Plastic Packaging in Washington

Assessing Use, Disposal, and Management

Prepared for the Washington State Department of Ecology

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Glossary of Key Terms and Acronyms

Material definitions are included in Appendix A. Material Definitions. Cited definitions are taken mostly verbatim, with minor adjustments, from the source.

Backhaul	Also called "reverse logistics," using the return movement of a vehicle from its destination to its initial point of departure to transport materials collected at retail locations or other points of collection.
Bales	A compacted and wire-bound cube or block of recyclable material [1].
Chemical recycling	Any process by which a polymer is chemically reduced to its original monomer form so that it can eventually be processed (re-polymerized) and remade into new plastic materials that go on to be new plastic products [2].
Closed-loop recycling	A recycling process by which waste is collected and used again to make the same product. In a truly circular loop, no new raw materials are introduced into the process and no unusable material leaves the process as waste, allowing the process to continue indefinitely [3]. Most plastic recycling usually requires some amount of virgin resin to be added to compensate for the shortening of polymer chains during the mechanical recycling process. While it depends on the resin and end product, plastic can usually only be mechanically recycled a few times before it becomes too degraded to recycle.
Commercial sector	Includes solid waste and recyclable materials collected from businesses, industrial operations, institutions, and other non-residential sources as well as self-hauled materials delivered to transfer stations or other drop-off collection locations and reported or estimated to be from non-residential sources.
Contamination	The result of an unaccepted material or a contaminant entering a recycling or organics stream. Common recycling stream contaminants include electronics and small appliances, tanglers like cords and garden hoses, diapers, household hazardous waste, textiles and shoes, furniture, etc.
Cross-contamination	Cross-contamination is when one type of recyclable material ends up in a bale of a different material (e.g., plastic bottles are cross-contaminants in a bale of mixed paper).

Curbside collection	The collection method by which waste generators deposit specified materials in bins, carts, or dumpsters, and place those at the street or curb for periodic emptying by collectors [1].
Deposit Return System (DRS)	Also called container deposit systems or "bottle bills," these programs place a small, refundable deposit on beverage containers which is returned to consumers when they return empty containers to a redemption location. Ten states and one territory (Guam) in the U.S. have DRS laws covering 28 percent of the population. DRS programs account for 47 percent of all beverage containers recycled in the U.S. [4]
Drop-off	A form of collection of household recyclables wherein the generators deliver the items to a central aggregation location [1].
Dual stream	A curbside recycling practice in which two different groups of recyclable materials are collected separately, often in two different containers. In many jurisdictions, dual stream programs collect cans, bottles, and other containers separately from paper and cardboard [1]. In Washington, the most common dual stream collection model is glass collected separately from other commingled recyclables.
Engineered fuel products	Mixed non-hazardous waste materials shredded and blended to create a solid alternative fuel in industrial applications such as cement kilns or coal-fired power plants.
Extended Producer Responsibility (EPR)	A mandatory form of product stewardship that includes, at a minimum, the requirement that the manufacturer's responsibility for its product extends to post-consumer management of that product and its packaging. There are two related features of EPR policy: (1) shifting financial and management responsibility, with government oversight, upstream to the manufacturer and away from the public sector; and (2) providing incentives to manufacturers to incorporate environmental considerations into the design of their products and packaging.
Fines	Residual material, usually less than 2 inches in diameter, from a material recovery facility (MRF) or other sorting process, that is usually sent to landfill for disposal. This material usually consists primarily of small pieces of various types of paper and plastic but will also contain small pieces of broken glass and other materials.
Generation	The total amount of waste, including recyclable material, produced by a resident, household, business, or other waste generator. The basic formula is disposal + diversion = generation [5].

High-density polyethylene (HDPE)	A strong, durable, lightweight, and chemically resistant plastic material popular for a variety of applications, including rigid plastics. Coded as plastic resin #2. See Appendix A. Material Definitions for specific material types used for data reporting in this report.
Landfill	A specially engineered site for disposal of solid waste by burying in the ground. The waste is generally spread in thin layers which are then covered with soil or other materials [1].
Low-density polyethylene (LDPE)	A soft, flexible, lightweight plastic material. It is often used for sandwich bags and cling wrap. Coded as plastic resin #4. See Appendix A. Material Definitions for specific material types used for data reporting in this report.
Materials Recovery Facility (MRF)	Also sometimes called a recycling processor, an establishment primarily engaged in sorting fully or partially mixed recyclable materials into distinct categories and preparing them for shipment to recycling markets.
Mechanical recycling facility	A facility that reprocesses plastic through mechanical means, including grinding, washing, separating, melting, drying, re-granulating, and compounding [6].
Municipal solid waste (MSW)	Residential and commercial non-hazardous waste generated by municipalities and commercial entities, not including medical, industrial, or construction/demolition waste [1].
Open-loop recycling	A recycling process by which a product is broken down to allow its useful materials to be used to create a new, different product. The process is "open" since this material can't usually be recycled again and will become waste eventually. The most common example of open-loop recycling is using recycled PET to make synthetic fibers like polyester [3].
Pay-As-You-Throw (PAYT)	Also called unit pricing or variable-rate pricing, this term describes the system under which residents are charged for the collection of municipal solid waste, based on the amount of waste generated. This creates a direct economic incentive to recycle more and to generate less waste [7].
Plastic packaging	For the purposes of this assessment, material used for the containment, protection, handling, delivery, or presentation of goods by the producer for the user or consumer, ranging from raw materials to processed goods. Packaging includes, but is not limited to, all of the following: *(A) Sales packaging or primary packaging intended to constitute a sales unit to the consumer at the point of purchase and most closely contains the product, food, or beverage.*

	(B) Grouped packaging or secondary packaging intended to brand or display the product. *(C) Transport packaging or tertiary packaging intended to protect the product during transport.* For this study, "plastic packaging" includes the materials defined in the 2015-16 Washington Statewide Waste Characterization Study under the "Plastic Packaging" category except for PLA/compostable packaging (#28).
Plastic products	While outside the scope of this study, plastic products are an important component of the waste stream and can cause problems in the recycling system, end up as litter or marine debris, and have emissions and other environmental impacts associated with their production and transport. As defined in the 2015-16 Washington Statewide Waste Characterization Study, they include products made of #1-7 plastic resins (including single-use foodservice utensils and other plastic foodservice items not defined as packaging), PLA/compostable products, plastic garbage bags, non-bag plastic film products, bulky rigid plastic products, and composite plastic products.
Polyethylene (PE) film	An inclusive term for flexible plastic material made from HPDE, LDPE, or LLDPE. See Appendix A. Material Definitions for specific material types used for data reporting in this report.
Polyethylene terephthalate (PET)	A clear, strong, and lightweight plastic that is widely used for packaging food and beverages, especially convenience-sized soft drinks, juices, and water. Coded as plastic resin #1. See Appendix A. Material Definitions for specific material types used for data reporting in this report.
Polypropylene (PP)	A thermoplastic used in a variety of applications to include packaging for consumer products, like yogurt pots, margarine containers and many plastic bottle caps. Coded as plastic resin #5. See Appendix A. Material Definitions for specific material types used for data reporting in this report.
Polystyrene (PS)	A transparent thermoplastic that is found as both a typical rigid plastic and in the form of a rigid foam material. Coded as plastic resin #6. See Appendix A. Material Definitions for specific material types used for data reporting in this report.
Polystyrene foam packaging	A rigid cellular plastic foam including expanded polystyrene and extruded polystyrene found in a multitude of shapes and applications, commonly (though often incorrectly) referred to by the brand name Styrofoam™.
Polyvinyl chloride (PVC)	A common thermoplastic used in construction and generally known for its hardness. PVC is disruptive to the recycling of other plastic resin types. Coded as plastic resin #3. See Appendix A. Material Definitions for specific material types used for data reporting in this report.

Post-consumer	The status after an item has been used for its intended purpose. Post-consumer material may be generated by households or commercial establishments.
Post-consumer resin (PCR)	A type of recycled content that comes from material generated by households or commercial facilities as end users of a product or package which the consumer determines to no longer be useful for its intended purpose. This includes returning materials from within the distribution chain [8].
Post-industrial	Also called pre-consumer, post-industrial material has been processed initially and failed to meet specifications or is available in surplus and is then sold to another party for reuse or reprocessing. It can also include scraps left over from the manufacturing process that are often reincorporated back into the manufacturing process. Post-industrial material is not post-consumer material unless the manufactured item had been used for its intended use and was directed toward disposal [1].
Post-industrial resin (PIR)	Also called pre-consumer resin, this type of recycled content comes from material diverted from the waste stream during the manufacturing process [8].
Positive sort	The process of separating the desired resin type or material from the inbound recycling stream.
Recovery	Material that is diverted from the solid waste stream for the intended purpose of recycling, composting, burning source-separated materials for energy, anaerobic digestion, land application, and other beneficial uses [1].
Recyclable commodity	Also called a marketable commodity, material—such as PET bottles or PE film—that is collected, sorted into homogenous categories, baled, and sold to reprocessors other end users to recycle into new feedstock material for manufacturing or other production processes.
Recyclables/ recyclable materials	Those materials identified for collection, processing, recovery, or reuse as part of a local government, business, or other recycling collection program [1]. This term is not synonymous with "recycled materials," since not all recyclables end up being remanufactured into new items.
Recycling	Transforming or remanufacturing waste materials into usable or marketable items for use other than landfill disposal or incineration. The term "recycling" as it is commonly used often also refers to the process of

	collecting and sorting material for reprocessing into feedstock, as well as a term for the recyclable materials themselves.[1]
Reprocessor	Also called a reclaimer, these companies purchase post-consumer or post-industrial recycled commodities and process into resin feedstock to sell to manufacturers. For plastics reprocessors, end products include pellet, flake, and other resin products. Some vertically integrated reprocessors also have manufacturing operations and may use the recycled content feedstock that they reprocess in the production of their own products.
Residential sector	Includes solid waste and recyclable materials collected from single-family and multifamily residences as well as self-hauled materials delivered to transfer stations or other drop-off collection locations and reported or estimated to be from residential generators.
Residual	Material that is discarded in the sortation process because it is non-accepted material or contamination or is a recyclable material that is lost during sorting due to its small size or because or mis-sorting. Residual materials are typically sent for disposal.
Reverse logistics	The process where typically large businesses backhaul materials using their own supply chains and/or distribution channels.
Sent for reprocessing	Refers to tons of baled recyclable commodities that are sold by MRFs to reprocessors. We have avoided using the term “sent for recycling” since some of the material sent from MRFs will be lost during reprocessing and not end up being recycled.
Secondary MRF	An industrial facility that accepts low-volume or low-value materials from MRFs and conducts further separation, contamination removal, and aggregation to transform these materials into marketable grades for sale to recycling markets [1].
Self-haul	Waste that is hauled to a transfer, processing, or disposal facility by someone other than a waste hauler or by someone whose primary business is not waste hauling.
Single stream	A municipal, commercial, or industrial practice in which multiple recyclable materials are combined for collection, with no sorting required by the generator. Sorting is performed at a central location, such as a MRF [1].

[1] Where possible, we have tried to use precise language to indicate when we are referring to the process of collecting materials for recycling versus the actual transformation of used products and packaging into feedstock for new materials.

Source separation	A municipal, commercial, or industrial recycling practice that requires sorting of different recyclable materials such as glass, metals, paper, and plastics at the point of generation prior to collection. Source-separated materials may still be taken to a MRF for baling [1].
Transfer station	A facility that receives and consolidates solid waste and/or recyclables from collection trucks and other vehicles and loads the wastes onto tractor trailers, railcars, or barges for transportation to often distant disposal or recycling facilities [1].
Waste diversion	The act of redirecting waste away from landfill disposal and incineration and instead into recycling or other beneficial uses.
Waste-to-energy facility (incinerator)	A facility where recovered municipal solid waste is converted into a usable form of energy, usually through a process of combustion [1].
Waste stream	The flow of solid waste from its source, such as households or businesses, through to recovery, recycling or final disposal.
Yield	The proportion of material in a purchased commodity bale that a reprocessor can actually use to make recycled content feedstock.

Executive Summary

The Washington State Department of Ecology (Ecology) hired an independent third-party consultant team to study how plastic packaging is managed in Washington and assess various policy options to meet the following goals:

- Plastic packaging sold into the state is 100 percent recyclable, reusable, or compostable by January 1, 2025.
- Plastic packaging sold into the state incorporates at least 20 percent post-consumer recycled content by January 1, 2025.
- Plastic packaging is reduced when possible and optimized to meet the need for it.

As part of this assessment, the team researched and compiled data on plastic packaging waste generation, disposal, and management in Washington. This report describes these findings as well as the infrastructure necessary for a plastic packaging management system that meets the intent of the Legislature's goals under Chapter 70A.520 RCW.

To assess the current plastic packaging management system conditions, costs, and outcomes, the study team utilized data provided by Ecology, supplemented with additional reference data and further primary research where needed. There are currently no data available on the amount and types of plastic packaging sold into the state. While producers of plastic packaging—including brand owners, manufacturers, and importers—have internal records of this information, they do not disclose it voluntarily. In absence of available data on plastic packaging sales, the consultant team used data related to "downstream" management of plastic packaging waste to estimate the total amount of plastic packaging waste generated annually in the state.

Because the estimates developed for this study rely primarily on data from the 2015-16 Washington Statewide Waste Characterization Study, the definition of plastic packaging used for this study includes the materials defined under the "Plastic Packaging" category in that study, with the exception of polylactic acid (PLA)/compostable packaging (#28). For reporting purposes, plastic packaging types have been organized into two groups:

- **Rigid and foam plastic packaging** includes all rigid plastic bottles, containers, and other rigid packaging, foam packaging, and plastic composite packaging, which is predominantly rigid plastic but contains non-plastic elements.
- **Plastic film and flexible plastic packaging** includes all plastic bags (except trash bags as these were considered plastic products in the Statewide Waste Characterization Study), all industrial and non-industrial plastic film (except plastic sheeting, tarps, or other non-packaging film), plastic pouches, and all other flexible plastic packaging.

Plastic Packaging Amounts

In 2017, an estimated **410,300 tons of plastic packaging waste** was generated by residents and businesses in Washington State—the equivalent of roughly **112 pounds of plastic packaging waste per person per year**—though application of the waste composition confidence interval calculations suggests that actual generation could range between 316,190 tons (87 pounds per person per year) and 504,350 tons (138 pounds per person per year). Approximately half (211,340 tons) of all plastic packaging tons estimated is classified as **rigid and foam plastic packaging**, with the remaining material (198,960 tons) is classified as **plastic film and flexible plastic packaging.**

Table 1 shows the estimated amounts and types of plastic packaging waste generated in Washington State in 2017 (the most recent year for which all relevant datasets are available).

Table 1 Types and Amounts of Plastic Packaging Waste Generated Statewide, 2017

Plastic Packaging Waste Material Type	Est. Tons Generated	*Est. Tons Range (Low - High)*	% Residential Generation	% Commercial Generation
Rigid & Foam Plastic Packaging	**211,340**	*(161,100 - 261,580)*	**55%**	**45%**
#1 PET Bottles	55,730	*(44,880 - 66,560)*	61%	39%
#1 PET Other Packaging	35,950	*(27,970 - 43,930)*	55%	45%
#2 HDPE Natural Bottles	22,260	*(17,560 - 26,970)*	41%	59%
#2 HDPE Colored Bottles	19,870	*(16,260 - 23,470)*	64%	36%
#2 HDPE/LDPE Other Packaging	9,580	*(6,220 - 12,960)*	49%	51%
#5 PP Packaging	24,290	*(20,010 - 28,560)*	54%	46%
Other Rigid Plastic Packaging	12,930	*(8,870 - 16,980)*	62%	38%
Polystyrene Foam Packaging	23,350	*(15,660 - 31,030)*	57%	43%
Plastic Composite Packaging	7,490	*(3,760 - 11,210)*	24%	76%
Plastic Film & Flexible Packaging	**198,960**	*(155,120 - 242,800)*	**36%**	**64%**

Plastic Packaging Waste Material Type	Est. Tons Generated	*Est. Tons Range (Low - High)*	% Residential Generation	% Commercial Generation
PE Plastic Bags & Film	89,030	*(68,350 - 109,700)*	24%	76%
Other Plastic Film & Flexibles	109,930	*(86,760 - 133,090)*	46%	54%
Total Tons	**410,300**	*(316,190 - 504,350)*	**46%**	**54%**
Pounds Per Person Per Year	**112**	*(87 - 138)*		

Source: 2015-16 Washington Statewide Waste Characterization Study and Dept. of Ecology data.
Note: Due to data limitations, it is impossible to completely distinguish between packaging and non-packaging plastic in generation estimates for various categories, but this distinction has been made where possible.

Plastic Packaging Waste Management

There are several types of programs, activities, and entities that currently manage plastic packaging in Washington, including:

- **Reduction and reuse**: while there is no comprehensive statewide reduction and reuse strategy for plastic packaging, local initiatives such as plastic bag bans or requirements for recyclable/compostable food serviceware exist in many jurisdictions. There are also some small-scale refill and reuse initiatives operated by private businesses.
- **Recycling collection:** statewide, jurisdictions rely on a combination of methods for recycling collection, including residential and commercial (including industrial and institutional) curbside collection, self-haul/drop-off of recyclable plastics, and reverse logistics collection (backhauling) of recyclable plastic film from retail locations back to distribution centers.
- **Sorting and marketing of collected recyclables:** residential and commercial recyclables collected in a commingled stream generally flow through one of nine materials recovery facilities (MRFs) for sortation into recyclable commodities. Most MRFs in Washington typically produce at least three types of recyclable commodities that include plastic packaging: #1 PET bottles, #2 natural HDPE bottles, and #2 colored HDPE bottles. Depending on market dynamics, volume and material mix of incoming loads, local government contract requirements, and installed technological capabilities, some MRFs also produce additional recyclable plastic commodities like #5 PP, mixed rigid plastics, mixed bulky rigid plastics, and film.
- **Landfill disposal and incineration**: the majority of plastic packaging not collected for recycling is collected along with other solid waste for disposal, most of which is sent to

landfills in Washington or Oregon. The City of Spokane Solid Waste Department operates the one solid waste incinerator in the state—the Spokane Regional Waste-to-Energy Facility.

- **Litter clean-up:** a litter tax of 0.0015 percent on retail sales of 13 categories of products that are commonly littered generates about $11.4 million annually to fund litter clean-up and other waste reduction and recycling programs.
- **Contamination clean-up by recycling facilities, reprocessors, and end users**: contamination has been steadily increasing over the past two decades, and efforts and investments to address it have largely fallen to MRFs using manual sorting and additional sorting technologies, though state and local governments have also implemented education and outreach initiatives and contamination reduction plans. Reprocessors and end users of recyclable commodities, such as paper mills, as well as commercial composting operations that operate and receive materials generated within the state also invest a substantial amount of time and resources dealing with plastic packaging contaminants in materials received.

Plastic Packaging Contamination in Recycling and Compost Streams

While non-accepted plastic packaging is just one of multiple materials contributing to the increasing problem of undesirable materials in the commingled recycling stream, or recycling contamination, it is growing both in relative proportion and quantity. Contamination arriving at MRFs ends up in one of two places: ejected from the sortation process, thereby ending up as residuals disposed as solid waste, or inadvertently embedded in bales of recyclable commodities sold to reprocessors and end users of recyclable materials. While no statewide data exist, a recent study of Puget Sound MRFs found that, on average, two percent (by weight) of total inbound commingled recycling tons were non-program (not accepted by the collection program) plastic packaging. As plastic is so light, it can have a substantial volume to weight ratio and disproportional negative impact. Non-program plastic packaging represented approximately ten percent of total contamination, with non-recyclable glass, non-recyclable and compostable paper, and other mixed residue comprising the majority of remaining contamination [9].

The composition of materials ejected from the commingled recyclable sorting process and disposed as residual waste is largely undocumented, though the above-mentioned King County study found that more than eight percent (by weight) of sampled residuals ejected during the sortation process at four Puget Sound regional MRFs was recyclable plastic packaging and another six percent was non-recyclable plastic packaging [9].[2] Another study conducted as part of a pilot project assessing the feasibility of a secondary sorting facility in the Pacific Northwest

[2] These figures represent combined residential and commercial material as they are mixed together during the sorting process.

found that plastics represented approximately 17 percent of MRF residue samples collected for the pilot [10].

Very limited data are also publicly available about contamination in recyclable commodity bales, though the King County study found that contamination from plastic packaging ranged between 0.4 percent and 5.2 percent across the categories of commonly produced commodity bales by Puget Sound regional MRFs [9].

No one has yet conducted a statewide study about plastic packaging contamination in the compost stream. However, based on organics composition estimates from a recent Seattle Public Utilities study, as well as organics materials data reported to Ecology, we estimate that while plastic packaging only makes up 0.4 percent of total tons of organics collected containing post-consumer food waste, it represents 29 percent (by weight) of the total amount of contaminants.

Plastic Packaging Disposition

Disposal is the most common fate for plastic packaging in Washington. In 2017, Washington residents and businesses disposed of an estimated **330,990 tons of plastic packaging**. Just under half (155,220 tons) of all estimated plastic packaging tons disposed is classified as rigid and foam plastic packaging, with the remaining material (175,770 tons) classified as plastic film and flexible plastic packaging**.**

In the residential sector, rigid and foam plastic packaging types represent the majority (57 percent) of plastic packaging disposed (85,700 tons of 151,450 total tons). In the commercial sector, the majority (61 percent) of plastic packaging disposed is plastic film and flexible plastic packaging (110,020 tons of 179,540 total tons).

Substantial amounts of readily recyclable rigid plastic packaging types are also disposed by both residential and commercial generators. In fact, the three plastic packaging materials that make up the most commonly produced and marketable recyclable plastics**—*#1 PET Bottles, #2 HDPE Natural Bottles,* and *#2 HDPE Colored Bottles*—represent approximately 40 percent of all rigid and foam plastic packaging disposed** (62,070 tons of 155,220 total). This proportion is consistent across both residential and commercial sectors. Expanding the list of recyclable plastics to include *#1 PET Other Packaging, #2 HDPE/LDPE Other Packaging,* and *#5 PP Packaging* increases the proportion to nearly three-quarters **(74 percent) of all rigid plastic packaging disposed** (114,740 tons of 155,220 total).

Table 2 provides detailed data on plastic packaging disposed both by sector and material type.

Table 2 Plastic Packaging Disposed, by Sector and Material Type

Material	Residential Tons Disposed	Commercial Tons Disposed	Total Tons Disposed
Rigid & Foam Plastic Packaging	**85,700** (60,160-111,230)	**69,520** (44,830-94,250)	**155,220** (104,990-205,470)
#1 PET Bottles	20,610 (12,940-28,270)	14,290 (11,110-17,460)	34,890 (24,050-45,730)
#1 PET Other Packaging	17,210 (13,310-21,110)	11,850 (7,760-15,930)	29,060 (21,080-37,040)
#2 HDPE Natural Bottles	6,030 (4,520-7,550)	8,230 (5,040-11,430)	14,270 (9,560-18,970)
#2 HDPE Colored Bottles	8,380 (6,070-10,680)	4,540 (3,240-5,830)	12,910 (9,310-16,520)
#2 HDPE/LDPE Other Packaging	3,680 (2,250-5,110)	4,460 (2,520-6,410)	8,140 (4,780-11,520)
#5 PP Packaging	8,160 (6,720-9,590)	7,310 (4,470-10,150)	15,470 (11,190-19,740)
Other Rigid Plastic Packaging	6,930 (4,230-9,640)	3,620 (2,270-4,970)	10,550 (6,490-14,600)
Polystyrene Foam Packaging	12,890 (9,520-16,260)	9,560 (5,240-13,870)	22,450 (14,760-30,130)
Plastic Composite Packaging	1,810 (590-3,020)	5,680 (3,160-8,190)	7,490 (3,760-11,210)
Plastic Film & Flexible Packaging	**65,750** (53,920-77,590)	**110,020** (78,010-142,020)	**175,770** (131,930-219,610)
PE Plastic Bags & Film	16,320 (12,200-20,430)	50,960 (34,400-67,520)	67,280 (46,600-87,950)
Other Plastic Film & Flexible Packaging	49,440 (41,720-57,150)	59,060 (43,620-74,500)	108,500 (85,330-131,660)
Total Tons	**151,450 (114,080-188,820)**	**179,540 (122,840-236,270)**	**330,990 (236,920-425,080)**
Pounds Per Person Per Year			***91 (65-116)***
Pounds Per HH			***209 (149-268)***

Source: 2015-16 Washington Statewide Waste Characterization Study and Dept. of Ecology data

Plastic Packaging Recycling

In 2017, an estimated **69,410 total tons of plastic packaging were collected for recycling** from the residential and commercial sectors, representing approximately 17 percent of total tons of plastic packaging waste generated. An additional 9,890 tons (2.4 percent of total tons generated) of plastic packaging were collected but not effectively captured for recycling and/or were deemed non-recyclable and ejected from the sortation process as residuals.

Overall recycling rates for plastic packaging in Washington, calculated by combining the estimates for residential and commercial sector recycling and generation, are presented in Table 3 below. Regional patterns of rigid and foam plastic packaging across residential and commercial sectors are presented in Table 4 below.

Table 3 Plastic Packaging Recycling Rates, Overall

Material	Tons Collected for Recycling	Tons in Residue/ Rejected	Tons Sent as Commodities for Reprocessing	Total Tons Generated	Recycling Rate
Rigid & Foam Plastic Packaging	**56,110**	**5,980**	**50,130**	**211,340** (161,100-261,580)	**24%** (19-31%)
#1 PET Bottles	20,830	1,810	19,020	55,730 (44,880-66,560)	34% (29-42%)
#1 PET Other Packaging	6,890	370	6,520	35,950 (27,970-43,930)	18% (15-23%)
#2 HDPE Natural Bottles	8,000	140	7,860	22,260 (17,560-26,970)	35% (29-45%)
#2 HDPE Colored Bottles	6,950	350	6,600	19,870 (16,260-23,470)	33% (28-41%)
#2 HDPE/LDPE Other Packaging	1,440	40	1,400	9,580 (6,220-12,960)	15% (11-23%)
#5 PP Packaging	8,820	2,850	5,970	24,290 (20,010-28,560)	25% (21-30%)
Other Rigid Plastic Packaging	2,380	140	2,240	12,930 (8,870-16,980)	17% (13-25%)
Polystyrene Foam Packaging	900	260	640	23,350 (15,660-31,030)	3% (2-4%)
Plastic Composite Packaging	0	0	0	7,490 (3,760-11,210)	0% (0-0%)
Plastic Film & Flexible Packaging	**23,190**	**3,910**	**19,280**	**198,960** (155,120-242,800)	**10%** (8-12%)
PE Plastic Bags & Film	21,750	2,470	19,280	89,030 (68,350-109,700)	22% (18-28%)
Other Plastic Film & Flexible Packaging	1,430	1,430	0	109,930 (86,760-133,090)	0% (0-0%)
Total Tons	**79,300**	**9,890**	**69,410**	**410,300** (316,190-504,350)	**17%** (14-22%)

Table 4 Recycling of Rigid & Foam Plastic Packaging, by Region[3]

Region	Tons Sent for Reprocessing	Tons Generated	Regional % of Tons Sent for Reprocessing	Regional % of Tons Generated	Recycling Rate
Central	2,390	36,360	5%	17%	7%
East	3,890	31,490	8%	15%	12%
Northwest	4,540	12,710	9%	6%	36%
Puget Sound	32,650	104,440	65%	49%	31%
Southwest	5,240	19,820	10%	9%	26%
West	1,430	6,520	3%	3%	22%
State Total	**50,130**	**211,340**			**24%**

Little information is available about where these commodities are sent or what portion is ultimately recycled into new products and packaging. Although no reliable data are available to trace the flow of commodities to end markets, it is assumed that very little rigid plastic packaging collected in Washington is reprocessed in-state due, in part, to the lack of facilities in Washington that reprocess plastics collected from curbside recycling programs. As with the final destination of commodities, the end uses are also largely unknown.

Cost of Managing Plastic Packaging Waste

Though costs are incurred at various points throughout the waste management system, the net costs of managing plastic packaging waste ultimately fall on Washington residents and businesses. They pay through rates to service providers for garbage, recycling, and organics collection services, through tipping fees paid directly at disposal and recycling facilities, and through direct expenditure by businesses that generate plastic packaging waste and pay for its full management directly.

Residential recycling system costs attributable to plastic packaging—including collection, sorting, and disposal—total approximately $37 million annually. Commercial recycling system costs attributable to plastic packaging total approximately $26.8 million annually. Residential disposal system costs attributable to plastic packaging total approximately $44.4 million annually and commercial disposal system costs attributable to plastic packaging total approximately $56.8 million annually. Across both recycling and disposal systems, approximately two-thirds of these costs are incurred in the collection phase.

Overall, annual costs attributable to management of plastic packaging from the residential sector through recycling and disposal total approximately $81.4 million. Costs attributable to the

[3] These regional designations come from the Waste Generation Areas used in the 2015-16 Washington Statewide Waste Characterization Study and differ somewhat from Ecology's regional designations. See Figure 1 for a map of Waste Generation Areas.

commercial sector total approximately $83.6 million. Combined, these estimates indicate that **costs attributable to management of plastic packaging through recycling and disposal in Washington total approximately $165 million per year.**

We estimate that the costs of managing contamination in the organics stream attributable to plastic packaging contamination is approximately **$2.6 million** each year. As with all ratepayer-funded services, these costs are ultimately passed on to the ratepayers—residents and businesses—who pay more for organics collection services as a result.

The litter tax generates about $11.4 million annually, and we estimate that **$649,000 per year** is attributable to plastic packaging. Outside of the litter tax, local governments spent additional funds for litter clean-up but data are not sufficient to estimate how much is spent or how much can be attributed to plastic packaging management.

In addition to the economic costs incurred, plastic packaging waste that is generated in Washington represents substantial costs incurred by all current and future state residents, the global community, and the environment in the form of climate pollution from greenhouse gas (GHG) emissions associated with plastic packaging throughout its lifecycle, which are primarily generated during material acquisition and manufacturing using virgin inputs. Applying Washington's social cost of carbon of $74/ton and the latest WARM emissions factors to the generation data gathered, we estimate that plastic packaging waste—as generated and managed as of 2017—represents approximately 757,000 metric tons of carbon dioxide equivalent ($MTCO_2e$) and an externalized cost of roughly **$56 million annually**.

The environmental and social costs and impacts of plastic packaging waste generated in Washington that ends up as litter and marine debris is unable to be calculated at this time.

Contamination and Sorting Issues

Several issues and materials related to plastic packaging in the recycling system reduce the overall amount of collected material that can be recycled into new products and packaging. This includes operational contaminants that disrupt sorting equipment at MRFs—such as plastic bags and film, flexible packaging, small format packaging elements, and polystyrene foam packaging, especially foodservice packaging—as well as equipment at reprocessors and end users of other materials like paper, in which plastic contamination often ends up. Unmarketable commodities, including much of the non-bottle rigid plastic packaging, can technically be captured, but have insufficient generation volume at an individual MRF or insufficient end market demand to justify the investment needed to do so. Other components and formats, such as shrink sleeve labels, closures with metal components, multi-resin components, and non-recyclable lookalikes that are difficult to distinguish are additional sources of contamination in plastic bales. Finally, toxic chemicals and additives in plastics can limit recyclability of plastic as well as its safety for reuse, especially for food contact or other sensitive applications.

Recycling Plastic Packaging for Environmental Benefit

Recyclability is not an end goal itself but rather a means to achieving the larger goal of reducing the lifecycle impacts of production, consumption, and disposal, and delivering environmental benefits. For recycling of plastic packaging to deliver environmental benefits, collected materials must be reprocessed and used in new products and packaging in place of virgin resins and reduce resource extraction and prime plastic production overall. Moreover, plastic recycling itself must be done in a manner that protects human health and the environment. It cannot be assumed that simply designating plastic packaging as "recyclable" achieves the State's goal. To qualify as recyclable, plastic packaging must be shown to have been recycled—in practice and at scale—safely and with environmental benefit.

The current system lacks sufficient transparency and accountability around the final destination of plastic packaging sent for processing and therefore fails to provide assurance that materials are in fact responsibly recycled or that any environmental benefits are actually achieved. There is presently no verification that materials arrive at legitimate reprocessing facilities equipped to recycle plastics without causing harm to human health and the environment. And there is little information about how much of the materials received at reprocessing facilities is actually transformed into a recycled feedstock used to offset virgin materials in production of new products.

