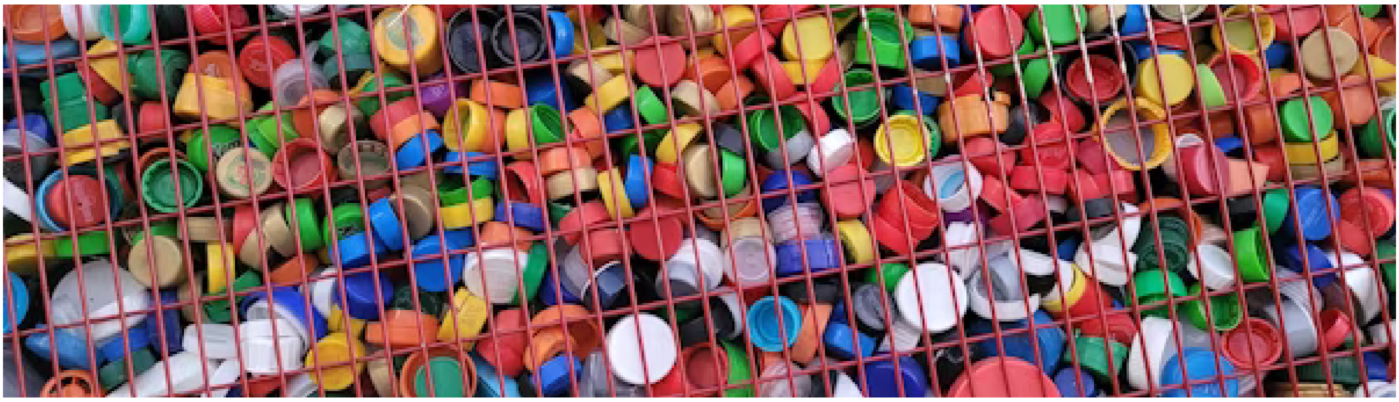
MODELING POLICY OPTIONS FOR REDUCING PLASTIC PACKAGING WASTE AND MICROPLASTICS IN THE UNITED STATES



Funded by The Pew Charitable Trusts and conducted with support from ICF

ABOUT

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Executive Summary

The United States is one of the largest plastic producers in the world (National Academies of Sciences, 2022) and is among the countries that generate the greatest amounts of plastic waste (Law et al., 2020; Kaza et al., 2018). Projections indicate that U.S. plastic consumption will more than double between 2019 and 2060 (Organization for Economic Cooperation and Development, 2022). While plastic plays a vital role across many sectors, including packaging, construction, transportation, health care, textiles, agriculture, and consumer products, its proliferation is also putting substantial strain on waste management systems and budgets. In 2019 alone, the United States spent $2.3 billion on plastic waste landfill disposal (Milbrandt et al., 2022).

Plastic pollution is now pervasive, found at the highest peaks on earth and in the deepest ocean trenches, and even in drinking water and human bodies. Mounting evidence links plastic exposure to significant health risks, including cancer, cardiovascular disease, asthma, decreased fertility, and cognitive and developmental issues (Landrigan et al., 2023). The need to reduce and manage plastic waste and pollution is widely acknowledged in the United States. Recognizing the urgency of this challenge, many states have adopted a variety of policy approaches, and several federal strategy and policy efforts have been deployed in the last 10 years.

With advisory support from seven academic and nonprofit partners, The Pew Charitable Trusts and ICF conducted this study to support evidence-based decision-making for U.S. plastic waste management and pollution reduction. The analysis focuses on three major sources of plastic pollution in the United States: microplastics from textiles and tires, and plastic packaging Municipal solid waste (MSW). MSW consists of everyday items thrown away by homes, schools, hospitals, and businesses. It excludes construction debris, industrial waste, and hazardous materials. Unless otherwise stated, all references to plastic waste, including that from plastic packaging, refer to MSW. It provides a data-driven assessment of their regional and national impacts under both business as usual (BAU) and policy scenarios, from 2025 to 2040.

We modeled a suite of upstream and downstream policy options for plastic packaging focusing on impacts associated with the waste management system. The policies were selected based on their current implementation in several U.S. states, with the goal of assessing the potential outcome of their broader implementation and expansion. We developed targets based on enacted legislation. The low targets are intended to reflect incremental or moderate action, while the high targets represent more transformative, yet still feasible, efforts. We assumed implementation of each policy scenario would begin in 2031, with all targets achieved by 2040. We evaluated three key impact categories[1]—costs, jobs, and greenhouse gas (GHG) emissions—for five distinct policy scenarios, summarized in Table ES-1.

[1] Due to data availability, impacts are associated with all MSW plastic, not just packaging.

Table ES-1. Summary of policy scenarios and targets

Policy Scenario	Low Target	High Target
Material phaseout *and* design optimization	• Shift mass of polystyrene (PS), expanded polystyrene (EPS), and polyvinyl chloride (PVC) to other plastic types • 10% reduction all plastic packaging	• Shift mass of PS/EPS and PVC to other plastic types • 20% reduction all plastic packaging
Reuse	• 10% market share beverage bottles • 5% market share all other packaging	• 30% market share beverage bottles • 10% market share all other packaging
Increase collection for recycling *and* improve sorting efficiency	• Double regional collection rates for in-scope packaging • Halve sorting losses for in-scope packaging in each region	• Quadruple regional collection rates for in-scope packaging (cap 90%) • Limit sorting losses to 10% for in-scope packaging in each region
Deposit return scheme	• 65% collection rate for high-density polyethylene (HDPE) and polyethylene terephthalate (PET) beverage bottles	• 90% collection rate for high-density HDPE and PET beverage bottles
All policies combined	• Low targets for all policy scenarios	• High targets for all policy scenarios

We also modeled select upstream and downstream policy levers addressing microplastics from textiles and tires. The microplastics policies were selected based on existing policies enacted outside of the United States, as U.S. policies for microplastics are currently limited. For textiles, we modeled policies that would reduce microfiber shedding rates, increase capture during washing. For tires, we modeled policies that would reduce tire abrasion rates and reduce passenger vehicle miles driven by increasing the use of public transportation. Banning application of biosolids on agricultural lands was modeled for both.

The data for this analysis are published on Zenodo and publicly available at this link: https://doi.org/10.5281/zenodo.17880491

Key Findings

I. Plastic MSW

- Unless action is taken, an additional 1 billion U.S. tons (hereafter, "tons")[2] of plastic will be generated in the United States between 2025 and 2040, leading to over 30 million tons of plastic pollution in U.S. lands and waters.
- Managing the plastic waste generated in 2040 under the BAU scenario—including capital and operating expenditures associated with collection and sorting, recycling, landfilling, and incineration—is estimated to cost $40 billion annually, of which an estimated $37 billion is borne by taxpayers.[3]

II. Plastic Packaging MSW Scenarios

Plastic packaging makes up 54% of the plastic material found in both MSW and in plastic pollution in 2025. Under the BAU scenario, it will pose an increasingly difficult challenge for U.S. waste management systems. Additional findings reveal that:

- Under the BAU scenario, annual plastic packaging waste is projected to increase by 31% from 2025 to 2040, from 30 million to 39 million tons per year.
- Flexible packaging makes up 50% of plastic packaging waste by mass under BAU and is one of the least recycled plastic packaging materials; it also makes up 50% of plastic packaging pollution by mass under BAU.

The combination of all four policies aimed at addressing plastic packaging waste and pollution can reduce plastic waste generation by 29% and pollution by 35%—a greater decrease than can be achieved by each individual policy scenario on its own. Each policy scenario targets different parts of the plastic value chain, and together they yield substantial reductions in plastic packaging waste generation, pollution, and disposal needs. Additional findings reveal that:

- Relative to the BAU scenario, every policy scenario reduces the amount of plastic packaging waste that is landfilled or incinerated.
- Phasing out PS/EPS and PVC and reducing plastic use in packaging by 20% reduces plastic packaging waste generation and pollution each by 20% by 2040 and makes plastic packaging more recyclable.
- A policy requiring reuse for a 30% market share for beverage bottles and 10% market share for all other packaging can reduce plastic packaging waste by up to 11% and pollution by 12% by 2040 relative to business as usual.

[2] This analysis presents results in U.S. tons (or "short tons"); a U.S. ton is equivalent to 2,000 pounds.

[3] Costs to taxpayers include the costs of formal collection, sorting, incineration, and landfilling. See Section 7.8.1 for detail.

- Quadrupling the regional collection rate and limiting sorting losses of plastic packaging waste to 10% can increase the national plastic packaging recycling rate from 6% to 19% by 2040, while reducing the amount of plastic packaging landfilled by 17% and incinerated by 18%.
- A deposit return scheme with a 90% collection target can substantially increase HDPE and PET beverage bottle recycling rates, minimize regional recycling rate disparities, and reduce the amount of waste that must be managed and disposed of through landfilling or incineration.
- None of the policy scenarios appreciably addresses waste generation or pollution from flexible packaging. While the combined policy scenario achieves reductions in flexible plastic packaging relative to BAU, it remains the most polluting packaging type.
- Combining the policies amplifies their impact due to the cascading benefits of upstream policies that reduce waste generation—like Phaseout and Optimize, and Reuse—on downstream parts of the value chain that manage waste and can reduce plastic packaging pollution by 35%.
- The Combined policy scenario increases the number of jobs in the waste management sector by 2% and reduces the costs of managing plastic waste by more than $1 billion compared to the BAU scenario.
- All of the policy scenarios reduce the annual greenhouse gas emissions from incineration. The Combined policy scenario achieves a substantial 20% reduction in annual greenhouse gas emissions from incineration by 2040 (-3.2 million metric tons of carbon dioxide equivalent [$MtCO_2e$]).

III. Microplastics Scenarios

Under the BAU scenario, tires and textiles will generate 1.2 million tons of microplastic pollution annually by 2040. This is equal to the estimated mass of pollution from plastic packaging in 2040 under the BAU scenario. The results reveal that:

- For microplastics generated from textiles and tires, combining upstream and downstream policies was most effective at reducing microplastic pollution relative to the BAU scenario.
- Of the individual policies modeled, those that target design are most effective for reducing microplastic pollution from textiles and tires as they prevent microplastic generation at the source (e.g., via manufacturing standards for textiles or minimum tire wear standards for tires).

If current trends persist, plastic waste and pollution will continue to escalate, further straining U.S. waste management systems and budgets. This analysis provides support for policymakers at all levels of government for evidence-based decision-making for policies addressing plastic packaging and microplastics from textiles and tires. These policies can help address the economic and environmental impacts of plastic waste and pollution while improving the well-being of communities across the United States.

1. Introduction

1.1 Background

Plastic is ubiquitous in modern society and is integral to an array of industries, including packaging, construction, transportation, health care, textiles, agriculture, and consumer products. Plastic's low cost, versatility, and diverse uses have led to a 20-fold increase in global production from 1966 to 2015, with about one-fifth occurring in North America (Geyer et al., 2017; National Academies of Sciences, 2022). However, plastic's linear value chain results in significant waste generation and pollution, with negative impacts on ecosystem health, habitats, and biodiversity (Macleod et al., 2021; Rosenberg et al., 2022). There is also increasing evidence of negative human health impacts from plastic, including cancer, cardiovascular disease, asthma, decreased fertility, and cognitive and developmental issues from pollution associated with production and disposal and via the chemicals used in plastic products (Landrigan et al., 2023; Halden, 2010).

The United States is one of the largest plastic producers in the world (National Academies of Sciences, 2022). The United States also has one of the highest levels of plastic waste generation in the world and is among the countries contributing most to ocean plastic pollution (Law et al., 2020; Kaza et al., 2018). In 2019, the United States spent $2.3 billion on domestic plastic waste landfill disposal (Milbrandt et al., 2022). These costs represent a loss: This plastic is not reused or recycled, and communities often pay the cost of waste management. The Organization for Economic Cooperation and Development projects that U.S. plastic use will more than double between 2019 and 2060 (Organisation for Economic Co-operation and Development, 2022), which means waste generation and pollution—from manufacture through end-of-life management—could also dramatically increase if no action is taken.

Plastic pollution encompasses both macroplastics (plastic items larger than 5 mm) and microplastics (plastic particles smaller than 5 mm). Microplastics are categorized into two main types: primary and secondary. Primary microplastics are intentionally manufactured to be small, such as microbeads for personal care products. Secondary microplastics result from the degradation of products over time due to abrasion and exposure to heat and sunlight. Therefore, all plastics have the potential to become microplastics over time.

There is increasing evidence that microplastics are ubiquitous worldwide, having been found everywhere from the depths of the oceans (Kane et al., 2020) to the highest mountain peaks (Napper et al., 2020) and scattered throughout remote landscapes of the United States (Brahney et al., 2020). Plastic pellets, also known as nurdles, have been found along the Gulf Coast (Jiang et al., 2021; Tunnell et al., 2020), in Southern California (Jones, 2024), in the Ohio River (Marusic, 2023), and in other places across the United States (Nurdlepatrol.org, 2025). Microplastics are also present in the food we eat, such as salt (Kosuth et al., 2018; Karami et al., 2017) and various protein sources (Milne et al., 2024), and in our drinking water (Kosuth et al., 2018). There is growing evidence that microplastics can affect ecosystem function and the health, growth, and reproduction of plants and animals (de Souza Machado et al., 2018; Foley et al., 2018), and there is increasing concern about their potential impacts on human health (Landrigan et al., 2023; Costa et al., 2020).

The challenge of reducing and managing plastic waste and pollution is widely acknowledged. It involves navigating the costs and trade-offs of different policy approaches, while addressing the widespread aquatic and terrestrial pollution from various sources and sectors. At the federal level, there are many laws that regulate waste disposal and pollution broadly and provide various levels of delegation to states and local authorities. These include provisions under the Resource Conservation and Recovery Act that provide basic requirements governing solid waste management, as well as statutes enacted to control the discharge of pollutants or hazardous substances from certain facilities into the environment such as the Clean Water Act, Clean Air Act, Toxic Substances Control Act, and Marine Debris Act as amended in 2018 (National Academies of Sciences, 2022). The Microbead-Free Waters Act of 2015 provides legislative action around plastic pollution specifically and in the context of aquatic environments. It prohibits manufacturing, packaging, and distributing rinse-off cosmetics and other products that contain plastic microbeads. Additionally, while not regulatory in nature, between 2020 and 2024, as directed by the Save Our Seas 2.0 Act, the Environmental Protection Agency (EPA) published a *National Recycling Strategy* (U.S. EPA, 2021), which set a national recycling goal of 50% by 2030 for MSW, and released a *National Strategy to Prevent Plastic Pollution* (U.S. EPA, 2024b).

Many states are tackling these issues through a variety of policy approaches that address different parts of the value chain. For example, some states have implemented policies addressing product design, such as postconsumer recycled content laws that reduce the demand for primary plastic production. Other states have implemented bans on the use of polystyrene for certain products as they are difficult to recycle. Still others are aiming to reduce plastic pollution by banning or introducing fees for certain types of single-use plastic and packaging. More complex policies aiming to reduce waste generation and increase material capture for recycling include deposit return schemes (or bottle bills) and extended producer responsibility (EPR) for packaging, in which producers are held responsible for financially supporting a materials management system. While there are many approaches to address plastic waste and pollution, they are not uniformly designed or implemented across states. Notably, many states also allow local governments to implement plastic regulations, which underscores the complex and very local nature of waste management in the United States. On microplastics, only one state, California, has addressed pollution from pre-production plastic pellets through legislation, as well as published a statewide microplastics strategy (California Ocean Protection Council, 2022).

The purpose of this white paper is to present the results of an analysis conducted by The Pew Charitable Trusts, and supported by ICF, to assess the potential impact of plastic policies on communities and the environment in the United States by evaluating the change in tonnage of plastic waste managed and plastic pollution generated, and the associated jobs, waste management costs, and greenhouse gas (GHG) emissions. In this analysis, we model U.S. plastic flows under a BAU scenario and under several policy scenarios targeting MSW plastic packaging and two sources of microplastics. Unless otherwise stated, all references to plastic waste, including that from plastic packaging, refer to MSW, which consists of everyday items thrown away by homes, schools, hospitals, and businesses. It excludes construction debris, industrial waste, and hazardous materials.

This project is an outgrowth of the research published in the 2020 *Breaking the Plastic Wave* report conducted by Pew and Systemiq and in the journal *Science* (Lau et al., 2020), which assessed plastic policy impacts at a global level. This study leverages the publicly available Pathways software developed through that work (Bailey et al., 2023) (more detail on Pathways is provided later in this section) and applies it to the United States using publicly available data. The results of this modeling can inform evidence-based decision-making for U.S. plastic waste management and pollution reduction at the local, state, regional and national levels. The findings can inform policy at every level of government and encourage conversation and political engagement to find solutions to reduce the impact of plastic on people and communities.

The following sections provide an overview of the project and its scope, summarize the methods, and present results from the analysis. The Technical Appendix (Section 7) provides additional details about the methodologies and data sources employed in this analysis.

1.2 Project Partner and Stakeholder Engagement

Pew initiated this project in late 2023 and invited key stakeholders to serve as project partners. The project partners are the Monterey Bay Aquarium, the San Francisco Estuary Institute, The Recycling Partnership, Upstream, U.S. Plastics Pact, World Wildlife Fund, and the University of Georgia. They are actively engaged in work across the plastic value chain and helped shape the scope of this project (discussed in Section 1.3) through sharing their expertise on the U.S. plastic value chain, identifying data sources and addressing data gaps where possible, providing an understanding of the policy landscape and challenges to policy adoption, and offering other strategic advice throughout this initiative.

Pew held three stakeholder workshops in 2024 to share progress and gather input for this effort. Attendees included the project partners and other stakeholders from academia, government agencies, and industry with expertise in the U.S. plastic value chain and policies related to plastic pollution reduction. Through these workshops, we obtained valuable information on key data sources, assumptions, and limitations, as well as on the design of policies to include in the modeling. Project partners, as well as formal and informal peer reviewers, provided feedback on drafts of this report and analysis prior to its finalization.

1.3 Project Scope

1.3.1 Modeling Scope

Pew and ICF worked with project partners to define the scope of this project, including key parameters, time period, geographic resolution, plastic life-cycle stages, and plastic categories, as summarized in Table 1-1 and Table 1-2. The geographic scope includes all 50 U.S. states organized into six regions (shown in

Figure 1-1). The analysis includes plastic in MSW, from both the packaging and nonpackaging sectors, as well as microplastics from textiles and tires.

The analysis estimates the stocks and flows of the modeled plastic at various stages of its life cycle. The system map for plastic MSW (Figure 1-2) identifies the modeled life-cycle stages as boxes. Inter-related stages are connected to one another via arrows or "flows." Each box and flow is labeled with a unique letter or number that is used in Pew's Pathways model (see Section 7.1 for a description of Pathways). The boxes with bold outlines are "stocks," or points at which the quantity of modeled plastic accumulates.

As shown in the system map, the modeled life-cycle stages are grouped into the following five modules: (1) waste generation; (2) waste collection and sorting; (3) recycling; (4) landfill and incineration (disposal); and (5) mismanagement of waste.

The analysis does not explicitly model the production stage of the plastic life-cycle in the United States, because it is not possible to determine the U.S. share of costs, jobs, and GHG emissions associated with plastic production and conversion due to production and trade data limitations. While some studies have attempted to approximate U.S. plastic production by scaling North American totals using measures such as gross domestic product and population (Heller et al., 2020), and others have relied on industry reports (Di et al., 2021), there are no comprehensive, publicly available data on U.S. plastic production. Trade data add further uncertainty, lacking the detail to track the plastic coming into and out of the United States, including primary packaging of finished goods (Barrie & Grooby, 2023). We recognize, however, that a significant share of the impacts associated with plastic occurs during the production stage (Landrigan et al., 2023, Karali et al., 2024).

The microplastic system maps have life-cycle stages grouped into the following five modules: (1) production; (2) use phase, (3) wastewater treatment; (4) landfill, incineration, and other waste management practices; and (5) mismanagement of waste (i.e., aquatic and terrestrial pollution) (Figure 1-3 and Figure 1-4). The microplastic analysis focuses only on the flows of microplastic masses through these life-cycle stages and does not include impacts on costs, jobs, or GHG emissions due to data limitations.

Outside of engineered landfills, waste can be disposed in dumpsites or unsanitary landfills. Dumpsites are locations where waste is disposed with little or no management, whereas unsanitary landfills are disposal sites with management but do not meet the criteria for MSW landfills under the Resource Conservation and Recovery Act, such as cover, liners or leachate control (Electronic Code of Federal Regulations, 2026). While there is documentation of dumpsites and unsanitary landfills in the U.S. (U.S. Environmental Protection Agency, 2025d, Environmental Protection Agency, 2025e), we do not model the movement of macro- and microplastics to and from dumpsites or unsanitary landfills due to limited data on the mass of plastic waste that enters them. However, they are represented in the system maps to acknowledge their existence.

While the model is constructed for the years 2017 to 2040 based on data availability, we present analysis results for 2025 to 2040. We assume that it will take roughly five years to introduce, pass, and enact legislation. If this process was started in 2025, the policies would be enacted in 2031. We, therefore, reflect this in the model and set most targets to be achieved by 2040.

Table 1-1. Plastic MSW modeling scope

Model Parameter	Scope
Time period	2017-40
Geographic resolution	Results are provided at the national level and for six regions: Midwest, Northeast, Pacific, Rocky Mountain, Southeast, and Southwest[a]
Plastic life-cycle stages	Waste generation through end of life, including formal and informal collection and sorting, waste imports and exports, recycling (open- and closed-loop mechanical, and chemical), incineration, landfilling, and mismanaged waste (including pollution)

Plastic types	MSW plastic disaggregated by:
	• application (packaging and nonpackaging)
	• format (rigid, flexible, multimaterial)
	• packaging product type (beverage bottles and nonbeverage bottles)
	• the seven polymer categories:
	  ○ High-density polyethylene (HDPE)
	  ○ Low-density polyethylene (LDPE)/linear low-density polyethylene (LLDPE)
	  ○ Polyethylene terephthalate (PET)
	  ○ Polypropylene (PP)
	  ○ Polystyrene (PS)/expanded polystyrene (EPS)
	  ○ Polyvinyl chloride (PVC)
	  ○ Other

Reuse business models and materials	Flows of return-based reuse in the packaging sector, for three materials: • Plastic • Glass • Metal
Material units	U.S. tons[b]
Impacts	There are three categories of impacts associated with plastic flows: GHG emissions,[c] costs,[d] and jobs[e]

[a] See Figure 1-1 for information on the states included in each region.

