Pacific Northwest Secondary Sorting Demonstration Project

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Summary

Secondary Material Recovery Facilities (MRFs) aggregate low-volume and/or difficult to manually sort materials, along with machine yield losses, from a network of existing Primary MRFs to reach the critical mass necessary to justify investments in automated technologies for sorting by material type. The Secondary MRF business model is designed to cost-effectively optimize our recycling infrastructure while delivering benefits to all stakeholders.

China's National Sword policy, along with the import ban on certain recyclables from some Southeast Asian countries, has significantly reduced the markets for and value of many of our recyclable materials. While some new capacities for recycling these materials were already under development, many more have been announced in the wake of National Sword. The United States, however, still lacks sufficient secondary sorting capacity to produce the feedstock materials for our domestic recycling markets.

The Pacific Northwest Secondary Sorting Demonstration Project utilized the Titus Portable Secondary MRF to successfully show recycling stakeholders from the region and across the country the value that can be extracted from landfill-bound or low-value mixed materials. While the feedstock to a Secondary MRF is a low-value mixture, once sorted, many of the individual products recovered have good value and well-established markets. Where markets do not exist for certain products, the process of sorting by material type and creating truckload quantities is an important and necessary step in new market development.

Based on the results of this project, an estimated 50,000 tons per year of additional recyclable materials could be recovered at a regional Secondary MRF servicing Oregon and Washington, including approximately 23,000 tons of mixed paper, 10,000 tons of polypropylene, 4,800 tons of PET bottles, 2,800 tons of cartons, 2,000 tons of polyethylene, and 800 tons of polystyrene[1]. Secondary sorting would improve overall recovery of residential recyclables by an estimated 3% to 6%, and would reduce greenhouse gas generation by more than 130,000 tons per year CO_{2eq}. This is equivalent to taking more than 27,600 cars off the road.[2]

The project also analyzed products recovered from the Oregon Metro region to determine the relative amounts of program versus non-program materials – those allowed and not allowed in the existing recycling collection program, respectively. This data not only highlighted the types of non-program materials entering the system, but also showed that there is potentially much more material that could be recovered if the collection program were expanded, and secondary sorting capability was added to service the region.

The Pacific Northwest Secondary Sorting Demonstration Project also provided a place for stakeholders to discuss the opportunities and challenges facing our recycling system.

[1] Based on the data obtained during this project and a regional model where MRFs recover 88% of recyclable materials.

[2] According to the Environmental Protection Agency's Greenhouse Gases Equivalencies Calculator

Key Findings and Takeaways

- Over 400 signatories to the New Plastics Economy Global Commitment, including brand owners, retailers, packaging producers, and resource management companies, have set ambitious goals to improve recyclability of plastics and to increase the use of recycled content in plastic packaging and products by 2025. New capabilities to effectively and efficiently sort post-consumer plastics and cartons will be required to meet the growing market demand for recycled content.
- Significant new processing capacity has been publicly announced for recycling all major resin categories and will drive demand for sorted post-consumer plastics. Much of the investment in processing capacity is a result of industry commitments to increase the use of recycled content.
- The Carton Council continues to drive ways to increase and improve the infrastructure in the United States for recycling cartons, including through the support of this project, to look for ways to capture cartons that end up as residue.
- U.S. resin manufacturers have set ambitious goals that all plastic packaging will be recyclable or recoverable by 2030 and recycled or recovered by 2040.
- Secondary MRFs offer a more efficient and cost-effective solution to upgrade our material recovery infrastructure. By focusing the effort on a regional approach, they also provide a solution that can be implemented within a timescale more likely to meet the marketplace demand.
- The Pacific Northwest is well-suited to benefit from the addition of a regional Secondary MRF; however, some investment would be required at Primary MRFs to isolate preferred feedstock materials from other waste streams.

Background

Recycling System

Our residential recycling system (shown in Figure 1) consists of several elements that must work together for the system to function. Residents offer their recyclable packaging and products for collection, municipalities establish the recycling program that identifies the materials that the system is designed to recover, haulers collect recyclables and deliver them to sorting facilities, Material Recovery Facilities (MRFs) sort the materials by type to meet specifications set by recycling companies, and recyclers clean, purify, and prepare materials for reintroduction into the manufacturing cycle. Manufacturers then incorporate post-consumer recycled (PCR) content into new products for sale to consumers.

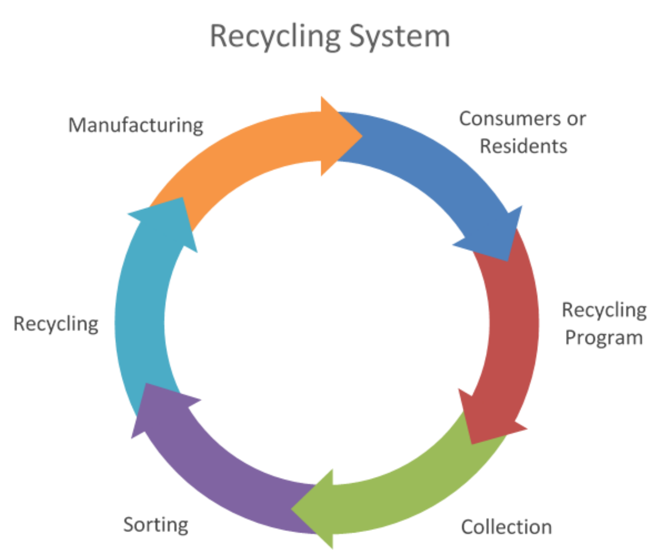

Figure 1. Recycling System

Unfortunately, our existing system has several significant limitations. In addition to issues with resident participation, which limit the quantity of material available for processing, residents often "wish-cycle" by placing non-program materials and other trash into their recycling bins. Recycling programs can be confusing and often lack harmonized messaging across regions. Sorting facilities, with few exceptions, lack the space and scale necessary to sort for low-volume and/or difficult to manually sort materials. And finally, domestic recycling operations only exist if there is enough high-quality feedstock available – materials must be included in the recycling program, collected, and sorted by material type to create the necessary supply chain for recycling to take place.

Fortunately, the addition of regional Secondary Material Recovery Facilities (Secondary MRFs) can help to alleviate these limitations. Through a combination of material aggregation and additional sorting capabilities, Secondary MRFs can allow recycling programs to be harmonized and expanded for an entire region. Not only would this simplify messaging and program compliance, it could also increase the production of a wider variety of commodities to supply and support the growth of domestic recycling operations.

Primary Material Recovery Facilities

Existing Primary MRFs typically recover 80% to 90% of materials collected for recycling and produce truckload quantities of direct-to-mill commodities that meet industry specifications. Most Primary MRFs can produce high-quality baled products for each of the top nine materials shown in Figure 2, independent of whether the MRF is highly automated or primarily a manual-sorting operation. Technology applied to processing these materials primarily improves efficiency, but not necessarily quality.

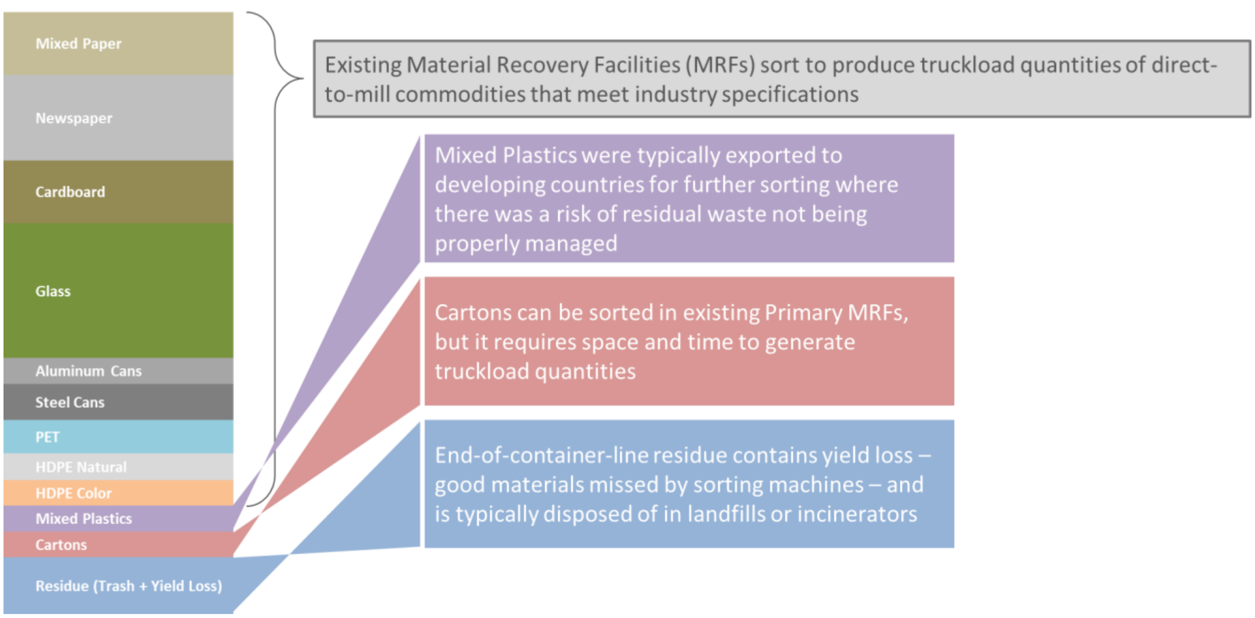

Figure 2. Commodities Recovered at Primary MRFs and Opportunities for Secondary Sorting