One of the primary reasons why so little is known about the recycling phase of plastic packaging collected from residents and business in Washington is that much of the material collected has also historically been exported outside of the U.S. for recycling (especially compared with states that have domestic reclamation capacity nearby). Relatively few companies operate plastic reprocessing facilities in the U.S. that handle post-consumer materials, and those that do often pay a premium for plastic scrap bales from deposit return systems, which deliver higher quality and larger volume materials than curbside system in Washington.

The economics of low oil prices and weak (if any) demand for many post-consumer recycled content plastic resins, access to historically cheap ocean shipping to Asia, and lack of regulatory controls on the export of plastic waste have all contributed to a "recycling" system for plastic packaging collected through curbside and commercial programs in Washington that cannot be said to reliably deliver environmental benefit. There is a large opportunity to transition to an optimized recovery system anchored in economically, socially, and environmentally sustainable management.

Necessary Infrastructure and Interventions to Manage Plastic Packaging Waste

The infrastructure needed for a plastic packaging recycling system that delivers environmental benefits is built upon:

- Creation of **demand** for recycled plastics
- Development of a **transparent system** for tracking collected plastics through to their final destination to ensure that they are recycled in ways that reduce overall environmental impacts and protect human health and the environment
- Enforcement of a system of **accountability** that holds those involved in plastic production and recycling responsible for the impacts of their operations

Until these three elements of infrastructure**—demand, transparency, and accountability—** are in place, discussion of other physical or operational infrastructure needs to manage plastic packaging through recycling is premature.

As noted in a recent report from a plastics industry initiative to evaluate the feasibility of recycling flexible plastic packaging, "demand for recycled feedstocks to replace virgin materials in products is required to justify the investment needed to collect, sort, and create a marketable commodity. … [Currently] the cost of collecting and processing flexible plastic packaging outweighs its value as a commodity that can be sold back to industry. Unless industry end users (product manufacturers, retailers and e-commerce), public works end users (government agencies) and consumers buy recycled products, the markets for the material put out at the curb or into store drop-off receptacles will remain anemic" [11]. Even though this initiative was focused on testing the technical feasibility of collecting and processing flexible plastic packaging for recycling, the top recommendation that surfaced from the multi-year effort was "build demand."

This need for increased demand to drive environmentally beneficial recycling applies not only to flexible plastic packaging but to all plastic packaging. Low oil prices and aggressive construction of prime plastics production facilities in the U.S. and globally have made it virtually impossible for recycled plastics of all resin types to compete with virgin resins in an unregulated open market [12]. In the current economic landscape, demand creation will rely on government interventions such as recycled content mandates, taxes on virgin materials (ideally on upstream feedstock such as oil and natural gas rather than on downstream feedstock such as virgin resin, paper, etc.), or other public policies to correct for the market failures that externalize the environmental and social costs of virgin plastic production and use. Demand for recycled plastic packaging must show up in the form of long-term, multi-year contracts that enable suppliers to make the capital investments required to build new infrastructure to fill the gaps in the recycling system and to operate responsibly.

In theory, all plastic packaging types that have demonstrated recyclability—including reliable end markets, and evidence that they can be recycled safely and with environmental benefits—can and should be consistently collected across all jurisdictions in Washington. Under current market conditions, however, very little plastic packaging meets this definition of recyclability, so much work remains to be done to assess the appropriateness of including plastic packaging types on a harmonized statewide collection list, even for standard plastic packaging types considered "recyclable" and widely collected under the current system. Such considerations also impact future packaging materials and formulations, which may not be compatible with current recovery systems and arguably should be assessed for appropriateness prior to being allowed entry to market.

In advance of addressing collection infrastructure considerations, system changes are needed to increase demand for recyclable plastics, install systems to ensure transparency and accountability for responsible recycling, improve product designs for recyclability, and develop infrastructure for more effective plastics separation. Assuming these elements are addressed, there is still more that can be done to increase the collection of non-reusable plastic packaging for recycling.

There are four avenues for improving plastic packaging collection in Washington, each with its own infrastructure and investment needs:

- Expanding access to recycling collection service
- Harmonizing plastic packaging types collected
- Aligning collection methods with sortation and reprocessing systems
- Improving participation in recycling collection systems

After it is collected, plastic packaging must be separated by resin type with existing commercial-scale technology in order to be effectively recycled for environmental benefit. To increase the responsible recycling of plastic packaging collected in Washington, additional sortation is needed. This could happen through several different possible configurations, including additional positive sorting for other plastic packaging types at primary MRFs, or through use of secondary processing (either via a secondary MRF or plastics recovery facility) to further process material from the primary MRF. Local reprocessing, such as through secondary MRFs or a plastics recovery facility (PRF), could add value to feedstock and contribute to the local economy, even if the material is then exported out of state.

1.0 Introduction

1.1 Background

In 2019, the Washington Legislature passed the Plastic Packaging Evaluation and Assessment law (Chapter 70A.520 RCW), which states that producers of plastic packaging should consider the design and management of their packaging in a manner that ensures minimal environmental impact. Per the law, the Washington State Department of Ecology (Ecology) hired an independent third-party consultant team to study how plastic packaging waste is managed in Washington and assess various policy options to meet the following goals:

- Plastic packaging sold into the state is 100 percent recyclable, reusable, or compostable by January 1, 2025.
- Plastic packaging sold into the state incorporates at least 20 percent post-consumer recycled content by January 1, 2025.
- Plastic packaging is reduced when possible and optimized to meet the need for it.

The consultant team was tasked with developing options to meet these goals that can be established and implemented by January 1, 2022 for the purposes of legislative consideration.

As part of this assessment, the team researched and compiled data on plastic packaging waste generation, disposal, and management in Washington. This report describes these findings related to the plastic packaging management system in accordance with the elements requested under Chapter 70A.520 RCW. The report is organized into the following sections:

- Section 2.0 Plastic Packaging Waste Types and Amounts
- Section 3.0 Plastic Packaging Waste Management Programs and Activities
- Section 4.0 Plastic Packaging Waste Contamination
- Section 5.0 Plastic Packaging Waste Disposition
- Section 6.0 Cost of the Current Plastic Packaging Waste Management System
- Section 7.0 Contamination and Sorting Issues
- Section 8.0 Necessary Infrastructure and Interventions to Manage Plastic Packaging Waste

1.2 Methodology

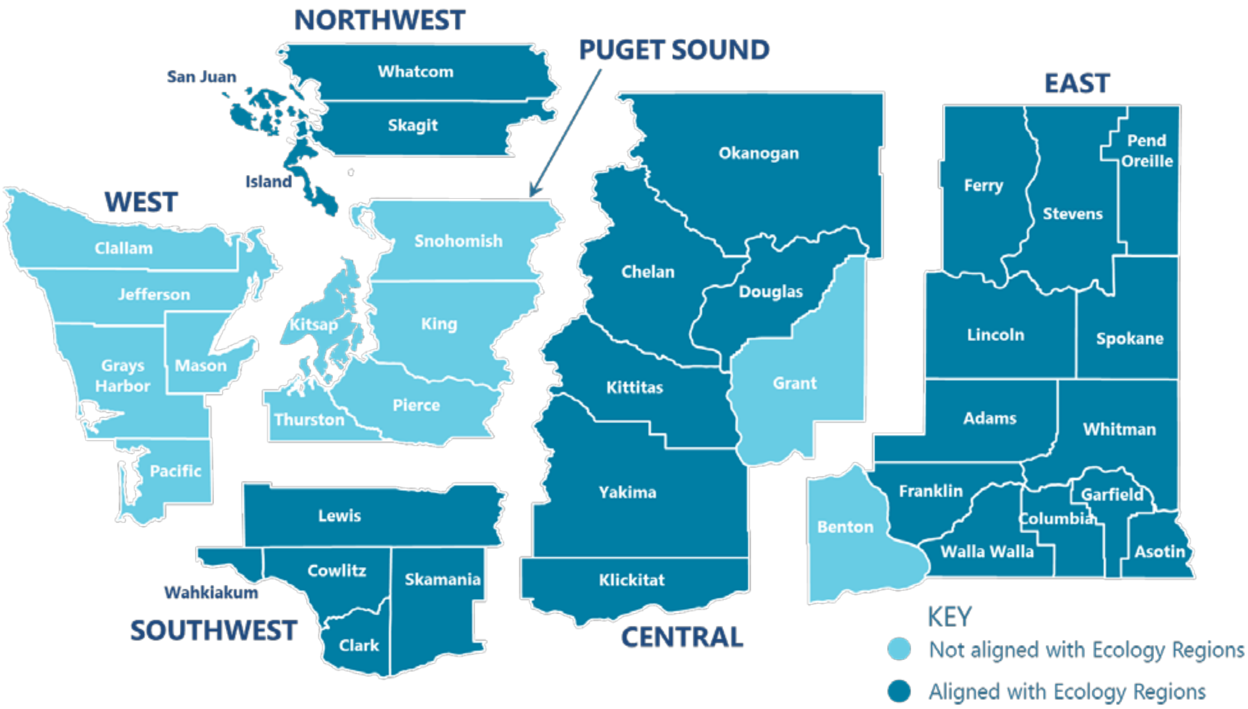
To assess the current plastic packaging management system conditions, costs, and outcomes, the study team utilized data provided by Ecology, supplemented with additional reference data and further primary research where needed. All data used were derived from Washington State sources except for the weight to volume conversion factors used for estimating costs of recycling collection and sorting on a volume basis.

A complete description of the data sources used, assumptions included in quantitative modeling, and of the additional primary research conducted is provided in Appendix B: Technical Methodology.

In order to combine and compare data from multiple sources, the study team developed a set of material categories that could be consistently applied to relevant source data. See Appendix A. Material Definitions for the list and definitions of material categories used across analyses presented in this report.

In addition, to maintain consistency across all the sources used, the consultant team categorized and analyzed data by region, using the six waste generation areas defined in the 2015-16 Washington Statewide Waste Characterization Study: Central, East, Northwest, Puget Sound, Southwest, and West. Figure 1 below illustrates the regional assignments for all counties in Washington, and these are the regions referenced throughout the rest of this document. Table 5 shows the comparison between regional assignment between Ecology's designation and the waste generation area from the Statewide Waste Characterization for each county. The regional categories were derived from two key sources used throughout the report. These two sources are the 2015-16 Washington Statewide Waste Characterization Study data [13], provided by Ecology, and the data on residential recycling and organics collection service access from a 2019 Zero Waste Washington report [14].

Figure 1 Washington State Waste Generation Areas as Used Throughout the Report



Source: 2015-16 Washington Statewide Waste Characterization Study

Table 5 Comparison of Ecology and Statewide Waste Characterization Regional Designations by County

County	Ecology Region	Waste Generation Area
Adams	Eastern	East
Asotin	Eastern	East
Benton	Central	East
Chelan	Central	Central
Clallam	Southwest	West
Clark	Southwest	Southwest
Columbia	Eastern	East
Cowlitz	Southwest	Southwest
Douglas	Central	Central
Ferry	Eastern	East
Franklin	Eastern	East
Garfield	Eastern	East
Grant	Eastern	Central
Grays Harbor	Southwest	West
Island	Northwest	Northwest
Jefferson	Southwest	West
King	Northwest	Puget Sound

County	Ecology Region	Waste Generation Area
Kitsap	Northwest	Puget Sound
Kittitas	Central	Central
Klickitat	Central	Central
Lewis	Southwest	Southwest
Lincoln	Eastern	East
Mason	Southwest	West
Okanogan	Central	Central
Pacific	Southwest	West
Pend Oreille	Eastern	East
Pierce	Southwest	Puget Sound
San Juan	Northwest	Northwest
Skagit	Northwest	Northwest
Skamania	Southwest	Southwest
Snohomish	Northwest	Puget Sound
Spokane	Eastern	East
Stevens	Eastern	East
Thurston	Southwest	Puget Sound
Wahkiakum	Southwest	Southwest
Walla Walla	Eastern	East
Whatcom	Northwest	Northwest
Whitman	Eastern	East
Yakima	Central	Central

2.0 Plastic Packaging Waste Types and Amounts

Plastic waste is a growing presence around the world, with plastic packaging as a major component. A research paper published by McKinsey & Company estimates that, on average, Americans generate approximately 100 pounds per person of packaging annually, and that packaging and single-use foodservice plastics represent approximately 43 percent of all plastic used each year [15]. Studies conducted for the European Commission and Canada's Environment and Climate Change department have reported similar findings [16], [17].

This section describes the amount and types of plastic packaging waste currently estimated to be generated annually in Washington. There are currently no available data on the amount and types of plastic packaging sold in the state. While producers of plastic packaging—including brand owners, manufacturers, and importers—have internal records of this information, they do not disclose it voluntarily. In jurisdictions where extended producer responsibility (EPR) systems or other regulations require producers to report on the amounts and types of packaging, including plastic, information of this nature is available, but such a reporting requirement is not currently in place in Washington.

In absence of available data on plastic packaging sales, the consultant team used data related to "downstream" management of plastic packaging waste to estimate the total amount of plastic packaging waste generated annually in the state. This type of estimation has been used as a proxy for plastic packaging sales for planning purposes in other jurisdictions in advance of implementation of EPR systems and has shown to be reasonably accurate for planning purposes.

The total tonnage of plastic packaging production is an estimate based on the aggregated tonnage estimates of plastic packaging found in the following waste management streams:

- **Disposal** through commercial collection of waste from residential and commercial sector generators and through self-haul to waste transfer stations and disposal facilities.
- **Recycling collection**, including through curbside single-family and multifamily residential and commercial collection as well as materials self-hauled to transfer stations, dropboxes, and other drop-off locations for recycling. This category includes:
    - Plastic packaging consolidated and sold as **marketed commodities** to reprocessors and end users.
    - Plastic packaging rejected as **recycling residuals** during sorting of materials collected from residential and commercial generators.

- **Reverse logistics collection** of plastic bags and film, including return-to-retail collection of plastic bags and film from consumers and plastic film packaging generated by retail locations and distribution centers.

Note that any tonnages managed but not reported to or estimated by Ecology are not included in the generation estimate, except where additional data were reported directly to the study team during the study review periods.

Data from the following sources were used to inform other sections of this report but tonnage data reported from these sources was not included in generation estimates because it was assumed that it was previously represented in disposal data.

- Plastic packaging separated as **contaminants in organics collected** for composting from residential and commercial generators.
- **Litter** cleared from roadways and public spaces through Ecology-supported programs

Details on the amounts and types of plastic packaging waste estimated in each of these sources are provided in Section 5.0 Plastic Packaging Waste Disposition.

Because the estimates developed for this study rely primarily on data from the 2015-16 Washington Statewide Waste Characterization Study, the definition of plastic packaging used for this study includes the materials defined under the "Plastic Packaging" category in that study, with the exception of PLA compostable packaging (#28)[4] [13]. For reporting purposes, plastic packaging types have been organized into two groups:

Rigid and foam plastic packaging includes all rigid plastic bottles, containers, and other rigid packaging, foam packaging, and plastic composite packaging, which is predominantly rigid plastic but contains non-plastic elements.

Plastic film and flexible plastic packaging includes all plastic bags (except trash bags as these were considered plastic products in the Statewide Waste Characterization Study) all industrial and non-industrial plastic film (except plastic sheeting, tarps, or other non-packaging film), plastic pouches, and all other flexible plastic packaging.

[4] The original version of SB 5397 excluded packaging that meets ASTM D6400 or ASTM D6868 standard specifications from the definition of "plastic packaging."

The complete list of material definitions and categories used in this study is provided in Appendix A. Material Definitions.

Table 6 shows the estimated amounts and types of plastic packaging waste generated in Washington in 2017 (the most recent year for which all relevant datasets are available). Due to the relatively high degree of uncertainty associated with the estimates for plastic packaging categories in the 2015-16 Waste Composition Study, Table 6 shows both the generation estimates derived from application of the mean composition percentages and the estimated tonnage ranges based on application of the confidence interval (calculated at a 90% confidence level) for each material category in the study. All estimates are presented in tons and are rounded to the nearest ten unit.

In 2017, an estimated 410,300 tons of plastic packaging waste were generated by residents and businesses in Washington—the equivalent of roughly 112 pounds of plastic packaging waste per person per year—though application of the waste composition confidence interval calculations suggests that actual generation could range between 316,190 tons (87 pounds per person per year) and 504,350 tons (138 pounds per person per year). Approximately half (211,340 tons) of all plastic packaging tons estimated is classified as **rigid and foam plastic packaging**, with the remaining material (198,960 tons) is classified as **plastic film and flexible plastic packaging.**

It is important to note that, because the generation estimates presented here are based largely on composition estimates derived from disposed waste (since the majority of plastic packaging is found in the disposal stream), the quantities of plastic packaging disposed are likely overestimated due to the presence of moisture and contamination from food and other materials. This is especially true for lightweight packaging formats that are highly absorbent and/or susceptible to contamination from food or other debris, such as polystyrene foam packaging, and plastic bags, film, and flexible packaging. No data are available to reliably correct for this issue, but analyses conducted by the Oregon Department of Environmental Quality (DEQ) indicate that as much as 50 percent of the weight reported for these categories in waste characterization studies may actually be moisture and contamination.[5] Due to data limitations, it is also impossible to exclude some amount of non-packaging plastic and plastic products in generation estimates for certain categories of plastics.

However, because collection and management of commercial recyclables by generators directly through reverse logistics that do not pass through sorting facilities is unregulated and reported to Ecology on a voluntary basis, it is likely that some quantity of material handled through these channels is not reported and therefore contributes to an underestimate of generation. It is also

[5] Data on contamination correction factors used by Oregon DEQ are available at https://www.oregon.gov/deq/mm/Pages/Waste-Composition-Study.aspx

possible that some tons classified in source data as plastic packaging are actually plastic products, and vice versa.

Data reported to the State indicate that slightly less than half (46 percent) of plastic packaging waste was generated by the residential sector, and slightly more than half (54 percent) was generated by the commercial sector, but these patterns differ between the two material classifications. The residential sector generates slightly more than half (55 percent) of **rigid and foam plastic packaging.** In contrast, the commercial sector generates nearly two-thirds (64 percent) of **plastic film and flexible plastic packaging**, with just over one-third (36 percent) estimated to be generated by the residential sector, based on reported data.

Among **rigid and foam plastic packaging** types, *#1 PET Bottles* represent the largest portion of generation by weight, with an estimated 55,730 tons generated. Nearly two-thirds (61 percent) of *#1 PET Bottles* are estimated to be generated by the residential sector. Additionally, *#1 PET Other Packaging* and *#5 PP Packaging* represent the second and third most prevalent rigid packaging types by weight. Rigid polyethylene (HDPE/LDPE) packaging is broken into three separate material types (*HDPE Natural Bottles, HDPE Colored Bottles, HDPE/LDPE Other Packaging*), as these different packaging formats are typically baled and sold as separate commodities but, if combined, would represent the second largest portion of rigid packaging generation by weight.

Among **plastic film and flexible plastic packaging**, *PE Plastic Bags & Film*, which includes packaging materials that could clearly be identified as made of polyethylene (PE) resin and generally considered recyclable if collected clean and free of contaminants, represents slightly less than half (45 percent) of all plastic film and flexible plastic packaging (89,030 tons). More than three-quarters (76 percent) of this material type, which includes pallet wrap and other film used in the process of distribution and transport of goods, is generated by the commercial sector.

The remainder (109,930 tons, 55 percent) is categorized as *Other Plastic Film & Flexibles* and includes film packaging made from non-PE resin as well as multi-material flexible packaging formats. Due to the nature of the definitions used in the 2015-16 Washington Statewide Waste Characterization Study [13], it is likely that this category also includes some packaging that should actually be categorized as *PE Plastic Bags & Film*.

Table 6 Types and Amounts of Plastic Packaging Waste Generated Statewide, 2017

Plastic Packaging Waste Material Type	Est. Tons Generated	*Est. Tons Range (Low - High)*	% Residential Generation	% Commercial Generation
Rigid & Foam Plastic Packaging	**211,340**	*(161,100 - 261,580)*	**55%**	**45%**
#1 PET Bottles	55,730	*(44,880 - 66,560)*	61%	39%
#1 PET Other Packaging	35,950	*(27,970 - 43,930)*	55%	45%
#2 HDPE Natural Bottles	22,260	*(17,560 - 26,970)*	41%	59%
#2 HDPE Colored Bottles	19,870	*(16,260 - 23,470)*	64%	36%
#2 HDPE/LDPE Other Packaging	9,580	*(6,220 - 12,960)*	49%	51%
#5 PP Packaging	24,290	*(20,010 - 28,560)*	54%	46%
Other Rigid Plastic Packaging	12,930	*(8,870 - 16,980)*	62%	38%
Polystyrene Foam Packaging	23,350	*(15,660 - 31,030)*	57%	43%
Plastic Composite Packaging	7,490	*(3,760 - 11,210)*	24%	76%
Plastic Film & Flexible Packaging	**198,960**	*(155,120 - 242,800)*	**36%**	**64%**
PE Plastic Bags & Film	89,030	*(68,350 - 109,700)*	24%	76%
Other Plastic Film & Flexibles	109,930	*(86,760 - 133,090)*	46%	54%
Total Tons	**410,300**	*(316,190 - 504,350)*	**46%**	**54%**
Pounds Per Person Per Year	**112**	*(87 - 138)*		

Source: 2015-16 Washington Statewide Waste Characterization Study and Dept. of Ecology data.
Note: Due to data limitations, it is impossible to completely distinguish between packaging and non-packaging plastic or plastic products in generation estimates for various categories, but this distinction has been made where possible.

3.0 Plastic Packaging Waste Management Programs and Activities

This section describes existing programs, activities, and entities that currently manage plastic packaging waste in Washington, including:

- Reduction and reuse
- Recycling collection
- Sorting and marketing of collected recyclables
- Landfill disposal and incineration
- Litter clean-up
- Contamination clean-up at recycling facilities

3.1 Reduction and Reuse

In its 2015 Solid and Hazardous Waste Plan Update, *Moving Washington Beyond Waste and Toxics*, Ecology set a goal of reduced waste generation by both businesses and residents (Goal SWM 4) and identified State actions to take in support of this goal including researching and supporting growing reuse, repair, and sharing networks and opportunities (Action SWM 4C) and encouraging grant-funded projects that help reduce or prevent waste (Action SWM 4E).

The onset of China's National Sword/Blue Sky and other similar foreign policies restricting scrap material imports shed light on the limits to the current recycling system and further steered focus back to prioritizing reduction and reuse over recycling, especially for plastic packaging, which faces major collection challenges and limited domestic markets for recycling for many commodity streams. However, a comprehensive statewide reduction and reuse strategy for plastic packaging has yet to be implemented in Washington.

Local initiatives to reduce plastic waste have largely centered around plastic bag bans, single-use foodservice product ordinances, and requirements to use compostable and recyclable alternatives. At the state level, a bill was passed by the Legislature in 2020 (and subsequently vetoed due to COVID-19 related fiscal impacts) to require increased use of recycled content in plastic beverage containers—a form of waste reduction if the use of recycled content reduces overall production of virgin plastic.

The City of Seattle mandates all food service businesses to use recyclable or compostable foodservice products and accessories, including containers, cups, straws, and utensils. These businesses must also provide clearly labeled bins for customers to compost or recycle the items [18].

Before Washington passed a statewide ban on single-use plastic bags in March 2020, cities were taking initiative to pass their own bans. Edmonds became the first city in Washington to pass a plastic bag ban in 2009. Bellingham, Mukilteo, Seattle, Bainbridge Island, Port Townsend, and Issaquah followed suit [19]. By mid-2020, a total of 39 jurisdictions across the state had adopted similar bans [20].

Many jurisdictions, including the City of Seattle, also provide technical assistance and education to the public, including businesses and residents, on waste reduction and reuse resources and tips [21].

Although there are a small number of local packaging refill and reuse initiatives operated by private businesses, such as glass milk bottles managed through a deposit return system operated by Fresh Breeze Organic Dairy, no refill or reuse programs for products in plastic packaging or designed to reduce the use of plastic packaging are known to be in widespread use in the state.

3.2 Recycling Collection

Statewide, jurisdictions rely on a combination of methods for recycling collection, including residential and commercial (including industrial and institutional) collection, self-haul/drop-off of recyclable plastics, and reverse logistics collection (backhauling) of recyclable plastic film from retail locations back to distribution centers.

The various collection services described below are not exclusively for the collection of recyclable plastics. In fact, other packaging types and materials—such as paper, cardboard, and metal—represent the majority of tons collected and/or provide the majority of revenue generated from commodity sales.[6] According to a 2019 King County MRF assessment and characterization of single-stream recyclables, paper packaging and products made up nearly two-thirds (63 percent) of materials collected in residential recycling loads and nearly three-quarters (74 percent) of materials in commercial recycling loads, by weight [9]. Metal packaging and products make up a relatively small portion of collected materials by weight (five percent of residential tons and three percent of commercial tons), but recycling metal typically generates an outsized portion of revenue, because the material has relatively strong, reliable domestic market demand due to the cheaper production costs of using recyclable metal feedstock compared to virgin metal. Glass, including both recyclable containers and non-recyclable glass,

[6] While paper products are generally heavier than plastics, plastic can have a substantial volume to weight ratio and impact quality and value of commodities sold by MRFs.

made up approximately 16 percent of residential tons and 9 percent of commercial tons. Due to its the low market value and negative impacts of glass on sorting equipment and other commodity values, it also has an outsized impact on system costs.

Plastic packaging deemed acceptable for recycling collection in commercially collected loads in King County made up approximately six percent of residential tons and five percent of commercial tons. Plastic packaging that is not accepted for recycling collection (i.e., non-program plastic packaging) made up approximately one percent of total tons collected in both residential and commercial sectors. The lightweight nature of plastic packaging, however, makes weight-based composition estimates somewhat misleading, as plastic packaging represents a more significant portion of materials collected and sorted for recycling by volume.

The relative proportion of plastic packaging in collected recyclables has increased substantially over time. In 2001, plastic packaging represented just two percent (1,493 tons) of residential recycling collected in Seattle, one year after the city switched from a three-bin system to single-stream collection [22]. As part of the new contract that allowed single-stream collection, the accepted materials list expanded to include milk cartons, juice boxes, plastic dairy and yogurt containers, and plastic bags [23]. By 2015, the amount of plastic packaging had more than doubled both as a percentage of overall recycling stream composition (five percent of residential recyclables collected) and in total weight, (4,311 tons) of residential tons collected for recycling [24]. Recent trends in packaging that have driven more products into plastic packaging formats in place of other packaging materials suggest that the proportion of plastic packaging found in the city's upcoming 2020 composition study is likely to be even higher.

3.2.1 Residential Recycling Collection

Under state law, counties and cities must consider and plan for the source separation of recyclable materials from solid waste generators—including programs for the collection of source-separated materials from residences in urban and rural areas—as part of their comprehensive solid waste management plans [25]. The types and extent of programs provided vary widely and are influenced by geographic factors, jurisdictional regulatory authority, existing infrastructure, and local population density.

The following section describes:

- Who receives recycling collection service?
- What material gets collected and how?
- Who provides recycling collection service?
- What does recycling collection service cost and where is the payment assessed?

3.2.1.1 Who Receives the Service?

Around 2.8 million (89 percent) of Washington's 3.2 million households have access to residential curbside collection of recyclables, including plastic packaging, either as a universal service provided alongside (and paid for through) garbage collection service (embedded), a mandatory subscription service, or an optional subscription service. Minimum service levels for residential recycling collection are established by local governments as part of their Solid Waste Management Plans, as required by Chapter 70A.205 RCW.

Approximately two-thirds of households with access to curbside recycling reside in the Puget Sound region (1.9 million out of 2.8 million households with curbside access statewide), though the region represents a slightly smaller proportion (59 percent) of the state population overall. Many counties in the state require all residents with garbage service to have access to at least optional recycling service, and many require curbside recycling to be a universal service for all garbage customers. Access to service is not consistent statewide, however. As shown in Table 7, more than one-half (51 percent) of residents in the Central region, which represents eight percent of the state population, lack access to curbside recycling, and approximately one third of residents in the East and West regions lack access to curbside recycling (33 percent and 31 percent, respectively). When it is available, access in these regions is far more likely to be an optional service provided for a separate charge from garbage service. Residents in 11 of Washington's 39 counties have no access to curbside recycling anywhere in the county.

Table 7 Household Access to Residential Curbside Recycling Collection, by Region

Region	Total HHs (% of Total)	Access to Residential Curbside Recycling Collection: No RCY	Universal, Embedded	Universal, Mandatory	Optional Subscription
Central	244,233 (8%)	123,735 (51%)	38,055 (16%)	0 (0%)	82,443 (34%)
East	436,105 (14%)	142,402 (33%)	115,393 (26%)	9,982 (2%)	168,328 (39%)
Northwest	210,206 (7%)	14,169 (7%)	19,639 (9%)	123,402 (59%)	52,996 (25%)
Puget Sound	1,858,925 (59%)	173 (0%)	1,087,661 (59%)	771,091 (41%)	0 (0%)
Southwest	277,757 (9%)	35,627 (13%)	37,988 (14%)	203,895 (73%)	247 (0%)
West	143,378 (5%)	44,997 (31%)	24,383 (17%)	54,962 (38%)	19,036 (13%)
Statewide Total	**3,170,604 (100%)**	**361,103 (11%)**	**1,323,119 (42%)**	**1,163,332 (37%)**	**323,050 (10%)**

Source: primary analysis of 2019 data from Zero Waste Washington, WUTC tariffs, county Solid Waste Management Plans, and Washington Office of Financial Management.

As shown in Table 8, households that live in multifamily buildings are less likely to have access to recycling collection service than households in single-family dwellings. In places where recycling collection subscription is optional, current regulations allow property managers or owners—not tenants—to decide whether or not to subscribe. Approximately one-quarter of Washington households that live in multifamily dwellings do not have reliable access to recycling collection (though they may have some access to drop-off collection), including 15 percent that reside in areas where no multifamily recycling service is available and ten percent that live in areas where optional subscriptions are decided by property managers or owners. In contrast, only nine percent of residents in single-family dwellings reside in areas where no recycling collection service is available.

Table 8 Single-Family and Multifamily Household Access to Residential Curbside Recycling Collection, by Region

Region	Total SF HHs (% of Total SFs)	Total MF HHs (% of Total MFs)	No RCY		Access to Residential Curbside Recycling Collection: Universal, Embedded (% of Total SFs or MFs in each region)		Universal, Mandatory (% of Total SFs or MFs in each region)		Optional Subscription (% of Total SFs or MFs in each region)	
			SF	MF	SF	MF	SF	MF	SF	MF
Central	158,866 (8%)	85,367 (7%)	55,563 (35%)	68,172 (80%)	29,670 (19%)	8,385 (10%)	0 (0%)	0 (0%)	73,633 (46%)	8,810 (10%)
East	288,753 (14%)	147,352 (13%)	93,927 (33%)	48,475 (33%)	115,393 (40%)	0 (0%)	9,982 (3%)	0 (0%)	69,451 (24%)	98,877 (67%)
Northwest	146,264 (7%)	63,942 (6%)	811 (1%)	13,358 (21%)	15,438 (11%)	4,201 (7%)	84,628 (58%)	38,774 (61%)	45,387 (31%)	7,609 (12%)
Puget Sound	1,125,232 (56%)	733,693 (64%)	152 (0%)	21 (0%)	575,261 (51%)	512,400 (70%)	549,819 (49%)	221,272 (30%)	0 (0%)	0 (0%)
Southwest	194,150 (10%)	83,607 (7%)	24,745 (13%)	10,882 (13%)	28,550 (15%)	9,438 (11%)	140,714 (72%)	63,181 (76%)	141 (0%)	106 (0%)
West	101,931 (5%)	41,447 (4%)	11,583 (11%)	33,414 (81%)	18,919 (19%)	5,464 (13%)	54,962 (54%)	0 (0%)	16,467 (16%)	2,569 (6%)
Statewide Total	**2,015,196**	**1,155,408**	**186,781 (9%)**	**174,322 (15%)**	**783,231 (39%)**	**539,888 (47%)**	**840,105 (42%)**	**323,227 (28%)**	**205,079 (10%)**	**117,971 (10%)**

Source: primary analysis of 2019 data from Zero Waste Washington, WUTC tariffs, county Solid Waste Management Plans, and Washington Office of Financial Management.

No comprehensive data are available about subscription rates in areas where curbside collection is optional, but anecdotal data suggest it is low. For example, in Richland, only 27 percent of residents are reported to subscribe to curbside recycling collection service [26], and in Yakima, only seven percent of residents subscribe [27].