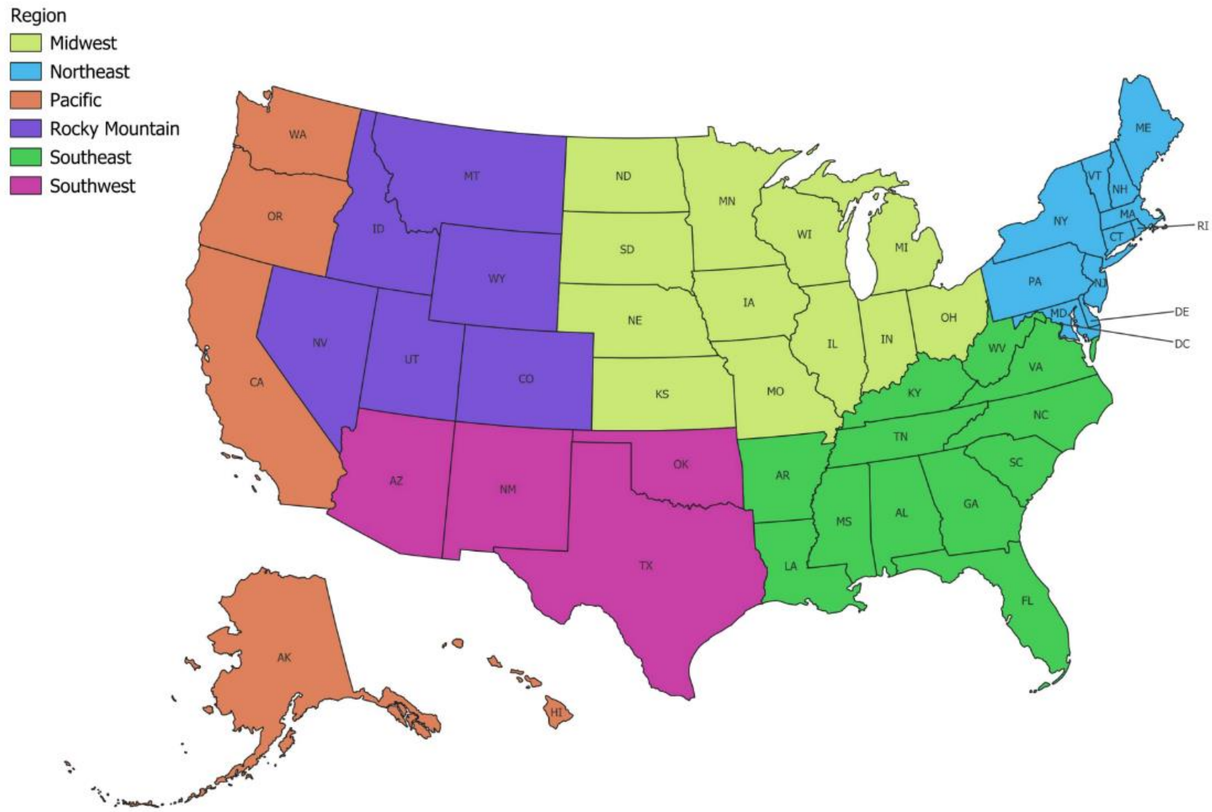
[b] While the model inputs are in metric units due to general consistency in source data, the outputs have been converted to imperial metrics, because the primary audience for this report is based in the United States.

^{c} GHG emissions are estimated for the following life-cycle stages: formal collection, formal sorting, import sorting, informal collection and sorting, closed-loop mechanical recycling, open-loop mechanical recycling, chemical conversion P2P (plastic-to-plastic), chemical conversion P2F (plastic-to-fuel), incineration, and landfilling.

^{d} Capital expenditures (CAPEX) are estimated for the same life-cycle stages as GHG emissions, while operating expenditures (OPEX) are estimated for all except import sorting.

^{e} Jobs are estimated for the same life-cycle stages as GHG emissions except import sorting.

Figure 1-1. Map of U.S. regions used in the plastic packaging modeling



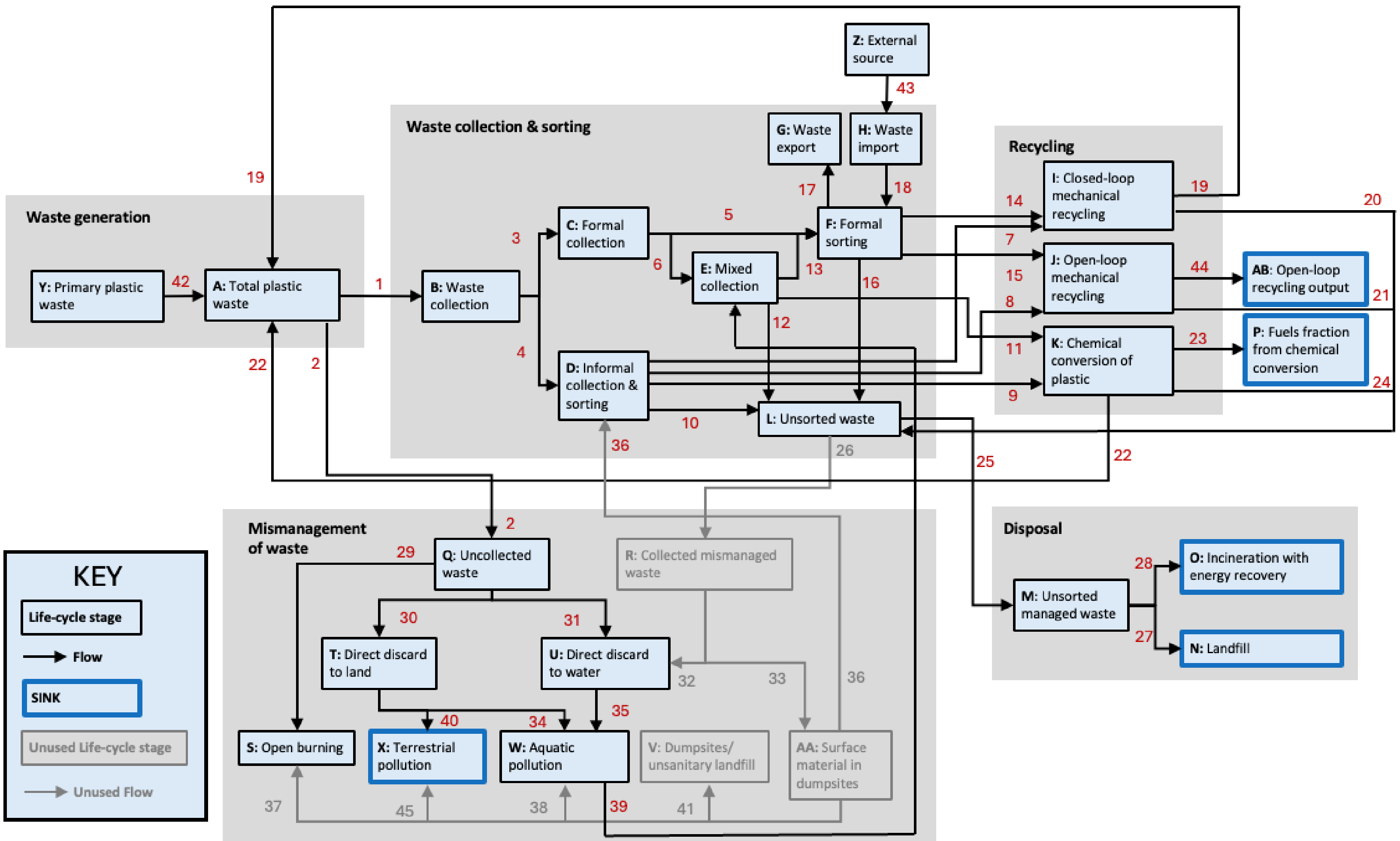
Source: ICF based on Milbrandt et al., 2022

Table 1-2. Microplastic modeling scope

Model Parameter	Scope
Time period	2017-40
Geographic resolution	Results are presented at the national level with data calculated for two populations: rural and urban
Life-cycle stages	Use phase through end of life, including wastewater treatment, incineration, landfill, other disposal methods (e.g., storage), aquatic pollution, and terrestrial pollution

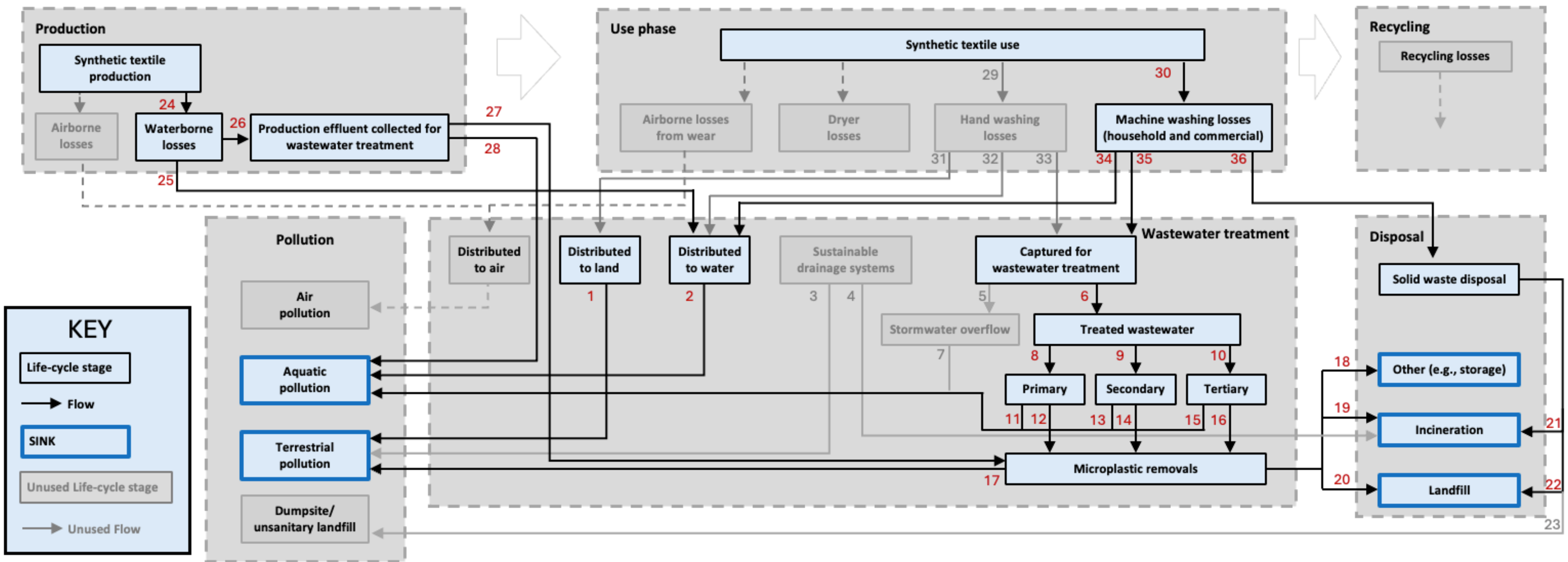
Microplastic types	Secondary microplastics resulting from synthetic microfibers (i.e., textile microplastics); includes microplastics generated during the manufacturing stage of textiles produced in the United States, and microplastics resulting from the breakdown of textiles during machine washing
	Secondary microplastics resulting from tire wear; includes microplastics generated from the tires of motorcycles, passenger cars, light-duty vehicles, heavy-duty vehicles, and airplanes

Figure 1-2. Plastic packaging system map



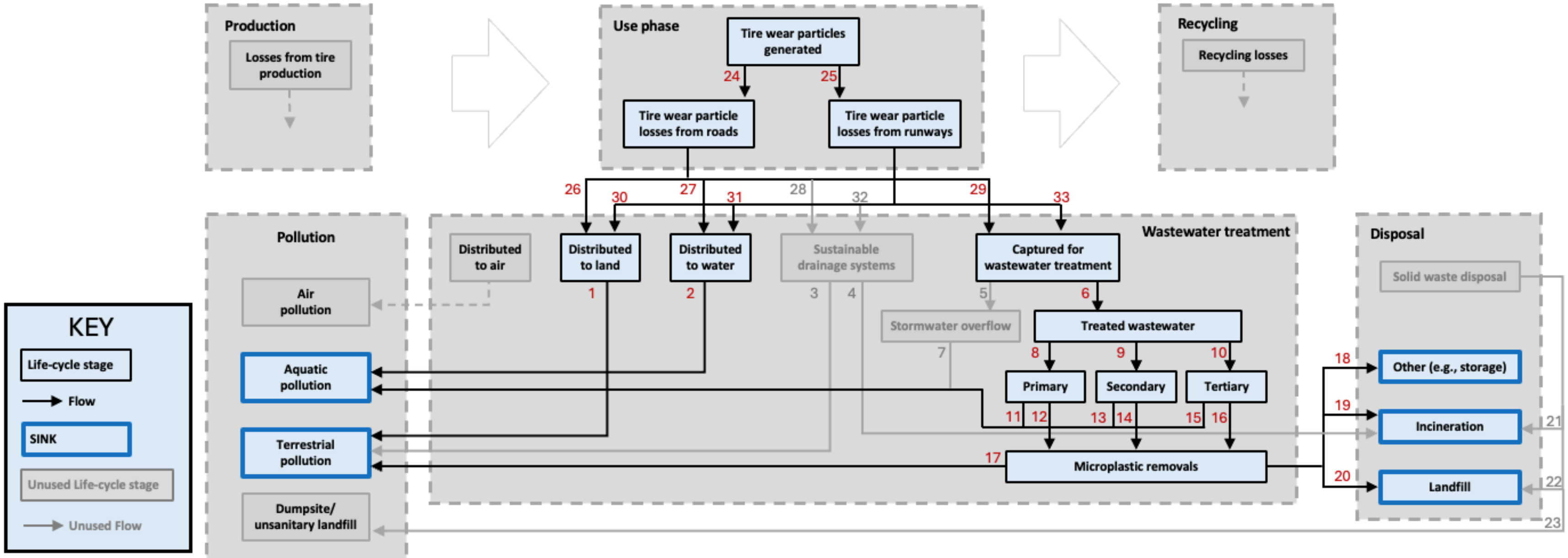
Note: the plastic packaging system map is adapted from Lau et al. (2020). Gray boxes and arrows are not modeled in this report due to lack of data in the U.S.

Figure 1-3. Textile microfiber system map



Note: the textile microfiber system map is adapted from Lau et al. (2020). Gray boxes and arrows are not modeled in this report due to lack of data in the U.S.

Figure 1-4. Tire wear particles system map



Note: the tire wear particles system map is adapted from Lau et al., (2020). Gray boxes and arrows are not modeled in this report due to lack of data in the U.S.

1.3.2 Focus on Plastic Packaging

This analysis explores policy options to reduce plastic MSW and pollution in the United States, focusing on plastic from the packaging sector. We estimate that plastic packaging constitutes the largest share (54%) of plastic pollution from MSW. Single-use plastic packaging—such as beverage bottles, food wrappers, and takeout containers—are especially problematic due to their short lifespan and tendency to become aquatic or terrestrial pollution. According to a recent annual U.S. beach cleanup report, 87% of items collected were plastic (Surfrider Foundation, 2023).

Single-use plastic packaging follows a linear life cycle wherein resources are extracted, converted into products, used once, and then discarded. In contrast, a circular economy keeps materials in use for a longer period of time using strategies like reuse, repair, and recycling, thereby minimizing resource use, waste, and pollution. The plastic packaging sector offers significant policy and business opportunities to transition from a linear model to more circular and sustainable systems. This analysis highlights several of those opportunities.

1.3.3 Focus on Microplastics From Textiles and Tires

This analysis assesses policy options for addressing pollution from secondary microplastics from synthetic textiles—hereafter referred to as microfibers—and secondary microplastics from tires. Although there are many other types of microplastics, these are the sources for which U.S.-specific data are readily available. In addition, a recent study in California identified these microplastics as the most abundant (Zhu et al., 2021). This finding informed California's Statewide Microplastics Strategy, which lists tires and textiles as priority microplastics sources to address (California Ocean Protection Council, 2022). Other microplastic sources include agriculture (Kumar et al., 2020), paint (Diana et al., 2025), pellets (Jiang et al., 2022), personal care products (Bikiaris et al., 2024), and recycling (Brown et al., 2023).

There is growing evidence of the negative impacts of microplastics from textiles and tires. Once in the environment, microfibers can be ingested, and studies have shown that they can reduce feeding rates in marine invertebrates and impact their reproduction and development (Weis & De Falco, 2022). The elongated shape of microfibers relative to other forms of microplastics can contribute to greater toxicity (Bucci & Rochman, 2022). Due to growing concerns about textile microplastics, some states are considering policies that would require filters on new washing machines or rebates for filter installation (Ocean Conservancy et al., 2024). In addition, textile brands and manufacturers are investigating solutions for microfiber shedding that occurs during the production stage, including innovation in textile design and changes to manufacturing processes that would reduce shedding rates (Forum for the Future, 2023; Vassilenko et al., 2021).

Microplastics from tires are particularly challenging to address, as they disperse to the air, land, and water as vehicles travel on roads, carrying with them chemicals and other additives used to manufacture tires (Mayer et al., 2024). Some chemicals used to make tires can be hazardous, such as 6PPD, a chemical additive used to prolong the life of a tire. When it reacts with ozone, 6PPD transforms into 6PPD-quinone, which is a toxic compound. The adverse effects of 6PPD-quinone were first linked to juvenile coho salmon mortality in Washington state (Tian et al., 2021). In response, state agencies, nongovernmental organizations, academics, industry, and other stakeholders in Washington and California are exploring ways to reduce tire-related microplastic and chemical pollution.

This analysis highlights several of the policy opportunities available to reduce the release of microplastics from these sources and/or capture microplastics that are generated, thereby reducing microplastic pollution to the environment.

2. Methods for Constructing the Business-as-Usual Scenario

In this chapter, we describe the methods underlying the BAU scenario for plastic packaging MSW (Section 2.1) and microplastics (Section 2.2). Section 2.3 provides an overview of key limitations. The Technical Appendix (Section 7) provides additional details on the methods, data sources, and sources of uncertainty.

2.1 Plastic Packaging MSW

In the BAU scenario, we did not model any policy interventions that would affect current plastic-related policies, economics, infrastructure, or materials, and we assumed that cultural norms and consumer behaviors do not change. In addition, we did not place any constraints on the capacity of the waste management system in the BAU scenario. In other words, as the amount of waste grows over the time frame of the analysis, we assumed a corresponding increase in capacity for collection, recycling, landfilling, and incineration, without financial or other limitations.[4] Additionally, we did not model any reuse systems in the BAU scenario, because they are not yet widely instituted in the United States.

2.1.1 Plastic Waste Generation

We estimated MSW generation as a starting point for understanding the flow of plastic through the U.S. plastic value chain. The U.S. EPA defines MSW as follows:

> *MSW, more commonly known as trash, comprises various items we commonly throw away. These items include packaging, food, grass clippings, sofas, computers, tires and refrigerators. In this analysis, however, EPA does not include materials that also may be disposed in non-hazardous landfills but are not generally considered MSW, including construction and demolition (C&D) debris; municipal wastewater treatment sludges; non-hazardous industrial wastes (U.S. EPA, 2025c).*

We used data from Milbrandt et al. (2022) to estimate the mass of each plastic polymer present in MSW. To estimate how the total mass of each polymer is distributed across product categories, we used data from Milbrandt et al. (2022) along with other waste characterization studies (see Section 7.4.1) (Table 2-1). For additional information on the plastic types included in the analysis, see Section 7.3.1. We projected national plastic waste generation through 2040 using a compound annual growth rate (CAGR) of 1.79%. This rate is based on historical plastic waste generation data from 2012 to 2018 from U.S. EPA (2024c) and is applied uniformly across all plastic types.

To estimate waste generation by region for the time frame of this study, we distributed national-level waste generation over time to six U.S. regions: Midwest, Northeast, Pacific, Rocky Mountain,

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[4] In reality, the waste management system would likely face capacity constraints as waste generation increases, including budget limitations, space restrictions, and other barriers.

Southeast, and Southwest. We used state population data from projected state population counts through 2040, aggregated to regional population counts, and estimated the share that each region contributes to the total U.S. population (Table 2-2) (University of Virginia, 2024). We used this share as an estimate for that region's share of plastic waste generation, assuming that population has a positive, linear correlation with plastic waste generation (Milbrandt et al., 2022).

Table 2-1. Estimated product category proportions by polymer

Product Category	HDPE	LDPE/ LLDPE	PET	PP	PVC	PS/EPS	Other
Beverage bottle[a]	11%	0%	67%	0%	0%	0%	0%
Nonbeverage bottle[a]	9.9%	0%	6.9%	0%	0%	0%	0%
Rigid packaging	18%	2.3%	14%	28%	15%	15%	0%
Rigid nonpackaging	9.5%	6.2%	5.9%	26%	20%	68%	57%
Flexible packaging	14%	57%	0%	21%	37%	8.7%	0%
Flexible nonpackaging	29%	29%	0%	3.1%	5.8%	1.3%	0%
Multimaterial packaging	0.61%	0.46%	0.87%	0.83%	3.7%	0.42%	0.80%
Multimaterial nonpackaging	7.5%	5.1%	5.4%	20%	18%	6.6%	42%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Note: All values are rounded to two significant figures. Numbers may not sum to total due to rounding.

[a] Plastic bottles can contain polymers other than PET and HDPE, but this analysis is based on sources that report composition only in terms of these two.

Table 2-2. Share of U.S. population by region in 2020, 2030, and 2040

Region	2020	2030	2040
Midwest	21%	20%	19%
Northeast	20%	19%	19%
Pacific	16%	16%	16%
Rocky Mountain	5%	5%	5%
Southeast	26%	26%	26%
Southwest	13%	13%	14%
Total[a]	**100%**	**100%**	**100%**

Note: All values are rounded to two significant figures.

[a] Regional percentages may not sum to 100% due to rounding.

2.1.2 Waste Collection and Sorting

Waste Collection

MSW includes both residential and commercial waste, and waste collection refers to the collection of MSW for end-of-life management, including recycling, plastic scrap export, landfilling, and incineration. In the United States, formal waste collection is considered the regulated and organized system of waste management operated by officially recognized, often public or private, companies and entities that comply with national and regional laws and standards. The formal waste collection sector provides services such as garbage collection, recycling pickup, and dumpster rental, with defined collection routes, schedules, and fees. Informal waste collection in the United States includes individuals, groups, and small businesses that collect waste—generally recyclables—from public bins or other waste sites and sell them to dealers and recycling companies working within the formal sector (U.S. EPA, n.d.).

In the BAU scenario, we assumed that 97% of plastic waste generated is collected for waste management, and the remaining 3% is uncollected and ultimately lost to the environment in the form of pollution (Jambeck, 2025). We assumed that all plastic packaging collection is conducted by the formal sector except in the case of beverage bottles. For beverage bottles, we assumed 99.9% are collected by the formal sector and 0.1% by the informal sector (Sure We Can, 2023). The informal sector in this case includes canners (also known as independent recyclers) who can redeem collected bottles for payment either through deposit return systems (DRS) in states with bottle bills or from private scrap buyers (Sure We Can, 2023).