Most MRFs are configured with an infeed system followed by a pre-sort line where contaminants that could damage or impact the operation of the downstream equipment are removed manually. Next, disc screens or ballistic separators are used to separate two-dimensional fiber from three-dimensional containers. Glass, if included in the collection program, is broken, screened out, and then separated from

other residual fines less than two inches in size. The disc screens or ballistic separators also sort the fiber commodities by size and are followed by optical or manual quality control sorting for each grade of fiber. The container sorting line consists of magnets to remove ferrous metal, eddy current separators to eject non-ferrous metal, and optical and/or manual sorting for the various grades of plastics and cartons.

Residual wastes are typically generated at several points in the process – pre-sort trash is positively sorted from the pre-sort line, fines (or "unders") less than two inches are removed by screening, post-sort trash is positively sorted from the fiber lines, and end-of-container-line residue remaining after all commodities have been positively sorted from the container line. The end-of-container-line residue contains machine yield loss (good materials that were not captured by the sorting system) and is therefore a good feedstock for Secondary MRFs. In some MRFs the various types of residue are kept separate, while others combine them into one disposal stream, in which case would require modifications in order to supply a Secondary MRF.

PET and HDPE bottles are usually present in quantities that can justify investments in optical sorting equipment and are also relatively easy to sort manually. These materials are often used for specific applications in which other resins are not used – PET water and soda bottles, HDPE-natural milk jugs, and HDPE-color detergent and shampoo bottles.

Beyond these resins and applications, most resins are not available in the quantities necessary to justify investments in optical sorting and are difficult to sort manually due to a variety of resins used for a wide range of similar applications (i.e., creating "look-a-like" materials and products). Therefore, most MRFs produce a mixed plastic, "#3-7" or "pre-picked" bale that requires further sorting prior to recycling.

Secondary MRFs can help to streamline Primary MRF operations by eliminating the unnecessary sorting step required to produce this intermediate, mixed product. Instead, the mixed plastics can be allowed to report with the end-of-container-line residue and then sent to a Secondary MRF for sorting by material type, maximizing recovery efficiency and value.

Cartons are easy to identify and can be sorted at Primary MRFs, but it requires space and time to generate truckload quantities that are necessary to market the material. Secondary MRFs can improve the efficiency of carton recovery by aggregating enough material to justify investments in optical sorting.

One final aspect of Primary MRFs is that they are typically located to facilitate collection route optimization. This helps to control the cost and minimize the environmental impacts associated with collection by allowing haulers to complete their assigned route and unload at a nearby MRF without wasting time traveling long distances in an expensive vehicle with a load of only 8 to 12 tons. Having many primary MRFs around a region serves and important function in the initial aggregation phase for recyclable commodities.

Secondary Material Recovery Facilities

The concept of a Secondary MRF is less about advanced sorting technologies and more about a business model that can achieve the economies of scale for sorting all materials by type within a regional wasteshed, such as Oregon and Washington in the Pacific Northwest. The equipment and technologies

utilized at Secondary MRFs are much like those found at modern Primary MRFs, but they are employed to dig deeper into the recycling stream to recover low-volume and difficult to manually sort materials along with machine yield losses (see Figure 3). The key is to concentrate these materials in the feedstock to a Secondary MRF by sorting out most of the high-volume and easy-to-sort materials at Primary MRFs, and then to aggregate the remaining mixed materials from a network of existing Primary MRFs within the region in order to reach the critical mass necessary to justify investments in automated technologies for a second level of sorting by material type.

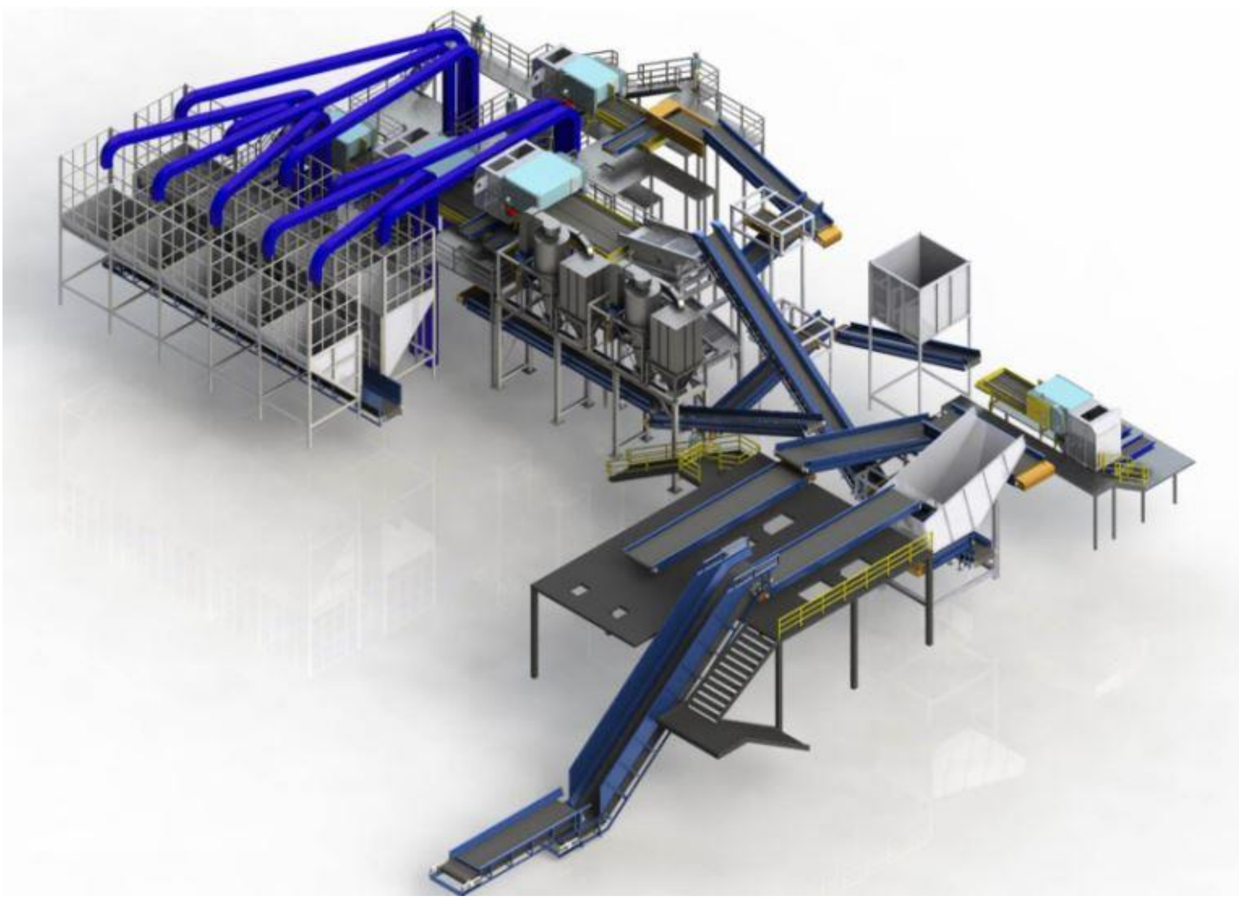

Figure 3. Example of a Full-Scale Secondary MRF

Secondary MRFs are designed to work with our existing recycling system and increase material recovery with the most efficient use of capital. One Secondary MRF can extend the capabilities of all Primary MRFs within a region, as shown in Figure 4.