Residents who do not have access to curbside recycling collection—or, where it is optional, choose not to subscribe—may self-haul recyclable materials to transfer stations or other publicly provided drop-off locations. The relative convenience of these drop-off collection locations for residents varies widely.

Some retail locations in Washington also operate return-to-retail collection points for use by residents for recycling plastic bags and film. According to the database listing participating retail locations, this network of retailers includes 453 participating locations in Washington as of January 2020, of which approximately 58 percent are located in the Puget Sound region [28]. The relative convenience and functioning of these sites can vary widely.

Access to residential recycling collection, whether curbside or drop-off, does not guarantee access to plastic packaging recycling collection. More details on which plastic packaging materials are collected is provided below.

3.2.1.2 What Gets Collected?

As with service level requirements, the list of designated materials to be collected for recycling is set by each local government in its Solid Waste Management Plan, as required by RCW 70A.205.040 [29]. Cities that provide municipal or contracted recycling collection decide, in coordination with the service provider, which designated materials will be collected through curbside service. Drop-off locations sometimes accept materials that are designated as recyclable but not included in curbside recycling collection programs.

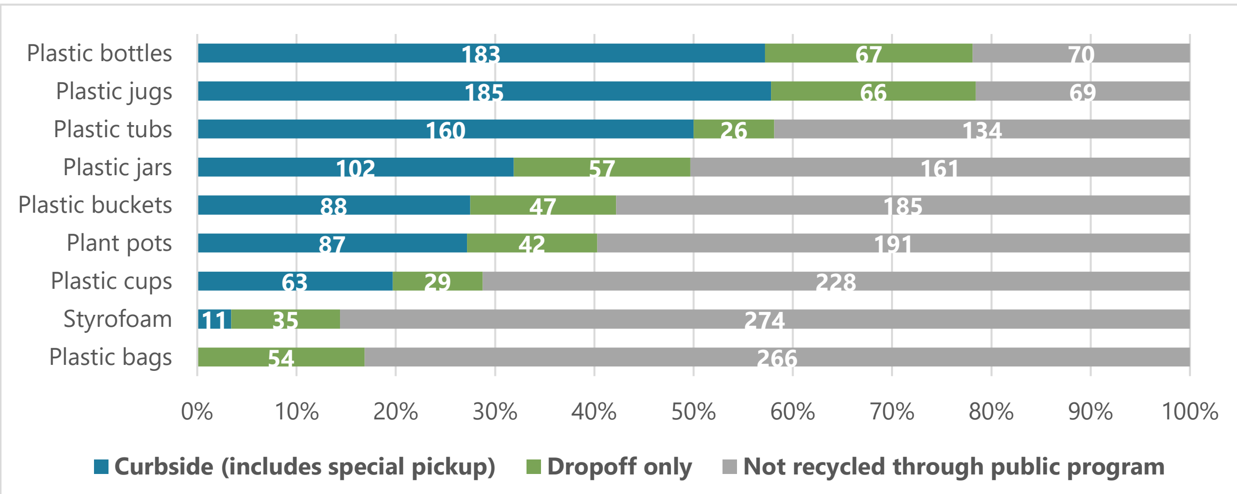
Whether a material is designated as accepted for recycling collection depends on multiple local factors, including recycling collection costs, distance to MRFs, existence of reliable recycling markets, and other considerations. Ecology’s guidelines recommend developing the recyclable materials list using criteria that align with the local government’s goals and that will help maintain a robust and efficient recycling system that can better withstand any unforeseeable market collapses and maintain consistency in what is collected [30].

A report published by Zero Waste Washington (ZWW) in November 2019 documented the types of materials collected by residential recycling programs across all 320 jurisdictions (representing 385 distinct service areas) in Washington. Figure 2 below illustrates the prevalence and methods of collection for the specific types of plastics included in the ZWW survey [14].

While the materials accepted for collection vary by service area, plastic bottles and jugs—which are typically blow molded and made from #1 PET, #2 HDPE natural or colored resins—

commonly make the list, due to the high volume (these materials make up approximately 30 percent of all residential plastic packaging, by weight, generated in Washington) and reliable markets for these items. Collection of plastic tubs, such as those used for dairy products—which typically are made from #2 HDPE and, increasingly, #5 PP resins—are also collected for recycling in a majority of service areas. A smaller portion of service areas (ranging from 20 to 32 percent) have residential recycling collection programs that accept plastic jars, buckets, pots, and cups. Even fewer include collection of other types of rigid plastic packaging not listed here, such as #1 PET thermoform containers (e.g., clear clamshells used for berries and washed salad greens) and other non-bottle containers, lids, and other packaging formats.

Figure 2 Residential Collection Methods For Plastics in Washington State Jurisdictions[7]



Source: Adapted from Figure 4 from Zero Waste Washington, *The State of Residential Recycling and Organics Collection in Washington State*, November 27, 2019; updated to reflect changes to collection of plastic bags in multiple jurisdictions as of Jan 1, 2020.

The distribution of these collection methods is not consistent across regions. For example, plastic tubs are commonly accepted as part of curbside recycling collection in some regions while generally not accepted in other regions. A number of jurisdictions in Washington have changed their accepted materials lists in recent years—some including cuts to the types of plastics accepted—following the implementation of China's National Sword/Blue Sky policies and the increasing costs of recycling programs incurred as a result of associated recycling market challenges. These changes have also been unevenly distributed across the state.

[7] The data reflect a snapshot of the prevalence and methods of collection in the state as of October 2019. However, several programmatic changes have been made since then that are not reflected in these counts.

A regional analysis of collection methods reported for plastic bottles indicates that nearly all service areas in the Northwest, Puget Sound, Southwest, and West regions have residential recycling collection programs that accept plastic tubs as part of curbside collection, and the majority of residents have access to curbside recycling, leading to high overall curbside collection acceptance for plastic tubs. In the Central and East regions, however, only a minority of service areas have curbside recycling collection programs. Those that do exist often do not accept plastic tubs, leading to very low overall curbside collection acceptance of plastic tubs (two percent and 11 percent, respectively). Most jurisdictions in the Central and East regions that provide any type of recycling collection for plastic tubs rely on drop-off collection, but the majority of jurisdictions in these regions do not provide residential recycling collection for plastic tubs at all.

Table 9 Acceptance of Plastic Tubs for Recycling Collection in Residential Service Areas

Region	Accept Curbside	Accept Drop-Off Only	Do Not Accept/ No Recycling
Central	1 (2%)	3 (5%)	62 (94%)
East	9 (11%)	19 (22%)	57 (67%)
Northwest	19 (83%)	3 (13%)	1 (4%)
Puget Sound	93 (99%)	1 (1%)	0 (0%)
Southwest	20 (69%)	0 (0%)	9 (31%)
West	18 (78%)	0 (0%)	5 (22%)
Total	**160 (50%)**	**26 (8%)**	**134 (42%)**

Source: Zero Waste Washington, *The State of Residential Recycling and Organics Collection in Washington State*, November 27, 2019

Disparities in acceptance of other types of non-bottle rigid plastic packaging across regions are even greater.

Plastic bags, film, and other flexible packaging are not accepted in curbside recycling collection programs throughout the state, due to sorting challenges and lack of reliable markets. While some curbside programs in Seattle and King County used to accept plastic bags and film, they began to reject these materials starting January 1, 2020 [31]. Both the City of Seattle and King County recognized the growing contamination issues created by plastic bags and film for sorting facilities, and given the lack of reliable markets [32], determined that the curbside collection of plastic bags and film did more harm than good [31].

No programs accept flexible plastic pouches, which are often used in food packaging [33].

A small number of jurisdictions, including the City of Seattle, offer special curbside collection of polystyrene foam (must be pre-scheduled by residential customers) [34]. A small number of drop-off collection locations in other jurisdictions—primarily located in the Puget Sound region—collect polystyrene foam directly from residents or businesses who self-haul the material to a collection point for recycling.

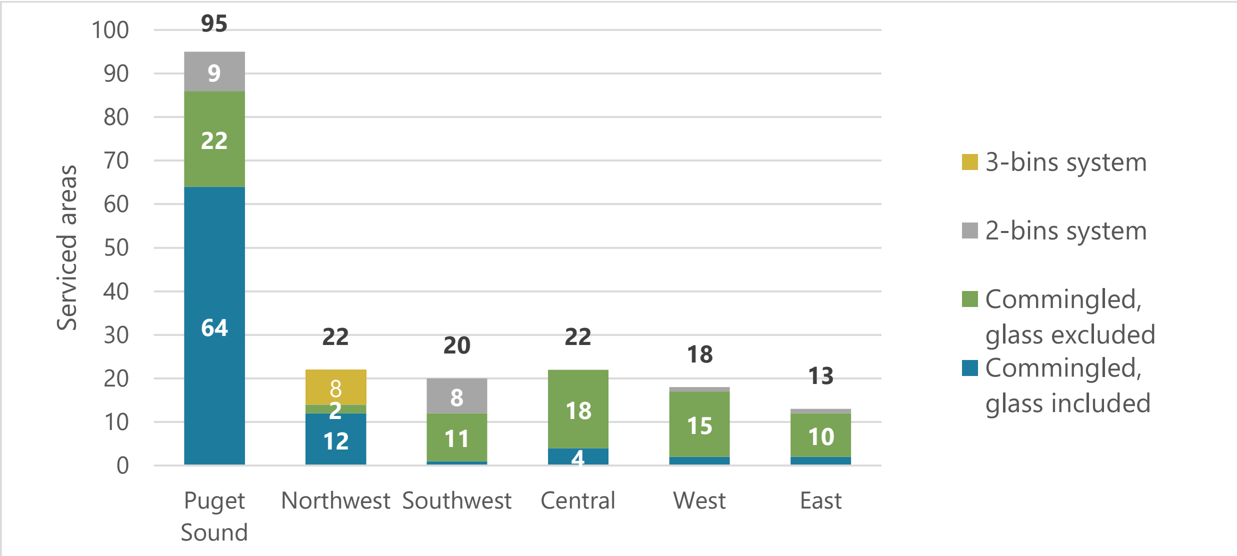
Return-to-retail collection points for use by residents for recycling plastic bags and film—such as those supported by the Wrap Recycling Action Program (WRAP) of the American Chemistry Council—are not included in the data presented above, which only represent public collection programs. According to WRAP, there are 453 retail locations participating as collection points in Washington. These locations typically accept clean, dry PE plastic bags and film packaging.

3.2.1.3 How Are Recyclables Collected?

Residential recyclables in Washington are collected curbside using one of three methods: through a single-stream system (where residents mix all accepted recyclables in one bin), a two-bin system, or three stackable bins. Two-bin systems—such as the ones in the City of Kennewick [35], Clark County [36], and Thurston County [37]—are typically single-stream systems that collect glass separately because glass often creates sorting challenges when mixed in with other recyclables, either by breaking into tiny shards and contaminating the other recyclables or by damaging the transportation and sorting equipment with its abrasive qualities [38]. A three-bin system—for source-separation of bottles and cans (collected together in a single bin), newspaper, and other paper—is in widespread use in Whatcom County but no longer used in any other part of the state.

Single-stream collection, also known as commingled collection, is the most common system across single-family and multifamily households throughout the state. Plastic packaging that is included in curbside recycling collection programs is collected through each of these three methods where it is in place throughout the state.

Figure 3 Residential Recycling Collection Methods by Washington State Jurisdictions



Source: Figure 3 from Zero Waste Washington, *The State of Residential Recycling and Organics Collection in Washington State*, November 27, 2019.

Materials collected through publicly operated drop-off locations, such as transfer stations and dropboxes, are sometimes accepted commingled, but more frequently are expected to be sorted into separate material categories by the generator for collection. Privately operated drop-off collection systems, such as the retail locations that operate return-to-retail collection points for use by residents, exclusively accept plastic bags and other clean recyclable plastic film items from customers for recycling. These residentially generated materials are combined with plastic films generated in the retailer's own operations, such as pallet and case wraps, and combined materials are then backhauled to distribution centers where they are consolidated with films from other chain locations and sent to a plastic film reprocessor/end user for recycling.

3.2.1.4 Who Provides the Service?

As part of their authority over solid waste management, city governments in Washington may choose to provide residential recycling collection service, either directly with municipal fleets or through a contracted service provider. In incorporated areas that do not provide service—either directly or through contracts—and in unincorporated areas that fall under county jurisdiction, the Washington Utilities and Transportation Commission (WUTC) grants certificates to solid waste collection companies for exclusive rights to provide solid waste collection, including residential recycling, in a designated territory.

As shown in Table 10, most households in the state that have access to curbside recycling collection are serviced by either a contracted hauler or a WUTC-permitted hauler. Ten local jurisdictions, serving eight percent of all households, provide residential recycling collection directly with municipal fleets.

Table 10 Residential Recycling Collection Service, by Provider Type

Region	HH Count	No Recycling	Contract Collection	Municipal Collection	WUTC-Permitted Hauler
Central	244,233	123,735 (51%)	52,685 (22%)	1,913 (1%)	65,900 (27%)
East	436,105	142,402 (33%)	95,036 (22%)	124,147 (28%)	74,520 (17%)
Northwest	210,206	14,169 (7%)	79,871 (38%)	15,105 (7%)	101,061 (48%)
Puget Sound	1,858,925	173 (0%)	977,430 (53%)	121,131 (7%)	760,191 (41%)
Southwest	277,757	35,627 (13%)	209,954 (76%)	0 (0%)	32,176 (12%)
West	143,378	44,997 (31%)	26,952 (19%)	0 (0%)	71,429 (50%)
Statewide Total	**3,170,604**	**361,103 (11%)**	**1,441,928 (45%)**	**262,296 (8%)**	**1,105,277 (35%)**

Source: primary analysis of 2019 data from Zero Waste Washington, WUTC tariffs, county Solid Waste Management Plans, and Washington Office of Financial Management.

3.2.1.5 What Does It Cost and Where Is the Payment Assessed?

Households that receive recycling collection service by WUTC-permitted haulers must pay a separate rate for recycling collection. Rates are set using formulas established and reviewed by the WUTC and cover the costs of collection and delivery of materials to a sorting facility. Net revenues generated or net costs incurred from sorting and marketing of collected materials are returned to residents in the form of a commodity credit (if net revenue) or debit (if net cost) separately.

As of October 2019, the average annual recycling collection charges for single-family residential customers of WUTC-permitted haulers are $121 per household ($108 in collection charges and $13 in commodity debit charges). For multifamily customers, the average annual collection charges are $45 per unit ($38 in collection charges and $7 in commodity debit charges) [39].

For areas where residential recycling collection is provided by municipal or contracted haulers as a universal service alongside garbage collection, local governments have generally chosen to embed the cost of recycling collection within the rates charged for garbage service, making it very difficult to determine how much of the household payment is going toward covering recycling collection. An analysis conducted on behalf of King County indicated that residential customers in Washington receiving curbside recycling service under these arrangements are likely paying $60 to $120 per year through costs embedded in residential garbage rates [40].

Following the market disruptions stemming from China's National Sword/Blue Sky policies in 2018, many contracted service providers sought to add recycling surcharges to residential rates, ostensibly to cover the costs of additional sortation and other contamination reduction strategies needed to achieve more stringent quality standards now required by reprocessors and end users of recycled materials; however, it is possible that these surcharges are also being used to cover losses due to decreased revenue from depressed market prices. Surcharge amounts approved by local governments in King County range from $0.76 to $2.26 per month, with an average of $1.40 per month [40]. In 2020, Tacoma residents began paying an additional $2.82 per month to maintain curbside recycling service [41].

Drop-off recycling collection at transfer stations and public dropboxes is generally provided at no charge to the individual dropping off the recyclables. These options are primarily for residents who lack curbside services, either for all or specific materials, but are also sometimes used by residents with excess materials or as a recycling option between collection periods. Privately-operated drop-off collection sites, such as those located in retail stores that accept plastic film and bags, are free for anyone to use. However, participation in this collection approach depends heavily on a retailer's ability to dedicate staff time to manage material collected from the public, having access to backhauling and storage space, and generating sufficient volume to make the effort to divert plastic film for recycling economically attractive. As a result, most of these drop-off locations are located at major chain grocery and retail locations and not widespread across retailers in Washington. See 3.2.1.1 Who Receives the Service? for a more detailed discussion of reverse logistics collection [42].

3.2.2 Commercial Recycling Collection

Similar to residential recycling collection, commercial collection varies from jurisdiction to jurisdiction in terms of access to and costs of service, materials collected, and collection methods used. A notable difference in the commercial sector is that—under RCWs 36.58.160, 70A.205.901, 81.77.140, and 35.21.158—source-separated recyclable materials are not subject to solid waste collection regulations as long as the activities adhere to the requirements for the recycling exemption. Such materials could include those generated from construction and demolition activities, as well as typical recyclable materials generated by residents.[8] This creates

[8] As per WAC 173-350-100, "recyclable materials" is defined as "those solid wastes that are separated for recycling or reuse, including, but not limited to, papers, metals, and glass, that are identified as recyclable material pursuant to a local comprehensive solid waste plan." "Source-separation" is defined as "the separation of different kinds of solid waste at the place where the waste originates." This definition allows

an opportunity for private, unregulated companies to be involved in recycling collection and the handling of recyclable materials and enables businesses to individually choose their recycling collection service providers, with very few restrictions.

3.2.2.1 Who Receives the Service?

All businesses in Washington are encouraged to find their own recycling collection services but commercial recycling collection is not mandatory statewide. In most cities in King County and a few in Snohomish County, commercial recycling collection is provided to eligible businesses as part of municipal or contracted solid waste collection service. Under these programs, all businesses with garbage collection have access to recycling collection service, with the costs of recycling included in the rates that businesses pay for garbage collection [43]. Elsewhere in the state, businesses that wish to recycle must make separate arrangements for recycling collection and must pay separately for the service, if required.

3.2.2.2 How Are Recyclables Collected and Who Provides the Service?

Washington State law does not currently authorize counties to limit provision of commercial recycling collection services to WUTC-permitted haulers, so recycling collection services are not regulated by the WUTC under solid waste carrier regulations. Cities that provide solid waste collection service, however, are not limited in this way. Cities with contracted waste service for businesses can, by contract, require their hauler to offer commercial recycling service and specify the level of service required. However, neither cities nor counties may restrict commercial sector businesses from selecting a recycling collection service provider of their own choosing instead of or in addition to the city's provider.

As a result, commercial entities have several non-exclusive options for recycling collection service:

- **City-provided recycling collection**. In a limited number of cities concentrated primarily in the Puget Sound region, businesses can opt into city-provided commingled recycling collection services, either provided directly by municipal fleets or by contracted service providers. In some cities, this option is only provided to small businesses, where the city/contracted hauler will accept their recyclables along with residential recyclables. In other jurisdictions, all commercial customers with garbage collection provided under the city's contracted or municipal service are eligible.

  An assessment conducted by the Office of the Washington State Auditor in 2018 found that the majority of commercial recycling collection offered through contracted service,

for collection of recyclable materials that are mixed together ("commingled collection") to be considered source separated, so long as they are not mixed with other types of solid waste [137].

especially where recycling was embedded in garbage rates, was provided by a small number of large solid waste hauling companies operating in the state [43].

- **Collection by private sector recyclers.** Under Washington State RCW 81.77.140, businesses that generate recyclable material are entitled to sell, convey, or arrange for transportation of their own recyclable materials to a recycler for reuse or reclamation however they so choose [44]. With this open-market style of commercial recycling collection protected in state law, some businesses hire separate, and sometimes multiple, collection service providers for various materials.

  Commercial recycling collection is provided by a mix of large and small solid waste collection companies as well as private recycling businesses that collect one or more source-separated recyclable materials for reprocessing. Because of the lower level of regulation of commercial recycling collection, there is no statewide database of private recycling businesses that collect recyclable materials from commercial generators and no details gathered on their activities directly.

  While Ecology gathers data on the types, amount, destination, and final use of recyclable materials through an annual state recycling survey, only regulated facilities under the solid waste handling standards that received recyclable or recoverable materials in the previous year are required to report. Other entities involved in recycling collection, sorting, marketing, and reprocessing are asked to voluntarily report information through the annual survey. Such entities can include county and city utilities, scrap metal collectors, brokers, commercial and industrial collectors, construction and demolition debris collectors or processors, energy recovery facilities, and others [45].

- **Self-haul.** Large businesses or other commercial and institutional entities that generate a significant amount of recyclable materials sometimes transport their own recyclables—whether commingled or separated by material type—directly to end users or to transfer stations or materials recovery facilities (MRFs) via their privately-owned trucks and often with their own access cards to those stations. Examples of such entities in Washington include Goodwill and the University of Washington. Some small businesses also self-haul recyclable materials to transfer stations and dropboxes. These materials are typically separated by material type by the business.

- **Reverse logistics.** Large businesses sometimes backhaul some materials using their own supply chains and/or distribution channels, a process called "reverse logistics." In some cases, reverse logistics is used for reusable materials such as pallets, crates, and other packaging and carrier materials for reuse. In other cases, reverse logistics is used for recyclable materials—such as pallet wrap and other plastic film, generated internally by the business or accepted from customers at a retail location—collected from multiple retail locations that is consolidated at a distribution center. From there, arrangements for recycling can be made more efficiently and with greater economic benefit due to the volume of material collected for recycling.

Management of commercial recyclables through reverse logistics is unregulated. This contributes to limited data availability and potential underestimation, as it is provided on a voluntary basis, about which commercial generators engage in it, how much and what types of materials are collected, how effectively materials are recycled, and where collected materials end up.

- **Post-industrial recycling.** Manufacturing businesses may choose to reincorporate scraps left from their processes back into their manufacturing cycle, or send those scrap materials to a recycler. This option differs from reverse logistics in that the scrap is generated in the production of the product itself and the material never reaches its intended end user prior to recycling. This type of recycling is considered "post-industrial" or "pre-consumer" and is not included within the scope of this study, except where intentionally or incidentally included with commercial sector material reports.

Which option(s) businesses choose could depend on their size, industry sector, solid waste generation, costs of both disposal and recycling collection service, and revenue potential for some recyclables. It is also dependent on available capital, including self-haul trucks and space available onsite for dumpsters, as well as the services offered by private collectors in their area. City-provided commingled and open-market collections, however, are the most common among small- and medium-sized businesses, while self-haul is more common among large businesses. Reverse logistics and post-industrial recycling are supplementary options utilized by businesses where appropriate, but typically cannot exclusively fulfill the full solid waste management and recycling needs of a business.

3.2.2.3 What Does It Cost and Where Is the Payment Assessed?

Depending on how a jurisdiction establishes a commercial recycling program, businesses that opt for city-provided collection services may pay for their fees separate from their garbage disposal fees, or the payment may be embedded into the garbage disposal fee.

Businesses that choose an open-market commercial collection will face more variability in payment structures and prices, though competition between the haulers may naturally lead to a certain level of rate matching. Solid waste haulers and private recyclers typically charge their customers by a scheduled or on-call pick-up rate by volume or, less frequently, a per-ton rate. If the revenue potential of a specific material is high enough, private recyclers may collect material free of charge or even pay the commercial generator for the material if it is source-separated and of sufficient quality and quantity.

Self-haul of recyclable materials, especially those separated by type, can often be delivered to transfer stations and dropboxes at no charge, from either residential or commercial sources.

Costs for reverse logistics recycling systems are minimal, as backhaul collection takes advantage of existing truck routes from a retail location back to a distribution center or warehouse for restocking. Once consolidated, recyclable materials such as plastic bags and film that are collected through reverse logistics usually offer sufficient volume to prove attractive to recyclers, who usually pay for the material (though transportation costs to the recycler are sometimes paid for by the commercial generator).

3.2.2.4 What Gets Collected?

Although counties do not have the authority to regulate commercial recycling collection, the lists for designated recyclable materials established in solid waste management plans for residential recycling often influence the list of materials accepted from commercial generators, at least when collected by solid waste collection companies involved in both residential and commercial recycling collection. In addition, private recyclers often collect specific materials for which there is sufficient revenue potential and/or reliable end markets.

The plastic packaging accepted for commercial recycling therefore varies significantly throughout the state. Plastic bags and other film and flexible plastic packaging is typically prohibited in most mixed commercial recycling collection programs, as is polystyrene foam packaging. However, private recyclers do exist in some parts of the state who collect, or accept via drop-off, these plastic packaging types from businesses that generate large volumes and/or clean, separated materials.

Flexible commercial plastic packaging, such as pallet wrap, and polystyrene foam used as protective transport packaging (such as for large appliances) are the only plastic packaging materials identified as regularly backhauled for recycling in the commercial sector. Commercially generated film and flexible plastic packaging is sometimes backhauled in combination with post-consumer residential film collected from customers via retail takeback. Reliance on voluntary data reporting makes it difficult to assess the amount and types of materials collected with confidence or determine where collected materials end up.

3.2.3 Public Space Recycling Collection

With the exception of mandatory recycling collection programs for public events [46], no statewide recycling collection system or requirement exists for public spaces. However, some local, typically urban, jurisdictions have taken initiative to invest in the provision of collection bins for waste and/or recycling in public spaces. Therefore, the definition of public spaces or the decision process for selecting where to place these bins varies based on the jurisdiction. For instance, in Seattle, anyone can request a recycling bin for a public space [47], and the City of Seattle will determine eligibility based on established criteria that measure need, logistics, and other considerations [48].

With public space recycling collection, jurisdictions can capture more plastic packaging, which is a common item found littered in public spaces given that its functional design facilitates on-the-go consumption [49]. In pilot projects for public space recycling collection in British Columbia, the capture rates for plastic containers ranged from 52 percent to 65 percent [50].

While public space recycling collection systems may reduce litter [51], several barriers—namely contamination and low participation—can make public space recycling collection programs a risky investment. Studies have found contamination rates of 35 percent or higher for public spaces in Washington and other locations, such as the city of Toronto [52]. In Toronto, the top contaminants in these spaces were identified as coffee cups, pet waste, food scraps, and black plastics (which most optical sorting systems at MRFs cannot identify) [53]. While limited studies have shown certain practices, like color-coded bins and clear signage, can help reduce contamination [54], the contamination and litter levels in these spaces remain high.

Contamination poses a technical and financial challenge for recyclers to effectively clean, reprocess, and market the collected plastic packaging items. Many of the items are of poor quality and therefore these steps may cost more than any revenue gained. Though the amount that Washington cities have invested in public space collection is unknown, one source estimates that public space collection infrastructure costs can range between $1,500 to $4,000 per bin for bin purchases alone. These estimates do not include the ongoing collection and maintenance costs to the city [52].

3.3 Sorting and Marketing

Once collected for recycling, plastic packaging goes through one of the many private recycling services and consolidators, gets sorted into separate recyclable commodities at MRFs, or gets sent directly to plastic reprocessors within and outside the state.

Residential and commercial recyclables collected in a commingled stream generally flow through the MRFs listed in Table 11 for sortation into recyclable commodities. Some separated commercial recyclable materials also flow through these MRFs, though they are often handled separately from commingled materials. Once sorted, recyclable commodities are sold to buyers under confidential arrangements made by the MRFs. Materials that are not effectively captured as recyclable commodities through sortation are considered residuals and disposed as solid waste.

Materials collected using the multi-stream collection method employed in Whatcom County also flow through a MRF, Northwest Recycling, which further sorts partially separated materials (plastic containers are collected with glass and metal containers but separate from paper) into recyclable commodities [33].

Recyclables that are collected as separated materials from commercial generators, whether by private recyclers, self-haul, or dropped off by businesses, are often sent directly to reprocessors or end users of the recyclable materials. Several large commercial generators also haul directly to reprocessors, who may then do some sortation as part of their quality control process prior to reprocessing recyclable materials into recycled content feedstock.

3.3.1 Sorting of Plastic Packaging from Recycling Collection Stream

Table 11 below lists the nine primary MRFs in the state where sortation of mixed recyclables, including plastics, into marketable recyclable commodities occurs. The table provides basic information about their service types and sorting technologies used, as well as which types of marketable commodities are produced from plastic packaging in collected recyclables. All but one of the listed MRFs handle commercial and residential materials; Seadrunar only accepts commercial recyclables [55].

Table 11 List of MRFs Involved in Sorting Plastic Packaging Wastes for Recycling in Washington

Facility Name (Company Operator)	Location	Year Built, Upgraded	Customer	Materials Delivered from (Counties) [56]	Available Technology/ Equipment	Plastic Bales Produced
JMK Fibers (WM)	Tacoma, Pierce County	2013, 2018	Residential, Commercial	• Clallam • Grays Harbor • King • Kitsap • Pierce	• Conveyors and screens • Optical sorter(s) • Plastic film capture system (not in use at this time) [57], [58]	• Clear PE film (from source-separated collection only) • #1 PET bottles • #2 HDPE natural bottles • #2 HDPE colored bottles • Mixed rigid plastics (pre-picked) **market dependent*
Cascade Recycling Center (WM)	Woodinville, King County	2003	Residential, Commercial	• Island • King • San Juan • Skagit • Snohomish	• Conveyors and screens • Optical sorter(s) [59]	• #1 PET bottles • #2 HDPE natural bottles • #2 HDPE colored bottles • Mixed rigid plastics (pre-picked) **market dependent*
Recology Seattle (Recology)	Seattle, King County	2014	Residential, Commercial	• King	• Optical sorters • Visual Identification System (VIS)	• #1 PET bottles • #2 HDPE natural bottles • #2 HDPE colored bottles • Mixed rigid plastics (pre-picked)

Facility Name (Company Operator)	Location	Year Built, Upgraded	Customer	Materials Delivered from (Counties) [56]	Available Technology/ Equipment	Plastic Bales Produced
3rd & Lander (Republic Services)	Seattle, King County	1988	Residential, Commercial	• King • Klickitat • Snohomish • Whitman	• Optical sorters	• #1 PET bottles • #2 HDPE natural bottles • Mixed rigid plastics (pre-picked)
Pioneer Tacoma (Pioneer Recycling Services)	Tacoma, Pierce County	2006, 2014	Primarily Residential	• Benton • Cowlitz • Franklin • Grant • Grays Harbor • Island • Jefferson • King • Lewis • Mason • Pierce • Skamania • Thurston • Walla Walla • Yakima	• Robotics units for PP • Video technology	• #1 PET bottles • #2 HDPE natural bottles • #2 HDPE colored bottles • #5 PP packaging

Facility Name (Company Operator)	Location	Year Built, Upgraded	Customer	Materials Delivered from (Counties) [56]	Available Technology/ Equipment	Plastic Bales Produced
SMaRT Center (WM)	Spokane, Spokane County	2012	Residential, Commercial	• Benton • Chelan • Douglas • Grant • Kittitas • Okanogan • Spokane	• Conveyors and screens • Optical sorter(s) [60]	• #1 PET bottles • #2 HDPE natural bottles • #2 HDPE colored bottles • Mixed rigid plastics (pre-picked) **market dependent* [61]
West Van Material Recovery Center (Waste Connections)	Vancouver, Clark County	1992	Residential, Commercial	• Clark	• Conveyors and screens • Hand sorting	• #1 PET bottles • #2 HDPE natural bottles • #2 HDPE colored bottles • #5 PP packaging • Mixed rigid plastics (pre-picked)
NW Recycling (Parberry's Inc.)	Bellingham, Whatcom County	1992	Residential, Commercial	• Whatcom	• Manual labor with a conveyor belt	• #2 HDPE natural bottles • #1-#7 bottles and small rigid plastics
Seadrunar Recycling	Seattle, King County	2001	Commercial only	• King • Pierce • Snohomish • Thurston	• Hand sorting	• #1 PET bottles • Mixed rigid plastics (pre-picked) • #1-#7 bottles and small rigid plastics • LDPE film (clear and colored)

3.3.2 Marketing of Plastic Packaging for Recycling

Under all but a few arrangements in the state, materials collected for recycling become the property and responsibility of the MRFs once they are delivered for sortation. MRFs sort and bale materials into marketable commodities in accordance with relevant contract terms and/or in response to market conditions, which include the demand and pricing for various commodity types and grades.

Most MRFs in Washington typically produce at least three types of recyclable commodities that include plastic packaging:

- #1 PET Bottles
- #2 HDPE Natural Bottles
- #2 HDPE Colored Bottles

Depending on market dynamics, volume and material mix of incoming loads, local government contract requirements, and installed technological capabilities, some MRFs also produce additional marketable plastic commodities, including one or more of the following:

- #5 PP Small Rigid Plastics
- Mixed Rigid Plastics: #1-7 Bottles and Small Rigid Plastics
- Mixed Rigid Plastics: #3-7 Bottles and Small Rigid Plastics (also known as Pre-Picked)
- Mixed Bulky Rigids (typically includes a mix of large plastic packaging and products)
- MRF Curbside Film (not currently marketed due to lack of demand)
- Clear film collected from commercial sources

The specifications for bales of these commodities are based on guidelines set by the Institute of Scrap Recycling Industries (ISRI) [62], the Association of Plastics Recyclers (APR) [63], and/or the requirements of specific buyers.