Collection for Sorting and Recycling

Only a small portion of plastic waste that is formally collected gets sent to recycling facilities; the majority is sent instead to incinerators or landfills. The share of plastic waste that is collected for recycling depends on its format and polymer, among other factors. To estimate regional recycling collection rates for rigid plastic packaging waste, we used state-level recycling data from Eunomia Research and Consulting (2021, 2023).[5] To estimate regional recycling collection rates for rigid nonpackaging plastic and flexible plastic, we used national recycling data from Stina (2021, 2024). For more information, please see Section 7.4.2. Figure 2-1 presents the resulting formal recycling collection rates by region under the BAU scenario in 2040.

[5] We assume that states with DRS include the recycling of beverage bottles with deposits in their reported recycling rates. Therefore, this recycling activity is accounted for in the BAU scenario.

Figure 2-2 shows the formal recycling collection rates by plastic packaging type. Under the BAU scenario, beverage and nonbeverage bottles have the highest collection for recycling rates at 29% and 30%, respectively. Other rigid packaging has a 9% collection for recycling rate, followed by 2% for flexible packaging, and 0% for multimaterial packaging.

Figure 2-1. Plastic packaging waste generation and formal recycling collection under the BAU scenario in 2040

Labels above the formal recycling collection bars indicate the formal recycling collection rate for each region.

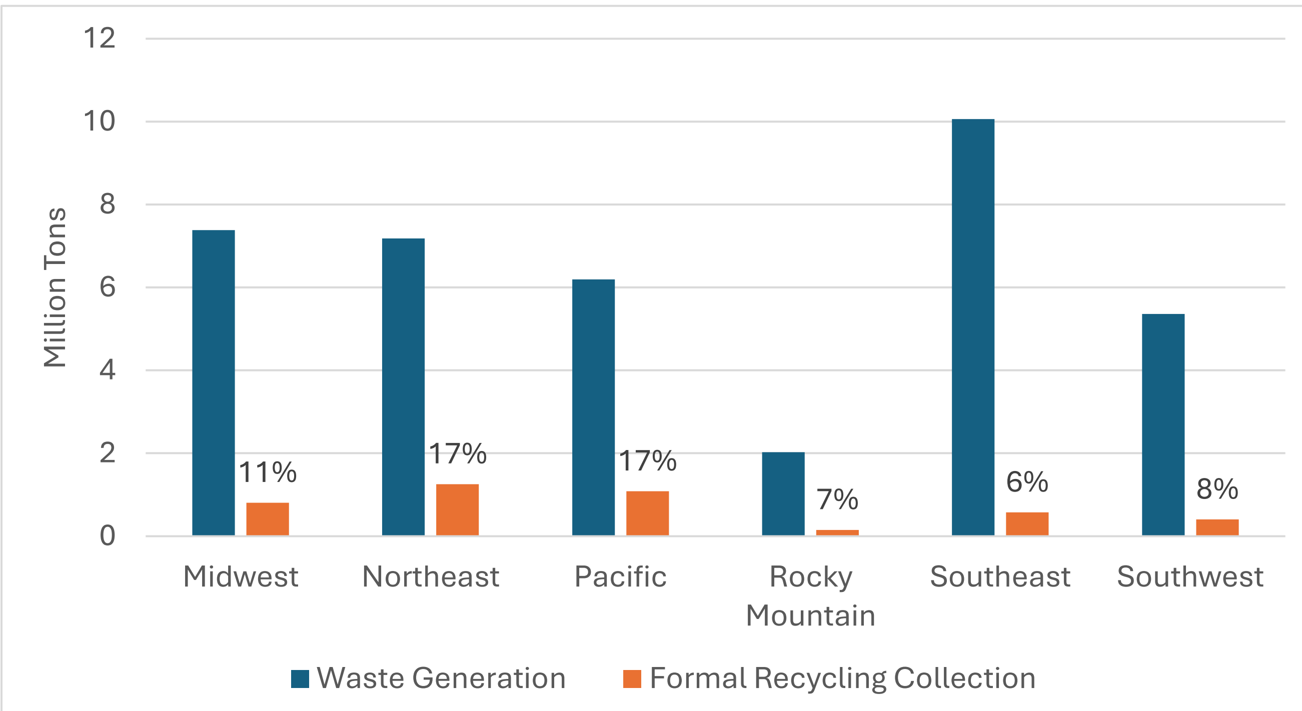
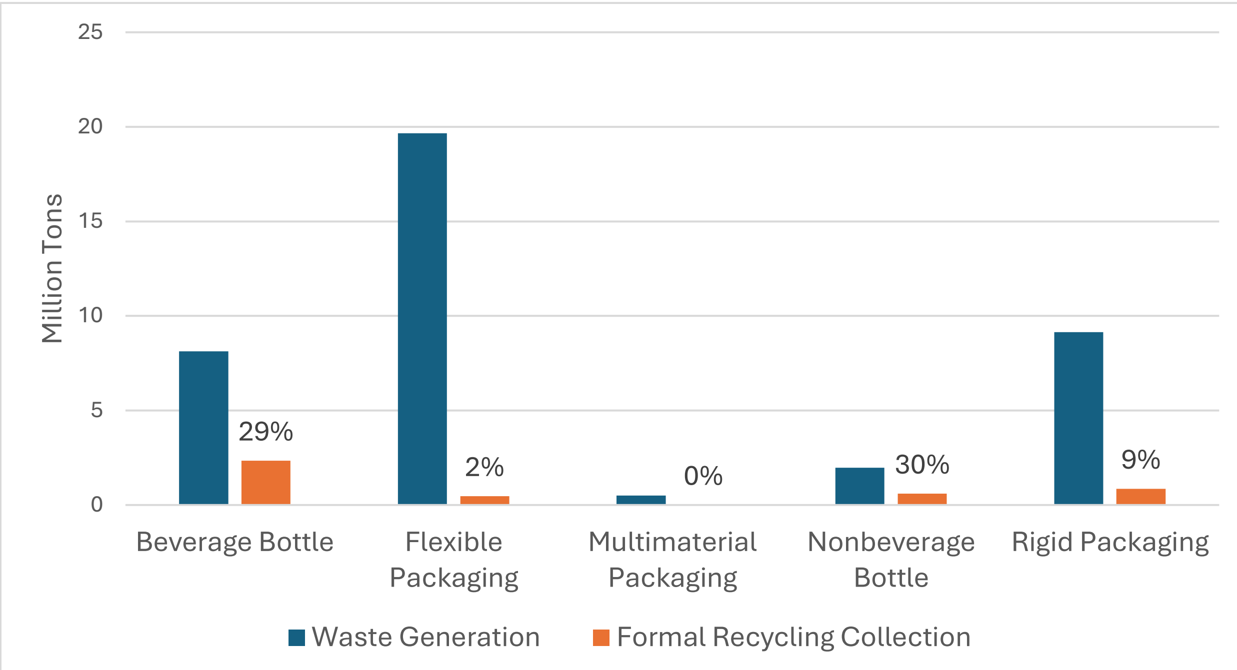


Figure 2-2. Waste generation and formal recycling collection by plastic packaging type under the BAU scenario in 2040

Labels above the formal recycling collection bars indicate the formal recycling collection rate for each plastic type.



Sorting Losses

Most plastic waste that is collected for recycling is sent to a material recovery facility (MRF), where it is sorted and screened to separate recyclables. Plastic waste can also be collected via drop-off at transfer stations, via reverse vending machines, or other mechanisms that support DRS, for example. During the MRF sorting process for comingled plastic, some of the plastic waste that was collected for recycling is discarded due to contamination (e.g., material with food residue) or because it is not viable for recycling. For example, items like plastic bags can clog machinery, and multimaterial items may not be compatible with machinery.

To estimate formal sorting losses, we relied on data from Eunomia (2023) (Table 2-3). For informal sorting losses, we assume a low loss rate (5%) since canners typically select high-quality, high-value plastic beverage bottles (Lau et al., 2020).

Table 2-3. Sorting loss rate by plastic type under the BAU scenario

Plastic Type	Sorting Loss Rate
PET bottles (beverage and nonbeverage)	13%
PET other rigids (packaging and nonpackaging)	47%
HDPE rigids (packaging, nonpackaging, beverage bottles, and nonbeverage bottles)	21%
PVC, LDPE/LLDPE, PS/EPS, other (rigid packaging and nonpackaging)	35%
PP (rigid packaging and nonpackaging)	35%
Flexibles	60%
Multimaterial[a]	0%

Sources: Eunomia (2023), with loss rates for rigids #3-#7 assumed for PVC, LDPE/LLDPE, PS, and other; The Recycling Partnership (2024) providing the loss rates for flexibles

[a] Multimaterial products are not collected for recycling, so they are not assigned sorting loss rates.

Mixed Collection

Mixed collection is the collection of plastic with other MSW. Mixed-waste MRFs, which process recyclables that are mixed with MSW, are rare in the United States and are concentrated in California (Bradshaw et al., 2025). State-level recycling data from Eunomia Research and Consulting (2023) does not distinguish the share of recyclate originating from mixed-waste MRFs versus MRFs that process source-separated recyclables. Because of this, the flow between formal collection and formal sorting aggregates recyclate from all MRF types, and we assume plastic that are collected as mixed waste are sent for disposal at landfills or incinerated.

Imported and Exported Waste

In the United States, imported plastic recyclate is used to meet growing demand for postconsumer recycled content in plastic packaging and other products. With domestic supply in high demand, low-cost recyclate from other countries increasingly competes for market share (Friedman, 2024). To model the import of plastic recyclate, we relied on import tonnage data by polymer from ICIS (2024). We used additional sources on end markets for imports to distribute the polymer-specific import data into the modeled plastic categories (see Section 7.4.2).

Plastic waste that is collected and sorted domestically may also be exported. However, two policies have reduced plastic waste exports from the United States: China's National Sword Policy, which restricted plastic waste imports in China starting in 2018, and the 2021 amendment to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, which limited the countries that could import plastic waste from the United States (Brooks et al., 2018). These policies were triggered by growing international concern over improper management of plastic waste and its leakage into the environment, particularly pollution to coastal environments and the ocean (Law et al., 2020).

To model plastic waste exports, we relied on data from Stina (2024). We estimate the share of collected plastic that are exported as follows: 12% for PET and HDPE bottles, 16.5% for rigid packaging and rigid nonpackaging plastic, and 13.7% for flexibles. Based on MORE Recycling (2020), we assume domestic reclamation capacity focuses on dry PE film or single resin material, and that multimaterial plastic are not collected for recycling or exported. The model structure allows for both domestically generated and imported plastic scrap to be exported. Imported plastic scrap may also be re-exported (Park, 2024), but the model does not distinguish between domestic exports and re-exports.

2.1.3 Mechanical Recycling

In the United States, mechanical recycling is the primary recycling technology and involves physically processing plastic waste without altering its chemical structure. There are two types of mechanical recycling: closed-loop recycling, in which materials are recycled into the same product (e.g., a plastic bottle into another plastic bottle), and open-loop recycling, in which materials are converted into different products (e.g., a plastic bottle into textile fibers). We use the retained value of recycled materials for each plastic type from Eunomia (2023) as a proxy for the split between closed- and open-loop mechanical recycling. In addition, we use Eunomia (2023) to estimate processing losses by plastic type (see Section 7.4.3 for more detail).

2.1.4 Chemical Conversion

Chemical conversion consists of two processes: plastic-to-plastic (P2P) and plastic-to-fuel (P2F). Plastic-to-plastic involves converting plastic waste back into monomers or other feedstocks that can be used to manufacture new plastic products. Plastic-to-fuel converts plastic waste into fuels through technologies like pyrolysis or gasification and is a form of disposal (discussed below).

To model chemical conversion, we relied on data on chemical conversion facility capacities in Bell & Gitlitz (2023). Based on reported operating capacities, we calculated the proportion of converted plastic that undergoes P2P. We then used data from Closed Loop Partners (2021) for the loss rate from chemical conversion and assumed the remaining plastic waste sent to chemical conversion undergoes P2F. We assumed the same proportion for P2P, P2F, and sorting losses for all plastic types. See Section 7.4.3 for more information.

2.1.5 Disposal

Plastic waste that is collected but not recycled (either because it is removed during sorting or was discarded as mixed waste) can be disposed via incineration, landfill, or chemical conversion to fuel (Section 2.1.4). We used data from Milbrandt (2024a) and Milbrandt (2024b), which provide state-level incineration and landfilling data by polymer. We aggregated that data to the regional level, applying the Milbrandt et al. (2022) polymer-plastic type proportions to arrive at the amount of plastic waste that is either landfilled or incinerated by plastic type and region. See Section 7.4.4 for more information.

2.1.6 Pollution

In this study, we define pollution as plastic that ends up in the natural environment, through land, water, or air. In our modeling, this is reflected in annual mass of plastic packaging and microplastics in terrestrial or aquatic pollution, and the annual mass of plastic packaging flowing to open burning. We do not model pollution associated with plastic exports.

In the Pathways model, waste flows to the pollution end points after entering the mismanaged waste module. This module models the mass of waste that is not collected, also known as escaped trash, and that is intentionally or unintentionally lost to the environment and results in pollution (U.S. EPA, 2025b). There are three end-of-life fates for escaped trash: open burning, terrestrial pollution, and aquatic pollution. Rural areas may not have regular waste management services; therefore, waste management at home may involve burning waste, including plastic (National Academies of Sciences, 2022). We used Wiedinmyer et al. (2014) to estimate the proportion of uncollected waste that is burned. The remaining waste is split between aquatic and terrestrial pollution, estimated based on the relative proportion of aquatic and terrestrial pollution in the high-income archetype from Lau et al. (2020). To model the movement of plastic waste from terrestrial to aquatic environments, we used data from the Escaped Trash Risk Map, which estimates the escaped trash density on land that is at risk of getting into waterways (U.S. EPA, 2025b). Additionally, we used estimates of plastic waste collection from aquatic environments using data from Ocean Conservancy (2022), aggregating state-level plastic cleanup totals to the regional level. See Section 7.4.5 for more information on the estimation of pollution flows.

2.1.7 Impacts

The impact of plastic extends beyond its physical flows across the value chain. Plastic has significant economic and environmental impacts, such as on employment and GHG emissions. Articulation of these impacts can support a more holistic understanding and comparison of policy impacts and trade-offs.

In this analysis, we estimate the combined impacts of all plastic flows (both packaging and nonpackaging plastic) on costs, jobs, and GHG emissions associated with the municipal waste management system. The following sections provide information on the underlying data sources and assumptions. For more information, see Section 7.5.

Costs

We estimate both capital expenditures (CAPEX) and operating expenditures (OPEX) associated with plastic flows in the municipal solid waste system. CAPEX represents investments in long-term assets that provide benefit for more than one accounting period, while OPEX includes the ongoing or day-to-day costs of running a business.

While we use U.S.-specific data where available, most of the data used for CAPEX and OPEX come from Lau et al. (2020), which provides data at the global high-income urban archetype level on packaging and consumer goods, including for some durable goods. U.S. data come from The Recycling Partnership (2021) on formal sorting for recyclable materials and Kaza et al. (2018) for incineration. In the United States, engineered landfills can be publicly or privately owned, with ownership affecting their economic structure. We use tipping fees, reported by the Environmental Research and Education Foundation (EREF, 2024) as a proxy for operating costs, recognizing that they do not fully capture all expenses. Notably, EREF is the only source that provides data at the regional level. However, the regional groupings do not match those from Milbrandt et al. (2022); from this we estimate the national value by taking an average of the regional values. Finally, expenditures related to the sorting of imports are not broken out and therefore not specified here. These data are directly used for BAU calculations. We inflated all cost estimates from their reported dollar years to 2024. Data and sources are detailed in Section 7.5. For estimating waste management costs to taxpayers, we include costs of formal collection, sorting, incineration, and landfilling.

Jobs

In general, data on jobs associated with the plastic value chain in the United States are very limited. The main source for U.S. jobs related to plastic is the Tellus Institute, which provides 2008 data (Tellus Institute, 2011). However, it is unclear how job efficiency (jobs per metric ton of material) may have changed since then.

For jobs in the informal sector, we developed an estimate by applying the Lau et al. (2020) ratio of jobs in the informal/formal sector to the U.S. data. For all other data, we reference Lau et al. (2020) or an original source cited in Lau et al. (2020), Hestin et al. (2015). We assume these rates stay constant over time in the model.

The job results are presented in full-time equivalents (FTEs), a unit of measurement representing the number of full-time employees.

Greenhouse Gas Emissions

We used emission factors to estimate GHG emissions associated with material moving through each part of the value chain, reported in million metric tons of carbon dioxide equivalent ($MtCO_2e$) units. We used U.S.-specific data sources to estimate emissions associated with all life-cycle stages except for formal and informal collection and formal sorting. For these stages, we used data for global high-income archetype countries from Lau et al. (2020). Sources used to estimate U.S. emission factors and other data to estimate GHG emissions include the U.S. EPA (2023b), Uekert et al. (2023), and Zheng & Suh (2019). See Section 7.5 for more information.

2.2 Microplastics

As discussed in Section 1.3.3, this analysis focuses on microplastics generated from textiles and tires. We modeled flows of these microplastics in the United States using unique system maps for each microplastic source (Figure 1-3 and Figure 1-4). Due to data limitations, we modeled microplastic flows at the national level rather than the regional level. We modeled national flows separately for urban populations and rural populations to reflect differences in wastewater treatment and road use between these populations. See Section 7.7 for additional information.

2.2.1 Textiles

Textiles are made of fibers from natural, semisynthetic, or synthetic materials, all of which can release microfibers (Athey & Erdle, 2022). In this analysis, we limit our scope to synthetic (plastic) microfibers because synthetic materials dominate global fiber production (Textile Exchange, 2023). Textiles shed microplastics throughout every stage of the life cycle, including during the manufacturing process, during the use phase through wear and tear and washing, and at the end of life when they degrade. In this analysis, we model textile microplastic pathways from washing during the production and use stages. The analysis captures washing of textiles by households but does not include commercial washing and therefore may underestimate textile microplastic generation.

To model flows of textile microplastics, we relied on studies reporting the mass of synthetic microfiber losses, or shedding rates, that occur during machine washing from textiles made of polyester (including fleece) and did not include semisynthetic materials. For detailed source information, please see Section 7.7. To estimate annual synthetic microfiber shedding in the United States, we combined these shedding rates with data on global synthetic textile production (Textile Exchange, 2019; Textile Exchange, 2020; Textile Exchange, 2021; Textile Exchange, 2022; Textile Exchange, 2023), U.S. textile production data (World Trade Organization, 2020), the number of U.S. households (United Nations Population Division, 2022), and the average number of wash cycles per household (Pakula & Stamminger, 2010).

After textiles are washed, the wastewater that is generated flows to wastewater treatment facilities and undergoes different levels of treatment, including primary, secondary, and tertiary or advanced treatment, with the last removing the highest number of microfibers. We used data from the EPA 2022 Clean Watersheds Needs Survey to split wastewater treatment by treatment level (U.S. EPA, 2022) and Lau et al. (2020) for wastewater treatment efficiency by treatment level.

Wastewater treatment facilities process sewage and separate the liquids and solids, producing nutrient-rich biosolids. During treatment, microplastics captured in the system can also accumulate in these biosolids. Once separated from liquids, biosolids can be managed in several ways, including landfilling, incineration, other waste management methods (e.g., storage), or land application. To allocate the collected microfibers to different biosolid management strategies, we used the EPA 2022 Clean Watersheds Needs Survey (U.S. EPA, 2022).

2.2.2 Tires

We modeled tire wear particle losses from five vehicle types: motorcycles, passenger vehicles, light-duty vehicles, heavy-duty vehicles, and airplanes. For each vehicle type, we applied vehicle-specific tire abrasion rates by vehicle type from Lau et al. (2020) and Allgemeiner Deutscher Automobil-Club (2021), which are largely based on tires in the European market. These data were used as a proxy for the U.S. market due to the lack of publicly available data on abrasion rates of tires produced in or for the United States. To estimate the mass of microplastics shed from tires in a given year, we multiplied the abrasion rates by the annual distance traveled by vehicle type, using data from the Federal Highway Administration (2022). For airplanes, we multiplied tire wear particle losses during takeoff and landing (Kole et al., 2017) by the annual number of flights originating from the United States (World Bank, 2021).

Tire wear particles may end up on land or in water or may run off roadways into stormwater systems and get captured during the wastewater treatment process. In the United States, there are two types of wastewater treatment: combined sewage systems, which treat both municipal wastewater and stormwater runoff; and separate sewage systems, which treat only municipal wastewater, while stormwater runoff flows directly to a waterway. Using models from Pitt et al. (2005) and Moran et al. (2023), we assumed that 91% of tire wear particles end up on land and the remaining 9% are transported via stormwater runoff to wastewater treatment facilities.

Urban and rural landscapes vary in their connectivity to combined sewage systems and the extent of impervious surfaces (e.g., roads and pavements), both of which influence the fate of stormwater runoff. Using data from U.S. EPA (2004), we estimate that approximately 16% of the U.S. population is connected to a combined sewage system. To represent this in the model, we multiply this percentage by the proportion of tire wear particles transported in surface water. Therefore, for the urban archetype, we assume that 1% of tire wear particles are collected in wastewater treatment facilities while the remaining 8% are washed into aquatic systems via stormwater runoff. For the rural archetype, we assume no connection to combined sewage systems and therefore no collection of tire wear particles in wastewater treatment facilities. Additionally, rural areas have lower impervious surface coverage than urban areas. We assume that the proportion of tire wear particles transported via stormwater runoff is half of that of urban areas, with the remainder retained on land.

Since wastewater treatment facilities can capture microplastics, like microfibers, tire microplastics collected in wastewater treatment facilities also accumulate in biosolids that can be managed via landfill, incineration, other waste management methods, or land application.

2.3 Limitations

2.3.1 Plastic Packaging MSW

As with many national modeling exercises, there are data gaps and limitations associated with this analysis. We provide a brief summary of key limitations associated with plastic flows, costs, jobs, and GHG emissions below.

Plastic Flows

- The BAU scenario assumes that no policy interventions are made relative to current plastic-related policies, economics, infrastructure, or materials, and that cultural norms and consumer behaviors do not change.
- In the BAU scenario, the model projects growth in plastic waste generation and does not place constraints on the capacity of the waste management system. In reality, the waste management system faces capacity constraints as the amount of waste increases. However, the purpose of the BAU scenario is to model a future in which the waste management system can readily scale up with projected increases in plastic waste generation. This may lead to an overestimate of the amount of waste able to be managed in the U.S. system.
- State-level waste characterization data vary in quality or do not exist for some states. While we use Milbrandt et al. (2022) data, which summarizes state-level waste characterization studies, the paper relies on 44 reports from 37 states, with four reports published before 2010. Additionally, the level of detail varies across reports, with some states reporting on plastic polymer, format, and use, whereas others provide information on format only. As a result, this analysis may not accurately reflect polymer and format composition of plastic waste in each region.
- We assigned national waste generation to regions based on their current and projected share of the U.S. population. While plastic consumption is correlated with population size (Milbrandt et al., 2022), other factors may influence plastic usage, such as socioeconomic status and policies already in place in particular states. Therefore, this analysis may not accurately represent regional consumption patterns.
- We treat open-loop mechanical recycling as a sink, which means that plastic products made from open-loop recycling do not end up as waste. In reality, these products may be longer lived than single-use plastic but would ultimately become waste. We assume that waste generation drives the total mass of plastic waste flowing to recycling, chemical conversion, landfill, and incineration. Although technological advances and changes in capacity could shift how much waste flows to each of these management pathways, we do not have data to model this change. Therefore, while waste generation may change, the percentage of waste flowing to each management pathway is held constant throughout the analysis.

