the paper, were equipped with 4 sets of disc screens: an OCC screen for separating cardboard or "old corrugated containers", 2 ONP screens for separating "old newspapers" and a polishing screen for cleaning up the mixed paper stream. The two medium MRFs had 1 less paper screen each. Depending on the facility, this study indicates that the extra screens can help improve the accuracy of the 2D/3D separation in single stream MRFs.

FORM

The form of a package had a strong influence on the loss of packaging to the paper streams. As can be seen in Table 1, the plastic clamshells had a much higher likelihood of flattening and moving with the paper streams. The rounder materials (including bottles, cups and containers) all had much lower loss rates, and less than 5% was lost at the top performing MRFs, Small, lightweight water bottles were more likely than other bottles to move with the paper with a loss rate of 15%. The cups, containers and clamshells still enter the MRFs in much lower quantities than bottles. They made up 11% of the plastics stream, even with the seeded materials. Aseptic and gable-top cartons had a higher average loss rate to the paper streams, although it is interesting to note it was the only packaging type to have one facility with no loss to the paper stream. In all five MRFs, they marketed a Grade 52 for cartons and pulled them from the container line.

OPTICAL SORTERS

Another piece of equipment in MRFs that can help improve separation of materials are optical sorters. Optical sorters can recognize materials based on what they are made of along with their size and shape. All four single stream facilities had at least one optical sorter, and the two large facilities had 3–4. Optical sorter efficiency was difficult to determine from this study because for each optically sorted commodity there were one or more manual sorters for quality control, both on the material that was positively sorted and what was missed. Therefore a manual sorter could remove a PET cup that was positively sorted by the optical sorter into the PET bale or another could mistakenly sort a PP cup that resembled one from PET into the PET bale. However, there were two interesting cases that are worth noting with the optical sorters.

Many of the materials that were tested as part of this study are light weight, meaning a sorter (either human or optical) needs to handle more pieces in order to sort a ton. At the only single stream facility without an optical sorter for the cartons, the manual sorter who normally sorts cartons was asked to positively sort any paper beverage cups and ice cream containers. With the volume of cups and ice cream containers, the sorter was overwhelmed and the manager chose to add a second sorter to that station. This implies that as more lightweight materials are added to the MRF, either more manual sorters will need to be added or optical sorters may be able to help increase the sorting throughput.

Even for a trained manual sorter, recognizing the resin type for each item as it goes by on a conveyor is very difficult. The PP and PET cups that were seeded for the test were both clear plastic and very similar in style. Averaged across all five facilities, approximately 20% of the PP cups were found in the PET bales. This is likely due to manual sorters positively sorting them to the PET stream because they so closely resembled PET cups. As more diverse packaging, including different sizes, shapes, colors, materials and purposes, continues to enter the MRF, improvements in technology and training to keep bale quality high will likely be necessary.

Similarly at one MRF, the optical sorter was set to sort all HDPE and PP and manual sorters then sorted that stream into nHDPE, cHDPE and a HDPE/PP Tubs and Lids grade. The cHDPE bale at that MRF had a much higher percentage of PP (8%) than the other MRFs (less than 2%). This further emphasizes the sorting challenges facing MRFs.

MATERIAL PREVALENCE

MRFs have been designed to separate bottles and cans from magazines and newspaper. During this study, extensive data was collected on the behavior of specific packaging types in the MRF environment. It shows that MRFs are doing quite well with these prevalent materials, although even these materials are not being correctly sorted at 100%. At best, the study showed a recovery of 93% of an individual package type, with much of the loss to other products and not to residue alone. Similarly for small (<1L), regular weight

TABLE 1

LOSS RATE OF PACKAGING MATERIALS TO THE PAPER STREAMS

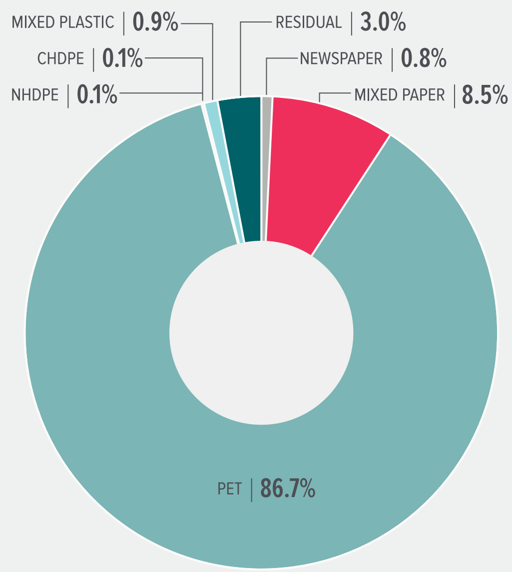
FORM	AVERAGE LOSS RATE TO PAPER STREAM	LOSS RATE AT BEST PERFORMING SINGLE STREAM MRF
Plastic Bottles	5%	2%
Plastic Cups	10%	3%
Plastic Containers	12%	2%
Plastic Clamshells	29%	12%
Aseptic and Gable-top Cartons	18%	0%

PET bottles and all size cHDPE bottles, results are shown in Figure 3. Compare those figures to results for small (<10") PET non-bottle containers and cHDPE non-bottle containers as shown in Figure 4. Note that for all results, the data from each of the five MRFs was averaged to form a composite of the behavior across all facilities. According to RRS's database, approximately 50% of the material nationally is processed through the largest 20% of MRFs. Therefore, the larger MRFs were weighted more heavily than the smaller facilities when combining the data.