Most local governments prohibit designated recyclable materials collected through residential or commercial recycling programs from being disposed with the exception of materials not effectively captured as recyclable commodities through sortation. These materials are generally considered residuals and disposed as solid waste, although a few facilities transform a portion of their residuals into engineered fuel products to be burned for energy. This is likely done in part to address contract requirements that include collection of #3-7 plastics and prohibit disposal of designated recyclables when there are not reliable end markets for these materials as baled commodities.

Plastic packaging materials collected separately from commercial generators or through drop-off collection and reverse logistics are sold as additional recyclable commodities, including various grades of HDPE/LDPE film, as well as polystyrene foam, which is densified through thermal or cold compaction prior to sale as a marketable commodity.

Recyclable plastic commodity bales are sold or otherwise transferred to plastics reprocessors and/or end users. Plastic reprocessing activities in Washington are detailed in the task-level report *Recycled Content Use in Washington: Assessing Demand, Barriers, and Opportunities* produced in a previous phase of this study. Data from the Ecology Recycling Survey and limited self-reporting by in-state plastic reprocessors indicate that only a small portion of the recyclable plastic materials collected in Washington stays in the state for reprocessing and remanufacturing. The majority of recyclable plastic commodities are sent to receiving facilities located in other states or outside of the U.S. Additional discussion of end markets for recyclable plastic commodities is provided in Section 5.2.5 End Markets.

3.4 Landfill Disposal and Incineration

3.4.1 Landfill Disposal

The majority of plastic packaging not collected for recycling is collected along with other solid waste for disposal, the majority of which is sent to landfills in Washington or Oregon listed below (see Table 12 and Table 13). This includes residential, commercial, and self-hauled waste. Washington landfills are spread throughout the state to meet demand and have varying levels of environmental remediation technology.

Counties have the ultimate authority to direct all municipal solid waste (MSW) collected within their jurisdiction to publicly owned or contracted facilities, and most county governments exercise this authority. As indicated in the tables below, most Washington disposal facilities are publicly owned, while all the Oregon facilities that service Washington jurisdictions are private but are contracted by Washington jurisdictions to receive solid waste collected within their boundaries.

Table 12 List of Washington Landfills

Facility Name	Location (County)	Region	Ownership
Asotin County Regional Landfill	Clarkston (Asotin)	East	Public
Cedar Hills Regional Landfill	Maple Valley (King)	Puget Sound	Public
Cheyne Road Landfill	Zillah (Yakima)	Central	Public
Cowlitz County Landfill	Castle Rock (Cowlitz)	Southwest	Public
Ephrata Landfill	Ephrata (Grant)	Central	Public
Greater Wenatchee Regional Landfill	E Wenatchee (Douglas)	Central	Private
Horn Rapids Sanitary Landfill	Richland (Benton)	East	Public

Facility Name	Location (County)	Region	Ownership
LRI Landfill	Graham (Pierce)	Puget Sound	Private
Northside Landfill	Spokane (Spokane)	East	Public
Okanogan Central Landfill	Okanogan (Okanogan)	Central	Public
Roosevelt Regional Landfill MSW	Roosevelt (Klickitat)	Central	Private
Stevens County Landfill	Kettle Falls (Stevens)	East	Public
Sudbury Regional Landfill	Walla Walla (Walla Walla)	East	Public
Terrace Heights Landfill	Yakima (Yakima)	Central	Public

Table 13 List of Oregon Landfills Accepting Waste on Contract From Washington

Facility Name	Location	Ownership
Columbia Ridge Landfill	Arlington (OR)	Private
Finley Buttes	Boardman (OR)	Private
Wasco County MSW Landfill	The Dalles (OR)	Private

3.4.2 Incineration

Incineration, also referred to as waste-to-energy (WTE), is the process of burning solid waste into recoverable energy. The City of Spokane's Solid Waste Department operates the one municipal solid waste incinerator in the state—the Spokane Regional Waste-to-Energy Facility [64]. The facility receives solid waste collected from residents and businesses from the City of Spokane, unincorporated Spokane County, and ten other jurisdictions in Spokane County that are members of the regional solid waste system. It also receives self-hauled waste at the facility, which sometimes includes materials generated outside of Spokane County. According to a City of Spokane Solid Waste Department representative, out-of-state wastes are primarily received from commercial entities seeking secure destruction or aiming to divert materials from landfill in order to achieve voluntary "zero waste to landfill" goals.[9] In operation since 1991, the facility has the daily capacity to burn up to 800 tons of municipal solid waste, which can then power 13,000 homes and generate an annual sales revenue of $5 million. Under the regulation of the Spokane Regional Clean Air Agency, the Spokane Regional Health District, and Ecology, the facility burns the solid waste at 2,500 degrees Fahrenheit and disposes the remaining ash in a special incinerator ash monofill in Klickitat County[10] [65].

[9] According to the State's waste management hierarchy, incineration is considered equivalent to disposal.
[10] Regulated in Special Incinerator Ash Management Standards, Chapter 173-306 WAC.

3.5 Litter Clean-Up

When not collected for recycling or properly disposed, waste materials often end up as litter found on roadways, public spaces, and in the environment, including waterways, beaches, and the ocean. Plastic packaging—especially plastic beverage containers, plastic bags and film, and other food and beverage packaging—is among the more common items found in litter. Although no recent, comprehensive data exist on the total amount and composition of litter in Washington, the statewide roadway litter study conducted on behalf of the Department of Ecology in 2004 found that plastic packaging represented 5.7 percent of the total weight of roadway litter [66]. Because plastic packaging is very lightweight and voluminous relative to other commonly littered items, it likely represents a larger portion of litter by volume and unit count. A recent study of roadway litter in Pennsylvania found that plastic packaging made up approximately 20 percent of all littered items by unit count [67].

Washington State instituted a litter tax in 1971, which charges a 0.0015 percent tax, paid by industries, on retail sales of 13 categories of products that are commonly littered, including most packaged food, beverage, and household items as well as fast food items, paper products, cigarettes, and other sundries [68]. The tax rate, which is equivalent to $150 in tax per $1 million in sales, has not changed since it was set in 1970.

Revenue generated from this tax amounts to about $11.4 million annually, and is directed to the Waste Reduction, Recycling, and Litter Control Account (WRRLCA), which funds litter pick-up and prevention programs run by Ecology and other state agencies (40 percent of funds), as well as waste reduction and recycling programs run by Ecology (40 percent of funds), and litter pick-up and prevention programs run by local governments (20 percent of funds) [69].

Collectively, clean-up programs funded by the litter tax collected nearly 2.9 million pounds of litter (and more than 1.7 million pounds of illegally dumped materials) and cleared almost 25,000 miles of roadways statewide (approximately 15 percent of total) in 2018 [69].

Funding for litter pick-up and prevention programs run by local governments are provided through Ecology's Community Litter Clean-Up Program (CLCP) [68]. Local governments also often dedicate additional local revenue to support litter clean-up. Apart from CLCP, Ecology operates its own litter clean-up program and has interagency agreements in the state to fund their litter clean-up initiatives. While Ecology does not have a direct agreement with the Department of Corrections (WADOC), the Washington State Department of Transportation (WSDOT) works with WADOC to coordinate a litter pick-up program. Program details for each are described separately below.

3.5.1 Ecology Youth Corps

Established in 1975, the Ecology Youth Corps (EYC) is a program run by Ecology to engage teenagers aged 14 to 17 and young adults 18 years and over to learn about the impacts of littering. Ecology hires roughly 300 Washington teens every summer and young adults every spring and fall to pick up litter, including plastic packaging, from highways [70]. More than 30 crews [71] are spread throughout the Northwest, Southwest, Central, and Eastern regions of the state [70]. In 2019, crews picked up over 1.2 million pounds of litter, and of this amount, they were able to recycle 102,253 pounds [70].

3.5.2 Department of Corrections

WADOC coordinates multiple community work crew programs to provide inmates the opportunity to build work skills and fulfill mandated community service or restitution requirements, while making a small income. The Department partners with government authorities (e.g., Department of Natural Resources and WSDOT) and non-profit organizations, such as the Salvation Army, to perform a wide variety of services including litter pick-up. Work crews of around ten inmates help the various partners. For WSDOT, for example, crews perform litter pick-up, debris removal, garbage clean-up, and hand shoveling debris tasks [72].

3.5.3 Department of Natural Resources

In partnership with the Department of Corrections and the Juvenile Rehabilitation Administration, the Washington State Department of Natural Resources (DNR) oversees a Correctional Camps Program that brings inmates to provide forest protection services, which includes illegal dump site clean-up. WADOC sends inmates from one juvenile and four adult correctional facilities to participate [73].

3.5.4 Department of Fish and Wildlife

The Washington State Department of Fish and Wildlife’s (WDFW) litter clean-up program is part of the maintenance of the lands and properties managed by the Department. Funds from Ecology help to cover the costs of the litter clean-up, including supplies, dump fees, and some labor. WDFW covers most of the labor costs.

3.6 Recycling Contamination Clean-up

Contamination—that is, the presence of materials not accepted for recycling in collected materials—has been steadily increasing over the past two decades. This is attributable to multiple factors, including the advent of single-stream recycling collection and the proliferation of packaging materials. There has also been a growing reliance on single-use plastics, takeout containers, plastic film and flexible laminates in packaging applications, and other disposable foodservice items. (See a more detailed discussion of the role of plastic packaging as a contaminant in the recycling system in Section 4.0 Plastic Packaging Waste Contamination, below.)

As contamination has increased, efforts and investments to address and reduce contamination have followed. Much of this work has fallen to the state's MRFs, who routinely report that the presence of plastic bags and film in commingled recyclables loads frequently leads to jammed machines, requiring them to be stopped so the plastic can be manually cut out. Many MRFs rely on manual sorting in addition to automated sorting technologies to reduce contamination rates and have added additional laborers to manually remove plastic film and other contaminant plastics. Despite these additional investments, MRFs have expressed concerns that their options for reducing contamination are limited without wider measures to decrease the number of contaminants collected and sent to the MRF in the first place [9]. Reprocessors and end users of recyclable commodities, such as paper mills, as well as commercial composting operations that operate and receive materials generated within the state also invest a substantial amount of time and resources dealing with plastic packaging contaminants in materials received.

Recognizing the importance of reducing contamination in inbound loads, King County and the City of Seattle recently coordinated action to no longer accept plastic bags and film in curbside recycling collection beginning January 1, 2020. Residents who would like to recycle plastic bags and film must take them to designated drop-off locations [31]. In March 2020, Governor Jay Inslee signed into law a statewide ban on single-use plastic bags that will go into effect at the beginning of 2021 [74], [75]. These actions have the potential to reduce the prevalence of plastic bags, which are commonly cited as a top contaminant in recycling streams [76].

In 2018, King County formed the Responsible Recycling Task Force in response to China's National Sword/Blue Sky policy and the ensuing market disruptions. The task force established a Recycle Right Communications Consortium to harmonize messaging about contamination across local jurisdictions [77]. In 2019, Ecology launched a statewide campaign building on the King County campaign, also under the name "Recycle Right", encouraging residents to "empty, clean, and dry" materials before placing them into recycling bins [78].

In 2019, furthering efforts to address domestic issues of high contamination rates, the Washington State Legislature mandated the development of a statewide Contamination Reduction and Outreach Plan (CROP) that would accompany solid waste management plans tailored to local jurisdictions throughout the state. A statewide plan detailing how Washington intends to reduce contamination in recycling streams was due from Ecology by August 31, 2020. Ecology will also connect with local governments as they work to develop their own CROP or tailor the statewide CROP to include in their solid waste management plans by July 1, 2021. This requirement applies to all jurisdictions with more than 25,000 residents [79]. Statewide and local

CROPs will address potential policies; research topics; collection, sorting, and processing infrastructure investments; and outreach strategies to increase public awareness about contamination and proper recycling methods.

4.0 Plastic Packaging Waste Contamination

This section describes plastic packaging waste contamination in the recycling collection stream—including its presence in inbound loads, MRF residuals, and contamination of recyclable commodity bales—and in organics collected for composting, as well as in litter.

4.1 Contamination in Recycling Collection Stream

Only a few jurisdictions in Washington regularly quantify and characterize the composition of materials collected for recycling. Most local governments rely on contracted service providers to self-report contamination rates, which are typically based on the receiving MRF's residuals rate—calculated as the tons ejected during the sortation process divided by total tons received—rather than on composition audits of incoming loads. By both measures, contamination has been increasing over the past two decades, especially within commingled loads.

In 2001, the contamination rate of the commingled residential recycling collection stream in the City of Seattle was 3.7 percent [22]. By 2015, it was calculated at 10.5 percent, and that was at a time when plastic bags and film, if properly bagged, were still included as an acceptable recyclable material and not counted as contamination [24]. In King County, the average contamination rate of incoming commingled recycling loads to Puget Sound area MRFs in 2006 was estimated to be 7.3 percent [80]. By 2019, that number had increased to 18.2 percent for the residential sector and 15.8 percent of the commercial sector [9].

While non-accepted plastic packaging is just one of multiple materials contributing to the increasing problem of recycling contamination, it is increasing both in relative proportion and total quantity of inbound tons received by MRFs.

Contamination arriving in inbound loads at MRFs ends up in one of two places: ejected from the sortation process, thereby ending up as residuals disposed as solid waste, or inadvertently embedded in bales of recyclable commodities sold to reprocessors and end users of recyclable materials.

4.1.1 Inbound Contamination

The recently completed assessment and characterization of single-stream recyclables conducted on behalf of King County found that, on average, only approximately one percent of total inbound tons of commingled materials collected for recycling were non-accepted plastic packaging, representing approximately five percent of total contamination [9].

The same study reported that while the single-family residential recyclables stream had more contaminants overall than the commercial stream, it had a lower percentage of non-accepted plastic packaging

Contamination from non-accepted plastic packaging in commingled commercial recyclable loads was found to be slightly higher in the Portland area according to a new study conducted by Oregon Metro, which found that plastic packaging made up approximately 20 percent of total contamination (2.8 percent of total tons collected) [81]. This is partly because the list of plastic packaging types accepted in commingled recyclable loads in the Portland area is somewhat narrower than in King County.

Although no third-party data on inbound contamination rates from multi-stream recyclable collection programs is available, Northwest Recycling—which sorts and markets all materials collected through the multi-stream collection system in place throughout Whatcom County, including residential and commercial sectors—reports that the contamination rate of inbound material is approximately one percent [82].

4.1.2 MRF Residuals

The composition of materials ejected from the commingled recyclable sorting process and disposed as residual waste is largely undocumented. The King County studies in 2006 and 2019 are the only known studies in Washington that have provided information about the composition of recycling residuals to local governments and the public.

According to the 2019 study, more than eight percent (by weight) of sampled residuals ejected during the sortation process at four Puget Sound region MRFs was recyclable plastic packaging and another six percent was non-recyclable plastic packaging (defined as foam plastic and film plastic—excluding disposal bags, which are not considered packaging—in the study).

See the detailed composition results for sampled residuals from the study presented in Table 14 below [9].

Another study conducted as part of a pilot project assessing the feasibility of a secondary sorting facility in the Pacific Northwest found that plastics represented approximately 17 percent of MRF residue samples collected from MRFs in Washington and Oregon for the pilot [10].

Table 14 Detailed Composition Results for Sampled Residuals from Puget Sound Regional MRFs, 2019

Material	Estimated Percent	+ / -
Recyclable Paper	**27.7%**	**12.5%**
Non-Recyclable Paper	**12.0%**	**5.9%**
Recyclable Glass (Containers)	**3.0%**	**1.9%**
Non-Recyclable Glass	**3.6%**	**2.9%**
Recyclable Metal	**3.5%**	**3.3%**
Non-Recyclable Metal	**0.5%**	**0.3%**
Recyclable Plastic	**8.4%**	**3.9%**
PET (#1) Bottles and Jars	2.7%	1.0%
PET (#1) Small Rigid Plastics	0.5%	0.5%
Clear HDPE Bottles and Jars	0.2%	0.1%
Colored HDPE (#2) Bottles and Jars	0.5%	0.5%
HDPE (#2) Other Containers	0.1%	0.1%
LDPE (#4)	0.0%	0.0%
PP (#5) Bottles and Jars	1.4%	0.3%
PP (#5) Small Other Rigid Plastics	2.8%	3.1%
PS Rigid Plastics	0.2%	0.2%
Foam Plastic	**0.4%**	**0.2%**
EPS Food Packaging	0.3%	0.2%
EPS Foam Blocks and Shapes	0.1%	0.1%
Non-Recyclable Plastic	**6.4%**	**2.7%**
Bulky Rigid Plastics	0.1%	0.1%
Compostable Plastics	0.5%	0.4%
Other Plastic	5.9%	2.6%
Film Plastic	**7.8%**	**3.5%**
Clean Plastic Bags and Film	3.6%	2.8%
Disposal Bags	2.1%	1.0%
Other Plastic Film	2.1%	0.9%
Organics	**3.5%**	**2.2%**
Edible Food	3.2%	2.2%
Non-edible Food	0.0%	0.0%
Other Compostables	0.1%	0.0%
Yard Debris	0.2%	0.3%
Contaminants	**23.0%**	**11.1%**
Tanglers	0.0%	0.0%
Household Hazardous Waste	0.0%	0.0%

Material	Estimated Percent	+ / -
Electronics and Small Appliances	0.1%	0.1%
Diapers	1.8%	2.0%
Textiles and Shoes	6.2%	4.0%
Construction and Demolition Debris	1.9%	1.6%
Furniture	1.4%	2.2%
Mixed Residue	11.7%	10.0%
Total	**100.0%**	
Sample Count		**26**

Source: Figure 14 from Cascadia Consulting Group, "Materials Recovery Facility Assessment and Characterization of Single-Stream Recyclables (pre-publication draft)," King County, Seattle, 2020.

4.1.3 Contamination of Commodity Bales

Contamination of recyclable commodity bales, as used in this section, refers to the presence of materials—whether designated recyclable or not—in recyclable commodity bales intended to be made of a different material. As with MRF residuals, very limited data are publicly available on the composition of commodity bales produced by MRFs in Washington. In general, recycling rates reported by state and local governments do not account for contamination of commodity bales (or other yield losses), and instead count all tons reported as sent to reprocessors and end users as "recycled" tons even though some portion of these tons are not the correct material and will ultimately be disposed as "outthrows" by the receiving facility.

The King County 2019 MRF assessment and single-stream recyclables characterization study found that contamination from plastic packaging ranged between 0.4 percent and 3.6 percent across the categories of commonly produced commodity bales by Puget Sound regional MRFs. Contamination from plastic packaging in non-plastic commodities was highest in mixed paper bales, where 3.6 percent of sampled materials destined for shipment to paper mills as "mixed paper" were found to be plastic packaging materials [9]. Another 3.2 percent was plastic products and compostable plastics. In the previous study (2006), plastic packaging and products combined represented three percent of material in mixed paper bales [80]. As a point of reference, China's new import restrictions set strict contamination rate thresholds of 0.5 percent for scrap material imports.

Contamination from plastic packaging was substantially lower for other non-plastic commodities, estimated as 1.1 percent of material destined to be baled as old corrugated cardboard (OCC), and less than 0.5 percent of materials destined to be baled as metal commodities [9].

Contamination from non-target commodity plastic packaging in plastic commodity bales is also an issue. Data from the King County 2019 MRF assessment indicate that between 1.0 percent and 3.2 percent of commonly produced plastic commodity bales—*#1 PET Bottles, #2 HDPE Natural Bottles,* and *#2 HDPE Colored Bottles*—is plastic packaging material that is not designated as an allowable commodity within standard bale specification guidelines [9]. While allowable levels of PET non-bottle packaging in *#1 PET Bottles* bales vary by buyer, it is possible that PET bales contain higher than desirable levels of PET non-bottle packaging, which is estimated to represent nearly one-quarter of materials destined for PET bales being produced by area MRFs, according to the study. A 2016 NAPCOR study found that reprocessors who handle curbside PET bales generally recycle non-bottle PET thermoform packaging along with PET bottles, though they are not yet a preferred material for reclaimers. But, the PET recycling market as a whole is moving toward greater inclusion of thermoforms in PET reprocessing activity [83].

As with inbound contamination and MRF residuals, commodity bale contamination rates are assumed to be substantially lower for bales produced from materials collected using multi-stream and fully segregated collection methods.

The Ecology report published in 2016 on recoverable material quality, yield losses, and material utilization found that commingled systems produce material loss rates of between 16.6 percent and 31 percent of collected tons across all steps of the recycling process (MRF, reprocessor, end user). This variability can stem from a variety of causes, including quality of inbound material, sorting and processing technology in place at the MRF or reprocessor, throughput rates of MRFs, and specific production processes of end users. The loss rates for dual stream and fully separate collection, taken from Table 1 of the Ecology report and shown below in Table 15, were found to be much lower [84].

Table 15 Material Loss and Utilization Rates by Material Recovery Collection System

Collection System for Recoverable Material	Material Loss Rates	Material Utilization Rates
Commingled/Single-Stream (Mixed Recyclables)	16.6-31.0%	69.0-83.4%
Dual Stream (Commingled with glass on the side)	2.0-6.0%	94.0-98.0%
Source Separated Materials	1.0-4.3%	95.7-99.0%
Commingled Construction & Demolition Materials	18.7-26.0%	74.0-81.3%
All Collection Systems	3.8-11.5%	88.5%-96.2%

Source: Washington State Department of Ecology 2016 Materials Recovery & Use Study

4.2 Contamination in Compost Stream

Plastic packaging is a contaminant of concern in organics collected for composting in Washington. As noted by Ecology in its 2016 *Materials Recovery & Use Study*, "for certain materials, such as organics, even a small amount of contamination might make a finished product unmarketable, such as bits of plastic in compost. Thus, even a seemingly low contamination rate can make a material useless for the intended market" [84].

The 2016 Seattle Public Utilities (SPU) study on organics composition—the only known publicly available study on the composition of organics collected for composting in Washington—found that while total contaminants made up just under one percent of organics tons collected from single-family residents in the city (the vast majority of material collected was yard debris), plastic packaging accounted for nearly one-quarter (24 percent) of all contamination (0.2 percent of total tons). For commercial organics, the report found that 4.5 percent of the stream was contaminant material, and plastic packaging accounted for more than one-third (37 percent) of all contamination (1.6 percent of total tons) [85].

Ecology collects and publishes annual data on tons of organic materials received by composting facilities and other organics processors [86]. By combining the data reported for 2018 with the organics composition estimates from the 2016 SPU study, this study estimated the amount of plastic packaging as a percent of the total residential and commercial organics collected for composting in the state. Because the SPU study only includes composition estimates for general residential and commercial organics streams, this estimate only includes tons reported to Ecology as "food waste (post-consumer)" and "yard and food scraps (mixed)." Note that this likely results in an underestimation of the quantity of plastic packaging in organics collected for composting, as it does not include estimation of any plastic packaging that may be in other organics streams reported to Ecology, including "yard debris" and "food processing waste (pre-consumer)." Table 16 shows the estimated results in detail.

Table 16 Tons of Plastics in Organics Collected in Washington State, 2018

Materials in Collected Organics*	Residential Tons yard and food scraps (mixed)	Commercial Tons food waste (post-consumer)	Combined Tons
Non-compostable Plastic Containers	370	270	650
Non-compostable Plastic Film	660	780	1,440
Other Plastic	130	170	300
Compostable Plastic	3,860	1,090	4,950
Total Curbside Organics Collected	**466,000**	**63,650**	**529,650**
Total Organics Contaminants	**4,263**	**2,846**	**7,109**
Plastic Packaging % of Total Contaminants by Weight	**24%**	**37%**	**29%**

*Estimates do not include plastic packaging that may be in other organics streams reported to the Dept. of Ecology, including yard debris and pre-consumer food processing waste.

It is important to note that these estimates measure contamination by weight instead of volume, which likely underrepresents the true impact of plastic packaging on composting operations.

A 2019 study by Oregon Metro on the commercial (food only) organics stream in the Portland region compared the measures of contamination by weight and volume and found that total contamination was twice as high when measured by volume compared to weight (six percent by volume, three percent by weight) [87].

A smaller study conducted in 2020 on contamination in residential organics loads collected in the City of Issaquah also compared the rates of contamination measured by weight and volume and found similar results. While non-compostable plastics, including plastic film, made up less than one percent of collected materials sampled when measured by weight, they made up four percent by volume [88].

4.3 Plastic Packaging in Litter

Comprehensive data on brand-specific plastic packaging in litter and recent data on litter by material type in Washington are not available. The most recent roadway litter composition study covering Washington was published in 2004 [66]. Since its publication, much of the state's litter tax funding was redirected to support other state budget needs, which postponed any plans for more litter composition studies. In early 2020, Washington State restored dedication of funding for litter-related activities, including a litter prevention campaign called "Litter and It Will Hurt," which includes a litter reporting hotline, online reporting tool, and a media campaign. Ecology reports that, before state budget cuts, litter amounts decreased by 25 percent during this campaign. While Ecology had plans to relaunch this campaign in 2020 and to conduct a litter study in 2021 [89], the timeline and budget are uncertain with challenges arising from COVID-19 [90]. Without recent litter composition data, it is challenging to accurately assess the relative role of plastic packaging in litter.

Ecology requires that other state agencies and local governments that receive funds from the WRRLCA account in support of litter clean-up activities report back to Ecology the total pounds of litter collected and total roadway miles cleared annually (see Section 3.5 Litter Clean-Up). By combining the data reported for 2018 with the litter composition estimates from the Washington State 2004 Litter Study—which calculated that plastic packaging materials accounted for approximately 5.7 percent of all roadway litter, by weight—this study estimated the amount of plastic packaging as a percent of the total litter collected by weight through litter clean-up activities in the state [66]. Table 17 shows the estimated results in detail.

Table 17 Estimated Tons Plastic Litter Cleared through Ecology-Funded Programs, 2018

Plastic Packaging Types	Central	East	NW	Puget Sound	SW	West	Statewide
Beverage Containers	1.32	1.17	0.53	19.46	2.14	0.82	25.44
Non-Food Packaging	0.14	0.23	0.10	0.29	0.22	0.07	1.05
Other Food and Beverage Packaging	2.28	3.67	1.61	4.67	3.50	1.06	16.80
Plastic Bags & Film	4.13	6.66	2.92	8.46	6.35	1.93	30.45
Single-Use Foodservice Items	1.28	2.07	0.91	2.63	1.97	0.60	9.45
Total Plastic Packaging	**9.16**	**13.80**	**6.07**	**35.51**	**14.18**	**4.47**	**83.19**
Total Litter Collected	**160.16**	**241.73**	**106.36**	**613.30**	**247.84**	**78.07**	**1,447.46**

5.0 Plastic Packaging Waste Disposition

This section assesses the final disposition of plastic packaging waste generated in Washington. The total amounts and types of plastic packaging waste estimated to be generated annually are presented and described in Section 2.0 Plastic Packaging Waste Types and Amounts.

Final disposition estimates are presented by generating sector—residential, commercial—and for plastic packaging overall. This section also includes discussion of the quantities and composition of plastic packaging disposed and collected for recycling, and of the estimated recycling rates currently achieved for plastic packaging materials. Except where noted, the analysis is based on facility-specific tonnage reports and Ecology tonnage estimates for 2017 (the most recent year for which complete data is available).

5.1 Disposal

Disposal is the most common fate for plastic packaging in Washington. In 2017, Washington residents and businesses disposed of an estimated 330,990 tons of plastic packaging. Just under half (155,220 tons) of all estimated plastic packaging tons disposed is classified as **rigid and foam plastic packaging**, with the remaining material (175,770 tons) classified as **plastic film and flexible plastic packaging.**

As noted in the discussion of generation, composition estimates derived from disposed waste are likely to overestimate certain plastic packaging categories—especially plastic foam, plastic film, and flexible plastic—due to the presence of moisture and contamination from food and other materials. No data are available to reliably correct for this issue, but analyses conducted by Oregon DEQ indicate that as much as 50 percent of the weight reported for these categories in waste characterization studies may actually be moisture and contamination.[11]

For the purposes of this study, it is assumed that all plastic packaging that ended up as contamination in collected organics or that was litter cleared through an Ecology-funded initiative was ultimately disposed as solid waste. Due to data limitations, these tons cannot be clearly differentiated from other disposed tons at a material-specific level and therefore the tons of plastic packaging presented as contamination in collected organics or collected as litter under Section 4.0 Plastic Packaging Waste Contamination, above, are assumed to represent a subset of

[11] Data on contamination correction factors used by Oregon DEQ are available at https://www.oregon.gov/deq/mm/Pages/Waste-Composition-Study.aspx

the total tons disposed reported below. Tons of plastic packaging found in recycling residuals are not included here but are described separately under Section 5.2 Recycling below.

Residential disposal includes solid waste collected curbside from residents for disposal as well as waste that is self-hauled to transfer stations, landfills, and other disposal facilities by residential generators. Commercial disposal includes solid waste collected from non-residential generators as well as waste that is self-hauled to disposal facilities by commercial generators. (See Section 1.2 Methodology for a description of how self-hauled tons were allocated to residential vs. commercial generators.)

In the residential sector, rigid and foam plastic packaging types represent the majority (57 percent) of plastic packaging disposed (85,700 tons of 151,450 total tons). In the commercial sector, the majority (61 percent) of plastic packaging disposed is plastic film and flexible plastic packaging, (110,020 tons of 179,540 total tons).

Among rigid and foam plastic packaging types, *#1 PET Bottles* accounted for the largest amount of material disposed by both residential and commercial sources, representing nearly one-quarter (22 percent) of total tons of rigid and foam plastic packaging disposed (34,890 tons of 155,220 total).

Substantial amounts of other readily recyclable rigid plastic packaging types are also disposed by both residential and commercial generators. In fact, the three plastic packaging materials that make up the most commonly produced and marketable recyclable plastic commodities**—*#1 PET Bottles, #2 HDPE Natural Bottles,* and *#2 HDPE Colored Bottles*—represent approximately 40 percent of all rigid and foam plastic packaging disposed** (62,080 tons of 155,220 total). This proportion is consistent across both residential and commercial sectors. Expanding the list of recyclable plastic commodities to include *#1 PET Other Packaging, #2 HDPE/LDPE Other Packaging,* and *#5 PP Packaging* increases the proportion to nearly three-quarters **(74 percent) of all rigid plastic packaging disposed** (114,750 tons of 155,220 total).

Among plastic film and flexible plastic packaging, *Other Plastic Film & Flexible Packaging* accounted for the majority (62 percent) of total tons of film and flexible packaging disposed (108,500 tons of 175,770 total). In the residential sector, it represented a larger portion (75 percent, 49,440 tons of 65,750 tons total) compared to the commercial sector (54 percent, 59,060 tons of 110,020 total).

Table 18 Plastic Packaging Disposed, by Sector and Material Type

Material	Residential Tons Disposed	Commercial Tons Disposed	Total Tons Disposed
Rigid & Foam Plastic Packaging	**85,700** (60,160-111,230)	**69,520** (44,830-94,250)	**155,220** (104,990-205,470)
#1 PET Bottles	20,610 (12,940-28,270)	14,290 (11,110-17,460)	34,890 (24,050-45,730)
#1 PET Other Packaging	17,210 (13,310-21,110)	11,850 (7,760-15,930)	29,060 (21,080-37,040)
#2 HDPE Natural Bottles	6,030 (4,520-7,550)	8,230 (5,040-11,430)	14,270 (9,560-18,970)
#2 HDPE Colored Bottles	8,380 (6,070-10,680)	4,540 (3,240-5,830)	12,910 (9,310-16,520)
#2 HDPE/LDPE Other Packaging	3,680 (2,250-5,110)	4,460 (2,520-6,410)	8,140 (4,780-11,520)
#5 PP Packaging	8,160 (6,720-9,590)	7,310 (4,470-10,150)	15,470 (11,190-19,740)
Other Rigid Plastic Packaging	6,930 (4,230-9,640)	3,620 (2,270-4,970)	10,550 (6,490-14,600)
Polystyrene Foam Packaging	12,890 (9,520-16,260)	9,560 (5,240-13,870)	22,450 (14,760-30,130)
Plastic Composite Packaging	1,810 (590-3,020)	5,680 (3,160-8,190)	7,490 (3,760-11,210)
Plastic Film & Flexible Packaging	**65,750** (53,920-77,590)	**110,020** (78,010-142,020)	**175,770** (131,930-219,610)
PE Plastic Bags & Film	16,320 (12,200-20,430)	50,960 (34,400-67,520)	67,280 (46,600-87,950)
Other Plastic Film & Flexible Packaging	49,440 (41,720-57,150)	59,060 (43,620-74,500)	108,500 (85,330-131,660)
Total Tons	**151,450 (114,080-188,820)**	**179,540 (122,840-236,270)**	**330,990 (236,920-425,080)**
Pounds Per Capita			**91 (65-116)**
Pounds Per Household			**209 (149-268)**

In Washington, disposed plastic packaging is sent to landfills, apart from a small portion sent to one waste-to-energy facility in Spokane. Section 3.4 Landfill Disposal and Incineration further describes these disposal facilities and locations.