Costs

- We do not have cost data specific to the private and public sectors. Therefore, we present total waste management costs (main report) and total costs by life-cycle stage (Section 7.8.1). Because private and public sectors may be responsible for different life-cycle stages, which can vary by municipality, this approach allows for flexibility in interpreting sectoral costs.

- We do not estimate the cost of pollution or the cost of managing potential health care risks from pollution.

Jobs

- The main source for jobs data in waste collection, incineration, and landfilling in the United States is from 2008. It is unclear how jobs per metric ton of material have changed over time, as technological advances, such as optical sorting, among others, could impact the number of jobs.
- We do not have U.S.-specific jobs data for recycling or chemical conversion and rely on data from the high-income archetype in Lau et al. 2020 as a proxy.

GHG Emissions

- Plastic production generates the greatest GHG emissions of all life-cycle stages (Organisation for Economic Co-operation and Development, 2024). Because the analysis is constrained to waste management, we did not assess the effects of the policy scenarios on GHG emission from plastic production.

2.3.2 Microplastics

Like many national modeling exercises, and similar to the plastic packaging modeling, there are data gaps and limitations associated with the microplastics analysis. We provide a brief summary of key limitations below.

- This study uses tire abrasion rates from tires sold in Europe due to the lack of publicly available data on abrasion rates for tires manufactured for the U.S. market. Pairing U.S. driving rates with U.S.-specific tire abrasion data would provide a more accurate estimate of tire abrasion in the United States.
- Textile data primarily come from studies on microfiber losses during washing, but microfibers can be lost to the air during wear or from clothes dryers. In our model, biosolids application is the only pathway for microfibers to be released to terrestrial systems. By not accounting for these additional loss pathways, this study underestimates terrestrial pollution, as well as aquatic pollution, from synthetic microfibers.
- Both microplastic sources lack economic data, preventing the estimation of economic impacts associated with microplastic pollution.
- This study is limited to two sources of microplastic pollution and does not include other large sources of microplastics, such as paint (Paruta et al., 2021; Boucher & Friot, 2017).

3. Methods for Constructing Policy Scenarios

The selection and design of policy scenarios for plastic packaging and microplastics were informed by desktop research, discussions with project partners, and engagement with stakeholders during the three U.S. modeling workshops. This section describes the modeling methods for each policy scenario; for more information, please see Section 7.6 and Section 7.7.

3.1 Plastic Packaging MSW Policy Scenarios

This analysis includes the following five policy scenarios for the plastic packaging sector:

1. Material phaseout and design optimization (hereafter, “Phase-out and Optimize”)
2. Return-based reuse (hereafter, “Reuse”)
3. Collection for recycling and sorting efficiency (hereafter, “Collect and Sort”)
4. Deposit Return Scheme (hereafter, “DRS”)
5. The combination of the above four policies (hereafter, “Combined”)

We evaluated each policy scenario individually, as well as together in a combined scenario. We set two target levels for each policy—low and high—based on existing state-level benchmarks and, where domestic data were limited, on national targets from international policies. The low targets are intended to reflect incremental or moderate action, while the high targets represent more transformative, yet still feasible, efforts. We assumed implementation of each policy scenario would begin in 2031, with targets being achieved by 2040. For each scenario, we estimate the changes in plastic packaging mass relative to the BAU scenario, as well as the changes in the costs, jobs, and GHG emissions associated with the plastic system.

3.1.1 Phaseout and Optimize

Material phaseout and design optimization are both forms of waste prevention that aim to reduce waste before it is created (also called source reduction). For the material phaseout policy, we modeled the elimination of PVC and PS/EPS from plastic packaging because both polymers are difficult to recycle, have limited end markets, and can contaminate the recycling streams of other polymers.

PVC is particularly problematic in recycling streams and can reduce overall recycling rates. For example, negative impacts of PVC contamination on recycling processes can occur at just 50 parts per million, or 0.05 kilograms of PVC in 1,000 kilograms of PET flake (or 1.76 ounces in 2,204 pounds of flake) (Amstar n.d.). Additionally, while all plastic contribute to environmental issues, the unique use of chlorine in PVC production and the reliance on toxic additives like phthalates and heavy metals make it particularly problematic compared to other plastic.

PS/EPS in the MSW stream is also difficult to recycle because it is often contaminated and has high feedstock costs and limited end markets (Xu et al., 2024). Other challenges include the very light and brittle nature of PS/EPS, which means it breaks down easily and can therefore quickly result in widespread pollution (Ocean Conservancy, n.d.). PS/EPS is also considered problematic due to the negative human health impacts of styrene as well as other chemicals that can leach out of PS/EPS and harm aquatic animals (Thaysen et al., 2017; OSHA, n.d.-b). Notably, certain types of PS/EPS packaging, such as that used in transport packaging to protect goods that are handled in bulk (ISO, 2016), may not enter the MSW stream. By staying within the business-to-business supply chain, transport packaging can avoid high rates of contamination and be collected in large quantities, leading to a higher recycling rate compared to that of PS/EPS packaging collected from MSW recycling streams (EPS Industry Alliance, 2024).

The impacts of PVC and PS/EPS are gaining both national and state-level recognition. While no state has banned PVC, several states have introduced bills to restrict PVC in packaging. In 2024, the U.S. EPA proposed designating vinyl chloride as a high-priority chemical under the Toxic Substances Control Act because it may present an unreasonable risk to people and the environment (U.S. EPA, 2024a). Some states have already banned or are phasing out PS, particularly for food service and packaging. States that have passed types of PS food packaging bans include California, Colorado, Delaware, Maine, Maryland, New York, New Jersey, Oregon, Rhode Island, Vermont, Virginia, and Washington; dozens of municipalities have also banned PS (Environment America, 2022). Businesses in these states tend to replace PS with paper or reusable plastic containers. While we recognize there may be challenges to fully eliminating EPS for protective packaging for large items (TVs, appliances, etc.),we assume new solutions will continue to be developed that serve a similar role.

Methodology

We implemented this policy in two phases. First, we modeled packaging optimization by implementing target-based reductions of plastic material across all packaging types. While we do not specify the mechanism for the modeled optimization (e.g., right-sizing, shifting to bulk packaging, etc.), the model reflects optimization as a reduction in primary plastic waste, which relates to the production and use of plastic (see Box Y, "Primary plastic waste," in the Figure 1-2 system map).

We set the low target for optimization at 10% (i.e., reducing the mass of plastic in packaging by 10%) based on available data from select consumer goods companies showing the feasibility of a nearly 10% source reduction over three years (Triodos Investment Management, 2024). However, the 10-year timeline in this model reflects the need to allow industry more time for implementation.

We set the high target for optimization at 20% based on California's 2022 Plastic Pollution Prevention and Packaging Producer Responsibility Act (S.B. 54) (CalRecycle, 2025). Although the timeline for achieving this target is 2032 in the California law, we extend this target date to 2040 in our analysis. The California law mandates a 25% reduction in single-use plastic packaging and food ware by 2032, achieved through a combination of reuse (4%), elimination without material substitution (6%), and optimization, such as right-sizing, shifting to bulk formats, or using nonplastic alternatives (15%). Combining the elimination and optimization targets requires a 21% reduction of plastic packaging demand, which informs the high-optimization target used in this analysis. To provide additional context for source reduction in the United States, Maine set an EPR packaging reduction target of 40% by 2040 (which covers all material types) (State of Maine, 2021). While Maine's target is much higher than California's, it covers a greater scope of materials and signals momentum toward upstream source reduction, providing support for selection of the 20% target.

The second phase in this methodology is elimination of the residual use of PVC and PS/EPS packaging and shifting of that tonnage to other polymers (assuming here that there is no substitution with other, nonplastic materials). This decision was informed by existing legislation banning PS/EPS in several states and municipalities; the Ellen MacArthur Foundation Global Commitment signatories' 2025 target of eliminating these materials; and the U.S. Plastics Pact's list of problematic and unnecessary materials, which includes PVC and PS/EPS (Ellen MacArthur Foundation, 2024; U.S. Plastics Pact, 2024; Environment America, 2022). For rigid PS/EPS packaging, we assume that the tonnage that is eliminated will be shifted equally between PET and PP. For flexible and multimaterial PS/EPS, we assume the tonnage will be shifted to LDPE film. While there is a shift of EPS and PS to fiber (in packaging, food service, and protective packaging for small items), and some EPS products are transitioning to biobased plastic, there is no publicly available data to quantify the amount, which is thought to be smaller than the transition to PET and PP. For PVC rigid packaging, the shift is to PET; for PVC film, the shift is to LDPE film. This full elimination and shift would be achieved in 2031 (accounting for the time required to enact legislation and allow companies to adjust operations) and is presented as part of both the high and low scenarios.

The underlying assumptions of this policy are as follows:

- Industry can achieve the optimization targets within 10 years.
- Optimization is represented as the same percentage reduction in plastic demand for every plastic packaging type.
- The elimination of PS/EPS will lead to a shift of rigid PS/EPS to PET, and PP and film PS/EPS to LDPE.
- The elimination of PVC will lead to a shift of rigid PVC to PET and film PVC to LDPE.
- The optimization target is achieved via a linear increase from 2031 to 2040.

3.1.2 Reuse

Reuse systems are upstream solutions that are a form of waste prevention and therefore contribute to waste reduction and circularity. While reuse is widely recognized as an important solution to reducing plastic waste generation, it is not yet widely institutionalized. There have been many pilots in the United States and internationally evaluating the best way to implement reuse (Moss et al., 2022), and some restaurants and service providers are launching reuse programs (Uber, 2024). Several U.S. cities and counties have reuse laws (Upstream, n.d.), and several states have passed EPR legislation with reuse requirements (including California, Colorado, Minnesota, Oregon, and Washington). Notably, California is the only state, as of the writing of this report, with published targets for plastic reuse. Therefore, the targets for this policy are informed by reuse targets in California and in other countries.

Reuse systems include return-based reuse, in which packaging is collected, washed, and refilled; and refill-based reuse, where consumers refill their own reusable containers (Ellen MacArthur Foundation, 2019). Our analysis models the waste management of reusable materials from return-based reuse and the associated impacts on plastic packaging mass flows, costs, jobs, and GHG emissions. While we model only return-based reuse due to data availability, we acknowledge that refill-based reuse systems may have distinct effects on plastic packaging mass flows, costs, jobs, and GHG emissions because of the differences in logistics between the two reuse systems.

Methodology

We model a shift from single-use plastic packaging to reusable packaging (made of plastic, metal, or glass) at the regional level. In this model, reusable plastic is set to have the same downstream characteristics as PET due to its durability, chemical resistance, and recyclability. However, we recognize that reusable plastic can be made of a variety of polymers, depending on intended function. Single-use plastic packaging eligible for reuse in this model includes beverage and nonbeverage bottles (PET and HDPE), rigid packaging (PET, HDPE, PP, PS/EPS), flexible packaging (HDPE, LDPE/LLDPE), and multimaterial packaging (PET, HDPE, PP, PS/EPS, LDPE). We assume that these return-for-reuse systems have a return rate of 95% (Ellen MacArthur Foundation, 2023).

Because of increased economic potential for the development of reuse infrastructure, or to leverage existing DRS collection infrastructure, we assume reuse rates increase with population density. Urban environments also provide more points of access for take-back logistics (e.g., retail stores, reverse vending machines, etc.). As a result, we modeled reuse scaled by urban and rural populations at the state level for a finite number of uses (details provided in Section 7.6). To estimate greater reuse in urban environments, we estimated a target-scaling coefficient as follows:

- **Calculate share of each region that is urban:** Aggregate state-level urban population data from the U.S. Census Bureau to the regional level (U.S. Census Bureau, 2023).
- **Normalize by the national average:** Compute the average percentage urban population across all regions to get a national average. Then, for each region, divide its percentage urban population by the national average to generate a scaling coefficient.
- **Apply the coefficient:** Multiply the national target (discussed below) by each region's coefficient to generate its region-specific reuse target. A coefficient of 1.0 means the region is expected to meet the national target; a coefficient > 1.0 indicates that the region is expected to exceed the national target (due to higher urbanization); a coefficient < 1.0 suggests that the region may fall short of the national target (due to lower urbanization).

We developed two sets of targets for a policy implemented in 2031 with targets achieved in 2040: a set of high and low targets specific to beverage bottles, and a second set of high and low targets for rigid and flexible packaging, as described below.

Targets for beverage bottles

We model a reuse target specific to HDPE and PET beverage bottles due to their well-established potential for reuse and widespread consumer familiarity with return systems for these containers. For example, beverage containers are already a target for DRS and refillable bottle models in the United States, making them more feasible and ready for scaling.

We reviewed international policies with reuse targets to inform the targets in this study. We acknowledge the differences in geography, market structure, and consumer behavior among the countries associated with these targets, as well as within the United States. Nonetheless, given limited data availability, we consider domestic and international country targets to bound the range of feasibility in this analysis (see Section 7 for a summary of identified reuse targets).

Based on the landscape review of policy, we apply a 10% reuse target by 2040 in the low scenario and a 30% target in the high scenario for beverage bottles. Note that we did not use the highest target reuse rate, which is from Germany (70%). Germany's first plastic laws date to 1991, which has allowed time for consumer behavior to change. Therefore, we do not include this target in our considered range because the modeling time period is considerably less than the duration the German policy has been in existence. However, Chile and Austria are the two other countries that report reuse targets, and both have a target of 30%. Chile's EPR was established in 2016 with a law that includes binding reuse targets established in 2021; in 2020, Austria introduced binding targets for reusable packaging, the first European country to do so. Therefore, we align with Chile and Austria's targets because they are more recent and are also binding.

Targets for all other packaging

We model a target for all other plastic packaging including nonbeverage bottles (HDPE and PET), rigid packaging (PET, HDPE, PP, PS/EPS), flexible plastic packaging (HDPE, LDPE/LLDPE), and multimaterial packaging (PET, HDPE, PP, PS/EPS, LDPE). This broader approach reflects emerging policy trends that aim to embed reuse across all plastic packaging categories, beyond beverage bottles. For more details, see Section 7.6.3.

The low target of 5% is similar to California's S.B. 54 requirement for a 4% shift to reuse for plastic packaging and food ware by 2032. Maine's reuse target—15% for all packaging by 2039, increasing to 30% by 2049—provides another point of reference. While the Maine target is not specific to plastic, it offers insight into the level of ambition some states are adopting for reuse more broadly. Therefore, the high scenario target is 10%. This is double the low scenario and also lower than Maine's 15% target because Maine's figure encompasses all packaging, not just plastic packaging (State of Maine, 2021).

The following are underlying assumptions for this policy:

- Several factors influence the adoption of reuse systems, including population density, collection infrastructure, availability of washing facilities, and consumer awareness and costs. While data on reuse uptake across the six modeled regions is limited, we use urban population as a proxy, based on the assumption that reuse systems are more likely to scale first in urban areas due to higher population density and the cost efficiencies on building out collection infrastructure and wash facilities.

- PET reuseable plastic is the only reusable plastic.
- Product material can be switched only to PET plastic, metal, or glass.

See Table 3-1 and Table 3-2 for information on the assumptions used for weight ratios and use cycles when shifting between single-use and reuse materials. Reuse materials are littered at half the rate of single-use plastic (Keep America Beautiful, 2021).

Table 3-1. Weight ratios for reuse materials to single-use materials

Single-Use Plastic Type	Weight Ratio of Reuse to Single-Use Material		
	Plastic (Rigid)[a]	Glass[b]	Metal[c]
Bottles (beverage and nonbeverage)	2.1	16.5	16.2
Rigid packaging	2	4.4	12.2
Flexible packaging	5	4.3	12.2
Multimaterial	5	4.3	12.2

[a] Based on weight data for various products in Ellen MacArthur Foundation (2023).

[b] Based on weight data for various products from Deeney et al. (2023).

[c] Based on weight data for various products in Ellen MacArthur Foundation (2023) and Eunomia (2023).

Table 3-2. Assumed number of uses for reuse materials

Reuse Material	Life-Cycle Ratio
Plastic	20
Glass	12
Metal	30

Source: Expert opinion from Lau et al. (2020)

3.1.3 Collect and Sort

Recycling rates are often set as targets by states, provinces, and countries, either as stand-alone goals in national action plans or tied to specific policies, such as extended producer responsibility. However, many factors contribute to a recycling rate, including packaging recyclability, access to and participation in collection programs, processing and sorting efficiency, consumer behavior, and end market availability. In this analysis, due to capacity and data constraints, we examine only formal collection for recycling and sorting loss targets and their impact on recycling rate, by region.

Methodology

The list of in-scope plastic types for this policy presented in Table 3-3 was developed by reviewing lists of materials accepted for recycling published by several states, including in the Colorado needs assessment (Circular Action Alliance, 2025), the Oregon Uniform Statewide Collection List (Oregon Department of Environmental Quality, 2024b) and Oregon's EPR covered materials list (Oregon Department of Environmental Quality, 2024a), and California's S.B. 54 (California, 2022). The "universal list" used in this analysis reflects commonly listed plastic types from these sources, which also have known end markets. Note that we are not accounting for any shift over time of plastic types from being out-of-scope to becoming in-scope plastic types.

Table 3-3. List of in-scope plastic types

In-Scope Plastic Types	
• PET beverage bottle	• HDPE rigid packaging
• PET nonbeverage bottles	• PP rigid packaging
• PET rigid packaging	• HDPE flexible packaging
• HDPE beverage bottles	• LDPE flexible packaging
• HDPE nonbeverage bottles	

We model a policy starting date of 2031, with targets attained in 2040. The collection for recycling rate target is developed to acknowledge the differences in baseline collection for recycling rate across the regions. The following are the low and high targets for collection for recycling and sorting.

Collection for recycling rate. Section 7.6.3 provides a table showing baseline collection for recycling rates based on BAU.

- **Low target:** Double the current collection-for-recycling rate for in-scope packaging in each region and reduce the collection-for-recycling rate for out-of-scope packaging types to zero.
- **High target:** Quadruple the current collection-for-recycling rate for in-scope packaging in each region, capped at 90%, and reduce the collection-for-recycling rate for out-of-scope packaging types to zero.

Sorting losses. Section 7.6.3 provides a table showing baseline and target sorting and processing loss rates by plastic type based on data from Consulting (2023). The sorting loss rates and the targets here are also similar to capture rates set forth in Oregon's Plastic Pollution and Recycling Modernization Act (S.B. 528) (State of Oregon, 2021).

- **Low target:** Halve sorting losses for in-scope plastic packaging types in each region.
- **High target:** Limit sorting losses to 10% for in-scope plastic packaging types in each region.

The low-target scenario combines the low targets for collection and sorting efficiency while the high scenario reflects the high targets. The following are underlying assumptions for this policy:

- A sorting efficiency of 90% (or a 10% loss rate) is feasible given recent testing in HolyGrail 2.0 sorting trials of rigid packaging waste (End Plastic Waste, 2025).
- In the high-target scenario, sorting efficiency for flexible packaging is on par with that of rigid packaging.
- Sorting losses are capped at 10% (i.e., halving losses is not less than 10% for any plastic types).
- Sorting losses for rigids is the same across PVC, LDPE/LLDPE, PS, and other.
- HDPE nonbottle rigids sorting losses are the same as for HDPE bottles.
- Sorting efficiency is the same in every region.
- Materials not accepted under comingled recycling or via PRO/depot are sent to landfill or incineration.
- Export rates for PET and HDPE bottles are identical and as reported by Stina (2021).

3.1.4 Deposit Return Scheme

DRS exists in 10 U.S. states[6] and is shown to be one of the most effective policies for increasing beverage bottle recycling rates, regardless of beverage container material type (Association of Plastic Recyclers, n.d.; Reloop, n.d.). DRS works by placing a small refundable deposit on beverage containers. Consumers pay this deposit when they buy a drink in a bottle or can and get the deposit back when they return the empty container to a retailer or redemption center. This encourages reuse and recycling and reduces litter by creating a financial incentive for consumers to return containers.

Nine of the states with DRS rank in the top 10 states with the highest recycling rates (for containers of all material types) (Eunomia, 2023). Several of these states are working to modernize DRS by expanding the types of containers subject to refundable deposit as well as increasing the rebate to encourage higher rates of return. Studies show that when this has been done, collection rates of 90% or higher can be achieved for beverage containers (Reloop, 2024). Indeed, Oregon has achieved a collection rate greater than 90%, as have some Canadian provinces and European Union (EU) countries. Notably, the EU has set its targets in alignment with these findings. For example, the EU Single-Use Packaging Directive requires 90% of all single-use plastic beverage bottles to be separately collected (that is, not including containers extracted from mixed waste) by 2029, and will require the EU's 27 member states to set up a deposit return system by 2029 to achieve those targets (EU Single-Use Plastic Directive, 2019).

Methodology

In this analysis, we modeled DRS in every region for all PET and HDPE beverage bottles other than HDPE milk jugs. We assumed the policy would begin in 2031 (accounting for time required to enact legislation) and that the target would be achieved in 2036. A global review of DRS programs by Eunomia (2023) shows targets as high as 90% can be achieved in this time frame by implementing a

[6] The states with DRS are California, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont.

modernized DRS that expands in-scope formats and materials and sets certain redemption values. Therefore, we set the high collection rate at 90%. We set the low-target collection rate of 65% based on current performance of states with data. This is developed by taking the average of 2022 redemption rates for plastic beverage bottles for Hawaii, Iowa, and Oregon (the year in which plastic data for the greatest number of states with bottle bills—three—was reported) (Container Recycling Institute, 2023).

Assumptions include the following:

- Implementing a modernized DRS can lead to a 90% collection rate for plastic beverage bottles, and we cap maximum collection rate at this level.
- 35% of HDPE bottles are eligible for DRS (nonmilk bottles) (calculated using data from New York City Department of Sanitation [2023]).
- Bottles eligible for DRS collection are littered at half the rate as other single-use beverage bottles (Keep America Beautiful, 2021).
- DRS-collected beverage bottles have lower sorting and processing loss rates than non-DRS collected beverage bottles because they form a cleaner material stream than that from curbside collection. We assume a sorting loss rate of 1% for DRS-collected beverage bottles, and processing loss rates of 8% for HDPE beverage bottles and 12% for PET beverage bottles.
- DRS-collected bottles are more likely to be feedstock to closed-loop recycling than non-DRS-collected bottles because they are a cleaner material stream (Eunomia, 2023). Therefore, we assume closed-loop recycling for HDPE beverage bottles processed through DRS increases to 34% and to 71% for PET beverage bottles processed through DRS (Eunomia, 2023).
- Formal collection costs and jobs are used as a proxy for DRS-specific collection costs due to data limitations.