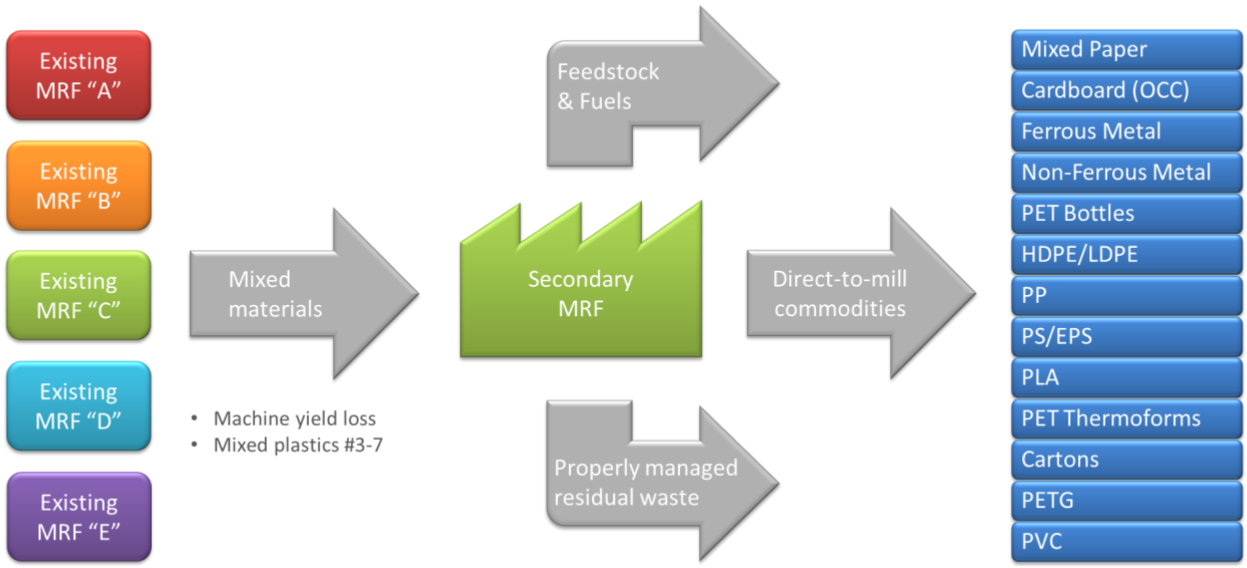

Figure 4. Secondary MRF Process Flow

In addition to increasing regional recycling rates, Secondary MRFs are more easily adaptable to changing packaging and sorting technologies, extend the capabilities of the existing MRF infrastructure, and deliver benefits to all recycling stakeholders.

Perhaps most important, secondary sorting can be implemented within a timescale more likely to meet the increased demand from new processing capacity coming online domestically. Secondary MRFs will help brand owners and other signatories meet their New Plastics Economy Global Commitments to drastically increase usage of PCR content – an initiative of the Ellen MacArthur Foundation.

Plastics Recovery Facilities

Plastics Recovery Facilities (PRFs) are another type of secondary sorting process, but they differ from Secondary MRFs in a few key ways. PRFs are designed to sort mixed plastics and then typically continue with the recycling process to produce a flake or pelletized resin product for one or more of the sorted commodities. Secondary MRFs, on the other hand, source a wider range of materials, including mixed plastics, end-of-container-line residue, and other low-volume materials such as cartons, and produce baled commodities sorted by material type. This difference allows Secondary MRFs to recover a larger portion of the recycling stream and reduce the size of the wasteshed necessary to fill the capacity of a regional sorting facility.

Portable Secondary MRF

The Portable Secondary MRF was designed to demonstrate how additional value can be extracted from machine yield loss (end-of-container-line residue) and/or mixed plastics from Primary MRFs. The system consists of a feed hopper, vibratory screener, air classifier, high-speed conveyor, and a dual-eject near-infrared optical sorter. The purpose of the equipment upstream of the optical sorter is to prepare the material for improved sorting – the vibratory screener removes materials smaller than two inches, the air classifier removes film plastics, and the high-speed conveyor puts space between materials to be sorted.

The optical sorter utilizes near-infrared reflectance to identify materials by type, and then ejects materials up or down with compressed air according to the recipe programmed into the machine. Materials that were not targeted for ejection report to a third channel – the neutral fraction. The machine typically produces a higher-purity product (~95%) when ejecting up and lower-purity (~90%) when ejecting down, mostly due to the proximity of the air nozzles to the targeted materials.

Mixed materials must be processed through the Portable Secondary MRF several times in order to simulate the optical-sorting capabilities of a standard commercial-scale Secondary MRF that only requires a single pass to recover all commodities. The portable system is also not equipped with magnets and eddy current separators for sorting metals, so these materials must be sorted manually.

Figure 5. Titus Portable Secondary MRF

Secondary Sorting Process Description

In order to simulate the sorting equipment available at a Secondary MRF, materials were processed through the Portable Secondary MRF in a series of passes according to the sorting strategy provided below.

Pass 1:

- PE ejected up, followed by manual quality control to produce **polyethylene** product
- Fiber and cartons ejected down, mixture to be further sorted in Pass 1a
- Neutral mixture to be further sorted in Pass 2, ferrous and non-ferrous metals removed manually

Pass 1a:

- Cartons ejected up, followed by manual quality control to produce **carton** product
- Contaminants ejected down
- Neutral fiber followed by manual quality control to produce **mixed paper (hard mix)**

Pass 2:

- PP ejected up, followed by manual quality control to produce **polypropylene** product
- PS ejected down, followed by automated quality control sorting in Pass 2a
- Neutral mixture to be further sorted in Pass 3, ferrous and non-ferrous metals removed manually

Pass 2a:

- Contaminants ejected up
- Neutral **polystyrene** product

Pass 3:

- PET ejected up, followed by manual sorting and quality control to produce **PET bottle** and **PET thermoform** products
- PVC ejected down
- Neutral mix polished to remove PVC and create a potential feedstock for conversion technologies

Samples were prepared by collecting material at regular intervals throughout each processing period and at suitable sample points to best assure that the samples were representative.

Sample analysis was completed in two phases. First, the basic material characterization was accomplished by manual sorting materials into the following categories: Fiber (OCC), Fiber (MWP), Cartons, Non-Ferrous Metal (Aluminum UBC), Non-Ferrous Metal (other), Ferrous Metal, Glass, Plastic (rigid), Plastic (film), Plastic (foam), Trash (including wood, aggregate, rubber, etc.), and Fines (<2”). Next, the detailed plastics characterization was accomplished by manual sorting based on Resin Identification Codes (RIC) and by near-infrared (NIR) spectroscopy where RICs were not available or not visible.

Results & Discussion

The Pacific Northwest Secondary Sorting Demonstration Project successfully showed recycling stakeholders from Oregon and Washington, and across the country, that additional value can be extracted from landfill-bound or materials that are low value due to being mixed. More importantly, it provided a place for recycling stakeholders to discuss the opportunities and challenges facing our recycling system.

China's National Sword policy highlighted some inefficiencies and issues with our recycling system and drastically cut demand and value for many of our scrap commodities almost overnight, especially for mixed paper and mixed plastics. As a result, many communities have had to increase rates for recycling services to cover the increasing costs of processing and decreasing revenues from material sales. Many communities have also cut back their recycling programs in response to the lack of markets and the lower value of materials, which could have long-term impacts on recycling rates, the availability of recycled feedstock for manufacturing, and our ability to realize the economic and environmental benefits of recycling this material.

But there is also a very positive side effect of National Sword. The United States has increased investment in domestic recycling infrastructure. Several new paper mills have been announced, and many more are retrofitting their processes to be able to consume the higher-quality mixed paper that is now being produced. There is also an increase in announced plastics processing capacity scheduled to come online over the next few years – much of it using what's been generically called "chemical recycling," a suite of technologies that are designed to produce recycled resin equivalent to virgin material.

Another driver for positive change in plastics recycling is the Ellen MacArthur Foundation's New Plastics Economy Global Commitment, under which over 400 signatories have pledged to significantly increase the use of post-consumer recycled (PCR) content resin over the next several years.

Secondary MRFs will provide the necessary sorting capabilities to recover the plastics, sorted by material type, to feed these emerging markets. At the same time, they will boost recovery of fiber, cartons, and metals.

Preferred Feedstock Materials

The preferred feedstock for Secondary MRFs is a combination of mixed plastics, end-of-container-line residue, and other low-volume materials such as cartons. While these materials could be supplied individually, Primary MRFs will realize improved operational efficiency by avoiding the unnecessary sorting step required to produce mixed plastics. Collaboration between Primary and Secondary MRFs is necessary to provide the greatest benefit to the Primary MRF and the best possible feedstock for the Secondary MRF.

Mixed plastics should include all resin except those that are sorted by material type at the Primary MRF, most commonly PET bottles, HDPE, and increasingly PP.