5.2 Recycling

In 2017, an estimated 69,410 total tons of plastic packaging were sent for reprocessing from the residential and commercial sectors, representing approximately 17 percent of total tons of plastic packaging waste generated. An additional 9,890 tons (2.4 percent of total tons generated) of plastic packaging were collected but not effectively captured for recycling and/or were deemed non-recyclable and ejected from the sortation process as residuals.

5.2.1 Residential Recycling Rates

Most plastic packaging recycled from the residential sector is *#1 PET Bottles*, which represents 40 percent of all marketable plastic commodities sent for reprocessing from the residential sector (12,090 tons of 30,150 total). Even still, the estimated recycling rate for *#1 PET Bottles*—that is, the percent of all tons generated that were collected, sorted into marketable commodities, and sent for reprocessing —is 36 percent. This is the highest recycling rate of all plastic packaging generated by the residential sector.

Overall, less than one-quarter (23 percent) of rigid and foam plastic packaging from the residential sector is collected and sorted into marketable commodities.

Very little plastic film and flexible plastic packaging from the residential sector is sent for reprocessing. The vast majority of residential film recycled is collected through return-to-retail collection programs and managed through reverse logistics (94 percent, 3,240 of 3,430 tons).

Most plastic film and flexible plastic packaging used and sold by producers to consumers is not considered readily recyclable with current technology due to market conditions or packaging makeup. Most residential recycling collection programs do not accept plastic film and flexible plastic packaging. Even still, nearly 3,000 tons of the estimated 6,160 total tons of plastic film and flexible plastic packaging collected are from the residential sector through curbside and public (non-retail) drop-off recycling programs. Only a small portion of MRF-collected film was reported as recycled, with the rest being considered contamination, posing numerous problems for sorting facilities and is ultimately disposed as part of recycling residuals.

Table 19 Plastic Packaging Recycling Rates, Residential Sector

Material	Tons Collected for Recycling	Tons in Residue/ Rejected	Tons Sent as Commodities for Reprocessing	Total Tons Generated	Recycling Rate
Rigid & Foam Plastic Packaging	**30,890**	**4,170**	**26,720**	**116,590** (91,050-142,120)	**23%** (19-29%)
#1 PET Bottles	13,360	1,270	12,090	33,970 (26,300-41,630)	36% (29-46%)
#1 PET Other Packaging	2,710	260	2,450	19,920 (16,020-23,820)	12% (10-15%)
#2 HDPE Natural Bottles	3,070	100	2,970	9,100 (7,590-10,620)	33% (28-39%)
#2 HDPE Colored Bottles	4,380	250	4,130	12,760 (10,450-15,060)	32% (27-40%)
#2 HDPE/LDPE Other Packaging	1,050	30	1,020	4,730 (3,300-6,160)	22% (17-31%)
#5 PP Packaging	4,870	1,990	2,880	13,030 (11,590-14,460)	22% (20-25%)
Other Rigid Plastic Packaging	1,140	100	1,040	8,070 (5,370-10,780)	13% (10-19%)
Polystyrene Foam Packaging	430	180	250	13,320 (9,950-16,690)	2% (1-2%)
Plastic Composite Packaging	0	0	0	1,810 (590-3,020)	0% (0-0%)
Plastic Film & Flexible Packaging[12]	**6,160**	**2,730**	**3,430**	**71,910** (60,080-83,750)	**5%** (4-6%)
PE Plastic Bags & Film	5,160	1,730	3,430	21,480 (17,360-25,590)	16% (13-20%)
Other Plastic Film & Flexible Packaging	1,000	1,000	0	50,440 (42,720-58,150)	0% (0-0%)
Total Tons	**37,050**	**6,900**	**30,150**	**188,500** (151,130-225,870)	**16%** (13-20%)

Regional patterns in residential recycling of rigid and foam plastic packaging indicate a correlation between the levels of residential recycling collection service described in Section 3.2.1 Residential Recycling Collection, above, and the recycling rates achieved.

Nearly two-thirds (62 percent) of rigid and foam plastic packaging sent for reprocessing from the residential sector is generated in the Puget Sound region even though the region represents less than half (47 percent) of all tons of rigid and foam plastic packaging generated from the residential sector statewide. All households in the Puget Sound region have some level of access to curbside recycling collection programs. In contrast, the Central region—where less than half of households (49 percent) have access to curbside recycling collection—represents nearly one-fifth (18 percent) of total residential generation of rigid and foam plastic packaging, but contributes only one percent of the total tons of rigid and foam plastic packaging sent for reprocessing statewide; the region achieves an estimated recycling rate for this category of just two percent.

Table 20 Recycling of Residentially Generated Rigid & Foam Plastic Packaging, by Region

Region	Tons Sent for Reprocessing	Tons Generated	Regional % of Tons Sent for Reprocess-ing	Regional % of Tons Generated	Recycling Rate	Lbs. Recycled Per HH
Central	350	20,540	1%	18%	2%	3
East	3,010	17,980	11%	15%	17%	14
Northwest	1,700	4,830	6%	4%	35%	16
Puget Sound	16,650	54,990	62%	47%	30%	18
Southwest	3,890	14,250	15%	12%	27%	28
West	1,120	4,000	4%	3%	28%	16
State Total	**26,720**	**116,590**			**23%**	**17**

Data about the regional distribution of plastic film and flexible plastic packaging from the residential sector collected through return-to-retail are not available, but the distribution of retail locations participating in return-to-retail collection of plastic bags and film indicate that approximately 58 percent (261 of 453 listed locations) are located in the Puget Sound region. At least some of these are directly related to efforts in 2020 to provide more consumer access to recycling after film was removed from curbside collection in Seattle and other cities in King County.

5.2.2 Commercial Recycling Rates

The majority of plastic packaging recycled from the commercial sector is *PE Plastic Bags & Film*, which represents 40 percent of all marketable plastic commodities sent for reprocessing from the commercial sector (15,850 tons of 39,260 total). The estimated commercial sector recycling rate for *PE Plastic Bags & Film* is 23 percent. Most of this material is collected through reverse logistics and/or self-hauling of clean PE film directly to reprocessors (60 percent, 9,500 of 15,850 tons). The remainder is collected through private arrangements between commercial generators and private solid waste or recycling collectors.

Overall, approximately 25 percent of rigid and foam plastic packaging from the commercial sector is collected and sorted into marketable commodities. *#1 PET Bottles* make up nearly one-third (30 percent) of these tons (6,930 tons of 23,410 total). Three other recyclable commodities—*#2 HDPE Natural Bottles, #1 PET Other Packaging, and #5 PP Packaging*—represent the majority (51 percent) of total rigid and foam plastic packaging tons sent for reprocessing (12,050 tons of 23,410 total).

Table 21 Plastic Packaging Recycling Rates, Commercial Sector

Material	Tons Collected for Recycling	Tons in Residue/ Rejected	Tons Sent as Commodities for Reprocessing	Total Tons Generated	Recycling Rate
Rigid & Foam Plastic Packaging	**25,220**	**1,810**	**23,410**	**94,740** (70,050-119,470)	**25%** (20-33%)
#1 PET Bottles	7,480	550	6,930	21,770 (18,590-24,940)	32% (28-37%)
#1 PET Other Packaging	4,180	110	4,070	16,030 (11,940-20,110)	25% (20-34%)
#2 HDPE Natural Bottles	4,930	40	4,890	13,160 (9,970-16,360)	37% (30-49%)
#2 HDPE Colored Bottles	2,580	110	2,470	7,120 (5,820-8,410)	35% (29-42%)
#2 HDPE/LDPE Other Packaging	390	10	380	4,850 (2,910-6,800)	8% (6-13%)
#5 PP Packaging	3,950	860	3,090	11,260 (8,420-14,100)	27% (22-37%)
Other Rigid Plastic Packaging	1,240	40	1,200	4,860 (3,510-6,210)	25% (19-34%)
Polystyrene Foam Packaging	470	80	390	10,030 (5,710-14,340)	4% (3-7%)
Plastic Composite Packaging	0	0	0	5,680 (3,160-8,190)	0% (0-0%)
Plastic Film & Flexible Packaging[13]	**17,030**	**1,180**	**15,850**	**127,050** (95,040-159,050)	**12%** (10-17%)
PE Plastic Bags & Film	16,600	750	15,850	67,560 (51,000-84,120)	23% (19-31%)
Other Plastic Film & Flexible Packaging	430	430	0	59,490 (44,050-74,930)	0% (0-0%)
Total Tons	**42,250**	**2,990**	**39,260**	**221,790** (165,090-278,520)	**18%** (14-24%)

Regional patterns in commercial recycling of rigid and foam plastic packaging are largely similar to residential recycling except that the Central region appears to have slightly more recycling activity in the commercial sector, while the East region appears to have relatively less commercial sector activity compared to its residential sector.

Table 22 Recycling of Commercially Generated Rigid & Foam Plastic Packaging, by Region

Region	Tons Sent for Reprocessing	Tons Generated	Regional % of Tons Sent for Reprocessing	Regional % of Tons Generated	Recycling Rate
Central	2,030	15,820	9%	17%	13%
East	880	13,510	4%	14%	7%
Northwest	2,840	7,880	12%	8%	36%
Puget Sound	16,000	49,440	68%	52%	32%
Southwest	1,360	5,570	6%	6%	24%
West	310	2,520	1%	3%	12%
State Total	**23,410**	**94,740**			**25%**

Some data are available on the regional distribution of commercial recycling of plastic film and flexible plastic packaging but inconsistencies and gaps in reporting on the location of the generating source make this information unreliable for analysis of regional trends.

5.2.3 Overall Recycling Rates for Plastic Packaging

Overall recycling rates for plastic packaging in Washington, calculated by combining the estimates for residential and commercial sector recycling and generation, are presented in Table 23 below. Regional patterns of rigid and foam plastic packaging across residential and commercial sectors are presented in Table 24 below.

[13] As noted in Table 19, the data from 2017 reflect circumstances before import restrictions were imposed in 2018. Tons collected for recycling are likely lower currently due to the loss of export markets for this material.

Table 23 Plastic Packaging Recycling Rates, Overall

Material	Tons Collected for Recycling	Tons in Residue/ Rejected	Tons Sent as Commodities for Reprocessing	Total Tons Generated	Recycling Rate
Rigid & Foam Plastic Packaging	**56,110**	**5,980**	**50,130**	**211,340** (161,100-261,580)	**24%** (19-31%)
#1 PET Bottles	20,830	1,810	19,020	55,730 (44,880-66,560)	34% (29-42%)
#1 PET Other Packaging	6,890	370	6,520	35,950 (27,970-43,930)	18% (15-23%)
#2 HDPE Natural Bottles	8,000	140	7,860	22,260 (17,560-26,970)	35% (29-45%)
#2 HDPE Colored Bottles	6,950	350	6,600	19,870 (16,260-23,470)	33% (28-41%)
#2 HDPE/LDPE Other Packaging	1,440	40	1,400	9,580 (6,220-12,960)	15% (11-23%)
#5 PP Packaging	8,820	2,850	5,970	24,290 (20,010-28,560)	25% (21-30%)
Other Rigid Plastic Packaging	2,380	140	2,240	12,930 (8,870-16,980)	17% (13-25%)
Polystyrene Foam Packaging	900	260	640	23,350 (15,660-31,030)	3% (2-4%)
Plastic Composite Packaging	0	0	0	7,490 (3,760-11,210)	0% (0-0%)
Plastic Film & Flexible Packaging	**23,190**	**3,910**	**19,280**	**198,960** (155,120-242,800)	**10%** (8-12%)
PE Plastic Bags & Film	21,750	2,470	19,280	89,030 (68,350-109,700)	22% (18-28%)
Other Plastic Film & Flexible Packaging	1,430	1,430	0	109,930 (86,760-133,090)	0% (0-0%)
Total Tons	**79,300**	**9,890**	**69,410**	**410,300** (316,190-504,350)	**17%** (14-22%)

Table 24 Recycling of Rigid & Foam Plastic Packaging, by Region

Region	Tons Sent for Reprocessing	Tons Generated	Regional % of Tons Sent for Reprocessing	Regional % of Tons Generated	Recycling Rate
Central	2,390	36,360	5%	17%	7%
East	3,890	31,490	8%	15%	12%
Northwest	4,540	12,710	9%	6%	36%
Puget Sound	32,650	104,440	65%	49%	31%
Southwest	5,240	19,820	10%	9%	26%
West	1,430	6,520	3%	3%	22%
State Total	**50,130**	**211,340**			**24%**

The available data are less reliable for calculating recycling rates at the regional level on a material-specific basis because the level of specificity in reporting of tons sent for reprocessing varies across regions. Tons reported as "mixed recycling" or "mixed plastics" must be broken out by material type using proxy composition data, making material-specific recycling rate estimates less accurate for regions where a larger proportion of tons are reported in this way.

Nonetheless, assessing the regional differences in recycling rates for the most prevalent rigid plastic packaging type—*#1 PET Bottles*—provides some indication of important correlations between the extent and method of recycling collection and the recycling rates achieved.

As shown in Table 25, more than half (54 percent) of PET bottles generated in the Northwest region—where the majority of jurisdictions accept plastic bottles in curbside recycling programs where curbside and commercial recycling programs are widespread—were estimated to be collected, effectively sorted, and sent for reprocessing.

In the Puget Sound region—where access to curbside and commercial recycling is widespread and acceptance of plastic bottles is nearly universal but where single-stream collection leads to higher rates of contamination and greater loss of collected materials during sorting—just under half (48 percent) of PET bottles generated were effectively captured and sent for reprocessing.

The Southwest and West regions—where curbside recycling is provided as a universal service to the majority of residents but where plastic bottles are less commonly included in curbside and commercial collection programs—just over one-third of plastic bottles were captured.

Unsurprisingly, recycling rates for PET bottles are lowest in the Central and East regions—where only a minority of residents have universal curbside recycling collection and where most jurisdictions do not collect plastic bottles for recycling, even if they offer curbside collection.

Table 25 Recycling of #1 PET Bottles, by Region

Region	PET Bottles RCY	PET Bottles GEN	Regional % of PET Bottles RCY	Regional % of PET Bottles GEN	PET Bottles RCY Rate
Central	690	11,980	4%	21%	6%
East	1,420	7,570	7%	14%	19%
Northwest	2,160	4,010	11%	7%	54%
Puget Sound	11,960	24,780	63%	44%	48%
Southwest	2,210	5,870	12%	11%	38%
West	590	1,520	3%	3%	39%
State Total	**19,020**	**55,730**			**34%**

Source: 2015-16 Washington Statewide Waste Characterization Study

5.2.4 Recycling Utilization and Bale Contamination

The recycling rates for plastic packaging presented in the preceding tables represent the portion of all tons generated that were collected, sorted into marketable commodities, and sent to plastics reprocessors or end users for recycling. These rates provide a more accurate assessment of recycling than the collection rates—which count all tons collected for recycling as "recycled" without accounting for contamination or losses during sortation—that are sometimes used to describe recycling performance.

However, the recycling rates above still fail to fully reflect the true rate at which plastic packaging materials are utilized as recycled feedstock in new products because they do not include corrections for the presence of contaminants in commodity bales sent for reprocessing and also do not account for yield losses during reprocessing.

Data on both bale contamination and yield losses are extremely limited and no sufficient sources were available to incorporate quantitative estimates in this study, but recent findings from the King County 2019 MRF Assessment are described in detail in Section 4.1.3 Contamination of Commodity Bales.

A study conducted by Ecology in 2016 estimated the overall material loss/utilization rates for recyclable commodities, including plastics, accounting for all material losses incurred from collection through to end use. According to the study, material loss rates for plastics are between 18 and 29 percent. Put another way, these findings suggest that for every 100 tons of plastics collected for recycling, only between 71 and 82 tons makes it into a new product [84]. Another study, focused specifically on PET bottle recycling, found that 17 percent of PET that travels through a MRF is not captured in the PET bale. The same study estimated that the average yield of curbside PET bales is 62 percent, while the remaining 38 percent of "PET bottle" bales was composed of caps and labels, other plastic packaging, fines, and moisture [91]. This underscores the disparity between the number of tons *sent* to be recycled and the number of tons *actually* recycled, and the challenges to be addressed if those numbers are to move closer together.

5.2.5 End Markets

Under most collection arrangements in Washington, recyclable materials become the property of the private companies that collect them and/or the MRFs and other private recyclers that receive collected materials as part of the terms established for collection and/or sorting of the materials. Sales of these materials as marketable commodities are then made under business-to-business arrangements and, because many of these businesses wish for this information to remain confidential, little information is available about where these commodities are sent or what portion is ultimately recycled into new products and packaging. Even when information is provided, there is no independent verification of the claims made.

Regulated recycling facilities—both permitted and exempt—are asked to report annually on the destination of materials handled to Ecology, including the company name, city, state, and country to which each material type handled was delivered, as well as tons sent to each receiving facility within the past calendar year. But many regulated facilities do not provide responses in these sections. Of all plastic tons reported as collected from Washington generators and sent for reprocessing on recycling destination forms in 2017, less than ten percent listed destination facilities that are known plastics reprocessors or end users of recycled plastics. The majority of plastic tons reported (62 percent) listed scrap brokerage companies or MRFs as the destination facilities. These companies broker and export scrap to international buyers but are subject to virtually no oversight or regulatory control except through customs inspections of incoming materials by the governments of the receiving countries at receiving ports.

A substantial portion (29 percent) of plastic tons reported included no specific destination facility or provided vague responses such as “various” or “export to China.” Ecology has limited resources to pursue incomplete submissions and lacks authority to require responses or obtain verification of reported information. There is no requirement for brokers or other so-called “intermediate handlers” to report to Ecology on the final destination of brokered plastics or to provide documentation of any kind that brokered plastics were responsibly recycled.

Although no reliable data are available to trace the flow of recyclable commodities to end markets, it is assumed that very little rigid plastic packaging collected in Washington is reprocessed in-state. Of the 11 plastics reprocessors identified in Washington and the surrounding region (including Oregon and British Columbia), only a few handle post-consumer rigid plastics and, among those, only one—located in British Columbia—accepts predominantly curbside materials and mixed rigid plastic bales [92]. Some recyclable rigid and foam plastic commodities are thought to be sent to these regional reprocessors. Others are sent to reprocessors in other parts of the U.S. and still others are exported to reprocessors in other countries.

As with the final destination of recyclable commodities, the end uses specific to Washington-generated material are also largely unknown. According to the U.S. EPA, the predominant use for recycled PET is in an open-loop recycling application, in which the material is transformed into a synthetic fiber (polyester) and used in non-packaging applications including clothing, carpet, and other synthetic textiles. Secondarily, it is used in closed-loop recycling to produce PET packaging with recycled content [93].

The majority of recycled natural HDPE is used in closed-loop recycling to produce HDPE packaging with recycled content. The majority of recycled colored HDPE, however, is used in open-loop applications to produce opaque durable plastic products such as crates, pallets, and pipes.

Recycled PP has recently begun to be used in closed-loop production of packaging, as well as in open-loop production applications of other PP products made with recycled content [94].

Most of the plastic film collected through reverse logistics in Washington is sent to a single, out-of-state end user that uses the material in the production of a composite lumber product. Other regional plastic film reprocessors receive some commodity bales from within Washington, but it is unknown how much in-state material they handle and how much of it is post-consumer packaging film.

Polystyrene foam packaging, which is primarily collected through drop-off programs and then consolidated and densified by a single company operating in the Puget Sound region, is currently sold to domestic (U.S. but outside of Washington) and international end users.

End markets and applications for plastic packaging sold as part of mixed rigid commodities to export markets are highly uncertain, though the amount of material collected and sold as mixed rigids has fallen over the last several years for both export and domestic use. Numerous investigative reports have indicated that plastics sold as “mixed” commodities are simply sorted to extract the high-value materials—such as PET bottles and HDPE and PP bottles and containers that were not effectively separated into single-resin commodity bales—and remaining materials are then disposed or discarded, in some cases in ways that pose significant harm to human health and the environment [95], [96]. Prior to China’s ban on imports of mixed plastic waste in 2018, it received the majority of mixed plastics exported. Since China’s ban went into effect, exported plastics have been redirected to other countries, primarily in Southeast Asia, that are not well equipped to handle the material, where negative environmental and human health impacts have been extensively documented [97].

For this reason, in 2019, 187 countries agreed to amendments incorporating regulation of plastic waste into the Basel Convention, a longstanding treaty with the goal of limiting global trade in hazardous wastes, especially between developed and developing countries. Under the new amendments, which go into effect January 1, 2021, only plastic scrap that has been sorted into a single polymer commodity or a limited mixed commodity of PET, PE, and PET scrap that is destined to be separately recycled will be allowed to be exported from Organization for Economic Cooperation and Development (OECD) member countries to developing countries [98]. Even though the U.S. has not ratified the Basel Convention, it will be subject to it under most circumstances because the treaty prohibits trade of regulated materials between participating countries (which represent the majority of nations globally) and non-participating countries unless a special valid multinational or bilateral agreement is in place that explicitly allows such trade [99].

Several major U.S. MRF operators—including Waste Management—have also publicly committed to no longer exporting plastic waste outside of North America [100].

6.0 Cost of the Current Plastic Packaging Waste Management System

This section describes findings from the modeling of full costs incurred under the current plastic packaging management system, including costs related to:

- Collection, sorting, and marketing of plastic packaging for recycling
- Collection and disposal of plastic packaging through landfilling and incineration
- Contamination clean-up associated with plastic packaging in collected organics
- Clean-up of plastic packaging discarded as litter
- Social cost of carbon emissions and other climate pollution associated with plastic packaging currently disposed

Overall, annual costs attributable to management of plastic packaging from the residential sector through recycling and disposal total approximately $81.4 million. Costs attributable to the commercial sector total approximately $83.6 million. Combined, these estimates indicate that **costs attributable to management of plastic packaging through recycling and disposal in Washington State total approximately $165 million per year.**

Costs for managing plastic packaging were modeled using a combination of weight and volume cost allocation methods, described in detail in the Costs section of Appendix B: Technical Methodology, and noted in the tables below where relevant. All cost estimates presented in the tables below are rounded to the nearest hundred for clarity.

The modeled costs of managing different types of plastic packaging items vary by material. Materials that are less dense when collected together take up a greater proportion of available space (per ton) in collection vehicles and sorting facilities. Additionally, different plastic packaging materials have different market values when sorted and sold to reprocessors. Materials that are sold for higher values have lower 'net costs' for recycling compared to materials that are sold for lower values or that are not sold.

Though costs are incurred at various points throughout recycling and waste management systems, **the net costs of managing plastic packaging waste ultimately fall on Washington residents and businesses** who pay through rates to service providers for garbage, recycling, and organics collection services, through tipping fees paid directly at disposal and recycling facilities, and through direct expenditure by businesses that generate plastic packaging waste and pay for its full management directly.

The local governments and private companies that operate the services involved in managing plastic packaging waste charge rates that generate revenues to cover their costs and, in the case of private companies, typically provide a profit margin for operating these services.

There are undoubtedly costs associated with the management and promotion/communication of recycling services borne by local governments that are not fully covered by collection rates and tipping fees and that are covered instead through grant funds from the State and general funds contributed via local taxation methods. However, given the lack of data on the contributions of funds toward these services across local governments in Washington, these costs are not factored into the modeled costs. For the purposes of this study, only costs directly attributable to rates paid by residents and businesses for solid waste and recycling services, as well as costs directly attributable to litter clean-up funded through the state’s Waste Reduction, Recycling, and Litter Control Account (WRRLCA), were included.

6.1 Recycling

Residential Recycling Costs

Single-family residents pay for recycling system costs through rates to service providers, either directly or indirectly through costs embedded in garbage rates. Multifamily residents sometimes pay these costs directly through utility fees charged by building managers but more often pay them indirectly as part of their rent payment. The rates paid cover the costs of collection and sorting of recyclable materials plus disposal of residuals rejected during sortation. This includes a profit margin for private companies involved in providing these services, minus revenues generated from the sale of recyclable commodities. As the value of recyclable commodities has declined over the past few years, the net costs have consequently increased.

While plastic packaging made up only approximately 5.6 percent of all tons collected for recycling (including through drop-off) from residents in Washington in 2017, it represents approximately 17.6 percent of the volume. The estimated system costs for residential recycling allocated to plastic packaging are calculated by volume rather than weight since recycling system costs are generally driven more by volume.

As shown in Table 26, residential recycling system costs attributable to plastic packaging total approximately **$37 million annually**. Most of these costs are incurred in the collection phase.

Table 26 Annual Residential Recycling System Costs Attributable to Plastic Packaging

Plastic Packaging Waste Material Type	SF RCY Collection	MF RCY Collection	All RES Sorting	All RES RSD Disposal	Total RES Recycling
Rigid & Foam Plastic Packaging	**$21,273,100**	**$4,617,500**	**$2,755,800**	**$48,800**	**$28,695,200**
#1 PET Bottles	$9,232,600	$1,997,100	$(25,400)	$14,800	$11,219,100
#1 PET Other Packaging	$1,877,000	$414,000	$386,200	$3,000	$2,680,300
#2 HDPE Natural Bottles	$1,638,100	$349,600	$(267,500)	$1,100	$1,721,400
#2 HDPE Colored Bottles	$2,336,700	$499,600	$(14,500)	$2,900	$2,824,700
#2 HDPE/LDPE Other Packaging	$698,500	$149,400	$239,800	$400	$1,088,100
#5 PP Packaging	$3,364,700	$735,400	$1,390,400	$23,200	$5,513,800
Other Rigid Plastic Packaging	$1,808,700	$400,600	$790,400	$1,200	$3,000,900
Polystyrene Foam Packaging	$316,700	$71,800	$256,300	$2,100	$646,900
Plastic Composite Packaging	$-	$-	$-	$-	$-
Plastic Film & Flexible Packaging	**$4,946,100**	**$1,142,900**	**$2,178,500**	**$31,900**	**$8,299,400**
PE Plastic Bags & Film	$3,014,900	$721,800	$1,409,000	$20,200	$5,165,900
Other Plastic Film & Flexible Packaging	$1,931,200	$421,100	$769,500	$11,700	$3,133,500
Total Costs	**$26,219,300**	**$5,760,400**	**$4,934,300**	**$80,700**	**$36,994,600**

Commercial Recycling Costs

Like Washington residents, Washington businesses that have access to recycling service generally pay for recycling system costs through rates to service providers, either directly or indirectly through costs embedded in garbage rates. As with multifamily residents, some businesses that lease their space sometimes pay these costs through utility fees charged by building managers as part of rent costs. Commercial recycling system costs have faced similar market dynamics as residential recycling, with declining commodity values driving up net system costs.

Some businesses also incur direct expenditures for management of plastic packaging recycling chains, such as through reverse logistics operations. Costs for those systems are unknown—though net costs are thought to be low, given that businesses that participate in them are primarily motivated to do so by the potential for cost savings relative to disposal—and not included in this estimate.

Plastic packaging made up approximately four percent of all tons collected (including through drop-off) from businesses for recycling in Washington in 2017 and represents approximately 15 percent of the volume. As with residential recycling system costs, the estimated system costs for commercial recycling allocated to plastic packaging are calculated by volume rather than weight.

Commercial recycling system costs attributable to plastic packaging total approximately **$26.8 million annually**. Approximately three-quarters of these costs are incurred in the collection phase.

Table 27 Annual Commercial Recycling System Costs Attributable to Plastic Packaging

Plastic Packaging Waste Material Type	COM Collection	COM Sorting	COM RSD Disposal	Total COM Recycling
Rigid & Foam Plastic Packaging	**$10,967,900**	**$2,382,400**	**$21,100**	**$13,371,500**
#1 PET Bottles	$3,265,800	$(318,000)	$6,400	$2,954,200
#1 PET Other Packaging	$1,828,100	$388,800	$1,300	$2,218,200
#2 HDPE Natural Bottles	$1,730,500	$(576,900)	$500	$1,154,100
#2 HDPE Colored Bottles	$904,600	$953,600	$1,200	$1,859,500
#2 HDPE/LDPE Other Packaging	$155,700	$76,100	$200	$231,900
#5 PP Packaging	$1,619,000	$975,900	$10,100	$2,605,000
Other Rigid Plastic Packaging	$1,246,400	$750,600	$500	$1,997,500
Polystyrene Foam Packaging	$217,700	$132,400	$900	$350,900
Plastic Composite Packaging	$-	$-	$-	$-
Plastic Film & Flexible Packaging	**$8,482,700**	**$4,931,100**	**$13,800**	**$13,427,700**
PE Plastic Bags & Film	$8,012,500	$4,646,600	$8,700	$12,667,900
Other Plastic Film & Flexible Packaging	$470,200	$284,600	$5,100	$759,800
Total Costs	**$19,450,600**	**$7,313,600**	**$34,900**	**$26,799,100**

6.2 Disposal

Residential Disposal Costs

Washington residents pay for disposal system costs in much the same way as for recycling. In addition, residents who self-haul materials pay tipping fees directly at disposal facilities.

Unlike recycling costs, the estimated system costs for residential disposal allocated to plastic packaging are calculated by weight, relative to the total weight of residential waste disposed. Although this approach is appropriate for apportioning garbage costs to plastic packaging, it is important to note that this approach counter-intuitively implies that where two trucks pass the same house, one collecting recycling and one collecting garbage, it would be cheaper to put a plastic bottle in the garbage truck than the recycling truck. While this may be true when considering only the direct costs associated with collection operations, it does not account for the externalized environmental and social costs associated with plastic packaging that could be reduced if that material was recycled rather than disposed. Incorporating consideration of such externalities in the cost calculation is therefore important for better representing the true costs of collecting plastic packaging for disposal compared to recycling.

Residential disposal system costs attributable to plastic packaging total approximately **$44.4 million annually**, with 61 percent of costs incurred in the collection phase and 39 percent incurred in the disposal phase.

Table 28 Annual Residential Disposal System Costs Attributable to Plastic Packaging

Plastic Packaging Waste Material Type	SF Garbage Collection	MF Garbage Collection	All RES Collected Disposal	All RES Self-Haul Disposal	Total RES Disposal
Rigid & Foam Plastic Packaging	**$11,164,800**	**$3,622,100**	**$9,067,700**	**$627,000**	**$24,481,500**
#1 PET Bottles	$1,879,900	$908,400	$2,076,100	$83,200	$4,947,600
#1 PET Other Packaging	$2,824,400	$720,400	$1,936,900	$115,900	$5,597,500
#2 HDPE Natural Bottles	$731,700	$273,300	$642,400	$34,200	$1,681,600
#2 HDPE Colored Bottles	$1,032,300	$379,400	$883,000	$66,300	$2,361,000
#2 HDPE/LDPE Other Packaging	$397,000	$126,200	$349,300	$78,400	$950,800
#5 PP Packaging	$1,007,100	$385,600	$884,200	$45,800	$2,322,600

Plastic Packaging Waste Material Type	SF Garbage Collection	MF Garbage Collection	All RES Collected Disposal	All RES Self-Haul Disposal	Total RES Disposal
Other Rigid Plastic Packaging	$1,155,300	$305,100	$786,900	$31,400	$2,278,700
Polystyrene Foam Packaging	$1,916,300	$474,500	$1,356,300	$116,800	$3,863,900
Plastic Composite Packaging	$220,800	$49,300	$152,500	$55,100	$477,800
Plastic Film & Flexible Packaging	**$9,843,400**	**$2,389,600**	**$7,036,300**	**$631,100**	**$19,900,400**
PE Plastic Bags & Film	$2,241,500	$588,800	$1,664,500	$197,000	$4,691,800
Other Plastic Film & Flexible Packaging	$7,601,900	$1,800,800	$5,371,800	$434,100	$15,208,600
Total Costs	**$21,008,200**	**$6,011,800**	**$16,103,900**	**$1,258,100**	**$44,381,900**

Commercial Disposal Costs

Washington businesses also pay for disposal system costs in much the same way as for recycling. In addition, businesses that self-haul materials pay tipping fees directly at disposal facilities.