3.1.5 Combined Policy Scenario

In the Combined policy scenario, we modeled the combination of each of the four policy scenarios described above. Coordinated sequencing of policies can improve efficiency through systems sharing infrastructure and costs (Eunomia & The Story of Stuff, 2025). We modeled the impacts of each policy sequentially by first reducing plastic packaging mass via the source reduction policies (Phaseout and Optimize and Reuse) and then applying the waste management policies to the remaining waste (DRS and Collect and Sort).

3.2 Microplastic Policy Scenarios

Microplastic policies are tailored to each microplastic source, featuring a combination of upstream and downstream measures to both reduce microplastic generation at the source and capture microplastics before they enter the environment. In line with the time frame for the plastic packaging policies, all microplastic policies are implemented in 2031 and targets are achieved by

2040. The below sections describe the policy scenarios modeled for textiles and tires. For more information, see Section 7.7.

3.2.1 Textiles

We modeled one policy focused on source prevention of textile microplastics. Specifically, we modeled the reduction in shedding rates that could be achieved through textile design improvements. Additionally, we modeled two policies focused on downstream management of textile microplastics: (1) installing filters on washing machines to capture microfibers that shed during washing, and (2) banning the application of biosolids on agricultural lands.

Reduce microfiber shedding rates

Recent studies have explored ways to reduce microfiber shedding through changes in textile design, such as modifying fiber composition, yarn characteristics, and fabric structure (Hazlehurst et al., 2024). For this analysis, we focused on synthetic microfibers and aggregated shedding rates across textiles made of polyester and nylon. However, fiber type, yarn characteristics, fabric construction, and other factors can influence microfiber shedding (Allen et al., 2024; Hazlehurst et al., 2024). To model the impact of reducing shedding rates, we removed the top 25% of loss rates from our compiled microfiber loss rate dataset and calculated a new average from the remaining data. This adjusted average represents a scenario in which improved textile design standards reduce microfiber release during washing.

Install washing machine filters

Napper et al. (2020) evaluated the effectiveness of microfiber capture technologies by comparing devices that are placed inside the washing machine with external filters installed on the drainpipe to filter effluent. Both types are commercially available. They found that external filters were more effective, with capture rates reaching up to 78% of microfibers. We developed a policy scenario, implemented in 2031, under which 67% of washing machines would be equipped with external filters by 2040. We assumed that filters remove 78% of microfibers that are shed during washing and that 50% of captured microfibers are then managed via landfilling or incineration.

Ban biosolids application on agricultural land

Wastewater treatment plants receive wastewater from residential homes and from commercial and industrial businesses connected to the municipal sewage system. Sewage sludge is generated through the treatment process after separating the liquids from solids, and biosolids refers to sewage sludge that has been treated to meet regulatory requirements. In 2024, the U.S. generated over 4 million metric tons of sewage sludge, of which over half is land-applied and approximately a quarter is landfilled (U.S. EPA, 2025a). We use national level data on biosolids application in 2024 from the EPA for this analysis, acknowledging that biosolids use varies by state (National Biosolids Data Project, 2018).

The U.S. EPA has a policy of promoting beneficial uses of biosolids, which are used for several purposes in the United States, including as fertilizer and soil amendments for agricultural lands, in land reclamation efforts, and as lawn and garden products for home garden use (U.S. EPA, 2025a).

Nationally, approximately half of the land-applied biosolids occurs on agricultural lands (U.S. EPA, 2025a), though biosolids management practices vary by state (Beecher et al, 2022). As a byproduct of wastewater treatment, biosolids contain microplastics from laundry (Geyer et al, 2022) and can be a source of microplastics in agricultural land (Corradini et al., 2019). Microplastics can be long-lasting in soils; fibers have been found in agricultural soil 20-30 years after biosolids application (Ramage et al., 2025; Adhikari et al., 2024; Weber et al, 2022). Research shows microplastics can alter soil structure, soil microbial communities, and the behavior of organisms that live in soil, leading to changes in nutrient availability, water movement, and soil conditions for plants (Lwanga et al., 2016; Machado et al., 2019; Rillig et al., 2019), although the levels at which these impacts may be observed is still an area of research. Ultimately, these changes may impact plant growth and productivity. Due to concerns about PFAS (perfluoroalkyl and polyfluoroalkyl substances) contamination in biosolids, which can further migrate to agricultural lands, plant uptake, and groundwater, a few states have regulatory measures restricting biosolids application on land (Saliu & Sauve, 2024; Hughes, 2023).

To inform microplastic mitigation strategies, in this policy scenario we limited the application of biosolids by banning their application on agricultural land, disposing of them instead through landfilling and incineration.

Combined textiles policy scenario

We developed a combined textiles policy scenario that integrates the three textile policies described above.

3.2.2 Tires

We modeled two policies focused on source reduction of tire microplastics: (1) reducing passenger vehicle miles traveled, and (2) reducing tire abrasion rates. In addition, we modeled a ban on the application of biosolids on agricultural land in line with the policy modeled for textiles. We recognize that there are other strategies for addressing tire microplastics, including use of green infrastructure, such as rain gardens, to help capture microplastics that are shed from tires and run off roadways (Gilbreath et al., 2019). However, due to data limitations, we focus on these three policies in this analysis.

Reduce passenger vehicle miles traveled

In this policy, we modeled a reduction in passenger vehicle miles via increased use of public transportation. We researched city-level projections for public transit growth across the United States and identified studies from seven metropolitan regions in California (California Metropolitan Transportation Commission, 2025), Illinois (CMAP, 2017), Massachusetts (City of Boston, 2017), Oregon (*2023 Regional Transportation Plan*, 2023), Texas (North Texas Council of Governments, 2025), Washington state (Puget Sound Regional Council, 2023), Wisconsin (City of Madison, 2022). We calculated the change in public transportation share between 2031and 2040 in each region using a population-weighted average, resulting in a 2% increase in public transportation use. We then reduced passenger vehicle miles traveled accordingly, beginning in 2031 and reaching the 2%

reduction target in 2040. Although a shift to public transportation could result in more buses (whose tires also generate microplastics), the sources we referenced did not disaggregate public transport projections by modes. We therefore assume no additional microplastic generation due to this policy.

Reduce tire abrasion rates

Reducing tire abrasion is a method to reduce microplastic generation upstream. Discussions are underway at the United Nations Economic Commission for Europe to establish tire abrasion limits for passenger cars, light commercial vehicles, and heavy-duty vehicles. Therefore, we modeled a reduction in tire wear across all vehicle types except airplanes. As there are no data on tire abrasion rates for tires made in or for the U.S. market, tire data available from Asia and Europe were used as a proxy for abrasion rates in the United States (Allgemeiner Deutscher Automobil-Club, 2021; Lee et al., 2020; Kole et al., 2017; Verschoor, 2016; Magnusson et al., 2016; Aatmeeyata & Sharma, 2009; Hillenbrand et al., 2005; Luhana et al., 2004). We used the average abrasion rate from this dataset for the BAU scenario. For the policy scenario, we removed the top 25% of abrasion rates and used the average rate from this reduced dataset.

Ban biosolids application on agricultural land

As discussed above in the textiles policy section, wastewater treatment facilities capture a portion of microplastics found in wastewater from multiple sources. Like microfibers, tire wear particles that are captured in these facilities can accumulate in biosolids, which can be landfilled, incinerated, managed using other methods, or applied to land. In line with the textile policy scenario, we modeled a ban on biosolids application on agricultural lands. They are instead disposed through landfilling and incineration.

Combined tires policy scenario

We developed a combined tires policy scenario that implements all three tire policies described above.

4. Business-as-Usual Scenario Results

In this section, we present the BAU results for both plastic packaging MSW and microplastics. This includes estimates of plastic packaging waste generation and microplastics release, as well as the end-of-life fates of these materials, including mechanical recycling and chemical conversion, incineration and landfill, and environmental pollution.

4.1 Plastic Packaging MSW BAU Scenario Results

We present a summary of the results first, in Tables 4-1 to 4-3, followed by more detailed discussion in subsequent sections. Table 4-1 presents the plastic packaging mass at key life-cycle stages in 2025 by region and at the national level. Table 4-2 presents the percentage change in annual plastic packaging mass from 2025 to 2040 under the BAU scenario. Table 4-3 presents the annual GHG emissions, costs, and jobs under the BAU scenario in 2025 and 2040.

Table 4-1. Plastic packaging mass in 2025 by region and at the national level (million tons)

Life-Cycle Stage	Midwest	Northeast	Pacific	Rocky Mountain	Southeast	Southwest	National
Waste generation	6.1	5.8	4.9	1.5	7.8	4.0	30
Recycling	0.37	0.56	0.49	0.06	0.23	0.16	1.9
Landfilling	5.3	3.3	4.0	1.4	6.5	3.7	24
Incineration	0.14	1.7	0.13	-	0.82	0.029	2.8
Pollution	0.18	0.18	0.15	0.045	0.24	0.12	0.90
Note: All values are rounded to two significant figures.							

Table 4-2. Percentage change in plastic packaging mass in 2040 under BAU

Life-Cycle Stage	Midwest	Northeast	Pacific	Rocky Mountain	Southeast	Southwest	National
Waste generation	25%	27%	31%	39%	32%	38%	31%
Recycling	30%	30%	33%	46%	42%	44%	34%
Landfilling	25%	26%	30%	39%	32%	37%	30%
Incineration	25%	26%	30%	0%	32%	37%	28%
Pollution	25%	27%	31%	39%	32%	38%	31%
Note: All values are rounded to two significant figures.							

Table 4-3. Change in annual GHG emissions, costs, and jobs associated with the waste management system in 2025 and 2040 under BAU

Impact Category	Scope	2025	2040	% Change
GHG emissions ($MtCO_2e$)[a]	Packaging only	11	17	52%
GHG emissions ($MtCO_2e$)[a]	All plastic	20	31	54%
Costs (billions $2024)[b]	All plastic	30	40	30%
Jobs (thousands)[c]	All plastic	110	140	31%

Note: All values are rounded to two significant figures.

[a] Estimates include GHG emissions associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[b] Estimates include CAPEX and OPEX associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[c] Estimates include jobs associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

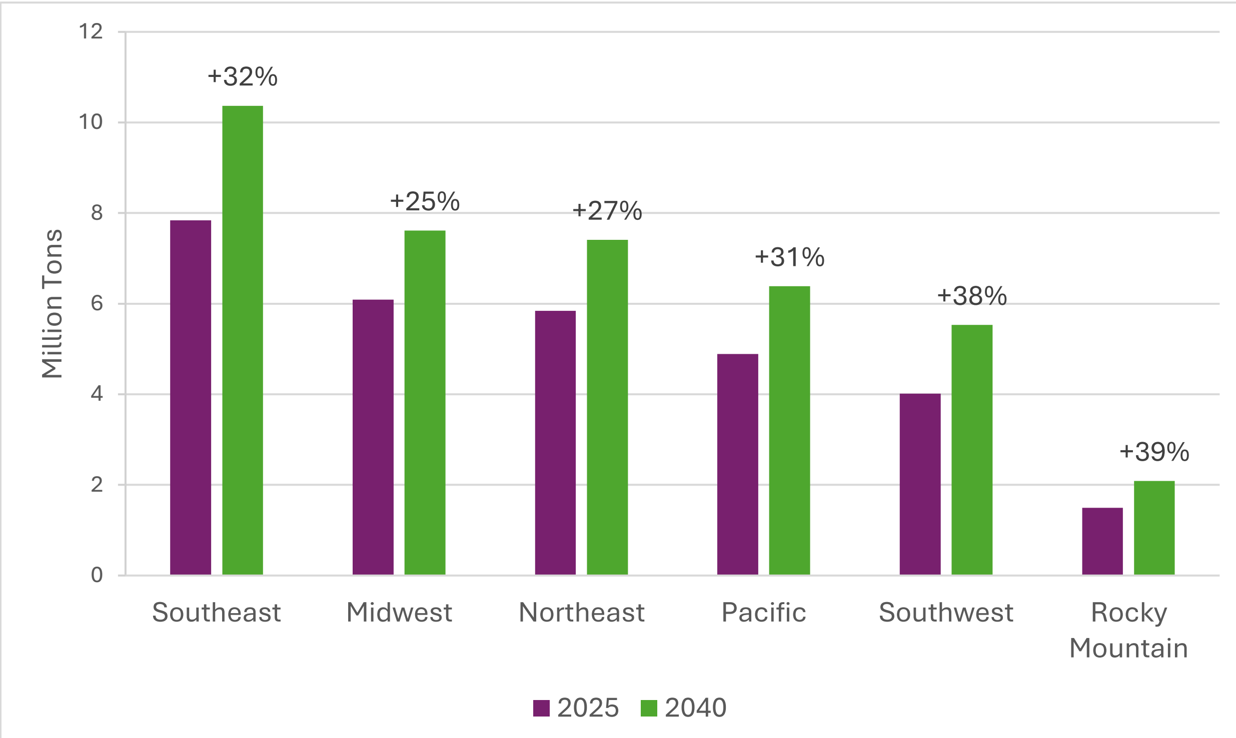
4.1.1 Waste Generation

Nationwide, we estimate total plastic MSW in 2025 at 56 million tons. Between 2025 and 2040, the U.S. is projected to generate an additional 1 billion tons of plastic waste. Plastic packaging accounts for 30 million tons, or 54% of the total. By 2040, plastic packaging waste is projected to increase by 31% to 39 million tons per year under BAU. This is equivalent to over 215 pounds of plastic packaging waste generated per person in 2040, or over half a pound each day. As described in Section 0, the focus of the analysis is on plastic packaging in the United States and evaluating the trade-offs of different policy approaches to address waste from this sector. As a result, we focus on the packaging sector in the remainder of this results section.

Waste generation is driven by population; therefore, the region with the highest population (the Southeast) generates the most plastic packaging waste (26%), followed by the Midwest (20%), and the Northeast (19%) (Figure 4-1). Over the 15-year period, waste generation grows by 31% nationwide, with the Southwest and Rockies experiencing the highest increases (38% and 39%, respectively), owing to the relatively higher population growth projected for these areas.

Figure 4-1. Plastic packaging waste generation by region under the BAU scenario, 2025 and 2040 (million tons)

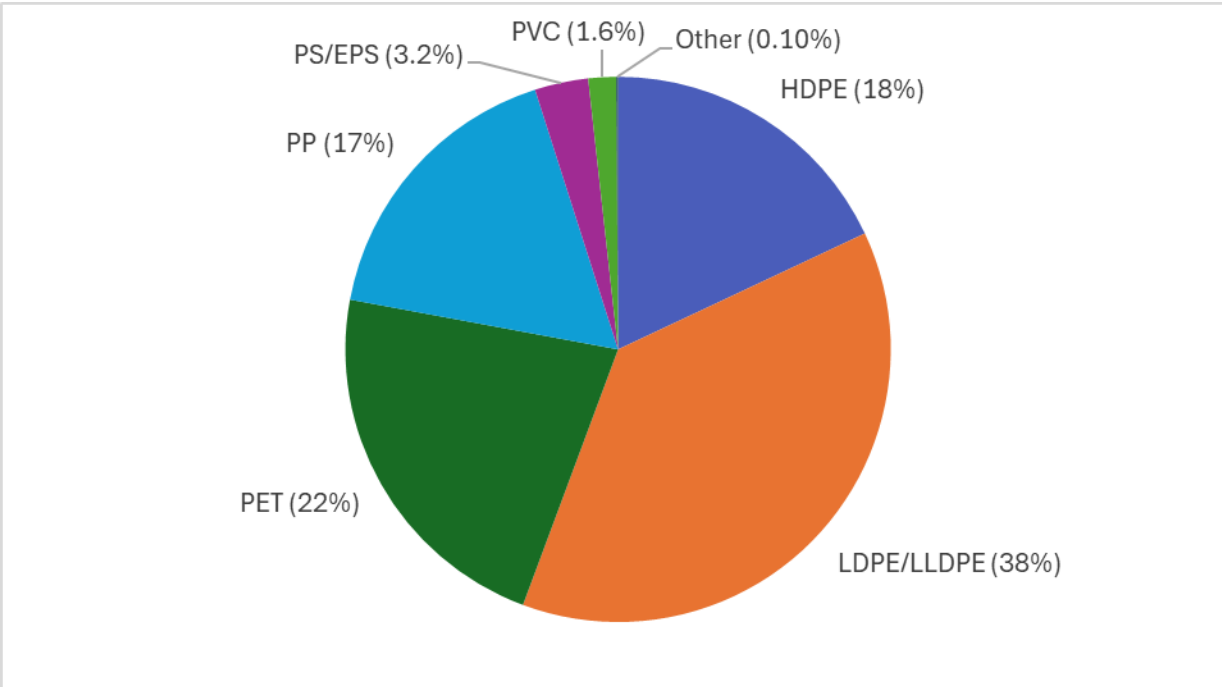
Labels above the 2040 bars indicate the percentage change from 2025 to 2040 under the BAU scenario.



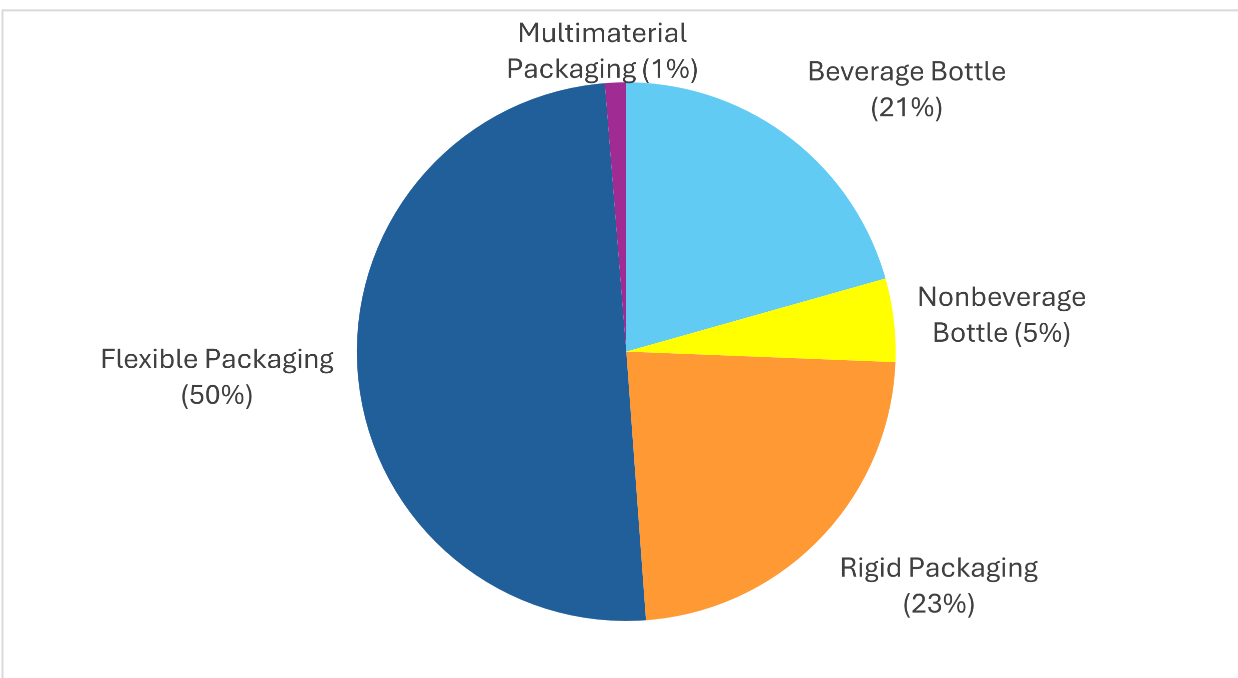
In analyzing the composition of plastic packaging waste in the United States, we find that under the BAU scenario, the majority by mass is LDPE/LLDPE (38%), followed by PET (22%), HDPE (18%), PP (17%), PS/EPS (3.2%), PVC (1.6%), and other polymers (0.1%) (Figure 4-2[a]). In terms of packaging plastic types, the majority of plastic packaging waste in the United States under the BAU scenario is flexible packaging (50%), followed by rigid packaging (23%), beverage bottles (21%), nonbeverage bottles (5%), and multimaterial packaging (1.3%) (Figure 4-2 [b]). Under the BAU scenario, we assume that the polymer and format type shares remain constant over the course of the modeling time frame and do not vary by region.

Figure 4-2. Share of plastic packaging waste by polymer and packaging type under the BAU scenario

(a) Share of plastic packaging waste by polymer



(b) Share of plastic packaging waste by packaging type



4.1.2 Recycling of Plastic Packaging Waste

In this analysis, we define the recycling rate as the share of plastic waste generated that is mechanically recycled or converted in P2P chemical conversion, after accounting for sorting and processing losses, as shown in the below equation:

$$Recycling\ rate = \frac{Mass\ of\ recycled\ plastic\ after\ sorting\ and\ processing\ losses}{Mass\ of\ plastic\ waste\ generated}$$

Mechanical recycling

The U.S. mechanical recycling rate for plastic packaging is 6.1% in 2025. Under the BAU scenario, the rate increases slightly by 2040 to 6.3%. The mechanical recycling rate varies by plastic packaging type, as shown in Figure 4-3. In 2040, beverage and nonbeverage plastic bottles each have a 20% mechanical recycling rate. Rigid plastic packaging has a relatively lower mechanical recycling rate at 4.1%, due to the lower rates of collection for recycling and higher sorting and processing losses for this category. Flexible packaging, which has the highest sorting and processing losses and generates the most waste of all plastic packaging types modeled, has a very low recycling collection rate (2.4%) and mechanical recycling rate (0.25%).

Figure 4-3. Waste generation and mechanical recycling by plastic packaging type under the BAU scenario in 2040 (million tons)

Labels above the bars indicate the mechanical recycling rate for each plastic packaging type.