Why do bottles flow more consistently to the proper bale than tubs and other non-bottle containers? There are many likely reasons for these results. The first, and likely most important, is relative amount of material. During the tests, there were greater than 20 times more regular weight PET bottles than small PET containers (by weight). Including all types of PET bottles and both large and small containers, there were greater than 30 times more bottles (by weight). Although not as pronounced, there were still 8 times as many colored HDPE bottles as containers and tubs. Package types that are more prevalent in the stream are more likely to be targeted by manual sorters if they are missed or misdirected by the optical sorters or disc screens, thereby increasing their recovery. In addition, the equipment is tuned to increase the recovery of the

FIGURE 3

DESTINATION OF SMALL, REGULAR WEIGHT (< 1L) PET BEVERAGE BOTTLES (TOP) AND ALL CHDPE BOTTLES



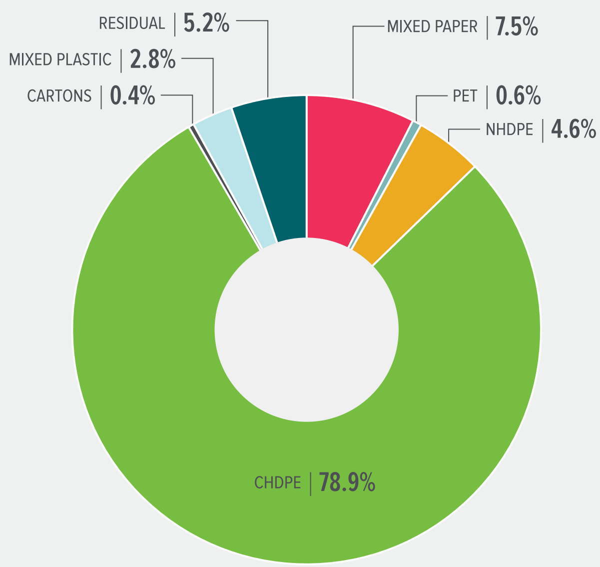
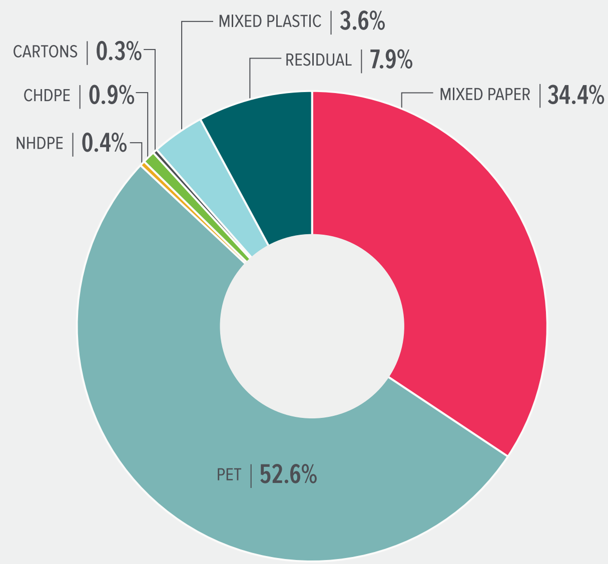


FIGURE 4

DESTINATION OF SMALL PET CONTAINERS (TOP) AND CHDPE CONTAINERS (ALL NON-BOTTLE CONTAINERS & TUBS, < 10" DIAMETER)