As with the residential sector, estimated system costs for commercial disposal allocated to plastic packaging are calculated by weight, relative to the total weight of commercial waste disposed (excluding construction and demolition and industrial wastes).

Commercial disposal system costs attributable to plastic packaging total approximately **$56.8 million annually**, with 63 percent of costs incurred in the collection phase and 37 percent incurred in the disposal phase.

Table 29 Annual Commercial Disposal System Costs Attributable to Plastic Packaging

Plastic Packaging Waste Material Type	COM Garbage Collection	COM Collected Disposal	COM Self-Haul Disposal	Total COM Disposal
Rigid & Foam Plastic Packaging	**$13,589,900**	**$7,844,700**	**$308,800**	**$21,743,500**
#1 PET Bottles	$2,986,200	$1,618,300	$41,000	$4,645,400
#1 PET Other Packaging	$2,040,800	$1,367,100	$57,100	$3,465,000
#2 HDPE Natural Bottles	$2,018,300	$900,700	$16,800	$2,935,800

Plastic Packaging Waste Material Type	COM Garbage Collection	COM Collected Disposal	COM Self-Haul Disposal	Total COM Disposal
#2 HDPE Colored Bottles	$801,400	$505,300	$32,700	$1,339,400
#2 HDPE/LDPE Other Packaging	$1,026,700	$466,200	$38,600	$1,531,500
#5 PP Packaging	$1,030,400	$879,700	$22,500	$1,932,700
Other Rigid Plastic Packaging	$577,900	$418,700	$15,400	$1,012,000
Polystyrene Foam Packaging	$1,904,300	$1,054,000	$57,500	$3,015,800
Plastic Composite Packaging	$1,203,900	$634,700	$27,100	$1,865,700
Plastic Film & Flexible Packaging	**$22,191,700**	**$12,538,300**	**$310,800**	**$35,040,900**
PE Plastic Bags & Film	$12,685,400	$5,473,400	$97,000	$18,255,800
Other Plastic Film & Flexible Packaging	$9,506,300	$7,064,900	$213,800	$16,785,000
Total Commercial Disposal Costs	**$35,781,600**	**$20,383,100**	**$619,600**	**$56,784,300**

6.3 Organics Contamination Clean-up

Contamination of organics loads with plastic packaging is a problem for commercial compost facilities. Plastic removal at the end of the composting process requires significant investment and resources to address, but the identification and removal of contamination is critical for composters to be able to produce a marketable product.

One large scale commercial composting company in Washington estimates spending approximately $17/ton due to contamination, of which plastic packaging was estimated to represent approximately 29 percent (by weight) of contaminants in organics collected with food scraps in Washington. These costs include labor for monitoring incoming loads and processing, contamination removal equipment (e.g., screens, vacuums, magnets), and disposal costs at the landfill.

Applying these per ton costs to the estimated 529,650 tons of organics collected, including food scraps, in Washington, the costs of managing contamination in the organics stream is estimated to be approximately **$9 million annually**, the estimate attributable to plastic packaging contamination is approximately **$2.6 million** of those costs each year. As with all ratepayer-funded services, these costs are ultimately passed on to the ratepayers—residents and businesses—who pay more for organics collection services as a result.

6.4 Litter Clean-Up

Litter clean-up in Washington is the only aspect of plastic packaging management that is funded, in part, by packaged goods producers. The state litter tax—equivalent to $150 in tax per $1 million in sales—generates approximately $11.4 million annually from industries based on retail sales of 13 categories of products that are commonly littered, including many plastic packaging items.

While it is not clear how much of these funds are attributable to activities that support litter clean-up of plastic packaging specifically, data on the proportion of plastic packaging in litter can be used to develop an estimate of how much of these funds ought to be attributable to plastic packaging if used for their intended purpose. Based on data from the Washington State 2004 Litter Study (the most recent data available on roadway litter composition in Washington) that indicates that plastic packaging materials accounted for approximately 5.7 percent of all roadway litter, by weight, it follows that 5.7 percent of litter tax revenue—equivalent to **$649,000 per year**—could reasonably be assumed to be attributable to plastic packaging [66].

Local governments also engage in additional litter clean-up activities, such as street sweeping and public space collection systems, funded through other local revenue sources. No data are available on litter clean-up spending by local governments or non-profit organizations in Washington outside of programs supported by the litter tax, but a recent study of litter programs in Texas found that local governments spent an average of $3.74 per person per year on litter abatement [101]. Applied to Washington's population, local government spending on litter clean-up would total an estimated $28.2 million annually.

There are no data on what portion of litter addressed through local government activities is plastic packaging (the 2004 Litter Study only characterized roadway litter, not litter in other public spaces), so it is not possible to estimate what portion of this expenditure might be attributable to plastic packaging. However, it is reasonable to assume that local governments in Washington dedicate additional funding generated from local taxes and fees beyond the litter tax to address plastic packaging discarded as litter.

6.5 Social Cost of Climate Pollution Associated with Plastic Packaging Waste

In addition to the economic costs incurred, plastic packaging that is disposed in Washington represents substantial costs incurred by all current and future state residents, the global community, and the environment in the form of climate pollution from greenhouse gas (GHG) emissions associated with plastic packaging throughout its lifecycle, which are primarily generated during material acquisition and manufacturing using virgin inputs.

The most recent Waste Reduction Model (WARM) produced by the U.S. EPA demonstrates that, in all cases, reduction of plastic packaging would provide GHG emissions savings compared to disposal through landfilling or combustion (assuming materials that are reduced/eliminated are not substituted with other materials that may have higher emissions impacts) [93]. Applying the latest WARM emissions factors to Washington data indicates plastic packaging waste—as generated and managed as of 2017—represents approximately 757,000 metric tons of carbon dioxide equivalent ($MTCO_2e$) of embodied carbon and emissions. Applying a value of $74 per ton as the social cost of climate pollution—the estimate produced by the Interagency Working Group on Social Cost of Greenhouse Gases and adopted by the WUTC to represent the broad array of economic and social damage caused by carbon and other greenhouse gas emissions—indicates that the current state of plastic packaging waste in Washington represents an externalized cost of roughly **$56 million annually** [102].

Due to limited lifecycle analysis data availability, WARM only models the relative GHG emissions savings realized through recycling for PET and HDPE plastics, but both analyses indicate that recycling would reduce net GHG emissions, and the externalized social costs of those emissions borne by all current and future state residents, compared with disposal of these plastic packaging types.

The externalized social costs associated with GHG emissions from plastic packaging still disposed in Washington are especially high for PET bottles, both because of the large proportion of disposed plastic packaging they represent (approximately ten percent of all plastic packaging disposed in the state, as shown in Table 18), and because recycling PET bottles delivers meaningful emissions reductions when used to displace virgin resin in production of new bottles or polyester products [103]. Applying the latest WARM emissions factors to Washington data indicates that disposal of the 34,890 tons of #1 PET bottles disposed in 2017 represents approximately 79,200 metric tons of carbon dioxide equivalent ($MTCO_2e$) of embodied carbon and emissions generated through disposal, or the equivalent emissions from over 17,000 passenger vehicles driven for one year [104].

Applying the social cost of climate pollution indicates that continued disposal of PET bottles in Washington represents an externalized cost of roughly **$5.85 million** annually, of which over $3.2 million could be offset if these bottles were recycled instead of disposed [102]. Externalized costs would be reduced even further through refill, reuse, material reduction, or elimination of PET bottles (as long as other higher-impact materials were not substituted in place of PET).

While outside the scope of this study, there are obviously much broader social and environmental impacts—in addition to GHG emissions and climate impacts—associated with the extraction, production, use, and disposal of plastic packaging. Air and water pollution and associated public health impacts, impacts to wildlife in marine and terrestrial ecosystems, and environmental justice considerations related to disproportionate siting of plastics production and solid waste facilities near low-income and communities of color add to the costs of plastic packaging. These costs, as well as the social costs and environmental impacts of other packaging materials that might be used as substitute materials, should be considered in development of strategies to reduce plastic packaging waste.

7.0 Contamination and Sorting Issues

This section describes the contamination and sorting issues facing the current plastic packaging recycling system, which ultimately impact the ability of material to be recycled into new products and packaging.

7.1 Materials of Concern

Materials of concern within the current plastic packaging recycling system fall into four primary categories:

- **Operational contaminants:** Items that pose serious and recurring challenges for sorting equipment, require additional labor to remove, and/or are not effectively captured due to technical challenges during sorting operations.
- **Unmarketable commodities and questionable sales:** Technically recyclable but due to low value and/or low volume, these materials are difficult or unable to be marketed and thus usually not recycled. These materials are generally baled together, combining plastic packaging types that are of relatively low value with materials of higher value and sending all to questionable destinations, with no verification as to which, if any, component materials were ultimately recycled.
- **Recycling system disruptors:** Components attached to packaging or characteristics of packaging that disrupt the recycling process, including labels and closures, multi-resin or multi-material formats, and remaining product residue.
- **Toxics:** Endocrine disrupting chemical additives, carcinogens, and bioaccumulative toxics are present in some packaging formulations. These pose health risks to workers during manufacture as well as to consumers. They also cause environmental harm through their presence in litter, landfill leachate, and marine debris. Toxics can also potentially contaminate recycled content feedstock.

7.1.1 Operational Contaminants

The following operational contaminants cause issues for sorting equipment at MRFs, as well as equipment at reprocessors and end users of other material like paper, in which plastic contamination often ends up:

- **Plastic bags and film** are identified as the greatest concern in terms of the issues they pose for sorting commingled materials (though this issue is not exclusive to MRFs which accept single-stream material). This category includes both shopping bags—which will soon be banned in thin format and required to be thicker and reusable under the new statewide bag ban—and other types of merchandise and food bags, as well as plastic mailing envelopes, dry cleaning and newspaper bags, case overwraps, etc. Bags and film tangle on sorting screens, slow down operations, and require additional labor to remove from sorting equipment and lines. They can also behave like two dimensional materials and end up in paper bales as a contaminant. While the bag ban will address part of this issue, there are many other types of bags and film that will not be impacted by the state law and so it is likely that this material will still cause issues for MRFs in the future.

- **Other flexible plastic packaging**, such as plastic coffee bags, food and candy wrappers, food and drink pouches, pouches for household cleaning products, sachets for food and drink, cleaning, and personal care products, and other similar items. These materials also often behave like two dimensional materials when going through sorting equipment and can end up in paper bales as a contaminant.
- **Small format plastic packaging elements** such as caps, lids, and small packages. These materials often separate from their primary packaging and fall through sorting equipment, getting stuck in machinery and creating operational challenges for MRFs. They also often do not end up in the appropriate marketable commodity bale.
- **Polystyrene foam packaging**, especially foodservice packaging. This material often breaks apart and/or flattens during collection and can then behave like two dimensional materials in sorting equipment, ending up in paper bales as a contaminant.

7.1.2 Unmarketable Commodities and Questionable Sales

Unmarketable commodities are materials that could technically be captured using existing mechanical recycling technology if positively sorted by MRFs or collected separately, but that lack sufficient generation volume at individual MRFs and/or lack sufficient market demand to justify investments in the technologies and/or infrastructure needed to produce marketable commodities on a reliable basis. The majority of non-bottle rigid plastic packaging falls into this category.

These materials are generally baled together, combining plastic packaging types that are of relatively low value with materials of higher value. These materials are then sent, as a mixed rigid plastic bale, sometimes to questionable destinations, with no verification as to whether all materials were recycled, or recycling only high-value materials (e.g., PET, HDPE, PP) with remaining materials being discarded.

Materials that are often sorted into **mixed rigid plastic** bales include other (non-bottle) PET thermoform and injection molded PET plastics, PP, rigid PS, and plastic squeeze tubes (typically HDPE or PP), as well as substantial amounts of PET bottles and HDPE bottles, which often make it through the sortation line without effective separation. Mixed rigid bales also often include non-packaging plastics, such as plastic toys, laundry baskets, etc.

There is sufficient volume and existing reverse logistics collection channels to be able to collect **clean PE film**, but currently there is insufficient market demand for this material as a commodity to support significant increases in collection and sorting. PE film collected and processed at a MRF is usually too contaminated to viably market.

Polystyrene foam transport packaging like that used to cushion electronics and other fragile products during transportation is marketable if collected separately. However, the amount collected in the commingled recycling stream is too contaminated and the quantity too low to be consistently marketable.

7.1.3 Recycling Disruptors

When packaging is not designed with recyclability in mind, components, additives and formats can disrupt the recyling process at several points. However, not all disruptors are created equal. For example, full-body shrink sleeves on PET bottles interfere with optical sorters at MRFs so these valuable bottles may be mis-sorted or lost entirely to residue. Even if they are sorted properly they are still problematic. One reclaimer interviewed for a report by Astrx, the Sustainable Packaging Coalition, and the Recycling Partnership about material flows at MRFs and reprocessors noted that approximately five percent of PET bottles they receive are rejected and not recycled due to barriers, full-body shrink sleeve labels, or closures with metal components [105]. Conversely, PP caps do contribute to the yield loss of reprocessors, but they are currently the best option because PET closures are not a functional alternative.

Current sorting and processing technologies are unable to handle most multi-resin or multi-material packages. Non-plastic components can damage processing equipment, and multi-resin plastics have few end users able to use a mix of resins in their manufacturing. PVC is particularly problematic to other resins, even when only a small part of bale contamination.

Compostable or non-recyclable lookalikes present challenges in some packaging categories because it is too difficult for consumers and human sorters to distinguish the recyclable packages from those that would disrupt the recycling process. This includes thermoformed packages sorted without use of optical sorters.

7.1.4 Toxics

Degradation of recycled plastic commodity value occurs due to factors beyond the physical attributes that impact collection, compaction, transport, sorting, and baling. The chemical constituents of plastic packaging can also challenge the economic value of recycled content plastic. Many plastic packages and packaging constituents, through deliberate or incidental introduction, contain toxics that can negatively impact human health and the environment [106]. Even mainstream reports now acknowledge that potentially toxic chemicals can be present in food wrap, coffee cup lids, yogurt containers, and other common consumer products and packaging (including but not limited to plastic) [107].

Chemical additives are added for a variety of purposes ranging from cosmetic and marketing, such as colorants, to function and performance, such as plasticizers and stablizers. Plastic packaging production using such chemicals can present human health and environmental risks at the point of virgin resin production, during product use, when recovered for recycling, and during reprocessing as feedstock and then remanufacture into recycled content products. While not all additives or chemicals may be harmful or will leach from plastic packaging, new additives are developed all the time and relatively little research has been done on their long-term impacts to human and environmental health.

One study found that of 34 products tested covering eight resin types, over 1,400 chemicals were identified, more than 80 percent of which were unknown, and three-quarters of which demonstrated some degree of toxicity, including endocrine disruption associated with various cancers and reduced fertility [107]. Some of the plastics tested induced lower or no toxicity, indicating that safer alternatives and applications are feasible but perhaps not always used due to factors like cost, scalability, and absence of baseline regulations. However, even chemicals that might be present in low volumes or exhibit low toxicity when tested individually could behave differently when mixed with other chemicals in various applications.

Replacing certain chemicals with other substitutes can have unintended consequences as there is often little known about the safety of the substitute. While solutions to these issues must ultimately be addressed in the upstream production of these materials, reprocessors and manufacturers using recycled content feedstock must be aware of the potential toxicity of their commodities and final products, test for chemicals of concern, and provide transparency in reporting regarding their finished products. This may also preclude some recovered plastics from being recycled and used in new products.

7.2 Drivers of Contamination and Sorting Issues

In addition to these physical and operational factors, recycling collection system designs directly impact the commodity value of plastic bales as well as usability or yield by reprocessors. Depending on the material, reprocessors can lose between 14 and 37 percent of the weight of material purchased, adding to their costs [105]. Bales of readily recyclable and highly marketable PET and HDPE bottles collected from commingled curbside recycling systems are lower quality and produce lower yields compared to dual stream or deposit return systems. According to data from the Container Recycling Institute, plastics recyclers report yields of between 68 and 70 percent for bales purchased from MRFs that process commingled material, while material from dual stream collection systems produces yields of between 75 and 78 percent. PET bales from deposit return systems by comparison usually produce yields of 85 percent [108]. More PET and HDPE bottles are also lost in MRF residuals or mixed rigid bales due to sorting errors and contamination.

Additionally, PE film has domestic markets if kept clean and dry through separate collection pathways and not via commingled collection.

Table 30 below summarizes some key drivers of the contamination and sorting issues posed by plastic packaging, though they are not ranked by magnitude or importance.

Table 30 Drivers of Contamination and Sorting Issues

Material	Contamination and Sorting Issues	Issue Drivers
Rigid & Foam Plastic Packaging		
#1 PET Bottles	• Low bale quality from curbside collection systems	• Contamination, moisture • High percentage of PET thermoforms
	• High loss/cross-contamination	• Increasingly lightweight, flatten in collection/sort
	• Disruptive packaging designs cause sorting issues and contribute to yield loss	• Opaque sleeves, heavily printed labels • Colors beyond light green or light blue (much of this material could be used by existing PET reclaimers if sorted into PET bales)
#1 PET Other Packaging	• Unmarketable commodity	• Insufficient market demand to justify investment in positive sortation
	• Disruptive packaging designs	• Lookalike resins (e.g., PET vs. PS clamshells, compostable lookalikes) • Aggressive labels
		• Black tint hinders optical sorting
#2 HDPE Colored Bottles		• Insufficient market demand • Mixed formats (blow molded vs. injection molded) • Black tint hinders optical sorting
#2 HDPE/LDPE Other Packaging	• Unmarketable commodity	• Insufficient volume to justify separation • Insufficient market demand to justify investment in positive sortation needed to create market value
#5 PP Packaging		• Insufficient volume for many facilities to justify separation

Material	Contamination and Sorting Issues	Issue Drivers
		• Insufficient market demand to justify investment in positive sortation needed to create market value
Other Rigid Plastic Packaging	• Unmarketable commodities	• Low volumes
	• Operational contaminants	• Small formats
	• Toxic recyclables	• PVC
		• Endocrine disrupting chemical additives
	• Disruptive packaging design	• Imposter resins (e.g., PET vs. PS clamshells, compostable lookalikes)
Polystyrene Foam Packaging	• Operational contaminant	• Breaks apart • Flattens, contaminates fiber
	• Unmarketable commodity	• Contamination, moisture • Insufficient market demand to justify separation
Plastic Film & Flexible Packaging		
PE Plastic Bags & Film	• Operational contaminant	• Tangles in sorting screens • Flattens, contaminates fiber
	• Unmarketable commodity	• Insufficient market demand to justify separate collection
Other Plastic Film & Flexible Packaging	• Operational contaminant	• Flattens, contaminates fiber • Few markets anywhere in the U.S. for this material

Note: #2 HDPE Natural Bottles is not included in this table as it generally does not experience the same contamination and sorting issues as other resin types (beyond some level of contamination that occurs from being collected through commingled recycling collection). This resin type is in high demand and highly marketable.

7.3 Actions and Policies to Address Contamination and Sorting Issues

There are several actions that stakeholders throughout the value chain could take to mitigate of issues caused by contamination and sorting challenges in the current recycling system. These actions, as well as supportive policies enacted by the State and local governments, could help to ensure that more plastic packaging material is recovered from the waste stream and safely made into new products and packaging. Potential actions and policies[14] include the following:

Develop Recycling Infrastructure

- Establish a **secondary MRF or PRF** in the Pacific Northwest to capture and further sort recyclable plastics that end up contaminating other streams or in MRF residuals.
- Invest in **additional sorting technology** and other **equipment upgrades** at existing MRFs to be able to better sort and capture valuable plastic packaging material.
- Conduct **pilot projects** to encourage the development of a domestic recycling infrastructure.
- Expand **retail drop-off programs** to establish an effective statewide program to capture plastic bags and film. This should be implemented in tandem with other policies that stimulate demand for recycled film, such as recycled content mandates for products like garbage bags, as is required in California.

Policy Actions

- Establish **recycled content mandates** for specific materials or packaging types to stimulate demand for high-volume, high-quality material and encourage investment in recycling infrastructure to capture it.
- Adopt an **extended producer responsibility framework** that includes stringent, material-specific recycling targets to spur investment in and development of a collection system to meet those targets.

Create Clean and Marketable Recyclable Material Streams

- Collaborate with producers and support efforts to **eliminate packaging elements that contain toxic chemicals or create recycling system disruptions** and improve designs for recyclability.
- Continue to **educate residents and businesses** about proper recycling behaviors, including the importance of leaving recyclables unbagged.
- Develop a methodology for **documenting the chain of custody** to monitor adherence to recognized environmental, human health, and safety standards (e.g., proof of recycling, documentation of residuals, etc.).

Policy Actions

[14] These actions and policies constitute potential, not necessarily recommended, options for consideration. Final recommendations will be presented in the final task-level report of this Study.

- Provide **statewide guidance on contamination** and identify actions that local governments can take to reduce contamination in local recycling programs. Ecology is already pursuing this through development of the statewide Contamination Reduction Outreach Plan (CROP), due to be published in July 2020.
- Consider **banning or taxing highly toxic or disruptive materials** to incentivize substitution with a less harmful material (and assess lifecycle impacts of substitute materials).
- Support and expand the Ecology's **Chemical Action Plan program**. Prohibit the use of plastic (and other fiber-based) packaging contaning specific additives or chemicals, either in the form or intentionally added substances (IAS) or non-intentionally added substances (NAIS).
- Adopt a statewide version of the European regulation **Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)**. Acknowledge the plastics industry's commitment to meet REACH targets in Europe, and require use of the industry-created Plastics Exposure Scenario Tool for assessming chemical safety.
- Adopt **regulations to address toxicity**, such as the Restriction on Hazardous Substances (RoHS) used in Europe to limit toxics in plastics used in the electronics sector.
- Consider adopting a comprehensive package of multi-faceted measures like the European Union's **Single-Use Plastics Directive**, which includes a combination of bans, fees, redesign mandates, recycled content requirements, and EPR programs to address commonly littered or other problematic plastic packaging.
- Support passage of a nationwide EPR system for packaging and other plastic waste reduction measures, such as the recently introduced "Break Free from Plastic Pollution Act" HR 5845.
- Develop a feasible **deposit return system for beverage container stewardship** in Washington similar to the Oregon Beverage Recycling Cooperative model to increase the quality and quantity of PET bottles and other beverage containers collected.
- As part of a producer responsibility framework, **link recycled content requirements to recycling rate targets**. If producers of consumer packaged goods are responsible for recovery and reuse of material in new packaging and products, it will be in their financial interest for the stream to contain as few toxics as possible, particularly if toxicity requirements are included as criteria in the recycled content mandates.

Increase Collaboration Across the Recycling Value Chain

- Provide resources to assist with **development of markets** for paper, plastic, and compost.
- Educate packaging designers and brands on how MRF technologies sort packaging and how to **design packaging that is more easily sortable**—including considerations of shape, certified or clearer labels, the use of materials that can ultimately be recycled together, lid and cap leashes or other similar design features, and the incorporation of

non-toxic, post-consumer materials. The Association of Plastics Recyclers' Design® Guide for Plastics Recyclability provides much of this information already, however there is currently no incentive for packaging designers and brand owners to use it. Alternatively, recyclability and other lifecycle considerations could be built into modulated fees as part of a producer responsibility framework.

Policy Actions

- Use the recently formed **Recycling Development Center to facilitate dialogue and coordinated policy development** across the value chain.
- Embed **toxicity assessment into recycled content requirement legislation**. In addition to percentage targets, additional criteria for recycled content legislation should build in assessment and scoring protocols that screen out recovered recyclables containing specified quantities and qualities of toxic constituents. Such protocols could inform what plastic packages should be prohibited from recycling collection, as well as point the way toward reformulation that would allow the packages to be safely used in the future.

Collect Data to Inform Action

- **Measure real recycling** by tracking and documenting MRF residuals, measuring contamination in bale breaks, conducting periodic MRF material characterization studies, and verifying how much material is actually recycled and into what kinds of new products.
- Track the **market price and conditions** of recyclable materials on a monthly basis.
- **Evaluate the impacts of policy and regulatory action** related to plastic packaging. For example, partner with MRFs to regularly monitor the effects of Seattle's ban on plastic film in recycling collection and the statewide bag ban on the volume of plastic bags and films that MRFs receive. There are several reference data sources recently or soon to be published that can provide useful information, including the King County 2019 MRF Assessment, the City of Seattle's 2020 waste characterization study, and Ecology's upcoming statewide waste characterization study.

Policy Actions

- Require **increased reporting on chemicals and additives** in plastic packaging. Publically available data are limited, both for IAS (to achieve desired product qualities) and NAIS (such as breakdown products, chemical reaction by-products, impurities, etc.).
- Require **increased material-specific reporting on final destination of materials** so that greater information is available about plastic packaging materials currently not separated during the sortation phase—namely, mixed rigid plastics—to ascertain whether and to what extent these materials are legitimate recyclable feedstocks or contaminants to the recycling system.

8.0 Necessary Infrastructure and Interventions to Manage Plastic Packaging Waste

This section describes the infrastructure necessary to manage plastic packaging in Washington according to the waste management hierarchy and in line with the sustainable materials management approach outlined in the State's 2015 *Moving Beyond Waste and Toxics* plan.

8.1 Reducing the Lifecycle Impacts of Plastic Packaging

8.1.1 Infrastructure for Reduction and Reuse of Plastic Packaging

Packaging has many valuable applications and delivers important benefits like protecting products from damage during transport, extending shelf life, and preventing spoilage of food products. Plastic also has attributes—lightweight, flexible, inert nature, barrier properties—that make it well-suited to many of these applications.

But some applications of plastic packaging pose more harm than benefit, resulting in negative impacts such as the introduction of toxics into the environment and human body, waste of natural resources and air pollution, and degradation of land and marine ecosystems caused by improper disposal. Many plastics are also not currently recyclable, either because of lack of existing collection and/or processing infrastructure, or lack of viable markets that make it economically feasible to do so.

There are many examples of plastic packaging applications that are unnecessary and could be eliminated entirely, transitioned to refill/reuse models, or replaced with alternative materials with lower impacts. Methods to reduce the amount of plastic packaging, whether through elimination or transition to reuse models, must factor in lifecycle impacts and unintended consequences of material substitution to ensure that these changes achieve better environmental outcomes overall.

Elimination of plastic packaging that is harmful or unnecessary requires formal engagement with the packaged goods producers responsible for placing such packaging on the market through a policy framework such as extended producer responsibility or through legislative action banning specific products, materials, or packaging attributes. Consistent policies, rules, and regulations create a level playing field applicable to all producers, thereby eliminating so-called early mover disadvantages to companies that would otherwise be willing to change their practices and products in the service of reduced environmental and human harm.

The reduction of plastic packaging through reuse systems requires supportive infrastructure to enable implementation at scale. The Ellen MacArthur Foundation's recent report on reuse models describes four different approaches, spanning refill and return for both at home and on-the-go applications, and outlines the types of infrastructure required for each [109].

Refill/return models could be applied broadly to products such as locally produced beverages, as has been done historically (e.g., beer, soda, milk), to grocery and household staples (e.g., bulk goods, soaps and cleaners, personal care products), on-the-go beverage and food service items, and even to transport packaging. Despite misinformation put forward by the plastics industry questioning the safety of reusables in the context of the COVID-19 global pandemic [110], public health experts have affirmed that reusable systems can be used safely and that single-use plastic is not inherently safer than reusables [111]. Many of the possible models for reusable systems involve commercial washing and sanitation of reusable packaging and can be employed using contact-free infrastructure.

The growth in e-commerce and direct delivery makes the potential for implementation of reusable models greater than ever, because there are latent reverse logistics channels already in place that would make household participation easier than traditional redemption and other return-to-retail models for many items. E-commerce is also leveraging hub and spoke systems, such as pick-up lockers, Amazon's centralized pick-up and return depot, and other models that would allow more efficient consumer and business returns.

Market signals alone are unlikely to drive the transition to reuse systems in the near term, since the negative costs of plastic packaging such as toxics and air pollution remain externalized and not properly reflected in product prices. Policy action to incentivize or require this transition is likely needed to facilitate the transition at scale. Attention to environmental impacts from other aspects of operations besides packaging is also needed to make a meaningful difference in reducing the use of plastic packaging and reducing overall lifecycle impacts.

8.1.2 Addressing Toxics in Plastic Packaging

In addition to resin type and format, toxicity can also play a role in the relative recyclability and market value of plastic packaging collected for recycling. Some common toxic constituents have already been addressed in legislation adopted by 19 states through Model Toxics in Packaging Legislation [112]. The legislation establishes prohibitions against both intentional and incidental presence of four heavy metals in any component of packaging, including inks: lead, cadmium, mercury, and hexavalent chromium. Companies ensure compliance both by providing certificates to downstream purchasers, and by reporting to the states. State implementation is coordinated by the Toxics in Packaging Clearinghouse which "protect[s] virgin material from contamination [to] improve the recyclability of post-consumer materials and protect public health."

In 2018, Washington was the first state to expand its adopted version of the model legislation to go beyond heavy metals and include per- and poly-fluorinated alkyl substances (PFAS), often used in paper and cardboard food packaging. PFAS are persistent, bioaccumulative chemicals and are associated with a variety of health problems including developmental harm in children and endocrine system disruption. In addition to health concerns, Washington State expressed concern over negative impacts to post-consumer composting and paper recycling processes.

Numerous other chemicals exist in plastic packaging and provide cause for concern and precaution [113], [114]. Intentionally added or utilized substances include ortho-phthalates, perchlorate, benzophenone, toluene, n-methyl-pyrrolidone and others. These ingredients and process agents are used in paper and plastic packaging, inks, packaging linings, and more, and may leave residues and expose consumers through tactile contact or consumption and then can be transferred into the environment via water and wastewater. Beyond exposure during initial use, such materials can continue the chain of exposure when reprocessed into recycled feedstock for use in new packaging and products.

While recycling regulations often do not address toxicity issues, many countries have taken the route of addressing such public health concerns through legislation in parallel to collection guidelines. For example, in Europe, extended producer responsibility laws for electronic products follow a regulatory framework, Restriction on Hazardous Substances (RoHS), which restricts ten substances used in the manufacture of such products.

Any revisions to Washington's recycling infrastructure should account for toxicity issues in order to maximize the value of recovered materials. The cleaner the incoming stream in terms of cross-contamination and toxicity inherent to the packaging, the more marketable and safer the reprocessed material will be.

8.2 Recycling Plastic Packaging for Environmental Benefit

8.2.1 Infrastructure for Responsible Recycling of Plastic Packaging

For the purposes of assessing necessary infrastructure for recycling in accordance with the State's goal of achieving 100 percent recyclable, reusable, or compostable packaging in all goods sold with plastic packaging, it is important to define what "recyclable" means in this context.

Recyclability is not an end goal itself, but rather a means to achieving the larger goal of reducing the lifecycle impacts of the production and consumption cycle and delivering environmental benefits. For recycling of plastic packaging to deliver environmental benefits, collected materials must be reprocessed and used in new products and packaging in place of virgin resins to reduce resource extraction and prime plastic production overall. Moreover, plastic recycling itself must be done in a manner that protects human health and the environment. It cannot be assumed that simply designating plastic packaging as "recyclable" achieves the State's goal. To qualify as recyclable, plastic packaging must be shown to have been recycled—in practice and at scale—safely and with environmental benefit.

The current system lacks sufficient transparency and accountability around the final destination of plastic packaging sent for "recycling" and therefore fails to provide assurance that materials are in fact responsibly recycled or that any environmental benefits are actually achieved. There is presently no verification that materials arrive at legitimate reprocessing facilities equipped to recycle plastics without causing harm to human health and the environment. And there is little public information about how much of the materials received at reprocessing facilities is transformed into a recycled feedstock used to offset virgin materials in production of new products, and how much is discarded as an out-throw or lost in the reprocessing cycle. Additionally, little is known about the ratio between exported recyclables and the fraction that remains in the U.S. economy, supporting domestic jobs.

One of the primary reasons why so little is known about the recycling phase of plastic packaging collected in Washington is that much of the material has historically been exported outside of the U.S. for reprocessing (especially compared with states that have domestic reclamation capacity nearby). Relatively few companies operate plastic reprocessing facilities in the U.S. that handle post-consumer materials, and those that do often pay a premium for plastic scrap bales from deposit return systems, which deliver higher quality and larger volume materials.