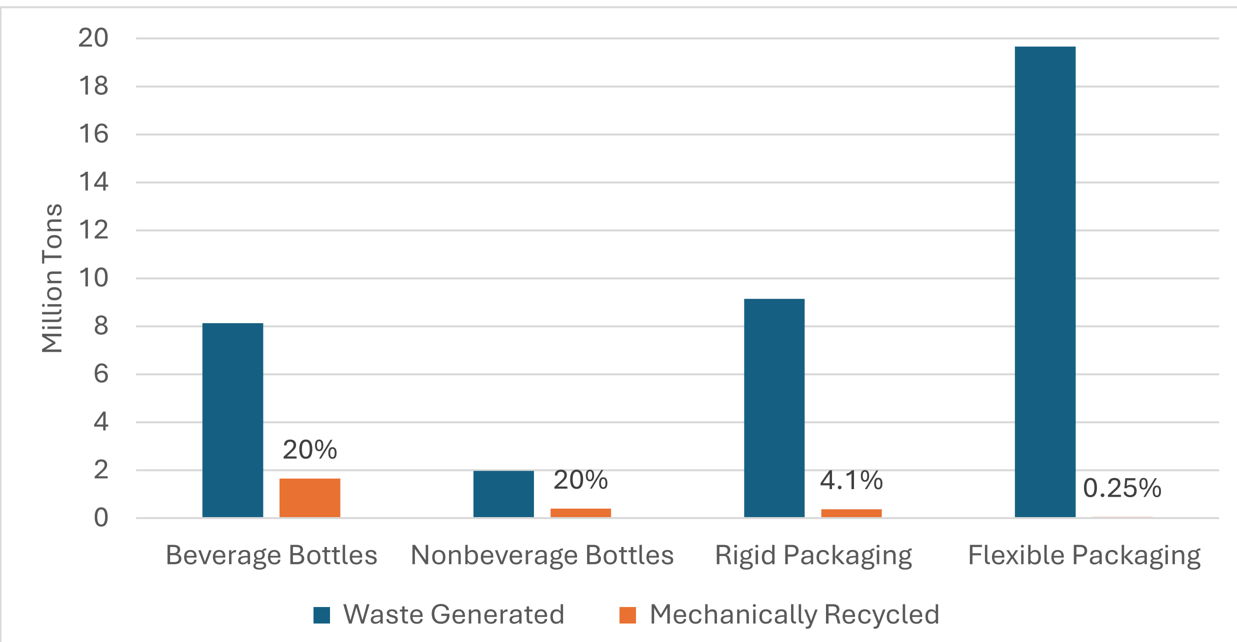
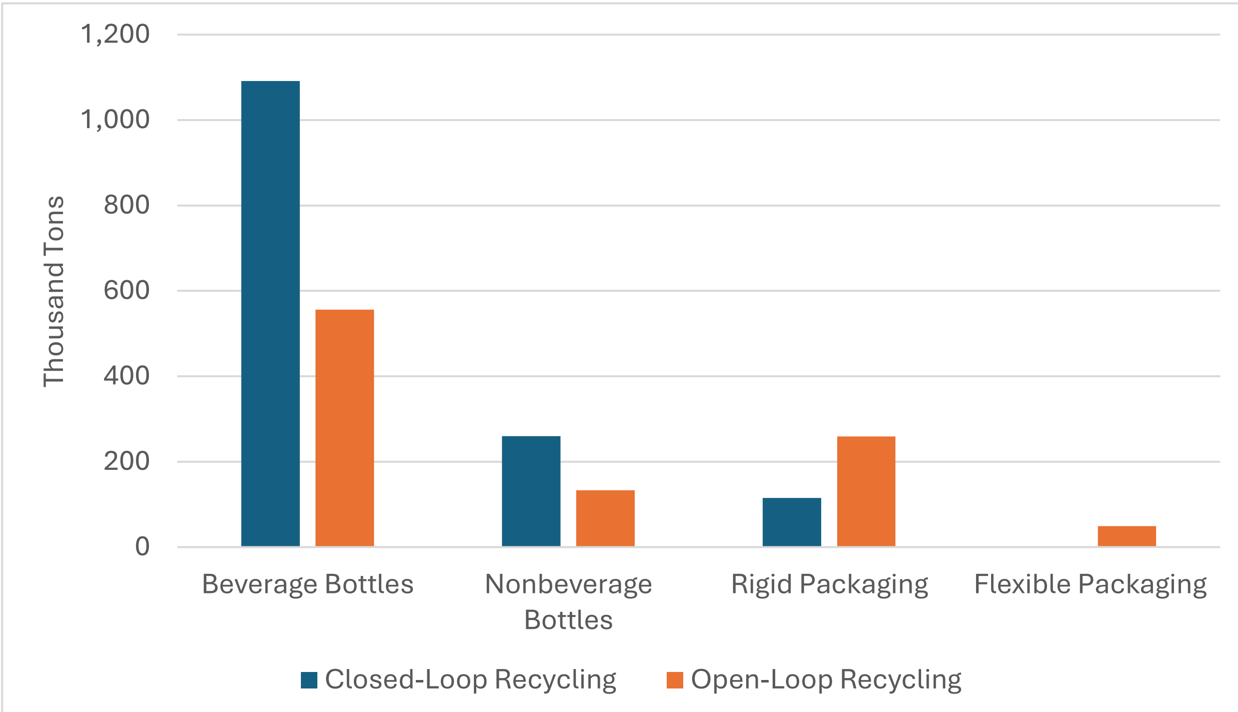


Figure 4-4 shows the breakdown of mechanical recycling by technology (open- or closed-loop recycling) and plastic packaging type. For beverage and nonbeverage bottles, the predominant mechanical recycling technology is closed-loop mechanical recycling at 13% of waste, followed by open-loop recycling at 7% of waste. For rigid packaging, this is reversed; this packaging type has an open-loop recycling rate of 2.8% and a closed-loop recycling for 1.3%. For flexible packaging, no material is processed via closed-loop recycling, and the open-loop recycling rate is 0.25%.

Figure 4-4. Open- and closed-loop mechanical recycling by plastic packaging type, 2025 (thousands of tons)



Mechanical recycling rates for plastic packaging vary significantly by region (Table 4-4). In 2025, the Pacific region has the highest rate at 9.9%, followed by the Northeast at 9.6% and the Midwest at 6%. The Rocky Mountain, Southwest, and Southeast regions have the lowest rates, at 3.9%, 3.9%, and 2.9%, respectively. In all regions, the closed-loop recycling rates are higher than the open-loop recycling rates, primarily driven by the mass of beverage bottles that are closed-loop recycled (Figure 4-4). Under the BAU scenario, these rates increase slightly by 2040 due to projected increases in plastic recyclate imports, but the regional rankings and allocation between closed-loop and open-loop remain the same.

Table 4-4. Mechanical recycling rates by U.S. region under the BAU scenario, 2025 and 2040

U.S. Region	Closed-Loop		Open-Loop		Total	
	2025	2040	2025	2040	2025	2040
Midwest	3.6%	3.8%	2.3%	2.4%	6%	6.2%
Northeast	5.6%	5.7%	3.9%	4%	9.6%	9.8%
Pacific	6.1%	6.2%	3.8%	3.9%	9.9%	10%
Rocky Mountain	2.4%	2.5%	1.6%	1.6%	3.9%	4.1%
Southeast	1.6%	1.7%	1.3%	1.3%	2.9%	3.1%
Southwest	2.2%	2.3%	1.7%	1.7%	3.9%	4%
National	3.6%	3.7%	2.5%	2.5%	6.1%	6.3%
Note: All values are rounded to two significant figures.						

Plastic-to-plastic chemical conversion

In 2025, the U.S. chemical conversion P2P rate for plastic packaging waste was 0.038%. In the BAU scenario, this rate increases slightly to 0.077% by 2040. The rates do not differ meaningfully across packaging format types or polymers.

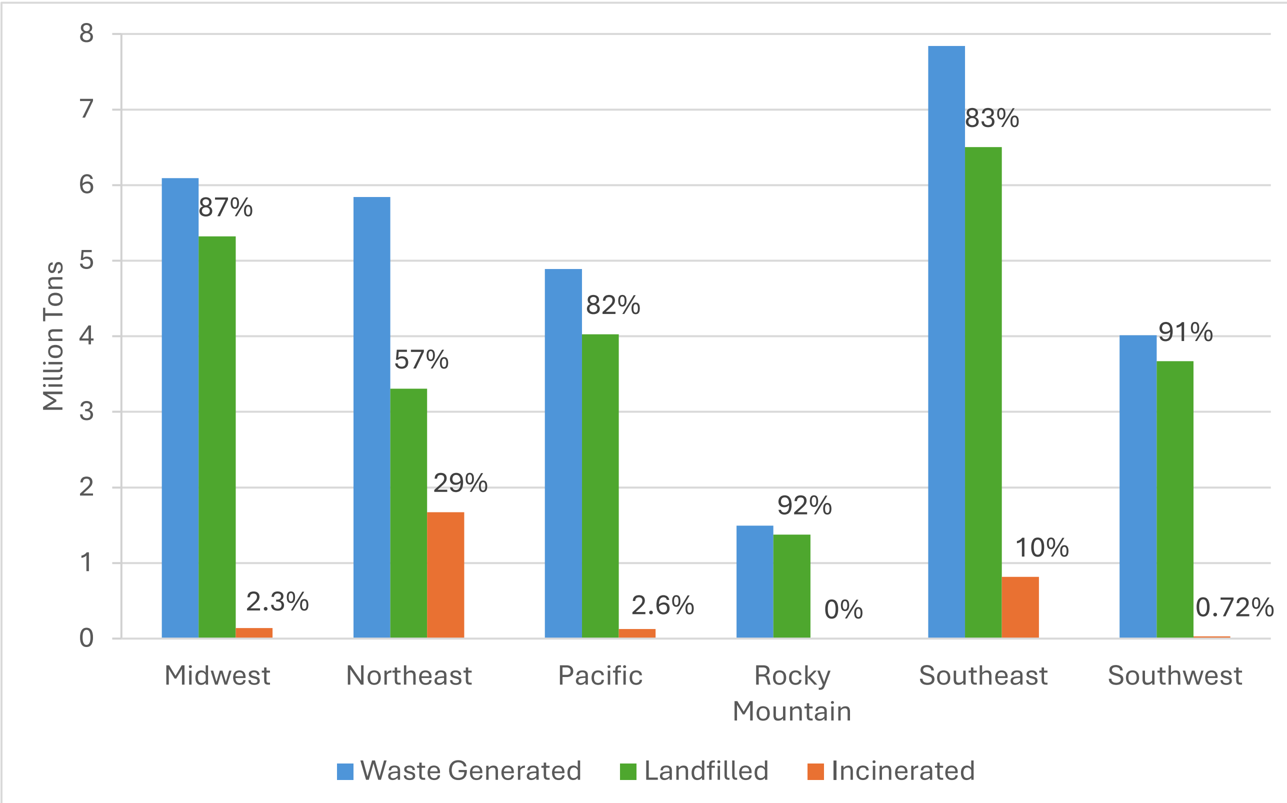
4.1.3 Disposal

While the mass of plastic packaging waste sent to disposal increases under the BAU scenario over the time frame of the analysis, we assume that the share going to each disposal pathway remains the same. In 2025, we estimate that 2.8 million tons of plastic packaging waste will be incinerated in the United States, accounting for 9.2% of the total generated. By 2040, this figure is projected to rise by 28%, reaching 3.6 million tons. Plastic packaging waste that is disposed of through P2F is less than 1% of waste generated (Section 7.8.1).

Landfilling represents a significantly larger share of plastic packaging waste disposal, by mass, compared to incineration. In 2025, we estimate that 24 million tons of plastic packaging waste (80% of the total) is landfilled. This figure is anticipated to grow by 30% by 2040, reaching 32 million tons. Figure 4-5 illustrates the regional distribution of landfilling and incineration of plastic packaging waste in 2025. As shown, incineration is concentrated in the Northeast, which accounts for 60% of the national total, followed by the Southeast at 29%. Other regions each contribute 5.1% or less. In contrast, landfilling is more evenly spread across the country, with the Southeast responsible for 27%, the Midwest 22%, the Pacific17%, and the remaining regions ranging from 5.7% to 15%.

Figure 4-5. Plastic packaging waste generated, landfilled, and incinerated by region, 2025 (million tons)

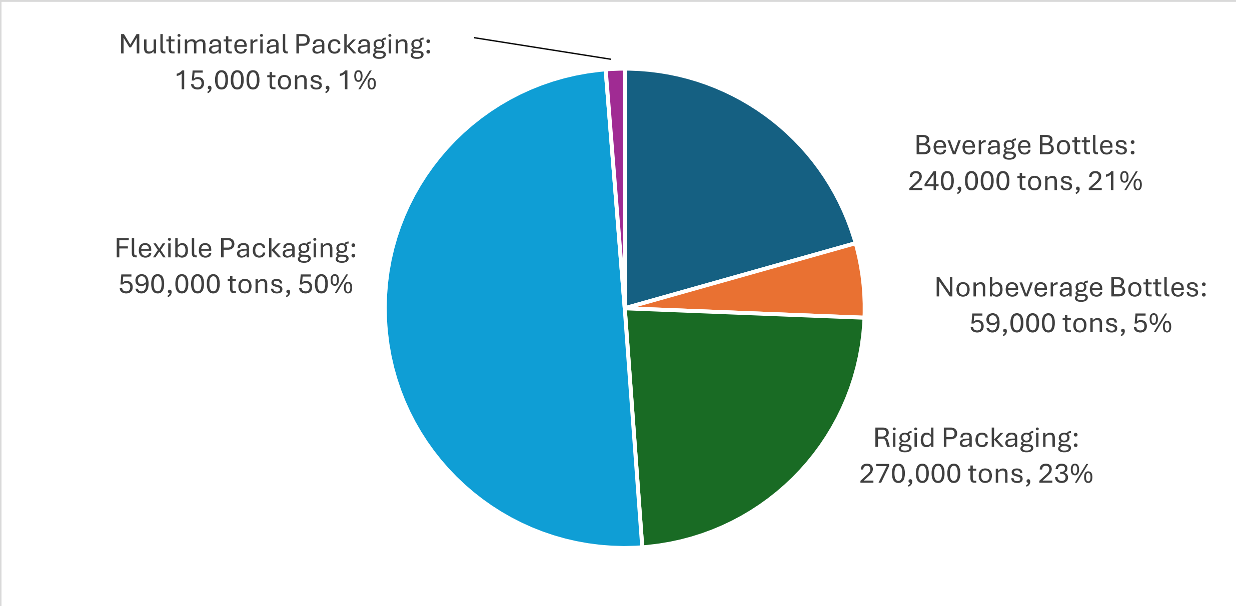
Labels above the bars indicate the percentage of waste landfilled and incinerated by region.



4.1.4 Pollution

In 2025, an estimated 1.7 million tons of plastic from MSW ends up in terrestrial and aquatic environments or flows to open burning. An estimated 54% of this mass (900,000 tons) is plastic packaging. In the BAU scenario in 2040, annual plastic packaging pollution increases by 31% to 1.2 million tons. Cumulative plastic packaging pollution from 2025 to 2040 is estimated to total 17 million tons. Flexible packaging contributes to 50% of plastic packaging pollution by mass in 2040, followed by rigid packaging (23%) and beverage bottles (21%) (Figure 4-6). Nonbeverage bottles and multimaterial packaging contribute the remaining 5% and 1.3%, respectively.

Figure 4-6. Share of plastic packaging pollution in 2040 by packaging type



4.1.5 Impacts

This section provides a summary of costs, jobs, and GHG emissions for the BAU scenario for plastic packaging. Note that the quantified impacts are associated with all MSW plastic rather than just plastic packaging, as it is not possible to disaggregate economic impacts by plastic sector in the model.

Costs

Table 4-5 presents the estimated CAPEX and OPEX modeled for key waste management stages under the BAU scenario in 2025 and 2040. The results are best used to understand *relative* costs for different stages rather than specific costs. The collection and sorting stage generates relatively high costs (11%), followed by incineration and landfill (2.9% and 2%, respectively). Mechanical recycling generates relatively lower costs (1%), due to the low rate of recycling under the BAU scenario.

Table 4-5. Annual costs by plastic life-cycle stage under BAU, 2025 and 2040

Life-Cycle Stage	2025		2040		% Change 2025-40
	Billions $2024[a]	% of Total	Billions $2024	% of Total	
Collection and sorting	$20	65%	$26	65%	30%
Mechanical recycling	$1.7	5.6%	$2.2	5.5%	28%
Chemical conversion (P2P)	$0.01	0.05%	$0.03	0.08%	140%

Chemical conversion (P2F)	$0.15	0.48%	$0.35	0.88%	140%
Landfilling	$3.5	17%	$4.6	17%	30%
Incineration	$5.2	12%	$6.6	12%	28%
Total	**$30**	**100%**	**$40**	**100%**	**30%**
Note: All values are rounded to two significant figures. [a] Dollar amounts are adjusted to 2024 dollars.					

Jobs

Table 4-6 presents the estimated jobs associated with plastic waste management under the BAU scenario in 2025 and 2040. The majority of waste management jobs are associated with formal collection and sorting (89% in 2025 and 88% in 2040). We assume the number of jobs required per ton of plastic at each stage of the waste management system remains constant over the time frame of the analysis.

Table 4-6. Jobs by plastic waste management stage under the BAU scenario, 2025 and 2040

Waste Management Stage	2025		2040		% Change 2025-40
	Jobs	% of Total	Jobs	% of Total	
Formal collection and sorting	96,000	89%	130,000	88%	31%
Informal collection and sorting	440	0.40%	570	0.40%	31%
Mechanical recycling	6,500	6%	9,000	6.3%	37%
Chemical conversion	300	0.28%	810	0.57%	170%
Landfilling	4,600	4.3%	6,100	4.3%	30%
Incineration	540	0.49%	690	0.48%	28%
Total	**110,000**	**100%**	**140,000**	**100%**	**31%**
Note: All values are rounded to two significant figures.					

Greenhouse gas emissions

Table 4-7 presents the estimated annual GHG emissions for all MSW plastic (in $MtCO_2e$) by life-cycle stage under the BAU scenario. The waste management stages contribute to 12% of the MSW plastic system's total emissions in 2025 and 13% in 2040, with incineration generating the most emissions of the downstream stages. Chemical conversion is the second-greatest generator of GHG emissions, even though the mass of plastic waste processed is less than a 10th of the mass that is incinerated (see Section 7.8.1).

Table 4-7. GHG emissions by plastic life-cycle stage under the BAU scenario, 2025 and 2040

Life-Cycle Stage	2025		2040	
	$MtCO_2e$	% of Total	$MtCO_2e$	% of Total
Collection and sorting	1	5.2%	1.4	4.4%
Mechanical recycling	1.7	8.6%	2.4	7.7%
Chemical conversion	3.6	18%	10	31%
Incineration	13	63%	16	53%
Landfilling	0.9	4.7%	1.2	3.9%
Total	**20**	**100%**	**31**	**100%**
Note: All values are rounded to two significant figures.				

4.2 Microplastic BAU Scenario Results

Under the BAU scenario, tires and textiles generated 1 million tons of microplastic pollution in 2025, the majority of which comes from tires. This is projected to increase to 1.2 million tons in 2040. This is equivalent to the estimated amount of pollution from plastic packaging in 2040 under the BAU scenario (see Section 4.1.4).

4.2.1 Textiles

Textiles are projected to generate 6,700 tons of synthetic microfibers in 2025, with this number growing 22% by 2040 to 8,100 tons in the BAU scenario. About 30% of microfibers generated are captured via wastewater treatment under BAU, and these are ultimately disposed of through landfill, incineration, or other waste management methods. In 2040, roughly 5,700 tons of microfibers (71% of those generated) are lost to the environment, with 62% entering the terrestrial environment and 38% entering the aquatic environment.

4.2.2 Tires

Tires are projected to generate 1 million tons of tire wear particles in 2025, with this number growing by 15% to 1.2 million tons in 2040. Less than 1% of tire wear particles enter wastewater treatment, meaning that 99% of tire wear particles generated are released directly into the environment. Of the tire wear particles released into the environment, 93% contribute to terrestrial pollution, while the remaining 7% result in aquatic pollution.

5. Policy Scenarios Results

5.1 Plastic Packaging MSW Policy Scenario Results

This section presents the results of the five policy scenarios described in Section 3.1, a summary of which is presented in Table 5-1. As detailed in Section 3.1, we modeled the policy scenarios with two sets of targets: low and high. This section presents the results associated with the high targets; for the low-target results, please see Section 7.8.2 of the Technical Appendix.

To account for uncertainty in the underlying data and assumptions used in this model, we conducted a Monte Carlo uncertainty analysis. See Section **Error! Reference source not found.** for an explanation of the methods used. The results of this analysis show that the most likely outcomes of each policy scenario are different from BAU (with limited overlap across these modeled outcomes). See Section 7.8.3 for the results of the Monte Carlo analysis.

Table 5-1. Summary of policy scenario targets

Policy Scenario	Low Target	High Target
Material phaseout *and* design optimization	• Shift mass of PS/EPS and PVC to other plastic types • 10% reduction all plastic packaging	• Shift mass of PS/EPS and PVC to other plastic types • 20% reduction all plastic packaging
Reuse	• 10% market share beverage bottles • 5% market share all other packaging	• 30% market share beverage bottles • 10% market share all other packaging
Increase collection for recycling *and* improve sorting efficiency	• Double regional collection rates for in-scope packaging • Halve sorting losses for in-scope packaging in each region	• Quadruple regional collection rates for in-scope packaging (cap 90%) • Limit sorting losses to 10% for in-scope packaging in each region
Deposit return scheme	• 65% collection rate for HDPE and PET beverage bottles	• 90% collection rate for HDPE and PET beverage bottles
All policies combined	• Low targets for all policy scenarios	• High targets for all policy scenarios

5.1.1 Phaseout and Optimize Scenario Results

Phasing out PS/EPS and PVC packaging along with reducing plastic packaging by 20% through design optimization reduces annual plastic packaging waste generation by 20% relative to BAU. It yields a corresponding 20% decrease in the mass of plastic packaging waste that gets landfilled and incinerated, and a 20% reduction in plastic packaging pollution (Table 5-2). The policy also results in a slight increase in the recycling rate (6.5% under the policy vs. 6.3% under BAU). This is because the policy eliminates PVC and PS/EPS, shifting BAU demand for these polymers to more recyclable plastic types.

Due to the reduction in waste generation and the elimination of unnecessary plastic, costs and jobs associated with the waste management system decrease by 11% relative to BAU 2040. These decreases are driven predominantly by reduced collection. GHG emissions also decrease by 11%, driven by the reduction in waste incineration.

Although the scope of this analysis is focused on waste management, phasing out and optimizing plastic packaging could have additional upstream benefits. For example, optimizing plastic packaging reduces the production of virgin plastic, which generates the greatest amount of GHG emissions of any plastic life-cycle phase (Organisation for Economic Co-operation and Development, 2024). As a result, lower plastic production leads to reduced GHG emissions across the plastic life cycle.

Achieving the outcomes from the Phaseout and Optimize scenario will require investment in plastic packaging design. A study by Earth Action (2025) assessed the global costs and benefits of banning and phasing out problematic plastic products. The study found that although there are short-term costs, such as private sector costs associated with shifting to alternative materials, and public sector administrative costs to implement policy, such policies resulted in long-term savings in waste management costs and reductions in the societal costs of mismanaged waste. Overall, that study found that investing in this transition would be more cost-effective than maintaining business as usual.