End-of-container-line residue is a subset of MRF residue that excludes positively sorted trash, film, and fines less than two inches.

In general, Secondary MRFs are not designed to process film and other trash that is positively removed during the pre-sort and post-sort processes at a Primary MRF.

During this demonstration project, samples were collected from four MRFs across Oregon and Washington (see Table 1.)

Table 1. Sample Descriptions

Sample ID	Category	Description
A	MRF Residue	End-of-container-line residue including remaining mixed plastics
B	MRF Residue	MRF residue mixture including end-of-container-line residue, post-sort trash, and fines less than two inches
C	Mixed Plastics	Positively sorted mixed plastics without residue
D	Mixed Plastics	Positively sorted mixed plastics without residue

Material Recovery Mass Balance Data

Mass balance data for the Pacific Northwest Secondary Sorting Demonstration Project are provided below for the two feedstock material types processed during this project. They are presented as averages so as not to reveal individual facility data.

California Data

For comparison purposes, Figure 6 shows the typical mass balance for processing California end-of-container-line residue at the Titus Secondary MRF in Los Angeles. Overall recovery is approximately 50%, which includes plastics (15.5%), metals (3.1%), fiber (30.0%), and cartons (1.3%). See Appendix A for additional information about the history and capabilities of the Titus Secondary MRF in Los Angeles.

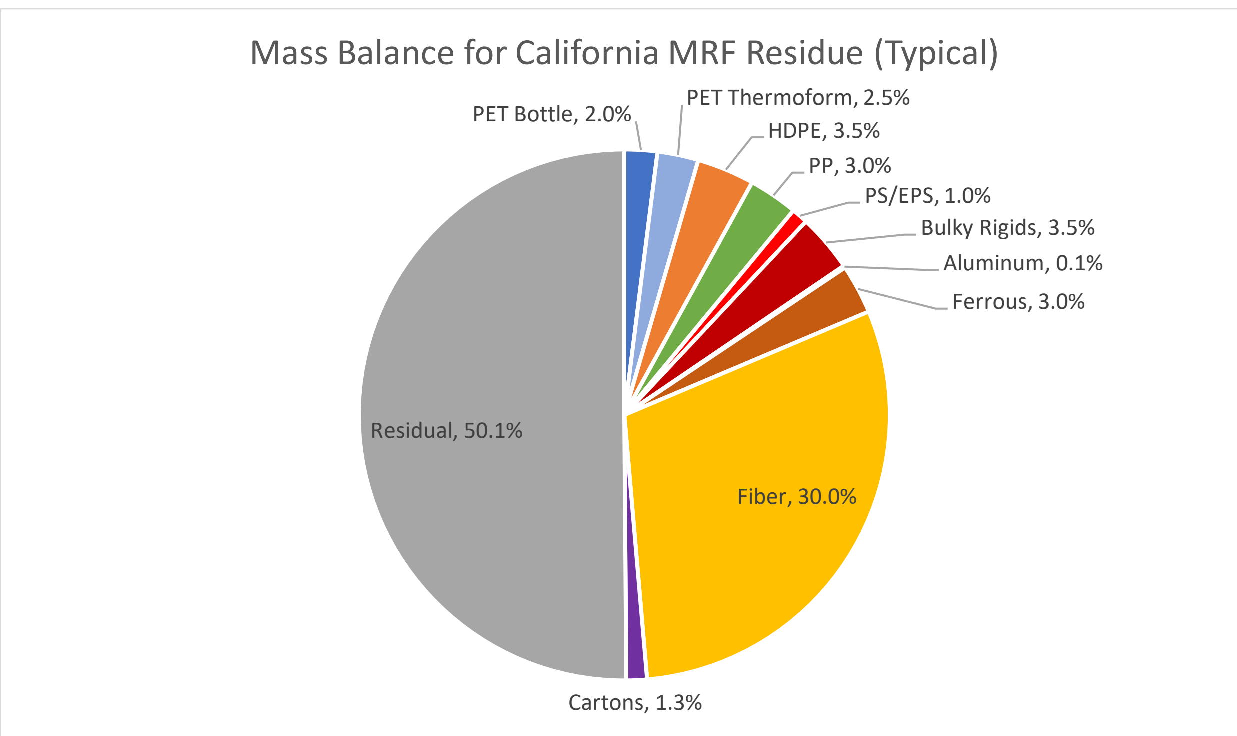

Figure 6. Mass Balance for California MRF End-of-Container-Line Residue (Typical)

Pacific Northwest Data for MRF Residue

The mass balance data for Pacific Northwest MRF Residue are shown as raw data in Figure 7. This data is an average of the preferred end-of-container-line residue from one MRF and a mixture of MRF residue, including positively sorted trash, film, and fines less than two inches, from another MRF.

In order to more accurately show the expected recovery if both facilities had provided materials that met the Titus incoming feedstock requirements, the mass balance for the facility that provided mixed MRF residue was adjusted by disregarding the pre-sort trash and fines contribution to the Secondary MRF residual data – 29% and 26% of the incoming feedstock sample, respectively. The mass balances for the two samples were then averaged, and the adjusted data are shown in Figure 8.

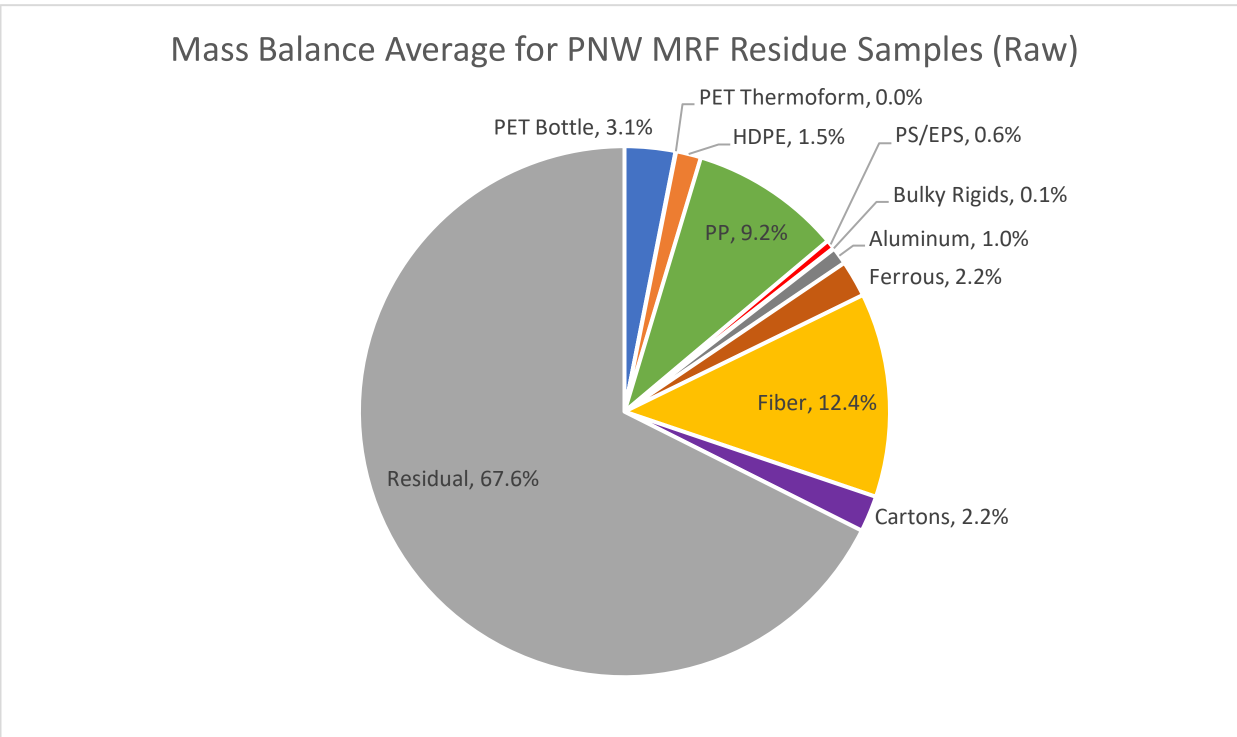

Figure 7. Mass Balance Average for PNW MRF Residue Samples (Raw)