The economics of low oil prices and weak (if any) demand for many post-consumer recycled content plastic resins, access to historically cheap ocean shipping to Asia, and lack of regulatory controls on the export of plastic waste have all contributed to a "recycling" system for plastic packaging in Washington that cannot be said to reliably deliver environmental benefit. This presents an opportunity to transition to an optimized recovery system anchored in economically, socially, and environmentally sustainable management.

The infrastructure needed for a plastic packaging recycling system that delivers environmental benefits is built upon:

- Creation of **domestic demand** for recycled plastics
- Development of a **transparent tracking system** for collected plastics to their final destination to ensure that they are recycled in ways that reduce overall environmental impacts and protect human health and the environment
- Enforcing **accountability** to hold those involved in plastic production and recycling responsible for the impacts of their operations

Until these three elements of infrastructure—**demand, transparency, and accountability—** are in place, discussion of other physical or operational infrastructure needs to manage plastic packaging through recycling is premature.

As noted in a recent report from a plastics industry initiative to evaluate the feasibility of recycling flexible plastic packaging, "demand for recycled feedstocks to replace virgin materials in products is required to justify the investment needed to collect, sort, and create a marketable commodity. … [Currently] the cost of collecting and processing flexible plastic packaging outweighs its value as a commodity that can be sold back to industry. Unless industry end users (product manufacturers, retailers, and e-commerce), public works end users (government agencies) and consumers buy recycled products, the markets for the material put out at the curb or into store drop-off receptacles will remain anemic" [11]. Even though that initiative was focused on testing the technical feasibility of collecting and processing flexible plastic packaging for recycling, the top recommendation that surfaced from the multi-year effort was "build demand."

This need for increased demand to drive environmentally beneficial recycling applies not only to flexible plastic packaging but to all plastic packaging. Low oil prices and aggressive construction of prime plastics production facilities in the U.S. and globally have made it virtually impossible for recycled plastics of all resin types to compete with virgin resins in an unregulated open market [12]. In the current economic landscape, demand creation will rely on government interventions such as recycled content mandates, taxes on virgin materials (ideally on upstream feedstock such as oil and natural gas rather than on downstream feedstock such as virgin resin, paper, etc.), or other public policies to correct for the market failures that externalize the environmental and social costs of virgin plastic production and use. Demand for recycled plastic packaging must show up in the form of long-term, multi-year contracts that enable suppliers to make the capital investments required to build new infrastructure to fill the gaps in the recycling system and to operate responsibly.

With demand in place for recycled plastics, plastic packaging collected from Washington residents and businesses will still need to be delivered to reprocessors and end users to be transformed for recycling. Due to the lack of reprocessors in the state, materials collected in-state may flow to other U.S. states or to other countries. It can be beneficial for recycled feedstock producers to operate near the facilities that utilize their feedstock for new production, and most of those facilities are outside Washington. Constructing new or expanded reprocessing facilities in Washington may be beneficial for meeting market demand and ensuring that plastics recycling operations adhere to Washington State's health and environmental standards.

Existing mechanical recycling technologies can reprocess the majority of plastic packaging types, provided that incoming materials are sufficiently separated by resin type and format (e.g., PET bottles separated from PP bottles), delivered at a sufficient volume to warrant processing, and are reasonably free of contaminants. The Association of Plastics Recyclers provides bale specifications for recyclable plastics that cover nearly all rigid plastic packaging types—PET, PE, PP, and PS—as well as PE film, indicating that North American plastics reprocessors have the technical capabilities to produce recycled feedstocks from these materials through mechanical recycling [115].

The flexible plastic packaging recycling industry initiative Materials Recovery for the Future (MRFF) research pilot demonstrated the potential for mechanical recycling of rFlex (mixed flexible plastic packaging) bales for use in production of composite building materials and plastics-only applications, though some outstanding technical challenges and market limitations were identified through the pilot [11].

Chemical recycling technologies—both polymer to monomer and polymer to fuel—also have the potential to recycle polyolefin (PE and PP) plastics that cannot be effectively recycled through mechanical technologies, but these technologies generally require more energy than mechanical recycling, require substantial time and investment to achieve commercial scale, and face similar economic barriers with the low cost of oil and gas (due to subsidies and externalized environmental costs in extraction). Additional data are needed on the energy intensity, air emissions, liquid effluent, and solid waste streams of these types of facilities before an assessment can be made on the potential for such infrastructure to deliver environmental benefits relative to other management options.

8.2.2 Infrastructure for Sorting Plastic Packaging for Recycling

In order to be effectively recycled for environmental benefit with existing commercial-scale technology, plastic packaging must be separated by resin types (e.g., PET, PE, PP, and PS). In rarer cases (usually for commercial grades of plastic), it must be sorted further to differentiate between production formats (e.g., blow molded vs. injection molded vs. thermoformed) as well as color (e.g., clear or natural pigment vs. colored).

As the breadth and complexity of plastic packaging types have grown over the past few decades, the ability to effectively sort plastic packaging for reprocessing has become an increasing challenge. Most MRFs in Washington separate only three plastic packaging types—PET bottles, HDPE natural bottles, and HDPE colored bottles—to a sufficient degree that they can be sent directly to reprocessors for reprocessing. Most other plastic packaging types are either not collected or are simply baled together and sent "away" to an uncertain fate. Currently, many bales are not even being sent "away," and instead are being stored as no markets exist for the material. Wherever they end up, they must be further sorted and sometimes purified for food grade safety, depending on the application, before they can be effectively recycled.

In order to increase the responsible recycling of plastic packaging collected in Washington, additional sortation is needed. This could happen through several different possible configurations, including:

- **Additional positive sorting for other plastic packaging types at primary MRFs.** Given the space and operational constraints faced by existing MRFs in Washington, this additional sortation would need to be targeted toward the highest volume materials, such as PET non-bottle packaging and PP packaging, meaning that lower-volume plastic packaging formats would still likely not be effectively separated for reprocessing. On its own, this approach would also not address the amount of recyclable plastics that are currently lost as processing residuals due to the challenges of sorting commingled material loads. The viability of this approach would depend on sufficient demand for additional separated materials to justify the costs of additional sortation equipment, system reconfiguration, and ongoing operations. As noted above, this demand likely must come in the form of long-term, multi-year contracts that make major capital investments financially viable for MRF operators.
- **Use of secondary processing to further process material from the primary MRF.** Rather than devote valuable space within a primary MRF for additional plastics sorting, secondary processing could be used to handle plastic beyond PET and HDPE bottles. This approach would enable primary MRFs to focus more on quality control of their primary commodities while improving the overall recovery and separation of plastic packaging for reprocessing.

- **Use of a secondary MRF to process primary MRF residuals and potentially mixed plastics (as well as other non-plastic residuals).** Sortation at a secondary MRF would likely focus on recovery of missed primary commodities (e.g., PET and HDPE bottles) as well as PP or PS not already separated at primary MRFs. Metals and fiber are also recovered at secondary MRFs. Materials targeted for separation would depend on the list of materials collected, the volumes accumulated through regional coordination with primary MRFs, and the demand for each material as a recycled feedstock. The viability of this approach would depend on capital investment, as well as assurance of demand for separated materials sufficient to result in net costs to MRFs that are lower than the tipping fees or alternative management fees MRFs would otherwise pay to dispose of residuals.
- **Use of a plastics recovery facility (PRF) for more effective sorting and separation of plastics.** Alternatively, further sortation of plastic packaging beyond PET and HDPE bottles could be transferred entirely to a dedicated PRF, which would employ extensive sortation technology to further separate plastics by resin. There are existing markets today in the U.S. and Canada that operate as PRFs, acquiring mixed rigid plastic commodities for further separation and processing material into a feedstock/end product. The viability of this approach is highly dependent on the business model and the demand for each material as a recycled feedstock.

Local reprocessing, such as through secondary MRFs or PRFs, can add value to feedstock and contribute to the local economy, even if the material is then exported out of state.

8.2.3 Infrastructure for Collecting Plastic Packaging for Recycling

In advance of addressing collection infrastructure considerations, system changes are needed to increase demand for recyclable plastics, install systems to ensure transparency and accountability for responsible recycling, improve product designs for recyclability, and develop infrastructure for more effective plastics separation. Assuming these elements are addressed, there is still more that can be done to increase the collection of non-reusable plastic packaging for recycling.

There are four avenues for improving plastic packaging collection in Washington, each with its own infrastructure and investment needs:

- Expanding access to recycling collection service
- Harmonizing plastic packaging types collected
- Aligning collection methods with sortation and reprocessing systems
- Improving participation in recycling collection systems

The infrastructure and interventions associated with each of these are described below.

8.2.3.1 Expanding Access to Recycling Collection Service

Although most areas in Washington already provide for and/or require recycling collection for residents and businesses, some parts of the state are left behind due to lack of policy action by local governments. State requirements related to recycling collection service access could be expanded to include:

- **Universal curbside recycling collection access for residents with curbside.** All residents receiving curbside garbage collection could receive parallel service for collection of recyclable materials. This would expand access to recycling collection to approximately 175,000 additional Washington single-family households.
- **Guaranteed access to recycling collection for residents in multifamily buildings.** Washington State regulations have long required multifamily buildings be built to provide space for the storage of recyclable materials and for local governments to ensure that programs for multifamily recycling collection are made available in urban areas. However, the decision around whether recycling collection service will be made available to residents of multifamily buildings is still one often made by property owners or managers, and is therefore not guaranteed to multifamily residents in many jurisdictions [116], [117]. Access to recycling collection could be expanded to all residents of multifamily buildings by defining access requirements as applying specifically to tenants, as was done in Oregon through the expansion of the Opportunity to Recycle Act in 2015 [118].
- **Universal recycling collection access for Washington businesses.** Not all businesses in Washington have access to commercial recycling collection service from their garbage hauler or other area service provider. Service access requirements could be expanded, including through defining access requirements as applying specifically to tenants, which would also affect businesses that operate as tenants in commercial buildings owned and managed by other entities.
- **Alternative collection channels for recyclable materials not compatible with curbside/commercial collection.** These channels, such as return-to-retail kiosks or standalone drop-off depots, are needed for materials deemed recyclable but not compatible with existing curbside/commercial recycling collection. In order to be successful, the collection infrastructure must be sufficiently convenient for residents and/or businesses to use, have a sustainable financing source or reliable demand sufficient to offset collection costs, and deliver net environmental benefits through recycling.
- **Public space collection infrastructure for responsible management of plastic packaging designed for on-the-go consumption.** Some types of plastic packaging, especially beverage containers and to-go foodservice containers, are specifically

designed to facilitate on-the-go consumption. Consumers then often find themselves in public spaces when they are ready to discard these items. Without adequate access to collection infrastructure, these items can become litter. While recycling of materials collected through public space bins can be challenging due to high rates of contamination, responsible management of plastic packaging designed for on-the-go consumption requires some form of public space collection to prevent litter and, ideally, recover collected materials for recycling where possible.

It is important to recognize that providing access to optional service does not guarantee that residents and businesses will choose to opt into the service, especially if subscribing adds costs to monthly bills. Adding recycling collection as a mandatory service to these remaining parts of the state where it is currently lacking under current rate structures threatens to burden residents and businesses in economically disadvantaged areas with high service costs due to the distance of these areas to sorting facilities and weak markets for collected materials.

8.2.3.2 Harmonizing Plastic Packaging Types Collected

Most recycling collection programs in Washington already accept a wide range of rigid plastic packaging, including bottles, jugs, and tubs. However, there are some jurisdictions in the state—namely in the Central and Eastern regions—that do not include some or all of these materials in recycling collection programs. And many more types of increasingly common rigid plastic packaging—such as #1 PET other (non-bottle) packaging trays, takeout containers, and thermoform clamshells—do not have consistent collection in any region.

Harmonization is beneficial for channeling a larger volume of collected materials into the recycling system, which makes sortation and reprocessing more viable for some lower volume materials. Harmonization also has the potential to reduce resident confusion and increase proper participation in recycling collection.

In theory, all plastic packaging types that have demonstrated recyclability—including reliable end markets and evidence that they can be recycled safely and with environmental benefits—can and should be consistently collected across all jurisdictions in Washington. Under current market conditions, however, very little plastic packaging meets this definition of recyclability, so much work remains to be done to assess the appropriateness of including plastic packaging types on a harmonized statewide collection list, even for standard plastic packaging types considered “recyclable” and widely collected under the current system. Such considerations also impact future packaging materials and formulations, which may not be compatible with current recovery systems and arguably should be assessed prior to being allowed entry to market.

8.2.3.3 Aligning Collection Methods With Sortation and Reprocessing Systems

Among the materials included on a harmonized recycling collection list, plastic packaging types that can be reasonably separated post-collection without degradation of their value or the value of other materials collected, can be collected together. The specific plastic packaging types that should be included in commingled recyclables depend on existing sorting infrastructure and on the economic considerations of both the collection and post-collection systems, including considerations around material quality driven by end users.

Experience from other jurisdictions indicate that foam, film and flexible packaging, and potentially other special format plastic packaging (e.g., small format items) may need to be collected separately, either in separate containers/bags curbside or through entirely separate collection channels (e.g., return-to-retail kiosks, depots, or commercial/e-commerce reverse logistics) in order to be effectively recycled without disrupting existing sorting systems or degrading the value of other recyclable materials collected [105].

Experience from other jurisdictions outside of Washington and from Whatcom County indicate that collection systems that separate paper from containers can improve recycling outcomes in terms of lower levels of contamination, fewer sortation losses, and higher quality bales [108], [82].

8.2.3.4 Improving Participation in Recycling Collection Systems

The final step in collection of plastic packaging for recycling—after establishing universal access to convenient collection service for a harmonized set of recyclable materials—is improving participation in collection systems among the residents and businesses who consume the products associated with the plastic packaging waste.

Increasing participation can be done through promotion and education, though this approach takes time and has shown to have limited long-term effectiveness on its own [119], [120]. The largest gains in recovery through promotion and education are likely to be in getting residents to unbag their recyclables (which can cause otherwise recyclable materials to be rejected as residual waste during the sortation process) and to reduce the presence of contaminants in collected materials [121]. There is also recent evidence that messaging around recycled content in new products motivates recycling behavior more than messaging concerning general environmental benefit. One study demonstrated that participants who viewed advertisements for products made from identified recycled plastic items were more likely to recycle (88 percent) than participants who viewed advertisements for products that only mentioned that the company engages in recycling practices (72 percent) [122].

Participation can also be increased using economic incentives. Washington already requires the use of variable fee pricing (pay-as-you-throw) rate structures for garbage service, which is the most common form of economic incentive identified as a strategy for increasing participation in recycling collection [123]. Washington also has among the highest tipping fees for disposal of solid waste in the U.S. [124].

For these reasons, further increasing prices on disposal is unlikely to make a significant difference in resident behavior and risks burdening low-income households with higher rates. Most single-family residents with access to recycling collection either receive the service embedded as part of bundled services financed through garbage rates (39 percent) or as a mandatory service (42 percent) for which they must pay separately but cannot choose to decline, so decreasing the cost of recycling collection service is also not likely to be an effective behavior change driver in Washington [125].

Deposit return systems, which use market signals by placing value on deposit-eligible items, are clearly shown to motivate higher levels of participation and material recovery and could make a meaningful difference for recycling rates of many packaging types in Washington. In Oregon, where the deposit return system for beverage containers was recently expanded to include additional types of containers and the deposit was increased to $0.10 in 2017, the redemption rate for deposit-eligible containers jumped from 64 percent in 2016 to 81 percent in 2018 (for all containers, not just plastic), and for plastic containers specifically, the redemption rate increased from 55 percent to 75 percent [126], [127]. In 2019, the overall redemption rate for all containers was 90.8 percent [125], suggesting that the economic incentives associated with deposit return systems can motivate behavior change and achieve greater participation in recycling collection systems.

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Appendix A: Material Definitions

Plastic Packaging Material Definitions Used in Study

All material definitions are from the 2015-16 Washington Statewide Waste Characterization Study [13] *except where noted.*

- **#1 PET Bottles**: includes plastic bottles and threaded jars of any color bearing the #1, such as carbonated drink bottles, water bottles, and peanut butter jars. (WA WCS Material 17).
- **#1 PET Other Packaging**: includes plastic non-bottle packaging bearing the #1 and would include oven-ready meal trays and other packaging. (WA WCS Material 18).
- **#2 HDPE Natural Bottles**: includes milk jugs and water jugs and any natural bottle bearing the #2. (WA WCS Material 19).
- **#2 HDPE Colored Bottles**: includes detergent bottles, some hair care product bottles, and any opaque plastic bottle bearing the #2. (WA WCS Material 20).
- **#2 HDPE/LDPE Other Packaging**: includes yogurt and margarine tubs and any packaging jar or tub bearing the #2 and any plastic bottle or container marked with the #4. This category includes 5-gallon plastic pails (with or without handles) and lids. (WA WCS Materials 21 and 23).
- **#5 PP Packaging**: includes any plastic packaging marked with the #5 as well as plastic straws. (WA WCS Material 24).
- **Other Rigid Plastic Packaging**: includes any rigid plastic packaging not included in definitions above, including all packaging with a #3, #6, #7 (except if noted as "compostable" or "PLA") and all all non-numbered plastic packaging that appears to be made entirely of plastic. (WA WCS Materials 22, 25, and 26).
- **Polystyrene Foam Packaging**: includes packing peanuts, polystyrene foam coolers, egg cartons, meat trays, take out containers, and other polystyrene foam packaging. (WA WCS Material 27).
- **Plastic Composite Packaging:** includes other types of packaging that are not one of the above materials and items that are composites of multiple plastics and plastics mixed with other materials. An example of this material type is some bathroom silicone sealant tubes designed to be used with an applicator gun. These tubes frequently have plastic bodies and tips but metal end caps. (WA WCS Material 33).

- **PE Plastic Bags and Film:** For disposal, this category includes include all grocery, shopping, and merchandise bags, and all bubble wrap, shrink wrap, and any other packaging film used in a typically industrial manner. (WA WCS Material 29 and 31).

  For recycling, this category includes all clean polyethylene (PE) consumer bags and film that would be accepted through a store-based collection program. Includes grocery "t-shirt" and retail bags; bread, produce, and newspaper bags; dry cleaner film; napkin, towel, tissue, and diaper overwrap; case and stretch wrap (e.g., for bottled water); plastic air pillows; clean PE food storage (Ziploc) bags; and clean pouches with the How2Recycle store drop-off label. (King County 2019 MRF Assessment and Single-Stream Recyclables Characterization Study Material 28: "Clean Plastic Bags and Film") [9].

- **Other Plastic Film & Flexible Packaging**: For disposal, this category includes other types of packaging film such as cling wrap, bread and food bags, and plastic potato chip bags, as well as means plastic pouches made of thicker, multi-layer flexible material. May have a flat bottom so that package would stand up on its own, but not always. Material is thicker than potato chip bags and frozen vegetable bags. Includes plastic coffee bags like Starbucks and Peets; Capri Sun pouches; baby food pouches – may have plastic screw top; soup pouches; salad dressing pouches; wine pouches; backpacking meals in pouches; soap refill pouches; laundry detergent pouches; and other similar items (WA WCS Material 30 and 32).

  For recycling, this category includes all film packaging other than clean PE bags and film, including multi-layer and opaque food packaging such as chip bags, candy bar wrappers, prewashed salad bags, frozen food bags, and other film items. Includes plastic (Saran) wrap, heavily contaminated film, dirty food storage (Ziploc) bags, dirty pouches with the How2Recycle (H2R) store drop-off label, and pouches WITHOUT the H2R label (clean or soiled). (King County 2019 MRF Assessment and Single-Stream Recyclables Characterization Study Material 30: "Other Plastic Film") [9].

Appendix B: Technical Methodology

This technical methodology includes a description of data sources, assumptions, and modeling methods used to produce the information provided in this report.

The model developed for this study includes both the flow of plastic packaging waste throughout Washington State and the cost of managing the plastic packaging waste. The model has two components:

- A quantities and service model to estimate the tonnage of plastic packaging waste generated, collected, and recycled across the six waste generation areas of Washington,[15] and the numbers of households covered by different recycling services
- A cost model to calculate and apply 'per ton' costs to collected and sorted streams of plastic packaging waste

Details related to each component of the model are provided below.

B-1.0 Quantities

B-1.1 Tons Disposed

To estimate total tons disposed by region, the study team used data published by Ecology on municipal solid waste disposal by county for 2017 [128]. Tons were then split into sectors (residential, commercial, self-haul) by applying sector percentage splits calculated for each region based on vehicle surveys conducted as part of the 2015-16 Washington Waste Characterization Study to the 2017 regional tonnage data [13]. Self-haul tons were further split into residential and commercial using a percentage split calculated for each region based on the same vehicle survey data, but the composition estimates applied to both were the same, based on the overall self-haul composition from the waste characterization study.

Composition of disposed tons was estimated by applying region- and sector-specific composition estimates from the waste characterization study to the region- and sector-specific tons estimated as described above. For a few categories, composition percentages were combined to create categories that could be comparable to the level of detail available from reference recycling composition data.

[15] These regional designations come from the Waste Generation Areas used in the 2015-16 Washington Statewide Waste Characterization Study and differ somewhat from Ecology's regional designations. See Figure 1 for a map of Waste Generation Areas.

B-1.2 Tons Collected and Sent for Reprocessing

Ecology provided the study team with data on tons of recyclable materials collected and sent for reprocessing in 2017 (the most recent year for which complete data are available) based on facility reports and annual recycling survey responses, and refined by Ecology staff as part of the development of the State's annual waste generation and recycling estimates. The data included tonnages sent for reprocessing by material, sector, and region. It also included tonnages identified as recycling residuals, also reported by sector and region. It did not differentiate between recyclable materials collected through curbside service versus drop-off, so this level of detail was not included in analysis of quantities collected, with the exception of PE plastic bags and film, the majority of which were assumed to be sent for reprocessing via reverse logistics channels based on review of the attributes of the reporting facilities.

Tons reported in the dataset provided by Ecology include five plastic packaging categories—PET, HDPE, LDPE, Other, and Mixed. To enable analysis of plastic packaging at a material-specific level, these categories were further disaggregated using supplemental composition data from the King County 2019 MRF Assessment and Single-Stream Recyclables Characterization Study [9]. Disaggregation of Ecology-provided data was conducted as follows:

Ecology Material Category	Study Material Category Assigned (*Assignment Method*)
PET	#1 PET Bottles
HDPE	Split into #2 HDPE Natural Bottles, #2 HDPE Colored Bottles *Based on relative proportions by sector from King County 2019 MRF Assessment and Single-Stream Recyclables Characterization Study*
LDPE	PE Plastic Bags & Film
Other	Split into #1 PET Other Packaging, #2 HDPE/LDPE Other Packaging, #5 PP Packaging, Other Rigid Plastic Packaging *Based on relative proportions by sector from King County 2019 MRF Assessment and Single-Stream Recyclables Characterization Study*
Mixed	Split into #1 PET Bottles, #1 PET Other Packaging, #2 HDPE Natural Bottles, #2 HDPE Colored Bottles, #2 HDPE/LDPE Other Packaging, #5 PP Packaging, Other Rigid Plastic Packaging, Rigid Plastic Products (excluded from packaging tonnage estimates) *Based on relative proportions by sector from King County 2019 MRF Assessment and Single-Stream Recyclables Characterization Study*

Assessment of tonnage estimates following this process revealed that estimated PE plastic bags and film tonnages sent for reprocessing were lower than expected with reference to industry data. To correct for this, industry data were used as the basis to add an additional 3,240 tons of PE plastic bags and film estimated to be collected from the residential sector via reverse logistics and not captured in voluntary reporting to Ecology.

A similar correction was made for polystyrene foam packaging, which did not appear to have associated tonnages reported to Ecology as recycled under the proper material category. To correct for this, information shared by the primary polystyrene recycling firm in Washington as part of interviews for this study and by the EPS Industry Alliance during the stakeholder comment period were used as the basis to add an additional 635 tons of polystyrene foam packaging collected and sent for reprocessing.

Ecology also provided data on final destinations of plastics as reported by facilities on final destination forms as part of 2017 annual reporting (identities of individual reporting facilities were redacted).

B-1.3 Tons of Plastic Packaging in Collected Organics

Estimation of tons of plastic packaging in collected organics was based on data published by Ecology on tons of organics materials received by composting facilities and other organics processors [86]. The study team used 2018 tons for this portion of calculations to reflect a change in reporting methodology to better differentiate between pre-and post-consumer tons collected.

The only reference data available on the composition of collected organics are from the 2016 Seattle Public Utilities (SPU) study on organics composition [85]. To estimate tons of plastic packaging in collected organics statewide, the study team applied the estimated composition percentages for the two plastic packaging material types used in the study—non-compostable plastic containers and non-compostable plastic film—to the estimated tons of residential and commercial organics collected for composting in the state.

Because the SPU study only includes composition estimates for general residential and commercial organics streams, calculations included only tons reported to Ecology as "food waste (post-consumer)" and "yard and food scraps (mixed)." Note that this likely results in an underestimation of the quantity of plastic packaging in organics collected for composting, as it does not include estimation of any plastic packaging that may be in other organics streams reported to Ecology, including "yard debris" and "food processing waste (pre-consumer)."

B-1.4 Tons of Plastic Packaging in Cleared Litter

Ecology provided tonnage data for litter cleared in Washington. Because data on litter clean-up costs were available for the 2018-19 biennium only, tonnage data from 2018 were used to facilitate cost per ton estimation. Note that tons provide by Ecology only include tons of litter reported as cleared as part of reporting requirements for recipients of funding from the WRRLCA account. Litter cleared outside of WRRLCA-funded activities is not included in this estimate and, perhaps more significantly, litter not cleared but rather remaining on roadways and in the state's land and marine environment is also not represented in this estimate.

To estimate the proportion of litter cleared that is plastic packaging, the study team applied composition estimates from the Washington State 2004 Litter Study, which is the most recent litter characterization study available that includes weight-based estimated that can be applied to reports of tons of litter cleared [66]. Due to the changing composition of the packaging mix and the increasing prevalence of plastic packaging over the past 15 years, it is possible that this results in an underestimation of the proportion of cleared litter that is plastic packaging.

B-1.5 Tons of Plastic Packaging Generated in Washington State

Total tons of plastic packaging generated were estimated by combining estimates for tons disposed and tons sent for reprocessing. Estimated tons of plastic packaging in recycling residuals, collected organics, and cleared litter were assumed to be included in total tons disposed, so these were not included in an additive manner for calculating total generation so as to avoid double counting.

B-2.0 Residential Collection Services

Data on residential collection services were based on a dataset developed by Zero Waste Washington in collaboration with Cascadia Consulting Group as part of a research initiative conducted in 2019. The full dataset compiled as part of this initiative is publicly available through Zero Waste Washington [129].

Additional information was compiled by Cascadia Consulting Group through a review of all current comprehensive solid waste management plans produced by counties and cities throughout Washington State that could be found online.

Information about service costs was compiled by Cascadia Consulting Group through review of WUTC regulated tariff rates (publicly available on the WUTC website), customer rates for garbage and recycling service posted on online by various local governments and collection service providers, and review of collection service contracts received via public information disclosure requests submitted to select local governments throughout the state.

B-2.1 Assumed Uptake of Optional Services

In some regions, curbside recycling service is optional for a percentage of households. Assumptions were made about the number of households that opt into the service based upon producing similar yield per household estimates as areas with mandatory only service.

The optional take out rates are shown in Table 31 below:

Table 31 Uptake Rate of Households with Optional Service

	Optional Uptake Rate – Single-family	Optional Uptake Rate - Multifamily
Central	10%	25%
East	100%	27%
Northwest	27%	0%
Puget Sound	27%	0%
Southwest	27%	0%
West	10%	0%

B-2.2 Material Acceptance Rates

The range of plastic packaging materials accepted for collection differs from jurisdiction to jurisdiction depending on the service provided. The relative acceptance rates of different plastic packaging types were used to apportion tons collected between curbside and drop-off service.

The Zero Waste Washington (2018) study reviewed 320 jurisdictions to assess the percentage of jurisdictions which targeted different types of plastic packaging through curbside and drop-off services [14]. Though not a precise match in terms of material categories, this was used to inform material-specific service coverage assumptions for each plastic category. The curbside coverage as a percentage of households was already known (see above in section) but these data were used to estimate what proportion of curbside services also target the other materials (alongside plastic bottles), and what proportion of households without curbside services are covered by drop-off locations accepting these materials.

Table 32 Targeting of Materials by Curbside and Drop-off Services

Plastic Packaging Type	Study Category Match	% of Curbside Services Covering This Material	% of Jurisdictions Covered by Depot Only	% jurisdictions With No Coverage at Curbside or Depot
# 1 PET Bottles	Plastic Bottles	98%	21%	22%
#1 PET Other Packaging	Plastic Cups	34%	9%	50%
#2 HDPE Natural Bottles	Plastic Jugs	99%	21%	22%
#2 HDPE Colored Bottles	Plastic Bottles	98%	21%	22%
#2 HDPE/LDPE Other Packaging	Plastic Tubs	86%	42%	42%
#5 PP Packaging	Plastic Tubs	86%	42%	42%
Other Rigid Plastic Packaging	Plastic Cups	34%	9%	50%
Composite Packaging	NA	0%	0%	0%
Polystyrene Foam Packaging	Styrofoam™	3%	11%	86%
PE Plastic Bags and Film	Plastic Bags	7%	5%	88%
Other Plastic film and Flexible Packaging	NA	0%	0%	0%

Breakdowns of coverage rate by plastic material were provided for each of the six regions the model. Table 32 above illustrates a summary of the state of plastic collection in Washington, but each region had its own set of coverage statistics which were used in modeling.

B-3.0 Allocation of Quantities by Sector and Collection Channel

Although not used to present quantity data, estimated tons of plastic packaging generated needed to be further allocated to support cost modeling. Further allocations of tons were completed as follows:

- Allocation of all tons to single-family and multifamily generators
- Allocation of recycled tons to curbside and drop-off collection

B-3.1 Allocation of All Tons to Single-family and Multifamily Generators

B-3.1.1 Allocation of Generated and Recycled Plastic Packaging Tons Between Single-family and Multifamily Generators

Because single-family and multifamily households have different costs of collection, the generation and collections had to be apportioned to each of the household types.

The single- and multifamily generation and collection split was based on SPU's Waste Management Report (2018) [130] as well as the Recycling Partnerships State of Curbside (2020) report [131].

- The State of Curbside report suggests multifamily households generate 75 percent of the waste that single-family households generate per household.
- The SPU report suggests the collection rates of single-family households are 100 percent higher than multifamily households.
- Using these assumptions, the tons generated by single-family and multifamily households were solved for by keeping the total generation constant.

This ratio between single-family household and multifamily household generation was used to apportion the total residential plastic waste generated in Washington (see Table 34) between single-family and multifamily households, based on the number of single-family (SF) and multifamily (MF) households (HH) in Washington, as follows:

Total tonnage = generation per SF HH x SF HH + generation per MF HH x MF HH

= (1 + MF/SF generation ratio) x generation per SF HH x total HH

The resulting split is illustrated in statewide results in Table 33 and Table 34 below:

Table 33 Plastic Packaging Generation by Household Type -Statewide Total

Material Type	Single-family (tons)	Multifamily (tons)	Total Residential
Total Plastic Packaging Generation	157,200	31,380	185,580

Table 34 Plastic Packaging Generation Per Household, By Type

Plastic Packaging Waste Material Type	Single-family per HH	Multifamily per HH	Total Residential
# 1 PET Bottles	0.012	0.009	0.011
#1 PET Other Packaging	0.004	0.003	0.006
#2 HDPE Natural Bottles	0.007	0.005	0.003
#2 HDPE Colored Bottles	0.003	0.002	0.004
#2 HDPE/LDPE Other Packaging	0.002	0.001	0.001
#5 PP Packaging	0.005	0.003	0.001
Other Rigid Plastic Packaging	0.003	0.002	0.003
Polystyrene Foam Packaging	0.005	0.003	0.004
Composite Packaging	0.001	0.000	0.001
PE Plastic Bags and Film	0.006	0.005	0.006
Other Plastic film and Flexible Packaging	0.012	0.007	0.016
Total Plastic	**0.07**	**0.05**	**0.06**

This calculation was replicated for each region because the relative number of single-family and multifamily households varies between regions.

B-3.1.2 Allocation of Generated Non-plastic Materials Between Single-family and Multifamily Households

Data on the total tons of other recyclables (paper, cardboard, metals, glass) were provided by Ecology as well. These residential tonnages were also apportioned in the same manner as the plastic packaging tons.