Table 5-2. Impacts of the Phaseout and Optimize scenario on annual plastic packaging mass and on plastic system costs, jobs, and GHG emissions

Life-Cycle Stage	2025	BAU 2040	Phaseout & Optimize 2040	Absolute Change From BAU 2040[a]	% Change From BAU 2040[a]
Waste generation (million tons)	30	39	32	-7.9	-20%
Recycling (million tons)	1.9	2.5	2	-0.45	-18%
Recycling rate	6.2%	6.3%	6.5%	0.2%	NA
Landfilling (million tons)	24	32	25	-6.3	-20%
Incineration (million tons)	2.8	3.6	2.9	-0.71	-20%
Pollution (million tons)	0.90	1.2	0.95	-0.24	-20%
Impacts[b]					
Waste management costs (billions $2024)[c]	30	40	35	-4.4	-11%

Waste management jobs (thousands)[d]	110	140	130	-16	-11%
Waste management GHG emissions ($MtCO_2e$)[e]	20	31	27	-3.3	-11%

Note: All values are rounded to two significant figures. NA indicates not applicable.

[a] Columns present the change from BAU 2040 to Phaseout and Optimize 2040.

[b] Results include impacts for all plastic, not just plastic packaging.

[c] Estimates include CAPEX and OPEX associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[d] Estimates include jobs associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[e] Estimates include GHG emissions associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

5.1.2 Reuse Scenario Results

The Reuse scenario considers only the flow of material generated from reuse through the waste management system and does not consider the impacts of the reuse system itself.

The Reuse scenario assumes that 30% of beverage bottles and 10% of all other single-use packaging transition to reusable packaging, resulting in an overall 13% shift of single-use plastic packaging to reusable plastic, glass, and metal by 2040, relative to the BAU scenario (Table 5-3). The policy reduces the amount of single-use plastic packaging waste generated annually by 13% by 2040 relative to the BAU scenario by replacing it with reusable material that is used more than once before it enters the waste management system. When accounting for total waste from the reuse system (including reusable plastic, glass, and metal after it exits the reuse system), the policy reduces annual packaging waste by 6.4% by 2040 relative to the BAU scenario. The overall material reduction is lower than the single-use plastic reduction, because reusable packaging is heavier than single-use plastic packaging to add durability and increase the number of use cycles relative to single-use plastic.

Table 5-3. Shift in packaging waste under the Reuse scenario (thousand tons)

Material	BAU 2040	Reuse 2040	% Change From BAU
Single-use plastic	39,000	34,000	-13%
Reusable glass	0	1,900	NA
Reusable metal	0	82	NA
Reusable plastic	0	650	NA
Total	**39,000**	**37,000**	**-6.4%**

Note: All values are rounded to two significant figures. NA indicates not applicable.

Table 5-4 presents a summary of the impacts of the Reuse policy on the plastic system. When considering single-use plastic packaging and reusable plastic packaging introduced by the policy, the Reuse policy achieves an 11% reduction in plastic packaging waste. As a result, the policy yields an 11% reduction in landfilling, a 10% reduction in incineration, and a 23% reduction in recycling of plastic packaging waste. By reducing the amount of plastic packaging waste generated, the policy effectively reduces the amount of waste that must be managed through recycling or disposal, as well as the amount of waste that becomes pollution (-12%).

Table 5-4. Impacts of the Reuse scenario on annual plastic packaging mass at key life-cycle stages

Life-Cycle Stage	2025	BAU 2040	Reuse 2040[a]	Absolute Change From BAU 2040[b]	% Change From BAU 2040[b]
Waste generation (million tons)	30	39	35	-4.5	-11%
Recycling (million tons)	1.9	2.5	1.9	-0.57	-23%
Recycling rate	6.2%	6.3%	5.5%	-0.81%	NA
Landfilling (million tons)	24	32	28	-3.4	-11%
Incineration (million tons)	2.8	3.6	3.2	-0.37	-10%
Pollution (million tons)	0.9	1.2	1	-0.15	-12%

Note: All values are rounded to two significant figures. NA indicates not applicable.

[a] Results include the mass of single-use and reusable plastic.

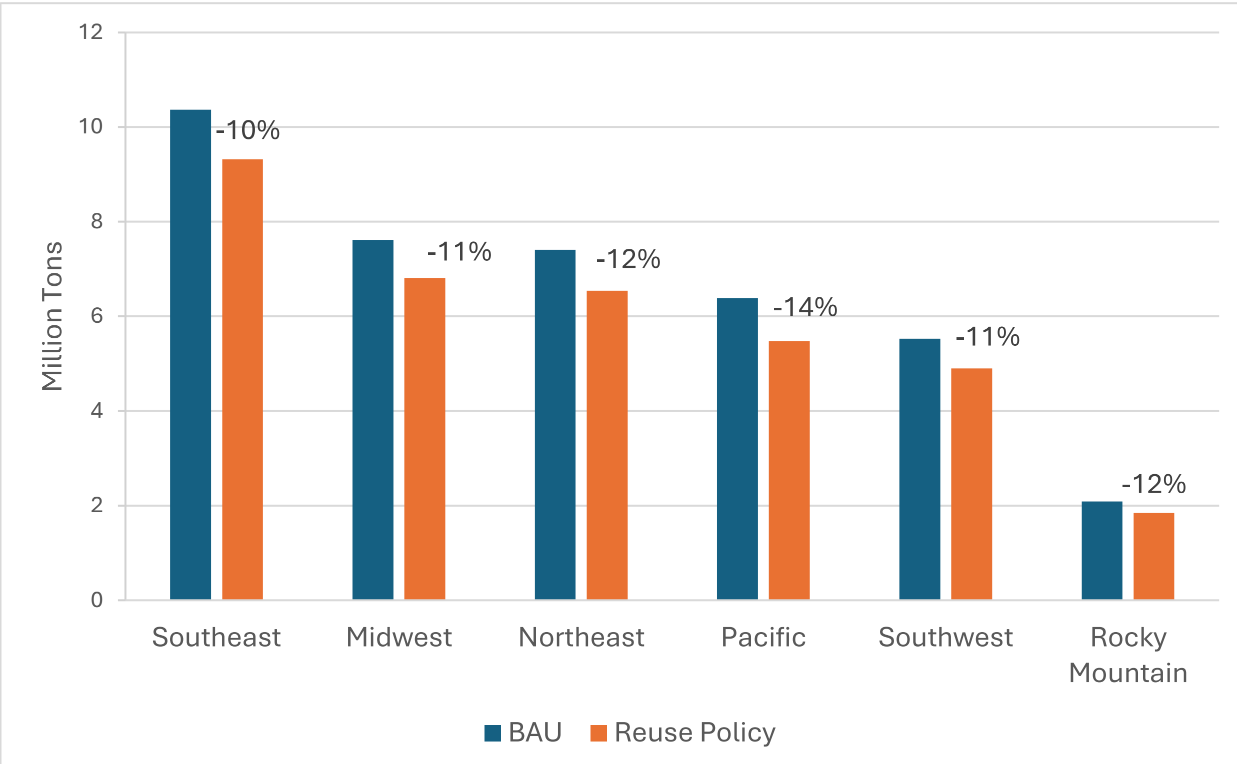
[b] Columns present change from BAU 2040 to Reuse 2040.

At the regional level, annual plastic packaging waste is 10% to 14% lower by 2040 under the Reuse scenario relative to BAU (Figure 5-1). The Pacific region sees the highest percentage decrease in waste (-14%), followed by the Northeast and Rocky Mountain regions (-12%). By mass, the

Southeast sees the greatest reduction in plastic package waste, at 1.1 million tons per year by 2040.

Figure 5-1. Annual plastic packaging waste by region under the BAU and reuse policy scenarios in 2040 (million tons) (single-use plastic packaging and reuse plastic packaging)

Labels above the policy bars indicate the percentage change in waste under the policy relative to BAU.



When including the reuse materials in the results, we see lower reductions in waste generation and disposal, and a slight (-3.8%) decrease in pollution compared to BAUTable 5-5. This is due to the addition of reusable glass and metal to the system. Once the reusable material exits the reuse system and becomes waste, it must be managed or may be leaked to the environment as pollution.

Table 5-5Table 5-5 Table 5-5 presents a summary of the impacts of the reuse scenario on packaging mass, and the associated impacts on waste management costs, jobs, and GHG emissions. When accounting for impacts associated with waste management of the reuse materials (including glass, metal, and plastic), the reuse policy results in a 3% decrease in GHG emissions, a 3.7% decrease in jobs, and a 3.2% decrease in costs, relative to BAU. By keeping materials in circulation for longer, the reuse scenario results in over $1 billion in annual savings associated with waste management for single-use plastic. Additional details on costs, jobs, and GHG emissions by life-cycle stage are provided in Section 7.8.

Table 5-5. Impacts of the reuse scenario on packaging mass, and on plastic system costs, jobs, and GHG emissions (including all reuse materials)

Life-Cycle Stage	2025	BAU 2040	Reuse 2040	Absolute Change From BAU 2040[a]	% Change From BAU 2040[a]
Waste generation (million tons)	30	39	37	-2.5	-6.4%
Recycling (million tons)	1.9	2.5	2.4	-0.055	-2.2%
Recycling rate	6.2%	6.3%	6.6%	0.29%	NA
Landfilling (million tons)	24	32	29	-2.3	-7.2%
Incineration (million tons)	2.8	3.6	3.5	-0.11	-3%
Pollution (million tons)	0.90	1.2	1.1	-0.045	-3.8%
Impacts[b]					
Waste management costs (billions $2024)[c]	30	40	38	-1.3	-3.2%
Waste management jobs (thousands)[d]	110	140	140	-5.2	-3.7%
Waste management GHG emissions (($MtCO_2e$)[e]	20	31	30	-0.92	-3%

Note: All values are rounded to two significant figures. NA indicates not applicable.

[a] Columns present the change from BAU 2040 to reuse 2040.

[b] Results include impacts for all plastic and reuse materials, not just plastic packaging.

[c] Estimates include CAPEX and OPEX associated with the following waste management stages: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[d] Estimates include jobs associated with the following waste management stages: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[e] Estimates include GHG emissions associated with the following waste management stages: formal collection and sorting, import sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

While this study addresses only impacts of reuse on waste management, it is important to acknowledge the full impacts of a reuse system on costs, jobs, and GHG emissions, briefly outlined here.

Costs

The reuse system represents a different business model than single-use systems, requiring initial investment to establish the necessary infrastructure and logistics. Return-based reuse systems have costs associated with filling, collection, sorting, washing, and return cycle transport for reusable packaging. In contrast, refill-based reuse systems do not have collection and redistribution logistics but will have costs to establish and maintain refill systems. Additionally, refill-based reuse systems may have unique effects on the plastic flows, costs, jobs, and GHG emissions compared with returned-based systems, which are not captured in this analysis.

For this analysis, we assumed a 95% return rate of reusable packaging. A higher return rate would increase container use, further reducing reliance on single-use plastic and result in lower costs (Peeters et al., 2023). While waste management costs are typically borne by governments using public funds, reuse systems are expected to be led by businesses and represent investment and business opportunities. This could also lead to public-private partnerships sharing initial capital investment. Although investment in infrastructure and operations is required, reuse systems can achieve a positive return on investment over time (Peeters et al., 2023).

Jobs

Outside of waste management impacts, reuse systems can bring jobs to the communities in which they are located that are tied to collecting, sorting, cleaning, and redistributing products (Ellen MacArthur Foundation, 2023; Upstream, 2023). Jobs in the reuse sector are also safer than those in waste management, which is one of the most hazardous occupations in the United States (OSHA, n.d.-a; U.S. Bureau of Labor Statistics, n.d.).

GHG emissions

In addition to reducing GHG emissions from waste management, reuse has additional GHG reductions upstream. For both single-use and reusable plastic packaging, the plastic production stage accounts for the majority of GHG emissions (Ellen MacArthur Foundation, 2023). However, for reusable plastic packaging, emissions from the production stage are distributed over many uses, resulting in lower GHG emissions overall relative to emissions from single-use packaging. At scale and accompanied by standardized packaging, high return rates, and shared infrastructure, reuse can further reduce GHG emissions compared to single-use plastic packaging (Ellen MacArthur Foundation, 2023).

5.1.3 Collect and Sort Scenario Results

By quadrupling collection rates of in-scope plastic packaging for recycling and reducing sorting loss rate to 10%, the Collect and Sort policy scenario increases the overall mass of packaging collected for recycling and reduces sorting losses. This, in turn, increases the mass of plastic packaging that is recycled. Although the mass of plastic packaging waste generated remains unchanged relative to BAU, the national recycling rate rises significantly from 6.3% to 19% by 2040Table 5-6. As a result, less plastic packaging waste is sent to landfills or incinerated, with national reductions of 17% and

18%, respectively. In the model, we do not account for any changes to the in-scope plastic types over time. While this simplifies the model, it is possible for states to expand the list of in-scope plastic types. This could lead to a higher recycling rate, larger waste diversion from landfills and incineration, and changes to costs, jobs, and GHG emissions of waste management.

Collection for recycling diverts plastic waste from disposal but does not address uncollected waste or the factors that cause pollution. Since waste generation—which drives pollution—is unaffected by this scenario, the overall amount of plastic packaging pollution remains the same as BAU.

Plastic waste management costs increase by 13% under this policy, driven by increased sorting and recycling of plastic packaging. Waste management jobs increase by 20%, shifting away from landfill and incineration jobs to sorting and mechanical recycling jobs. Though GHG emissions from waste management increase slightly, due to increased recycling, mechanical recycling emits less GHG than plastic production per ton (U.S. EPA, 2023a) as plastic production emits the most GHG out of all plastic life-cycle stages (Organisation for Economic Co-operation and Development, 2024). As a result, offsetting virgin plastic demand with mechanically recycled plastic can reduce GHG emissions overall (Lau et al., 2020).

Table 5-6. Impacts of the Collect and Sort scenario on annual plastic packaging mass and on plastic system costs, jobs, and GHG emissions

Life-Cycle Stage	2025	BAU 2040	Collect & Sort 2040	Absolute Change From BAU 2040[a]	% Change From BAU in 2040[a]
Waste generation (million tons)	30	39	39	0	0%
Recycling (million tons)	1.9	2.5	7.6	5.1	200%
Recycling rate	6.2%	6.3%	19%	NA	NA
Landfilling (million tons)	24	32	26	-5.3	-17%
Incineration (million tons)	2.8	3.6	2.9	-0.65	-18%
Pollution (million tons)	0.9	1.2	1.2	0	0%
Impacts[b]					
Waste management costs (billions $2024)[c]	30	40	45	5.2	13%
Waste management jobs (thousands)[d]	110	140	170	28	20%
Waste management GHG emissions ($MtCO_2e$)[e]	20	31	33	2	6.6%

Note: All values are rounded to two significant figures. NA indicates not applicable.

[a] Columns present the change from BAU 2040 to Collect & Sort 2040.

[b] Results include impacts for all plastic, not just plastic packaging.

[c] Estimates include CAPEX and OPEX associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[d] Estimates include jobs associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

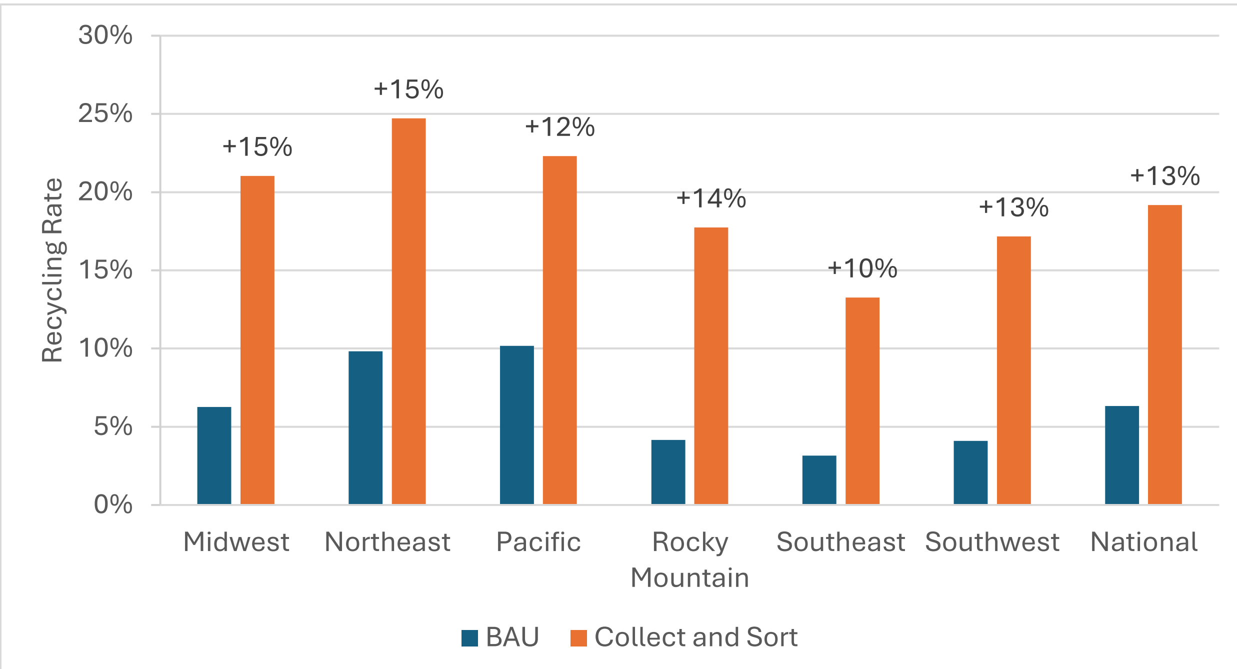
[e] Estimates include GHG emissions associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

By 2040, all regions experience substantial growth in recycling rates for plastic packaging under the Collect and Sort policy compared to BAU (Figure 5-2). The Northeast and Midwest see the largest gains, both increasing their recycling rates by 15 percentage points. In terms of the total mass of plastic packaging recycled, the Rocky Mountain, Southeast, and Southwest regions, which have the lowest recycled tonnage in 2040 under the BAU scenario, show the greatest improvements (see Section 7.6.3).

All regions see a decrease in landfilled waste, which corresponds to an estimated cost savings of $400 million annually (see Section 7.8.1). The Northeast, where remaining landfill space is particularly limited, achieves a 21% decrease in landfilled waste relative to BAU and associated landfill cost savings of 11%.

Figure 5-2. Plastic packaging recycling rates by region under the BAU and collect and sort scenarios in 2040

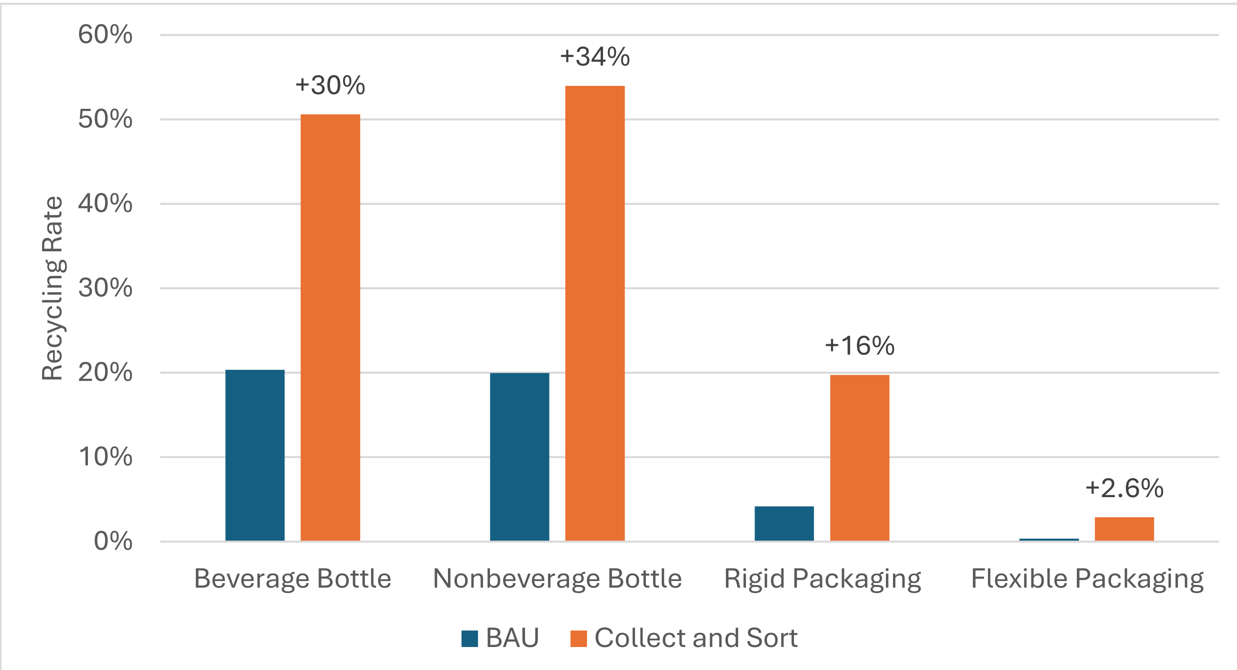
Labels above the policy bars indicate percentage point increases in the regional and national recycling rates under the policy relative to BAU.



The outcome of the scenario varies across plastic packaging types (Figure 5-3). Nonbeverage bottles have the largest percentage point increase (34%), followed by beverage bottles (30%) and rigid packaging (16%). However, flexible packaging achieves only a 2.6 percentage points gain. This limited improvement is driven by its relatively low collection rate for recycling and high sorting loss rate (see Table 7-8 in the Technical Appendix).

Figure 5-3. Plastic packaging recycling rates by plastic packaging type under the BAU and collect and sort scenarios in 2040

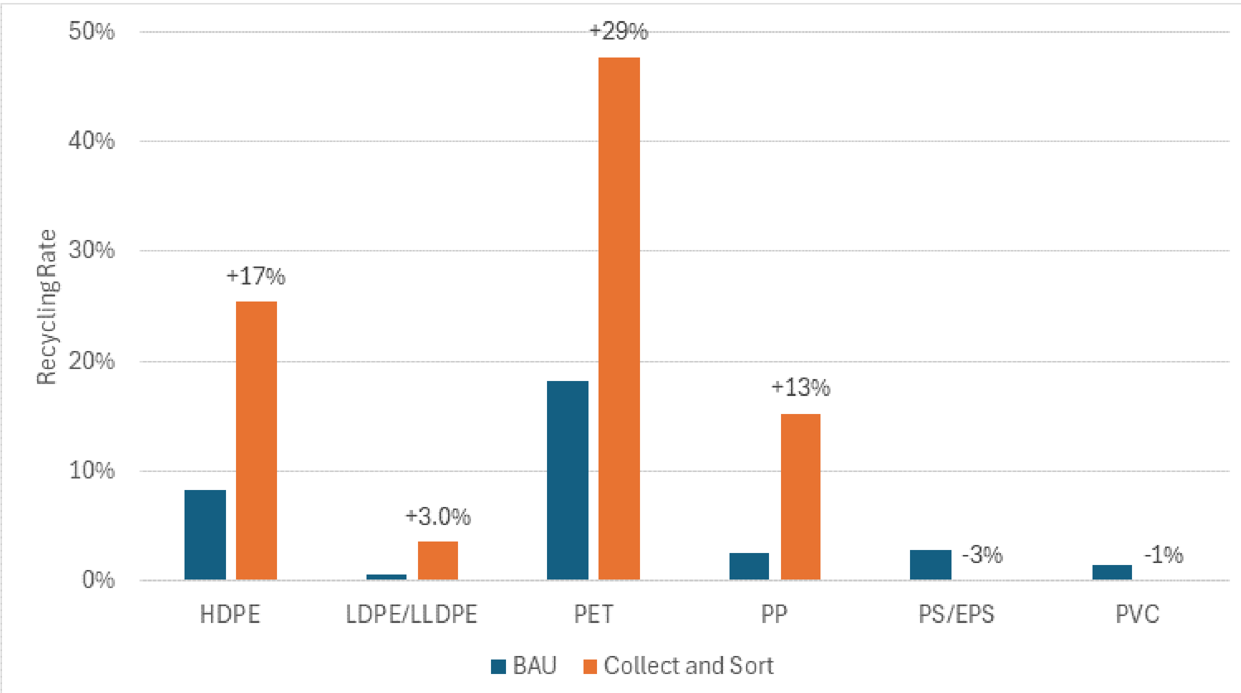
The labels above the policy bars indicate the percentage point increase under the policy scenario relative to BAU in 2040. Multimaterial plastic packaging is not included in the chart as it is not recycled under the BAU or the policy scenario.