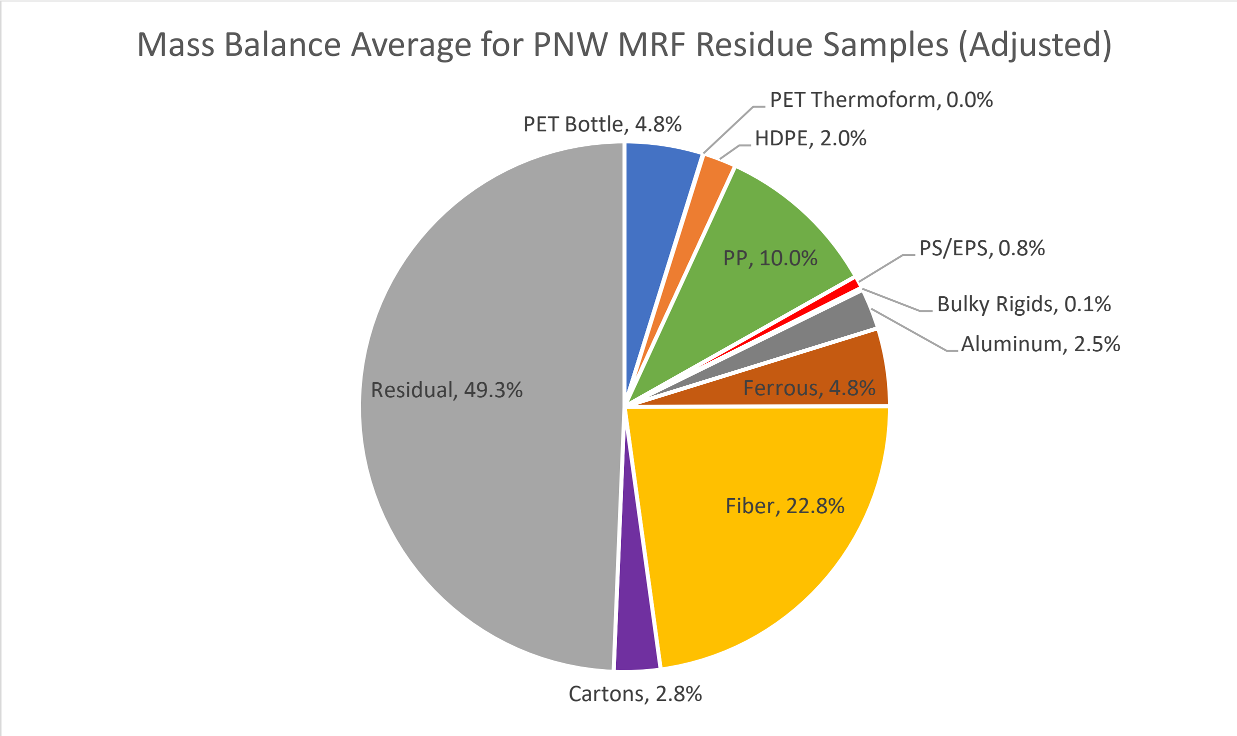

Figure 8. Mass Balance Average for PNW MRF Residue Samples (Adjusted)

Overall the data show similar levels of recovery between California and the Pacific Northwest. Average fiber recovery is about 7% lower in the Pacific Northwest; however, polypropylene recovery is significantly higher and makes up the difference in volume and improves the overall economics due to the relative value of polypropylene versus fiber. Carton recovery during this project was also noted to be more than two times the level typically recovered at the Titus facility in Los Angeles.

When comparing the raw data with the adjusted data, it becomes obvious why Secondary MRFs do not process all MRF residues. Materials that were positively sorted as trash or screened as fines at the Primary MRF would suffer the same fate at a Secondary MRF, but they also utilize valuable capacity and hinder one of the key advantages of Secondary MRFs – reduced downtime. Because Primary MRFs typically do the hard work of removing film and other trash that could affect the operation of sorting and material handling equipment, Secondary MRFs are designed to process and generally receive incoming feedstock that is cleaner and less likely to cause operational downtime.

Pacific Northwest Data for Mixed Plastics

The mass balance data for Pacific Northwest mixed plastics are shown in Figure 9. These data represent the average of mixed plastics material received from two Primary MRFs.

While this material is an excellent feedstock for a Secondary MRF, we believe that operational efficiency can be improved at the Primary MRF and additional recovery of machine yield losses can be accomplished when mixed plastics are allowed to report with the end-of-container-line residue. This is the preferred feedstock for Secondary MRFs and does the most to benefit the recycling system.

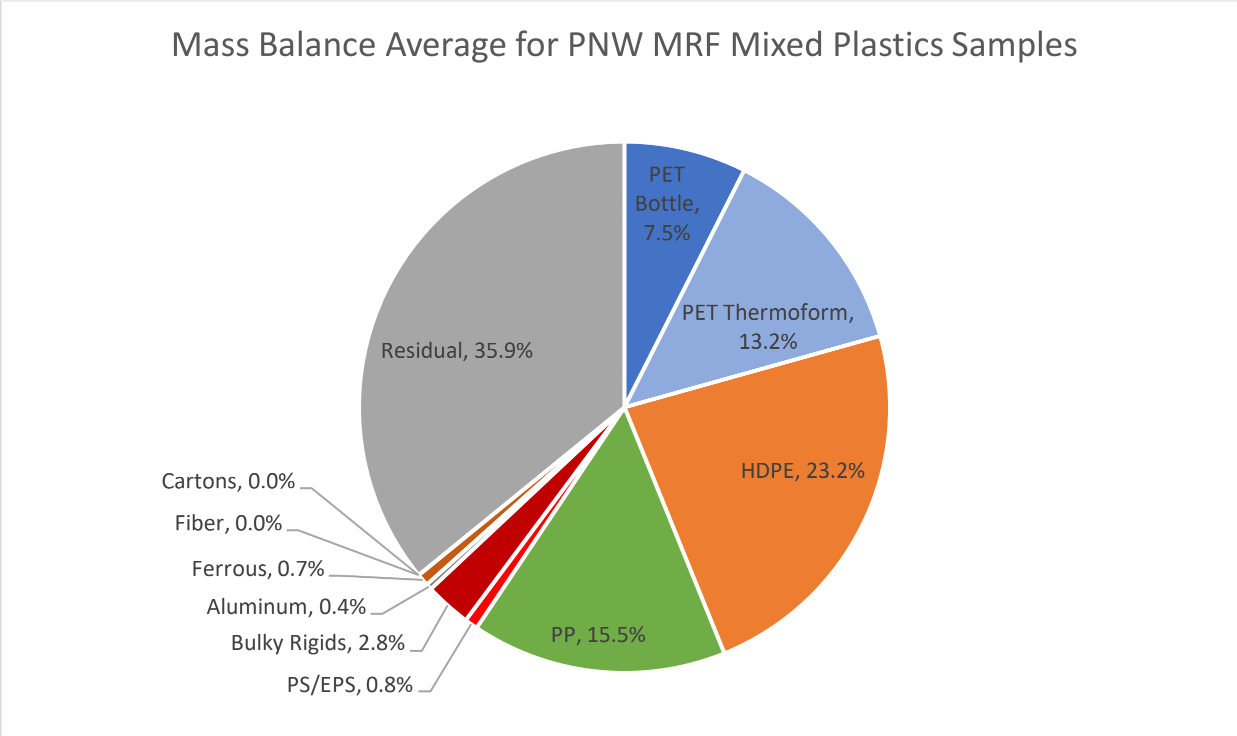

Figure 9. Mass Balance Average for PNW MRF Mixed Plastics Samples

Oregon Metro Program Material vs. Non-Program Material

One additional aspect of this project was to evaluate the products produced from materials collected within the Oregon Metro region and determine the proportion of each product that was program material versus non-program material. The specific products that were included in this analysis were plastics and cartons generated by secondary sorting of container-end-of-line residue from the Portland Metro region.

This analysis not only highlighted some of the confusion within the existing collection program, it also provided a glimpse of the opportunity to increase material recovery with the addition of a Secondary MRF to the region, coupled with an expansion of collection programs. Most notable was the recovery of non-program polypropylene and polystyrene. More than 40% of the polypropylene recovered was non-program material, and demand from existing reclaimers of polypropylene is not currently being met. The polystyrene data may be even more regionally significant – almost 90% of the polystyrene recovered was non-program material, and an emerging technology developed by Agilyx (now Regenyx) is located within the Portland Metro region. If recycling program planners were to add these materials to the collection program along with secondary sorting capacity, it would yield much-needed feedstock for these existing markets.

In order to complete this analysis, the composition of each product was compared to Oregon Metro's definitions of accepted program materials.

Program materials are described on Oregon Metro's website, and this information has been reproduced on the following pages as a reference for the analysis provided in the next section.

Plastic recycling

You can recycle plastic bottles, jars, round containers, buckets, and nursery pots at home.