One difference, however, is the large quantity of ferrous metal that is collected via curbside had to be discounted as many of these tons would be taken to a scrap yard or similar collection route, rather than by curbside and then through a MRF. The tons were then discounted from total generation by matching the composition of input tons in looking at the MRF composition data from the King County MRF Assessment (2006), as well as more recent MRF waste composition studies (e.g., ensure the percentage of weight sent into the MRF that is scrap metal in our model is equal to that of the King County MRF study). By weight, ten percent of the ferrous metal that is reported as recycled is assumed to pass through a MRF.

After determining the one percent figure, the percentage of ferrous metal that was collected via curbside or recycling depot and then sent to a MRF was assumed to be ten percent of reported recycled ferrous metal by weight.

After performing these processing steps, the generation of tons of non-plastic recyclables are shown in Table 35 below.

Table 35 Total Non-plastic Recyclables Generation by Household Type

	Single-family	Multifamily
Central	73,820	29,750
East	123,300	47,190
Northwest	37,950	12,440
Puget Sound	425,970	208,310
Southwest	96,210	31,070
West	32,500	9,910
Total	**789,750**	**338,670**

At the conclusion of this step, estimates were produced for the total tons of plastic packaging generated and collected, as well as for non-plastic recyclables, for each material type. The generated tons were also now split into single- and multifamily categories. However, the collected tons were not yet, nor were they apportioned into curbside versus depot sources.

B-3.2 Allocation of Recycled Tons to Curbside and Drop-off Collection

After splitting the generated recyclables into single- and multifamily tons for each material type, the generation tonnages were divided into curbside and depot collection. Because drop-off collection costs are covered and embedded in other recycling and garbage rates, they must be separated out before calculating the total cost of recycling collection.

The tons collected by depot and curbside service tons were apportioned into streams using the following equation for each material in each region:

*Coverage Rate Stream X * Capture Rate Stream X * Total Generation of Material = Tons in Stream X*

B-3.2.1 Coverage Rate

The coverage rate was calculated by taking the material specific "percent of curbside services covering this material" rates in Table 32 and multiplying them by the total number of households with curbside service in each region. For example, if 10,000 out of 20,000 households in region x had curbside service, and a material was accepted in 50 percent of all curbside services, the coverage rate would be:

*(50%*10,000)/20,000 = 25%*

This was also done for drop-off services by taking the percentage of non-curbside served households who had a depot, and following the same process for each material.

B-3.2.2 Capture Rate

The baseline capture rate had to be calculated for all streams of recycling collection. The baseline capture rate was calculated by determining what the percentage recovery rate of tons had to be collected by those households with curbside service. This was done by:

- Using the generation, coverage rates, and tons collected of each material as constants
- Assuming capture rate from single-family households is double the capture rate from multifamily households
- Assuming drop-off capture for single-family households is 50 percent of single-family curbside capture, and is 30 percent for multifamily households.

Using these assumptions, the tons collected in each stream were solved for by determining what percent capture households with coverage of a certain material would have to produce, know the relative capture rates of single-family and multifamily households, as well as curbside and depot, to collect the reported tonnage.

Table 36 Annual Tons per Household Collected by Curbside and Drop-off Services

	SF Tons of Recycling Collected by Curbside	SF Tons of Recycling Collected by Drop-off	MF Tons Collected by Curbside	MF Tons Collected by Drop-off	Total Collected
Central	8,500	2,840	980	1,340	13,660
East	58,880	3,880	3,790	2,740	69,290
Northwest	27,510	1,350	6,320	190	35,370
Puget Sound	312,920	3,990	73,050	1,880	391,840
Southwest	47,820	1,390	8,350	420	57,980

	SF Tons of Recycling Collected by Curbside	SF Tons of Recycling Collected by Drop-off	MF Tons Collected by Curbside	MF Tons Collected by Drop-off	Total Collected
West	15,640	760	480	610	17,490
Total	**471,270**	**14,210**	**92,970**	**7,180**	**585,630**

After calculating the tons collected by stream for single- and multifamily households, the total curbside tons were then divided by the number of households served in each region to arrive at a tons per household collected by curbside service of recyclables.

These regional tons of recyclables collected per households are produced in order to turn per household costs of service into per ton costs of service in Section B-4.0 Costs, drop-off tons are assumed to not have a direct cost themselves, and are covered and embedded by other recycling and garbage rates and/or tipping fees. The table of tons of curbside materials collected per household with service can be found below.

Table 37 Tons of Recyclables Collected per Household by Curbside

Region	SF Curbside Tons Collected per Household	MF Tons Collected Per Household
Central	0.265	0.086
East	0.302	0.115
Northwest	0.283	0.097
Puget Sound	0.276	0.098
Southwest	0.283	0.112
West	0.210	0.084

B-4.0 Costs

This section outlines the data sources and assumptions used to calculate per-ton costs for managing plastic packaging waste collected and sorted from different sources and in different waste streams. As part of the model, the following costs were calculated:

- Recycling costs paid by residential ratepayers, broken into:
  - Recycling collection costs
  - Recycling sorting costs
- Disposal costs paid by residential ratepayers, broken into:
  - Residual disposal costs for MRF residual tons
  - Curbside garbage collection costs

- Disposal costs for curbside garbage
- Recycling and disposal costs paid by commercial ratepayers, broken into the same categories as residential costs.
- Disposal costs for self-hauled tons from residential and commercial sources

Costs for organics contamination clean-up and litter clean-up were not integrated into the model due to insufficient data. It is assumed, however, that costs associated with disposal of plastic packaging due to these activities is incorporated into disposal cost estimates, as all tons of waste that are generated in Washington and sent for disposal must be reported to Ecology, and therefore included in cost calculations based on disposed tons.

The costs were calculated based upon identifying, for each collected stream:

- The tonnages of plastic packaging material managed; and
- The cost per ton of collection, sorting (if applicable) and processing/treatment.

Collection costs were mostly identified in costs per household ($/HH) for households who receive the service. The total cost for these services can be described both in terms of a cost per household and households who receive the service, and a cost per ton and tons collected, related by the following equation:

Total collection cost = $/HH x HHs serviced = cost per ton x tons collected

Residential collection costs per ton were therefore calculated from the cost of the services per household, the number of households serviced, and the tons collected.

Commercial collection costs were calculated from the estimated cost of service per cubic yard. Because commercial costs cannot be broken down into per business rates (such as is possible for per household), to arrive at a cost per ton, the cost of service per ton was derived by multiplying the cost per cubic yard by the total cubic yards collected from the commercial sector. The total costs were then divided by the total tons collected per week to arrive at a cost per ton.

Recycling sorting and marketing costs were mostly identified in the form of a per-ton gate fee or processing costs for a given waste stream (i.e., single-stream commingled into a MRF).

From the overall cost per ton for a collected stream, the cost attributable to the plastic packaging in that stream (and each type of plastic packaging within that) were identified based on apportionment of the costs between the materials that make up the collected stream.

Costs were calculated at the regional level for each of the six regions defined in the Washington State 2015-16 Waste Characterization Study and then combined into a statewide total cost.

B-4.1 Cost Allocation by Weight and Volume

Where costs are estimated for a mixed material stream (in collection or through sorting), costs attributable to individual materials could be estimated on the basis of the proportion of the individual material within the stream either by weight or by volume (or a mix of the two).

True Costs

When calculating the cost of a material that is collected with other materials, there is no cost that is applicable for all purposes. The 'true' cost is different from the additional cost:

- The 'true' cost is the portion of the cost is attributable to the material
- The 'additional' cost is the extra cost of managing this material compared to the cost of not managing the material

The 'true' cost is calculated in this report, most appropriately considered as the proportion of utilized assets and labor that is attributable to the material.

The 'additional' cost matters when you are choosing whether or not to pursue a course of action. There is no situation in which there is not plastic packaging waste to manage without an unknown counterfactual to consider.

Therefore, the 'true' cost calculated in this report is **not** a cost that could be saved if there were no plastic packaging waste to manage, but rather it is a best estimate accounting of the current costs of collecting and managing plastic packaging waste.

Recycling collection costs are scaled based on the relative volume of each material within the collected waste stream. This is because recyclable materials are overall relatively light compared to other types of solid waste, and recycling collection vehicles often fill up before they reach their load weight limit. The proportion of the assets used (bin, vehicle and driver) therefore depends on the space the material takes up—that is, the volume—more than its weight.

Garbage collection costs are calculated based on weight. This is because garbage loads are substantially denser, overall, compared to recycling loads, with collection vehicles often reaching their payloads before filling to volumetric capacity. Compaction is also often used during collection to condense voluminous materials. As a result, the marginal costs of collecting plastics in the garbage stream are low, and better accounted for by weight. Although this approach is appropriate for apportioning garbage costs to plastic packaging, it is important to note that this approach counterintuitively implies that where two trucks pass the same house, one collecting recycling and one collecting garbage, it would be cheaper to put a plastic bottle in the garbage truck than the recycling truck. While this may be true when considering only the direct costs associated with collection operations, it does not account for the externalized environmental and social costs associated with plastic packaging that could be reduced if that material was recycled and used as a feedstock for new products in place of virgin plastics. Incorporating consideration of such externalities in the cost calculation is therefore important for better representing the true costs of collecting plastic packaging for disposal compared to recycling.

The true costs of managing plastics waste in waste sorting plants are more complex, since after the initial conveyer belt infeed, different materials move through different parts of the sorting process and machinery specific to their sorting requirements (e.g., eddy current separators for aluminum, near-infrared sorting equipment for plastics, etc.) as well as different levels of manual sorting or quality check requirements. Specifically, the technology devoted to plastics operates on a per-unit basis, which is a separate attribute from either weight or volume. In the absence of material-specific cost accounting, however, volume is a better proxy than weight for plastic materials, since conveyer feeds and initial sorting stages tend to be space-constrained rather than weight-constrained. It is important to note, though, that attributing sorting costs by volume to the plastics stream may still underestimate the true costs of sorting plastics relative to other materials.

Table 38 Scaling Decisions and Rationale by Category

	Scaling	Rationale
Recycling Collection	Volume-based	Collection trucks are more likely to fill up by space than by weight
Residual Collection	Volume Based	Collection trucks are more likely to fill up by space than by weight
Dry Recycling Sorting	Volume-based	Equipment is more space constrained than weight constrained
Garbage Collection	Weight-based	Collection trucks are more likely to fill up by weight than by space
Garbage Disposal	Weight-based	Payment for disposal is per tonne
Organics Contamination Clean-up	Combination	Based on est. cost for contamination clean-up per ton total organics processed; costs are both weight-based (residuals disposal) and volume/unit-based (sortation equipment, labor)
Litter Costs	Weight-based	No data on volume

B-4.2 Residential Recycling Costs

B-4.2.1 Per Household Recycling Service Costs

Data on monthly charges to households for recycling service (inclusive of sorting costs) across all jurisdictions in Washington were obtained from WUTC regulated rate tariffs posted on the WUTC website, web-based research, review of rate information from select collection service contracts between private service providers and local governments. There were separate data on costs for households covered by WUTC vs contracted and municipally run services. The rates were reported either as embedded (where recycling and garbage collection is charged in one rate), or separately for garbage and recycling services, depending on the jurisdiction.

To split the single-family embedded rates into separate garbage and recycling services, the recycling and garbage rates that were supplied separately were broken down to the relative proportion of each cost (i.e., the rates were analyzed to find out what percent of total waste service was for recycling and what percent was for garbage). The proportions were then applied to the embedded rates.

Splitting the embedded single-family rates gave a larger sample of reported costs from which to derive an average, creating a more accurate per household cost for service estimate. Additionally, a weighted average of the documented rates was taken based on the population of people served by a WUTC rate versus a contracted one. For multifamily per household rates, there were not enough data to follow the same methodology. Data for rates existed for three regions, and these averages were used. Average rate costs per serviced household for each region were calculated from this dataset, shown in Table 39 below.

Table 39 Average Recycling Service Rates Per Household with Recycling Collection

Region	Collection Method	Single-Family		Multifamily
		WUTC	Contract	WUTC
Central	Single Stream	$ 14.13	$ 11.34	$ 2.91
East	Single Stream	$ 7.70	$ 7.24	$ 3.82
	Dual Stream	n/a	$ 4.82	n/a
Northwest	Single Stream	$ 8.74	$ 7.75	$ 3.82
	Three Stacking Bin	$ 6.37	*no data*	*no data*
Puget Sound	Single Stream	$ 9.46	$ 9.07	$ 3.82
	Dual Stream	$ 8.43	$ 9.20	*no data*
Southwest	Single Stream	$ 8.24	$ 5.04	$ 3.82
	Dual Stream	*no data*	$ 6.36	*no data*
West	Single Stream	$ 11.88	$ 8.86	$ 7.87

The final single-family rates used after accounting for the number of households served under WUTC regulated rates and those under contract or municipal service for each collection method, can be seen in Table 40 below.

Table 40 Weighted Average of WUTC and Contract Rates for Single-Family Recycling Collection

	Single Stream	Dual Stream	Three Stacking Bin
Central	$ 12.37	n/a	n/a
East	$ 7.58	$ 4.82	n/a
Northwest	$ 8.13	n/a	$ 6.37
Puget Sound	$ 9.14	$ 8.80	n/a
Southwest	$ 7.84	$ 6.36	n/a
West	$ 9.50	*No data, assumed same as Puget Sound*	n/a

A weighted average was not possible for multifamily households, as no data were available on the cost of multifamily recycling service under contracted or municipal service.

B-4.2.2 Per Ton Cost of Residential Recycling Service

The per household rates of recycling service were then divided by the tons per household, drawn from Table 41 of recyclables collected for each jurisdiction. This then revealed a per ton cost of recycling service for recyclables as a whole.

Table 41 Single-Stream Recycling Cost of Service Calculation Table

	SF Rate per HH per Month	SF Tons of Recycling Collected per HH per Year	SF Net Cost per Ton of Recycling Service
Central	$ 12.37	0.269	$ 552
East	$ 7.58	0.307	$ 296
Northwest	$ 8.13	0.289	$ 338
Puget Sound	$ 9.14	0.282	$ 389
Southwest	$ 7.84	0.285	$ 330
West	$ 9.50	0.213	$ 535

This process was repeated both dual and three stream households, as well as for multifamily households. Multifamily costs per ton are detailed below.

Table 42 Multifamily Cost Per Ton of Recycling Service

	MF Net Cost per Ton of Recycling Service
Central	$ 344
East	$ 299
Northwest	$ 465
Puget Sound	$ 396
Southwest	$ 407
West	$ 537

The cost per ton of recycling service includes both the cost of curbside collection and the net cost per ton of sorting, which represents gross sorting costs minus revenues generated from the sale of sorted materials. To distinguish how much of the cost that ratepayers pay is devoted to collection versus sorting, another level of calculations is necessary to separate the two from their current aggregated form.

B-4.2.3 Residential Recycling Collection Costs Per Ton

Costs were calculated for:

- Residential recycling collection (single and dual stream), from
  - Single-family households; and
  - Multifamily households

Section B-4.2.2 Per Ton Cost of Residential Recycling Service outlines how the costs per household of recycling service were translated into costs per ton. The next step in the per unit costs was to back out sorting costs from the total cost of recycling service in order to isolate the costs of collection alone.

A net sorting cost of $66.19 per ton was provided by Seattle Public Utilities based on their current processing contract terms. Because net sorting costs are likely to be less variable than collection costs, this net cost was used as a constant across regions to subtract from each regions collection cost. The calculation and results for single-family households can be found in Table 43 below.

Table 43 Cost of Curbside Recycling Collection

	Recycling Service Cost per Ton	Net Sorting Cost per Ton	Curbside Collection Cost per Ton
Central	$ 552	$ 66.19	$ 485
East	$ 296	$ 66.19	$ 230
Northwest	$ 338	$ 66.19	$ 272
Puget Sound	$ 389	$ 66.19	$ 322
Southwest	$ 330	$ 66.19	$ 263
West	$ 535	$ 66.19	$ 468

After backing out the sorting costs from the total recycling service cost, what is produced are two portions of the recycling service cost: collection and sorting, that can be used to convert costs from weight to volume separately.

B-4.2.4 Per Ton to Per Volume for Total Collection Cost

Because volume impacts collection and sorting costs more than weight does on its own, the collected tons need to be turned into a per volume metric before applying the costs calculated up to this point. Once it has been determined, for example, the percent by volume that PET bottles take up in MRF flow and collection trucks, the percent volume is multiplied by the collection and sorting costs per ton to determine how much of the cost per ton is devoted to PET bottles.

However, revenues at MRFs will also be assigned by material type. Theses are set by weight, in line with commodity pricing, and therefore, the revenues per ton and total outbound tons are sufficient to calculate total revenue for each material.

To determine percent of material collected by volume, the collected tons, which in the model are separated out by material type, are divided by their respective densities to achieve total volume.

Data on densities were drawn from Ontario's Pay-In Model (PIM) bulk densities of recyclables, which lists the density of different recyclable materials (shown below in terms of lb./CY). The bulk densities for collected recyclables are shown in Table 44 below.

Table 44 Ontario PIM Bulk Densities

	Density (lb/yd³)
Plastic Packaging	
PET Bottles	44
HDPE Bottles	56
Plastic Film	19
Plastic Laminates	47
Polystyrene	20
Other Plastics	47
Paper Packaging	
Cardboard	93
Mixed Paper	204
Cartons	56
Steel Packaging	
Cans, Aerosols, Paint Cans	140
Aluminum Packaging	
Cans, Other	59
Glass Packaging	
Clear and Colored Glass	532

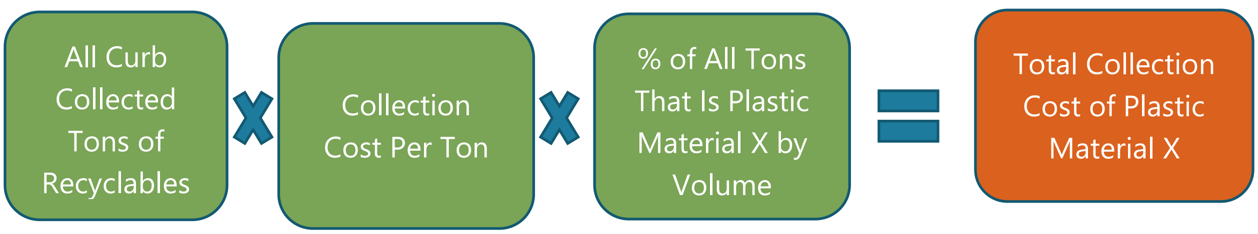
These bulk densities were applied to the total tons of residential recyclables collected at curbside for the collection portion of the model, and to all tons (drop-off included) sorted to find the respective volume measures at both stages of service. This led to the percent of total volume that plastic packaging was responsible for. The percentages for weight and volume of plastic packaging can be found in Table 45 below.

Table 45 Plastic Packaging Percentage of Residential Recyclables Collected, Weight and Volume

Plastic Material	% of Weight of RES Recyclables Collected	% of Volume of RES Recyclables Collected
# 1 PET Bottles	2.1%	6.3%
#1 PET Other Packaging	0.4%	1.6%
#2 HDPE Natural Bottles	0.4%	1.4%
#2 HDPE Colored Bottles	0.7%	1.1%
#2 HDPE/LDPE Other Packaging	0.2%	0.5%
#5 PP Packaging	0.9%	2.5%

Plastic Material	% of Weight of RES Recyclables Collected	% of Volume of RES Recyclables Collected
Other Rigid Plastic Packaging	0.3%	1.5%
Polystyrene Foam Packaging	0.1%	0.2%
Composite Packaging	0.0%	0.0%
PE Plastic Bags and Film	0.3%	2.1%
Other Plastic film and Flexible Packaging	0.1%	1.5%
Total Plastic Packaging	**5.6%**	**17.6%**

B-4.2.5 Total Recycling Collection Costs



After calculating these percentages, they were then applied to the cost per ton of material collected in each region. For example, if say PET bottles are responsible for 6.1 percent of the volume collected, they are assigned 6.1 percent of the cost per ton of collection. The total cost of PET bottles would therefore be:

*Total Cost = total tons collected by curbside * % by volume * cost per ton of collection*

B-4.2.6 Sorting Costs Per Ton

Outbound MRF tons were supplied by Cascadia, and cross checked against the model flow so that the sum of tons being collected from single-family, multifamily, and commercial sectors matched with Cascadia's estimates.

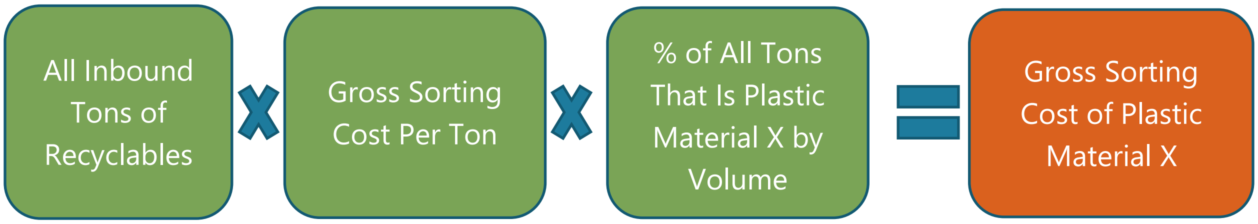
Gross sorting costs were supplied by Cascadia while revenues were provided by SPU's recycling program. The total gross sorting cost was $120 per ton.

In order to accurately measure the cost of sorting, the gross sorting cost had to be taken net of revenue, and the portion of the gross cost related to MRF residue disposal had to be separate out so that it would be applied to the residue tons only. Removing the residue disposal costs would also leave a sorting cost that would be applied only to the plastic that was recycled.

Data from Cascadia indicated that $17 of the gross sorting cost per ton was for residue disposal, the gross cost of sorting only the material that is recycled was therefore $103 per ton ($120-$17).

The $103 per ton gross sorting cost was multiplied by all the tons sent through MRFs, (Inbound tons), while the full the residual disposal cost of $17 was only applied to residual tons in the disposal cost portion of the model.

B-4.2.7 Sorting Costs by Volume



To account for the spatial constraints at sorting facilities, the same approach as collection costs was taken. The sorted tons were turned into a per volume basis, and the percentage of the volume that each plastic packaging type was responsible for was then applied to the cost per ton of sorting.

Table 46 Sorting Cost Example for PET Bottles

	All Inbound Recyclables SS Tons	Gross Sorting Cost per Ton All Material	% of Total MRF Volume that is PET	Gross Sorting Cost PET Bottles
PET Bottles – East Region	57,210	$103	5.6%	$330,650

Finally, after finding the gross sorting costs for each material type, the total revenue (revenue per ton * total outbound tons) was subtracted from the gross cost to arrive at a total net cost of sorting.

However, the residual tons (i.e., what gets lost between inbound and outbound) must still have a disposal cost attributed to them, which is addressed in the disposal costs section below.

B-4.3 Residential Disposal Costs

Residential garbage costs were calculated in a similar way to the recycling service cost.

- Garbage service costs were taken by dividing the average cost per household of garbage service by the total tons of waste collected per household.
- The disposal costs were backed out of the garbage service cost.
- This produced a separate disposal and collection cost per ton of material.

One addition to the residential garbage costs that was not in the recycling cost section is the inclusion of self-haul disposed tons. In addition, the costs of disposal for MRF residual material are also factored in here.

B-4.3.1 Single-Family Garbage Collection Costs

Monthly household garbage rates were based on monthly rates for weekly collection of a 35-gallon garbage cart (or approximately equivalent service) derived from WUTC rate tariffs, contract service rates from select jurisdictions published online, and consultations with select local governments to fill data gaps as needed.

Table 47 Single-Family Monthly Garbage Rates per Household

	Single-Family	
	WUTC	Contract
Central	$14.86	$13.57
East	$19.62	$16.60
Northwest	$20.30	$20.77
Puget Sound	$14.97	$27.16
Southwest	$17.31	$18.41
West	$18.63	$31.63

The garbage rates were then weighted by the number of households serviced that are within WUTC areas versus those are serviced by contracted or municipal service.

After this step, those costs were divided by the tons per household of garbage collected to derive a cost per ton for garbage collection.

Table 48 Cost of Garbage Service for Single-Family Households

	Cost per Household Garbage Service per month	Tons Collected garbage per Year	Tons per Household Garbage collection per Month	Cost per Ton of Garbage Service
Central	$14.15	1.42	0.12	$120
East	$18.74	0.94	0.08	$241
Northwest	$20.59	0.33	0.03	$761
Puget Sound	$20.82	0.53	0.04	$473
Southwest	$17.57	0.82	0.07	$259
West	$26.95	0.59	0.05	$551

B-4.3.2 Multifamily Garbage Collection Costs

Multifamily garbage costs could not be calculated the same way due to a lack of data. Costs were derived from WUTC rate tariffs published online based on estimated monthly rates for weekly collection of a two-yard dumpster. These costs could then be turned into per household costs by taking monthly cost for a two-yard container and turning it into a cost per volume per week, and then dividing this cost by the estimated volume collected from an average multifamily household per week.

B-4.3.3 Disposal Costs per Ton

In order to split the disposal service costs per ton into garbage collection versus disposal, the disposal costs per ton had to be backed out of the total household service rates.

Average disposal costs per ton based on tipping fees for each region were developed based on average tipping fees by county published by Ecology [132]. These costs are included in Table 49 below.

Table 49 Disposal Costs per Ton

Region	Disposal Cost per Ton
Central	$ 77.29
East	$ 102.46
Northwest	$ 179.26
Puget Sound	$ 129.26
Southwest	$ 116.50
West	$ 139.20

After backing out the disposal costs per ton, the following costs of collection were left for single-family and multifamily households.

Table 50 Garbage Collection Costs Per Ton for Residential Households

	Single-Family Garbage Collection Costs Per Ton	Multifamily Garbage Collection Costs Per Ton
Central	$ 42	$ 65
East	$ 138	$ 127
Northwest	$ 582	$ 98
Puget Sound	$ 344	$ 145
Southwest	$ 142	$ 121
West	$ 412	$ 72

B-4.3.4 Total Residential Garbage Collection Costs

Garbage Collection Cost Per Ton × Total Tons of Garbage Collected Curbside × % of All Tons That is Plastic Material X by Volume = Total Garbage Collection Cost of Plastic Material X

Garbage collection costs were then used on the material collected by curbside garbage services (excluding the self-haul tons) in a different method than the recycling costs. The cost per ton of collecting garbage was applied directly to the plastic tonnage, as opposed to first converting the tonnage into a volume measure. This process was the same for both single- and multifamily.

B-4.3.5 Total Residential Disposal Costs

Using the aforementioned landfill tipping fees, tons that are reported as disposed via garbage collection and self-haul methods were multiplied by their respective tipping fees based on the region in which they were disposed.

B-4.4 Commercial Recycling and Disposal Costs

As with residential recycling costs, commercial recycling costs were allocated to plastic packaging based on relative volume rather than relative weight. Calculations to determine the relative percent attributable to plastic packaging were done using the same density factors shown in Table 44, above, but with a different net result in terms of allocation of costs due to the differences in relative composition of commercial recycling tons compared to residential tons.

The percentages for weight and volume of plastic packaging are shown in Table 51 below.

Table 51 Plastic Packaging Percentage of Commercial Recyclables Collected, Weight and Volume

Plastic Material	% of Weight of COM Recyclables Collected	% of Volume of COM Recyclables Collected
# 1 PET Bottles	0.9%	2.4%
#1 PET Other Packaging	0.5%	1.3%
#2 HDPE Natural Bottles	0.6%	1.2%
#2 HDPE Colored Bottles	0.3%	1.9%
#2 HDPE/LDPE Other Packaging	0.1%	0.2%
#5 PP Packaging	0.5%	1.2%
Other Rigid Plastic Packaging	0.2%	0.9%

Polystyrene Foam Packaging	0.1%	0.2%
Composite Packaging	0.0%	0.0%
PE Plastic Bags and Film	0.9%	5.5%
Other Plastic film and Flexible Packaging	0.1%	0.3%
Total Plastic Packaging	**4.0%**	**14.9%**

Commercial garbage collection costs began in the same way as multifamily garbage rates, based on estimated monthly rates for weekly collection of a two-yard dumpster derived from WUTC rate tariffs and contract service rates from select jurisdictions published online. The estimated average rates are shown below:

Table 52 Average of Monthly Commercial Garbage Cost for Two Yard Dumpsters

Cost of COM Monthly Garbage Collection for a 2 Yard Container, Weekly Collection	
Central	$ 119
East	$ 149
Northwest	$ 192
Puget Sound	$ 164
Southwest	$ 179
West	$ 184

Information about commercial recycling costs was more limited, so estimates were based on fewer data points, including from rates reported online by the City of Spokane and Yakima Waste Systems, and the City of Tacoma, which provided a per yard monthly cost of service. Based on these available data, the estimated average cost per week for one cubic yard of collection capacity for recyclables was $13.51.

Following the same process as described in Section B-4.3.2 Multifamily Garbage Collection Costs for multifamily rates, the costs were turned into costs per cubic yard per week. However, because commercial costs cannot be broken down into per business rates (such as is possible for per household), to arrive at a cost per ton, the cost of service per ton was derived by multiplying the cost per cubic yard per week by the total cubic yards collected from the commercial sector. The total costs were then divided by the total tons collected per week to arrive at a cost per ton.

Table 53 and Table 54 show this process for recycling and garbage costs respectively.

Table 53 Commercial Recycling Service Cost Calculation

	Cost of Collecting 1 CY of COM Recycling per Week ($)	Total CY/week collected of COM recyclables	Total COM recycling tons/week collected	Total Cost per Ton of COM Recycling Service
Central	$ 13.51	23,203	1,110	$ 281
East	$ 13.51	26,421	1,340	$ 266
Northwest	$ 13.51	23,491	1,270	$ 250
Puget Sound	$ 13.51	214,517	11,860	$ 245
Southwest	$ 13.51	16,676	910	$ 246
West	$ 13.51	3,048	150	$ 284

Table 54 Commercial Garbage Service Cost Calculation

	Cost of Collecting 1 CY of COM Garbage per Week ($)	Total CY/week collected of COM garbage	Total COM garbage tons/week collected	Total Cost per Ton of COM Garbage Service
Central	$15	55,915	1,850	$450
East	$18	105,735	7,750	$254
Northwest	$24	49,427	4,030	$294
Puget Sound	$21	290,221	29,970	$198
Southwest	$22	56,098	4,290	$292
West	$23	15,211	1,540	$226

After deriving the cost per ton for both services, the process to calculate the total cost of managing plastic in the commercial sector was identical to that of the residential processes.

B-4.5 Self-Haul Disposal Costs

Self-haul costs, which have an assumed collection cost of zero, were calculated by taking the total tons of self-haul garbage reported, and multiplying them by the landfill disposal costs mentioned in Section B-4.3.3 Disposal Costs per Ton. Note that these tons are separate from the previous curbside garbage collection tons.

Because estimated tons of plastic packaging in self-haul garbage were split into Residential and Commercial sectors, the disposal costs for associated with each were integrated into total disposal cost estimates for each sector in final cost calculations.

B-4.6 Social Costs of Climate Pollution

The social cost of climate pollution associated with plastic packaging waste was estimated using the U.S. EPA Waste Reduction Model (WARM) to calculate the emissions reduction potential of source reduction as an alternative scenario compared to the baseline scenario of 2017 disposition. A value of $74 per $MTCO_2e$ was then applied to the WARM output to represent the social cost of climate pollution associated with the current quantity of plastic packaging waste generated and managed under the current system in Washington State. The estimated social cost of emissions was produced by the Interagency Working Group on Social Cost of Greenhouse Gases and adopted by the WUTC to represent the broad array of economic and social damage caused by carbon and other greenhouse gas emissions [102].

Because the WARM model does not allow for resin-specific calculation of impacts using specific resin types that represent the full range of plastic packaging types present in plastic packaging in Washington, the "mixed plastics" category in WARM was used for emissions calculations instead. This category represents the relative distribution of plastics by resin type based on the data presented in EPA's Advancing Sustainable Materials Management: 2015 Tables and Figures.

The distribution of landfilling versus combustion is not known specifically for plastic packaging, so the relative allocation of disposal methods for all tons (95% landfilled, 5% combusted) was used for modeling current disposition.

Inputs and outputs from the WARM model were as follows:

Table 55 U.S. EPA WARM Model Outputs for Social Cost of Climate Pollution Calculation

		Material: Mixed Plastics
Baseline Scenario: 2017 Disposition	Tons Recycled	69,240
	Tons Landfilled	323,836
	Tons Combusted	17,044
	Total $MTCO_2e$	-37,298
Alternative Scenario: Source Reduction	Tons Source Reduced	410,120
	Total $MTCO_2e$	-794,479
Change (Alt - Base)	Total $MTCO_2e$	-757,181