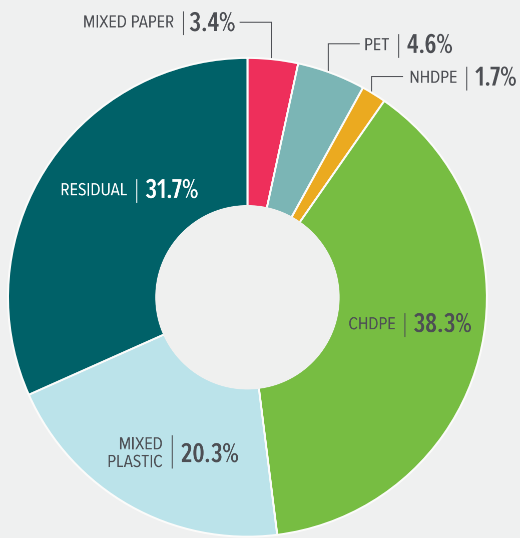
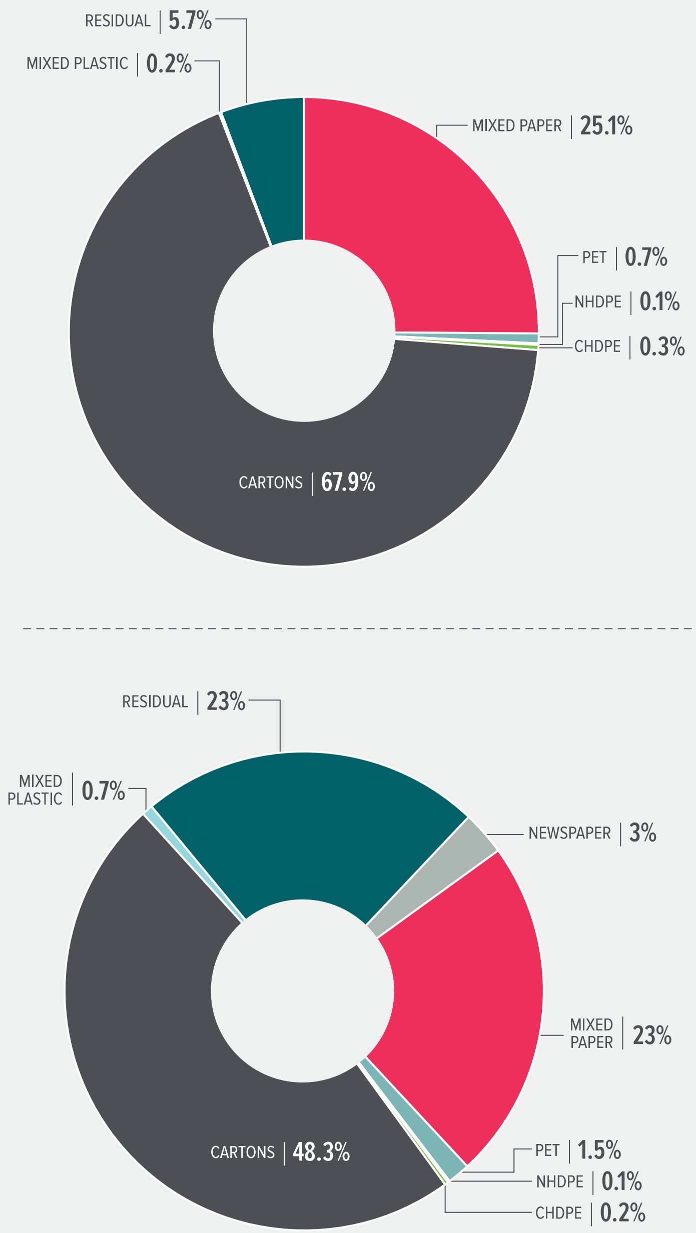


FIGURE 5
DESTINATION OF CARTONS (TOP) AND PAPER BEVERAGE CUPS



most common materials and may not perform as consistently on less common package types.

Secondly, to target the PET and cHDPE non-bottle containers would take two different strategies. The majority of the PET containers not in the PET bale are lost to the paper stream. However, very little of the cHDPE containers were in the paper stream, but most of the loss was to the residue stream, likely because they were not captured from the container line either by the optical or manual sorters. Finally, the size and shape of the containers can be quite varied in comparison to the bottles, with many containers being flatter and having open tops, which reduces the ability to hold the shape during handling and sorting. This will continue to cause less consistency on the disc screens and other equipment.

ADDING NEW MATERIALS

The study also specifically assessed the MRF "sortability" of some packaging materials that are not currently accepted extensively by recycling programs nationwide but are in fact growing in many communities, including: paper beverage cups, ice cream containers and polystyrene foam cups and clamshells. Figure 5 compares the behavior of aseptic and gable-top cartons to paper beverage cups.

As one example, the paper beverage cups had a strong tendency to flow to the container line (similar to cartons and plastic cups). A higher percentage were lost to residue which, based on review of the test setup and sorter training, was most likely from the container line. This could be due to manual sorters being less familiar seeing them or being overwhelmed when the optical sorter didn't catch them. Further study could be done to better understand the effectiveness of optical sorters on different types of cups and if programming could be improved to recognize them.

CONCLUSIONS

This study demonstrates the power of examining a material's inherent behavior in a MRF environment. Understanding how that material will flow allows for informed, operational actions to maximize recovery of that material. It is a useful exercise, as was done here, to look at not only new materials (that aren't currently accepted) to see which MRF end-products they can be a part of, but also to see how currently accepted materials, both prevalent and not, are being recovered. Recycling is a complicated system of consumer behavior, collection programs, sorting at MRFs and end markets. All stages of the value chain need to be similarly examined to create a full picture of recyclability. As shown in this study, examining and solving material processing challenges at the modern MRF is a necessary step in achieving success for the recycling industry of the future.

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