Sort plastic by shape, not by number

Whether you've been recycling since the 1990s or you're navigating plastic packaging newer to the market, you may be wondering, "Which numbers can I recycle?" Don't. The numbers you see on plastics, often in a triangle of chasing arrows, do not mean anything when it comes to what goes in your home recycling bin. Those numbers are typically used by the industry to indicate what type of plastic it is, not whether it is part of a local recycling program.

Ignore the numbers. Ignore the arrows. Sort by shape.

Reproduced from https://www.oregonmetro.gov/tools-living/garbage-and-recycling/recycling-home

These items are OK in your recycling container – rinse thoroughly

- **Plastic bottles, jugs and jars** 6 ounces or larger, any container with a threaded neck (for a screw-on lid) or neck narrower than the base. This includes milk jugs, peanut butter jars, and bottles that held personal care and cleaning products (shampoo, laundry soap, etc.).
- **Round plastic containers** that can hold 6 ounces or more, with a wider rim than base, and typically contain products such as salsa, margarine, cottage cheese, hummus, etc. (no drink cups).
- **Planting/nursery pots** larger than 4 inches in diameter and made of rigid (rather than crinkly or flexible) plastic. Remove any loose dirt.
- **Buckets** 5 gallons or smaller. Handles are OK.

Do not include these items in your recycling container

- **Plastic bags.** They are recyclable, but not at the curb. Plastic bags are a serious problem for recycling facilities. They get caught in machinery, which causes costly shut-downs of sorting lines to cut the bags out of the equipment. Take plastic bags back to stores or drop them off at recycling centers where they are collected separately from other plastics.
- **Bottles that have contained hazardous materials** such as motor oil, pesticides, or herbicides. Bottles that have contained cleaning products are OK.
- **Lids**. They are too small or too flat to be sorted out of recyclables and usually end up at paper mills where they contaminate the paper. These items are garbage.
- **Trays** from microwaveable meals, deli products, prepackaged meals, and snacks. Take-out, deli or other food containers that are not specifically round plastic containers, including hinged containers, square snack containers, food containers with a plastic pull-tab, bowls, etc. These items are garbage.
- **Styrofoam** or other foam products (cups, meat trays, egg cartons, packaging foam, packing peanuts, etc.).
- **Plastic or plastic-coated beverage cups, lids, or straws**. These are garbage at home.
- **Plastic packaging that doesn't conform** to the bottle, jar, bucket, or round container shapes, such as blister packaging or plastic wrap (stretch or shrink wrap, bubble wrap, and bags), or containers smaller than 6 ounces.

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Paper recycling (section regarding cartons)

These items are OK in your recycling container – rinse thoroughly

- **Milk cartons and juice or soup boxes** (called aseptic boxes). Rinse thoroughly; no need to flatten.

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PET Bottles

PET bottle product was produced using optical sorting followed by manual quality control to remove non-program thermoforms and other known contaminants such as PETG bottles. Overall PET content was 97.1% and program PET content was 91.6% (Figures 11 and 12). Non-program material included thermoforms (4.9%, Figure 13), caps and lids (0.2%), small containers (0.1%), hazardous material containers (0.1%, Figure 14), and other PET (0.2%). Total contamination was 2.9%, with PETG as the largest contributor (1.2%, Figure 15).

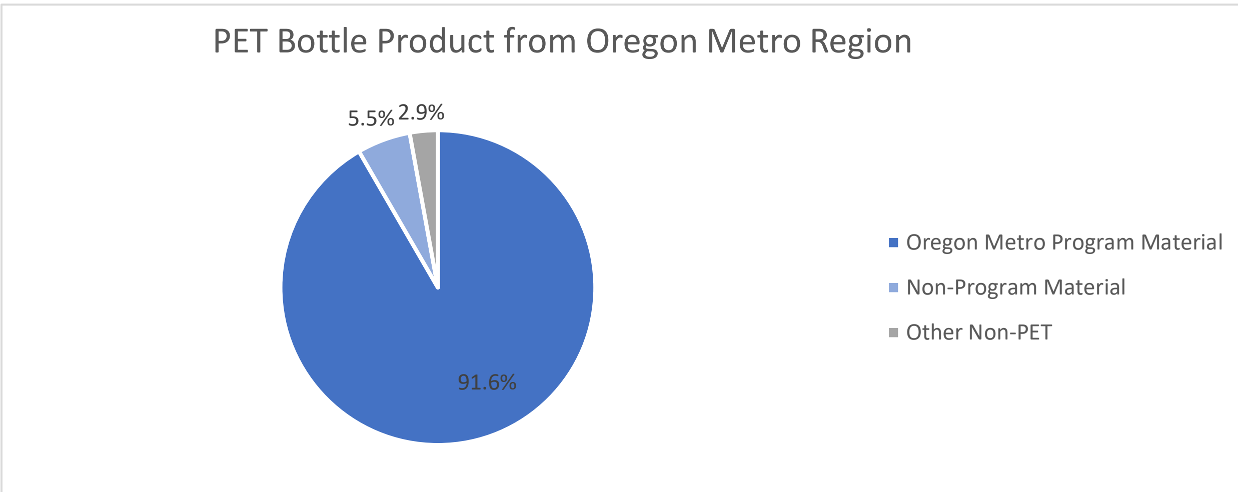

Figure 10. PET Bottle Product from Oregon Metro Region

Figure 11. Program PET

Figure 12. Program PET

Figure 13. Non-Program PET

Figure 14. Non-Program PET

Figure 15. Contamination

PET Thermoforms

PET thermoform product was produced using optical sorting followed by manual sorting to remove the thermoforms from PET bottles and produce a lower-value product with an overall PET content of 98.3%. Program PET content was 1.8% due to bottles (Figure 17) and tubs (Figure 18). Non-program PET primarily consisted of thermoformed clamshells or similar containers (96.8%, Figure 19) with a small amount of cups (0.4%).

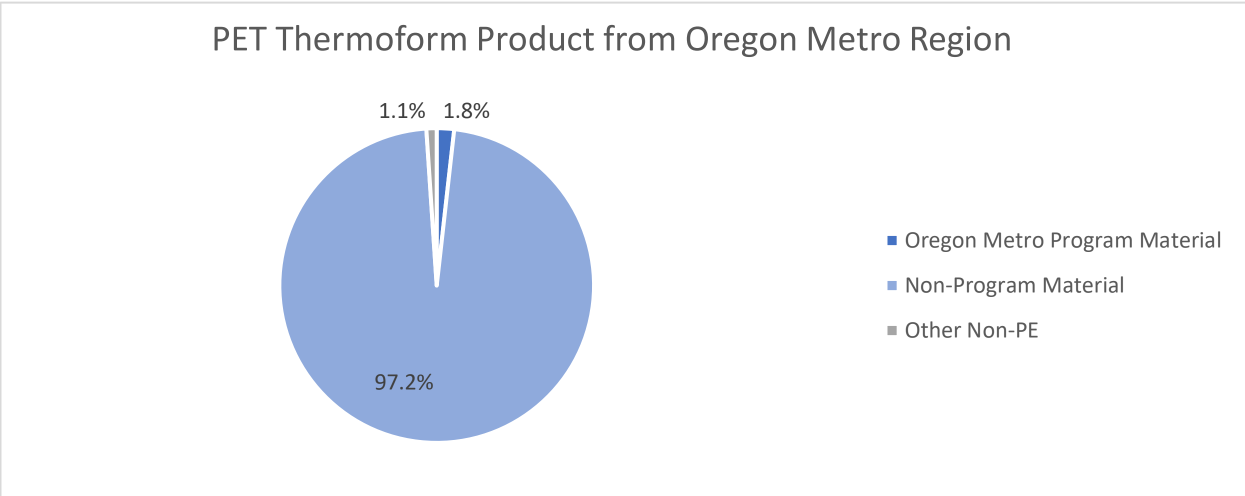

Figure 16. PET Thermoform Product from Oregon Metro Region

Figure 17. Program PET

Figure 18. Program PET

Figure 19. Non-Program PET

Polyethylene

Polyethylene product was produced using optical sorting followed by manual quality control to remove contaminants. Overall PE content was 90.9% and program PE content was 65.0% (Figure 21). Non-program material included caps and lids (5.9%, Figure 22), hazardous material containers (4.9%, Figure 23), small containers (4.2%, Figure 24), beverage handles (1.8%, Figure 25), and other PE (9.1%, Figure 26). The primary source of contamination was polypropylene at 7.8%.

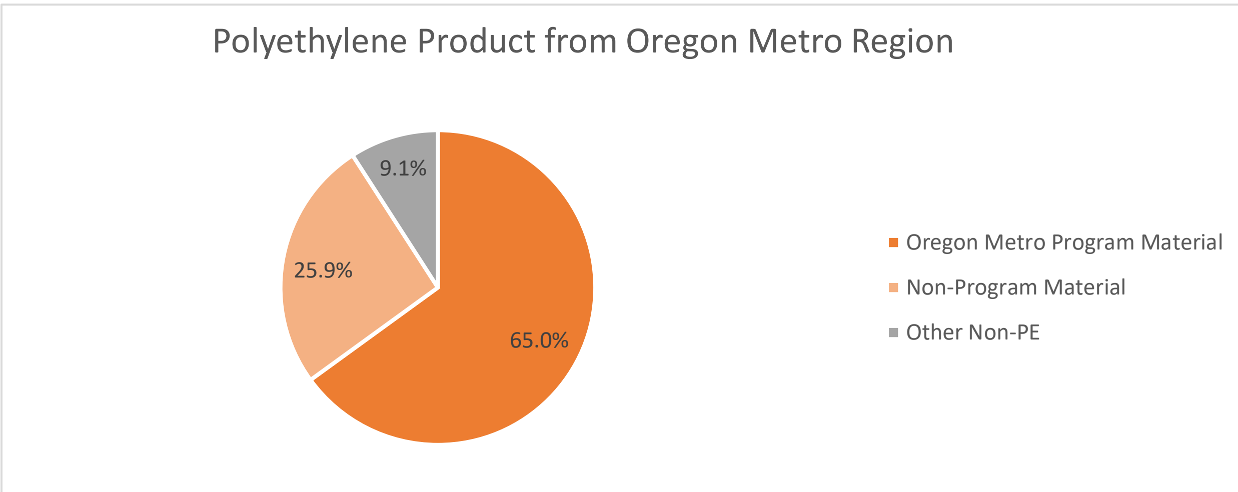

Figure 20. Polyethylene Product from Oregon Metro Region

Figure 21. Program PE

Figure 22. Non-Program PE

Figure 23. Non-Program PE

Figure 24. Non-Program PE

Figure 25. Non-Program PE

Figure 26. Non-Program PE

Polypropylene

Polypropylene product was produced using optical sorting followed by manual quality control to remove contaminants. Overall PP content was 96.1% and program PE content was 54.9% (Figure 28). Non-program material included cups (14.3%, Figure 29), trays and other non-round containers (9.0%, Figure 30), caps and lids (8.8%, Figure 31), prescription bottles (0.6%), small containers (0.6%), and other PP (8.0%, Figure 32). A significant source of contamination was caused by attachment, overlapping, or stacking with polypropylene (Figure 33).

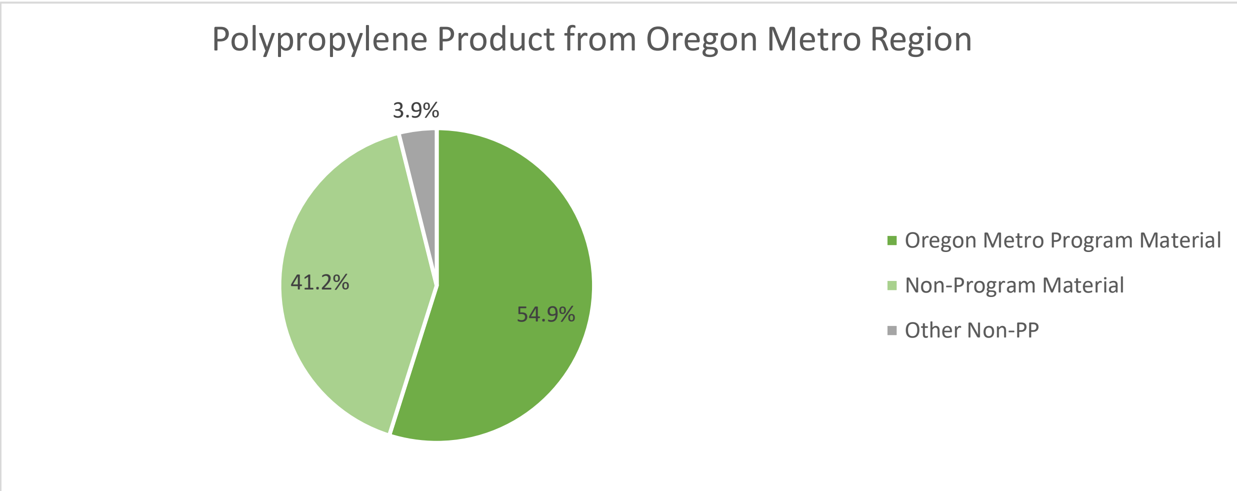

Figure 27. Polypropylene Product from Oregon Metro Region

Figure 28. Program PP

Figure 29. Non-Program PP

Figure 30. Non-Program PP

Figure 31. Non-Program PP

Figure 32. Non-Program PP

Figure 33. Contamination

Polystyrene

Polystyrene product was produced using positive optical sorting followed by automated quality control using negative optical sorting. Overall PS content was 91.6% and program PS was only 2.8% (Figure 35). Non-program material included transportation packaging foam (28.1%, Figure 36), cups (19.1%, Figure 37), cleaning product refill packaging (9.1%, Figure 38), trays (9.0%, Figure 39), caps and lids (2.0%), square nursery pots (2.0%, Figure 40), small containers (1.2%), foodservice or food packaging foam (0.7%), foam insulation (0.1%), and other PS (17.5%, Figure 41).

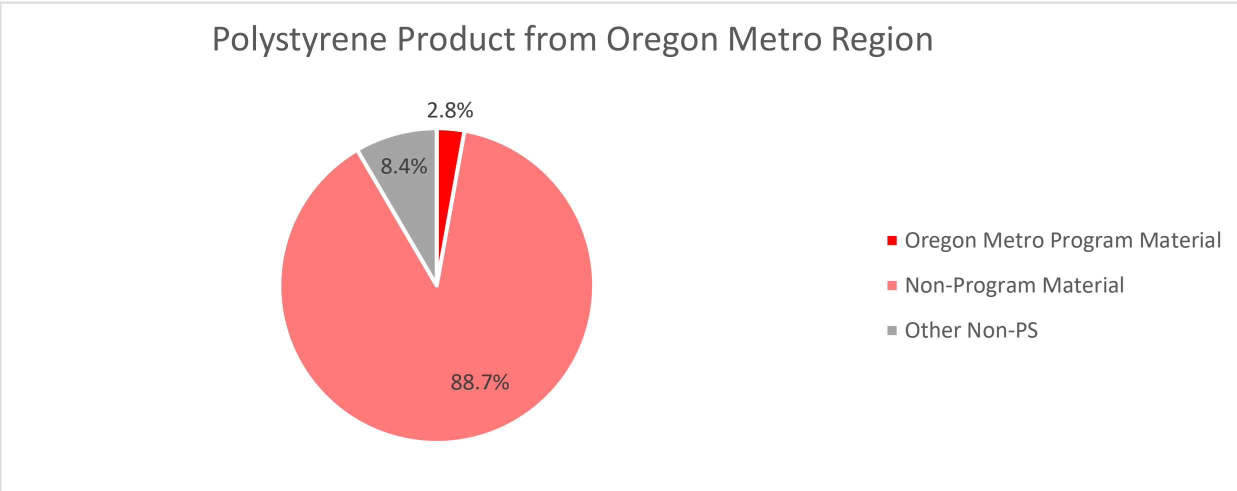

Figure 34. Polystyrene Product from Oregon Metro Region

Figure 35. Program PS

Figure 36. Non-Program PS

Figure 37. Non-Program PS

Figure 38. Non-Program PS

Figure 39. Non-Program PS

Figure 40. Non-Program PS

Other materials attached, overlapped, or stacked with polystyrene material were a significant source of contamination (Figure 42); however, the single largest contributor was a specific brand of almond milk containers made of PET with an oriented polystyrene full shrink sleeve label (Figure 43).

Figure 41. Non-Program PS

Figure 42. Contamination

Figure 43. Contamination

Cartons

Carton product consisting of aseptic and gable-top cartons was produced using positive optical sorting to eject all fiber plus cartons, followed by automated quality control using positive optical sorting to eject cartons. Overall carton content was 83% and, by definition, all of this was program material because Oregon Metro's curbside program material description matches the ISRI specification for this material. Gable-top cartons accounted for 68.3% of the product (Figure 45) and aseptic cartons for 14.7% (Figure 46).

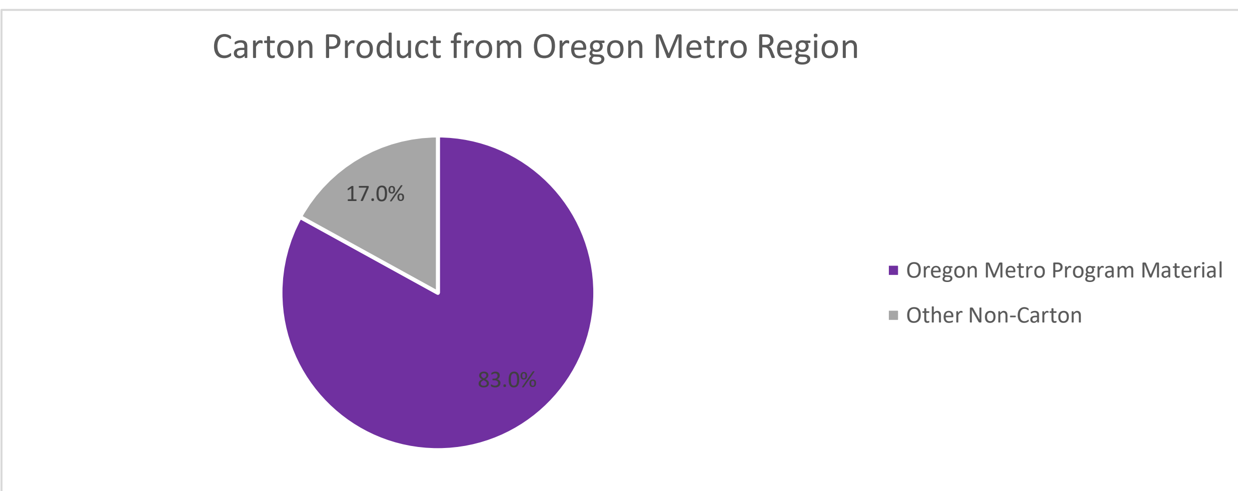

Figure 44. Carton Product from Oregon Metro Region

Figure 45. Program Cartons

Figure 46. Program Cartons


Figure 47. Contamination

The primary sources of contamination were a variety of types of fiber (15.9%), with most of this material having structures similar to those of the program materials. Fiber contamination included cups (5.9%, Figure 47), ice cream containers (3.8%, Figure 48), other food packaging (3.1%, Figure 49), and other mixed paper (3.1%). As with other products, non-target materials attached, overlapped, or stacked with cartons or other similar materials were a source of contamination (Figure 50).


Figure 48. Contamination

Figure 49. Contamination


Figure 50. Contamination

Impact Estimates for the Pacific Northwest

Secondary MRFs are intended to benefit all recycling stakeholders and produce measurable positive environmental impacts, including increased material recovery/landfill diversion, reduction of greenhouse gas generation, and reduced risk of plastics leakage to the marine environment.

Material recovery opportunities are estimated based on several factors, including population served[3], household recyclable material generation rates[4], percentage of materials sent for secondary processing, and secondary recovery rates. Based on the data available for the Pacific Northwest along with the recovery rates observed during this project, a single Secondary MRF designed to service all Primary MRFs

[3] United States Census Bureau, www.census.gov
[4] Marshall, C. (2017). *The 2016 State of the Curbside Report*. The Recycling Partnership.

in Oregon and Washington would be expected to recover more than 50,000 tons per year of recyclable commodities sorted by material type and improve the recovery of residential recyclables by 3% to 6%.[5]

Greenhouse gas reduction opportunities are estimated based on the material recovery rates achieved during this project and assume that the recovered materials are recycled instead of landfilled. Using a combination of the EPA WARM Model and the CalRecycle Carbon Calculator, greenhouse gas reductions for the Pacific Northwest are estimated to exceed 130,000 tons per year CO_{2eq}.

Secondary MRFs also reduce the risk of potential mismanagement and pollution by sorting mixed plastics domestically and disposing residual waste within a well-regulated solid waste system. McKinsey and the Ocean Conservancy have identified several of the countries to which the United States sells mixed plastics as the leading contributors to ocean plastics, and have reported that approximately 25% of ocean plastics are from waste that was previously collected.[6] Many of the MRF operators in the Pacific Northwest and across the country[7] have discontinued this practice; however, this had led some facilities to stockpile this material while trying to identify new markets and avoid landfill disposal.

Conclusions and Recommendations

With the emerging demand for recycled feedstock growing to meet sizeable 2025 goals, the industry is seeking to find solutions that will quickly enhance the existing domestic recycling capabilities. Meeting this growing demand will require investment in a number of areas, including in Primary MRFs and secondary sorting capacity. Secondary sorting can be viewed as a complement to the existing system by establishing capability for additional recovery, creating a viable business model for recovering lower-volume types of packaging, and adapting to recover emerging packaging forms. Through the ability to target more "look-a-like" and low-volume packaging, adding secondary sorting to a region allows municipalities to harmonize programs across the state as well as expand the range of items on the accepted list without significant investment. Secondary sorting also allows for the recovery of feedstock for emerging technologies, something that Primary MRFs would struggle to supply due to the additional sorting steps required to meet specifications.

The Pacific Northwest would benefit from the addition of a regional Secondary MRF to process mixed plastics and other low-volume materials such as cartons along with end-of-container-line residue in order to recover feedstock for existing reclaimers and emerging technologies. Among the many benefits, it is estimated that a Secondary MRF would generate 46 green jobs, increase material recovery or landfill diversion by more than 50,000 tons per year, reduce the generation of greenhouse gases by more than

[5] Estimated recovery based on data from this project, a regional model where MRFs recover 88% of recyclable materials, and data reported by the Oregon Department of Environmental Quality (https://www.oregon.gov/deq/FilterDocs/2017mrwgrates.pdf) and the Washington State Department of Ecology (https://ecology.wa.gov/Research-Data/Data-resources/Solid-waste-recycling-data).
[6] *Stemming the Tide: Land-based strategies for a plastic-free ocean*. McKinsey & Company and Ocean Conservancy, September 2015.
[7] Rosengren, C. (2019). Waste Management and Casella confirm plastic export policies. Waste Dive. October 17, 2019.

130,000 tons per year CO_{2eq}, and provide enhanced recovery and traceability for all materials offered for recycling, thereby reducing the risk of potential mismanagement and pollution.

In order to move forward with an effective and viable project to build a Secondary MRF in the Pacific Northwest that would service both Oregon and Washington, it will be necessary to establish long-term supply agreements between the existing Primary MRFs and the regional Secondary MRF. It may also be necessary to fund modifications to the Primary MRFs to facilitate the production of suitable feedstock materials for the Secondary MRF. Expanding and harmonizing recycling collection programs and developing complementary policies could also help to further assure that the system remains sustainable.

There is also a possibility that some additional cost to the system might need to get passed from the MRFs to the rate payers if the difference between the Secondary MRF's processing fee and the Primary MRFs' landfill disposal cost avoidance are not sufficiently covered by the revenue sharing from commodity sales. Any increase in rates would of course come with an increased level of service as measured by improved recycling rates and an expanded list of program materials.

The conditions that would make secondary sorting successful in the Pacific Northwest would be similar for other metropolitan areas across the country. There will always be a need to aggregate lower-volume materials in order achieve the economies of scale necessary to sort by material type and produce products in truckload quantities for recycling markets. The addition of secondary sorting capability to the system has the potential to help further extract value from our material streams, offering benefits for all stakeholders from consumers to end users.

Appendix A

History and Capabilities of the Titus Secondary MRF in Los Angeles

2001 Titus Maintenance & Installation Services founded as a service provider to the waste and recycling industry as the shift to single-stream recycling expands.

2008 Titus builds the Portable Secondary MRF (Porta-Sort) in response to recognizing the opportunity to recover machine yield loss and the practical limitations for sorting low-volume materials at Primary MRFs.

2012 Titus purchases a small MRF in Los Angeles and converts it into a Secondary MRF demonstration facility with a single-shift processing capacity of 1,200 tons per month.

2017 Titus refines the Secondary MRF business model and initiates plans to expand processing capabilities along the West Coast with three full-scale facilities designed to service the Pacific Northwest, Northern California, and Southern California.

The Titus Secondary MRF in Los Angeles has been used to demonstrate the value of secondary sorting to recover valuable commodities from end-of-container-line residue, mixed plastics, and other low-volume materials such as cartons.

Products recovered at the Los Angeles facility include:

- Mixed paper
- Cardboard (OCC)
- Cartons
- Ferrous metal
- Aluminum, UBCs
- Aluminum, low-grade
- PET bottles
- HDPE/LDPE
- PP
- PS/EPS
- PLA
- PET thermoforms

Additional information can be found at http://www.titusmrfservices.net/.