In addition to variation by plastic packaging format, the Collect and Sort scenario produces distinct outcomes by polymer (Figure 5-4). PET has the largest percentage point gain (29%), followed by HDPE (17%) and PP (13%). In contrast, LDPE increases by only 3 percentage points. Because most LDPE plastic packaging is flexible, the recycling rate is constrained by the low collection rate for recycling and high sorting loss rate for flexibles overall. Since PS/EPS and PVC are not on the list of polymers accepted for recycling in the scenario, their recycling rate is zero.

Figure 5-4. Plastic packaging recycling rates by polymer under the BAU and collect and sort scenarios in 2040

The labels above the policy bars indicate the percentage point increase under the policy scenario relative to BAU in 2040. The "other" polymer category is not included in the chart, as it is not recycled under the BAU or the policy scenario.



5.1.4 Deposit Return Scheme Scenario Results

The DRS scenario increases the collection of plastic beverage bottles for recycling, lowers the sorting and processing loss rates due to collection of a cleaner waste stream, and increases the share of plastic sent to recycling, particularly closed-loop recycling. Even though DRS does not reduce waste generation, increasing collection for PET and HDPE beverage bottles significantly increases the plastic packaging recycling rate from 6.3% to 15% by 2040. At the same time, DRS reduces the amount of waste sent to landfill and incineration by 12% and lowers plastic pollution by 8.4%Table 5-7. Notably, by 2040, this scenario reduces annual plastic bottle pollution by 41% (99,000 tons) relative to BAU and aligns with empirical observations in various states with DRS (Keep America Beautiful, 2021).

Waste management costs, jobs, and GHG emissions increase slightly under the DRS scenario relative to BAU (noting that we use formal collection costs and jobs as a proxy for DRS-specific collection costs and jobs). These changes are driven by the increase in sorting and recycling of plastic packaging waste under the policy.

While this study addresses impacts of DRS only on waste management, it is important to acknowledge the full impacts of a DRS system on costs, jobs, and GHG emissions, briefly outlined here and summarized in Table 5-7.

With respect to costs, a DRS system represents a different business model than single-use systems, requiring investment to establish necessary partnerships (e.g., for retail bottle return), infrastructure (e.g., depots, reverse vending machines), and logistics. Under a modernized DRS, it is producers who are expected to finance the system so that municipalities and taxpayers are not left to pay the costs of managing DRS-eligible materials (Reloop, 2024).

While the DRS policy creates roughly 11,000 recycling jobs and more than 7,000 collection and sorting jobs, there are other jobs associated with a DRS system that we do not include here (e.g., administrative jobs). Additionally, while job safety data are limited, the nature of the work suggests that jobs within a DRS are likely safer due to the separation of a clean, high-value waste stream that avoids many of the significant hazards inherent in traditional MSW collection and disposal.

Finally, though GHG emissions from waste management increase due to increased recycling under a DRS policy, overall GHG emissions are expected to decrease as an increase in available recycled plastic material would offset primary plastic and the GHG emissions associated with its production (Lau et al., 2020).

Table 5-7. Impacts of the DRS scenario on annual plastic packaging mass and on plastic system costs, jobs, and GHG emissions

Life-Cycle Stage	2025	BAU 2040	DRS 2040	Absolute Change From BAU 2040[a]	% Change From BAU 2040[a]
Waste generation (million tons)	30	39	39	0	0%
Recycling (million tons)	1.9	2.5	6.0	3.6	140%
Recycling rate	6.2%	6.3%	15%	NA	NA
Landfilling (million tons)	24	32	28	-3.7	-12%
Incineration (million tons)	2.8	3.6	3.2	-0.41	-12%
Pollution (million tons)	0.9	1.2	1.1	-0.099	-8.4%
Impacts[b]					
Waste management costs (billions $2024)[c]	30	40	43	3.4	8.5%
Waste management jobs (thousands)[d]	110	140	160	18	12%
Waste management GHG emissions (($MtCO_2e$)[e]	20	31	32	1.7	5.6%

Note: All values are rounded to two significant figures. NA indicates not applicable.

[a] Columns present the change from BAU 2040 to DRS 2040.

[b] Results include impacts for all plastic, not just plastic packaging.

[c] Estimates include CAPEX and OPEX associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

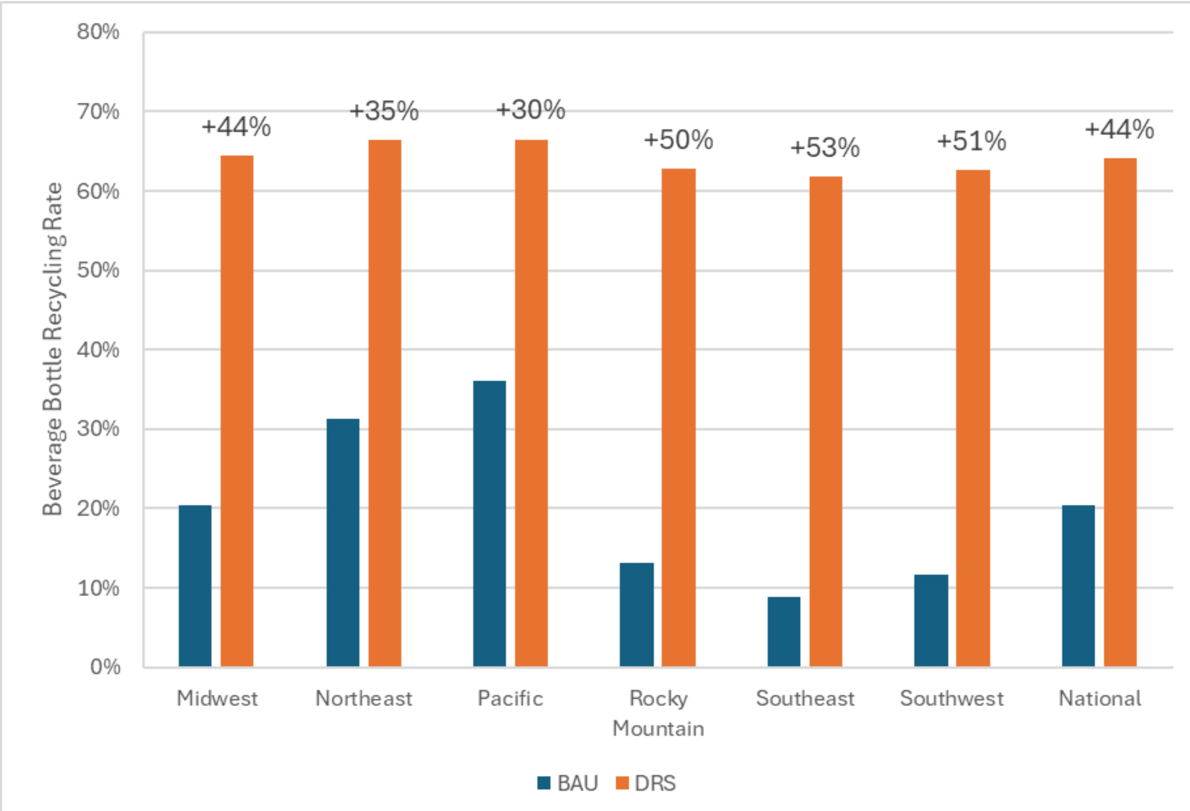
[d] Estimates include jobs associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[e] Estimates include GHG emissions associated with the following stages of the plastic life cycle: formal collection and sorting, import sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

Figure 5-5 shows the regional beverage bottle recycling rates under the BAU and DRS scenarios in 2040. There is a significant increase in beverage bottle recycling across all regions, based on the 90% collection target, which reduces the disparity in beverage bottle recycling rates across the regions compared to BAU. Some regions, like the Southeast, show more than fivefold increases in beverage bottle recycling rates.

Figure 5-5. Beverage bottle recycling rates under the BAU and DRS scenarios in 2040

Labels above the policy bars indicate the percentage point increases in the regional and national beverage bottle recycling rates under the policy relative to BAU.



5.1.5 Combined Policy Scenario Results

Table 5-8 presents a summary of the impacts of the Combined policy scenario on plastic packaging mass in 2040 relative to the BAU scenario. Together, the policies under the Combined scenario achieve a 29% reduction in plastic packaging waste generation by 2040 relative to BAU. The reduction in waste generation has cascading benefits across the country for both waste management needs and pollution. By 2040, the Combined policy scenario nearly halves the annual amount of plastic packaging waste sent to landfills and incinerators. At the same time, the plastic packaging recycling rate increases nearly fourfold from 6.3% in the BAU to 22%. As a result of these improvements, 35% less plastic packaging waste becomes pollution.

Table 5-8. Impacts of the Combined scenario on annual plastic packaging mass

Life-Cycle Stage	2025	BAU 2040	Combined Policy Scenario 2040 [a]	Absolute Change From BAU 2040 [b]	% Change From BAU 2040 [b]
Waste generation (million tons)	30	39	28	-12	-29%
Recycling (million tons)	1.9	2.5	6.0	3.5	140%
Recycling rate	6.2%	6.3%	22%	NA	NA
Landfilling (million tons)	24	32	18	-14	-44%
Incineration (million tons)	2.8	3.6	2.0	-1.6	-44%
Pollution (million tons)	0.90	1.2	0.77	-0.41	-35%

Note: All values are rounded to two significant figures. NA indicates not applicable.

[a] Results include the mass of reusable plastic modeled as part of the Combined scenario.

[b] Columns present the change from BAU 2040 to Combined 2040.

Table 5-9 presents the impacts of the policy scenarios on annual plastic packaging pollution by 2040, broken down by plastic packaging format type. The Combined policy scenario is most effective at reducing pollution from beverage bottles (-67%) and least effective at reducing pollution from flexible plastic packaging (-27%). Additionally, flexible packaging remains the format type that contributes the most to overall packaging pollution in 2040.

Table 5-9. Impacts of the policy scenarios on annual plastic packaging pollution by format type

	2025		BAU 2040		Phaseout & Optimize 2040		Reuse 2040		Collect & Sort 2040		DRS 2040		Combined 2040	
Format Type	**Million Tons**	**% Total[a]**	**Million Tons**	**% Total**	**Million Tons (% Change[b])**	**% Total**	**Million Tons (% Change)**	**% Total**	**Million Tons (% Change)**	**% Total**	**Million Tons (% Change)**	**% Total**	**Million Tons (% Change)**	**% Total**
Beverage bottles	0.19	21%	0.24	21%	0.19 (-20%)	21%	0.17 (-30%)	15%	0.24 (0.0%)	21%	0.14 (-41%)	13%	0.081 (-67%)	10%
Nonbeverage bottles	0.045	5.0%	0.059	5.0%	0.047 (-20%)	5.0%	0.053 (-10%)	4.7%	0.059 (0.0%)	5.0%	0.059 (0.0%)	5.5%	0.043 (-28%)	5.0%
Rigid packaging	0.21	23%	0.27	23%	0.22 (-20%)	23%	0.25 (-9.2%)	22%	0.27 (0.0%)	23%	0.27 (0.0%)	25%	0.20 (-28%)	23%
Flexible packaging	0.45	50%	0.59	50%	0.47 (-20%)	50%	0.54 (-8.2%)	48%	0.59 (0.0%)	50%	0.59 (0.0%)	54%	0.43 (-27%)	51%
Multimaterial packaging	0.011	1.3%	0.015	1.3%	0.010 (-30%)	1.1%	0.01 (-8.4%)	1.2%	0.015 (0.0%)	1.3%	0.015 (0.0%)	1.4%	0.010 (-37%)	1.1%
Reusable plastic[c]	0	0%	0	0%	0 (NA)	0%	0.01 (NA)	0.83%	0 (NA)	0%	0 (NA)	0%	0.0078 (NA)	0.92%
Reusable metal	0	0%	0	0%	0 (NA)	0%	0 (NA)	0.38%	0 (NA)	0%	0 (NA)	0%	0.0038 (NA)	0%
Reusable glass	0	0%	0	0%	0 (NA)	0%	0.10 (NA)	8.4%	0 (NA)	0%	0 (NA)	0%	0.077 (NA)	9%
Total packaging pollution[e]	**0.90**	**100%**	**1.2**	**100%**	**0.95 (-20%)**	**100%**	**1.10 (-3.8%)**	**100%**	**1.2 (0.0%)**	**100%**	**1.1 (-8.4%)**	**100%**	**0.85 (-28%)**	**100%**

Note: All values are rounded to two significant figures.

[a] Represents the percentage of total packaging pollution. Percentages may not sum to 100% due to rounding.

[b] Represents the percentage change from BAU 2040.

[c] Reuseable plastic packaging implemented under the reuse policy scenario comprises beverage and nonbeverage bottles and other rigid packaging.

[d] Includes single-use plastic packaging and all reusable materials. For the reuse scenario, plastic packaging comprised 91% of total packaging pollution and is reduced by 12% relative to BAU. For the combined policy scenario, plastic packaging comprised 91% of total packaging pollution and is reduced by 35% relative to BAU.

Because the Combined scenario includes reuse, some of the single-use plastic packaging is shifted to reuseable plastic, glass, and metal. When accounting for all reuse materials (plastic, glass, and metal) in addition to plastic packaging, there is still 25% less annual waste generated by 2040 relative to BAU. As a result, less material is sent to landfills (-41%) and incinerators (-38%), and pollution is reduced by 28%.

Table 5-10. Impacts of the Combined scenario on all modeled packaging mass and on plastic system costs, jobs, and GHG emissions (including reuse materials)

Life-Cycle Stage	2025	BAU 2040	Combined Policy Scenario 2040	Absolute Change From BAU 2040[a]	% Change From BAU 2040[a]
Waste generation (million tons)[b]	30	39	29	-10	-25%
Recycling (million tons)[b]	1.9	2.5	6.4	3.9	160%
Recycling rate[b]	6.2%	6.3%	22%	NA	NA
Landfilling (million tons)[b]	24	32	19	-13	-41%
Incineration (million tons)[b]	2.8	3.6	2.2	-1.4	-38%
Pollution (million tons)[b]	0.9	1.2	0.85	-0.33	-28%
Impacts[c]					
Waste management costs (billions $2024)[d]	30	40	38	-1.1	-2.9%
Waste management jobs (thousands)[e]	110	140	150	2.8	2%
Waste management GHG emissions (($MtCO_2e$)[f]	20	31	28	-2.3	-7.4%

Note: All values are rounded to two significant figures. NA indicates not applicable.

[a] Columns present the change from BAU 2040 to Combined 2040.

[b] Values include only the portion of glass and metal that was used to substitute for plastic and does not include the other uses of glass or metal found in MSW.

[c] Results include impacts for all plastic and reuse materials, not just plastic packaging.

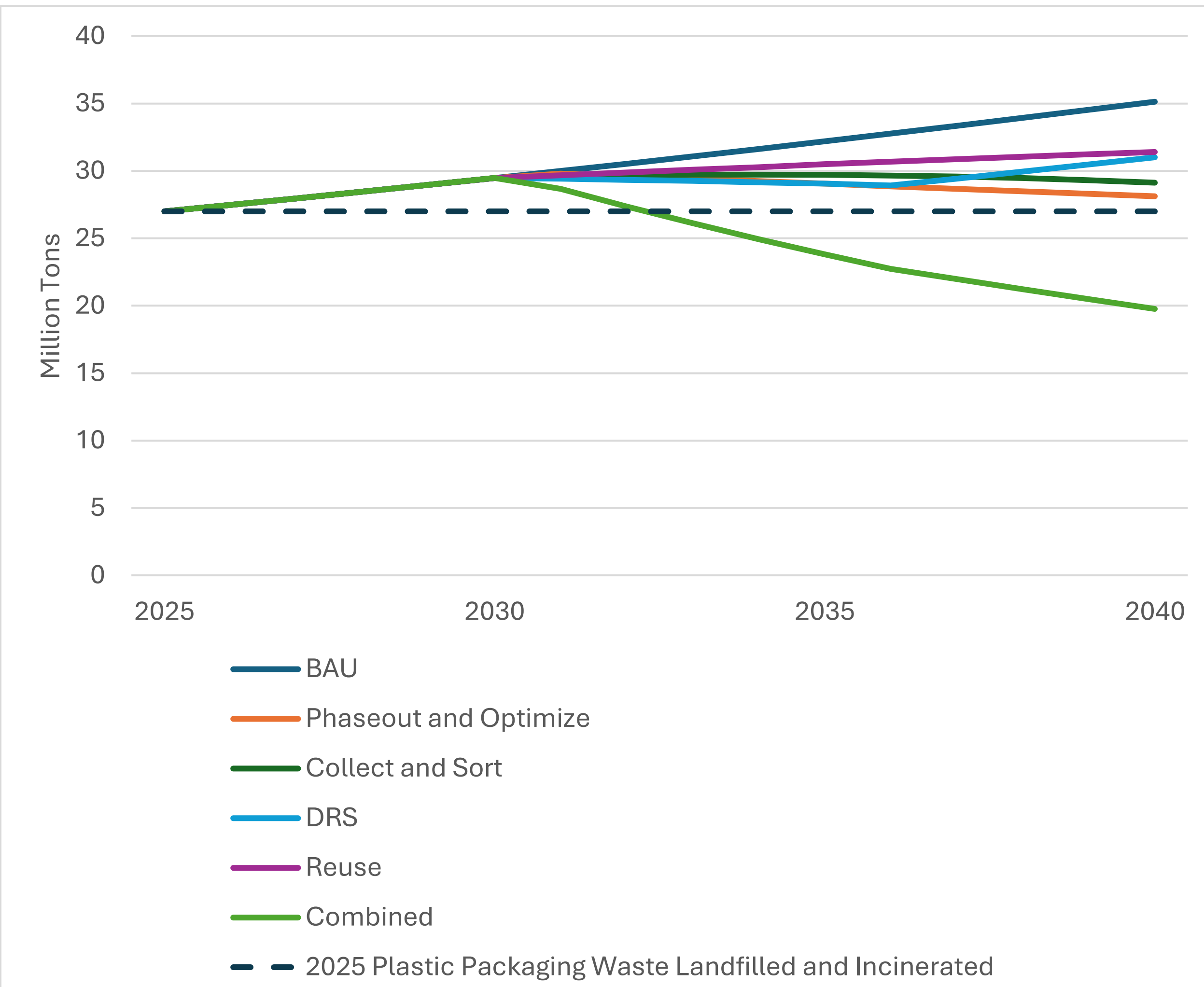
[d] Estimates include CAPEX and OPEX associated with the following waste management stages: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[e] Estimates include jobs associated with the following waste management stages: formal collection and sorting, import sorting, informal collection and sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

[f] Estimates include GHG emissions associated with the following waste management stages: formal collection and sorting, import sorting, mechanical recycling, chemical conversion (plastic-to-plastic and plastic-to-fuel), incineration, and landfilling.

The reduction in annual waste sent to landfills and incinerators under the Combined scenario is substantially greater than the reduction achieved by each individual policy. As shown in Figure 5-6, while most policies achieve modest reductions, the Combined scenario brings the total mass sent to landfills and incinerators below 2025 levels, reversing the growing trend in waste generation and management needs. By contrast, in the DRS scenario, while DRS-eligible beverage bottles achieve a 90% collection rate within five years of policy implementation, the total volume of plastic packaging waste requiring disposal in fact continues to grow.

Figure 5-6. Annual plastic packaging waste landfilled and incinerated under BAU and policy scenarios, 2025-2040



Looking across the impacts to the plastic system associated with the Combined policy scenario, there is a decrease in GHG emissions (-7.4%), a 2.0% increase in jobs, and a 2.9% decrease in costs (Table 5-10). Costs could be further reduced by sequencing policies to improve efficiency through systems sharing infrastructure (Eunomia & The Story of Stuff, 2025), as well as increasing the scale of reuse and using standardized packaging with high return rates (Ellen MacArthur Foundation, 2023).

These results reflect the sequencing of policies in this analysis, first implementing source reduction policies (Phase-out & Optimize and Reuse), followed by waste management policies that act on the remaining waste (Collect & Sort and DRS). The intent is to demonstrate the amplification of impacts when policies are implemented together. However, we do not examine how these outcomes could vary under different sequences of policy implementation. For example, implementing DRS before or alongside reuse can result in shared infrastructure and logistics between the two systems, which could lead to reduced costs (Eunomia & The Story of Stuff, 2025). Future analyses could explore alternative sequencing of scenarios, as well as a dedicated cost-benefit analysis, to better understand how coordinated policy implementation could benefit the environment and economy.

5.2 Microplastic Policy Scenario Results

Microplastic pollution from tires and textiles amounts to 1.2 million tons in 2040 under BAU, with the majority coming from tires. This is equal to the estimated amount of pollution from plastic packaging in 2040 under the BAU scenario (see Section 4.1.4).

Due to the level of uncertainty in the data underlying the microplastic analysis, we cannot wholly distinguish the effects of the policy scenarios from BAU (there is some degree of overlap across these modeled outcomes). Nonetheless, the most likely outcomes of each scenario are different, and we can interpret the estimates presented in this section as providing firm indication of the relative trends across scenarios. See Section 7.8.4 for results with uncertainty ranges. If available, better data could improve modeling results and provide more informative guidance to policymakers.

Overall, the policy scenarios targeting microfibers are more effective in reducing pollution than the scenarios targeting tire wear particles. The combined policies reduce annual microfiber pollution by 70%, compared with only 15% for tire wear particles by 2040, relative to the BAU scenario. However, since pollution from tire wear particles is approximately 2.3 orders of magnitude greater than microfiber pollution in this model, combined policies for both sources together reduce overall microplastic pollution by 15%.

5.2.1 Textiles Scenario Results

Under BAU, 5,700 tons of synthetic microfibers from textiles are released into the environment by 2040. Under the Combined policy scenario, which includes all three modeled policies (reduce shedding rates, install filters, and reduce land application of biosolids), microplastic pollution from textiles is reduced by 70% by 2040 relative to BAU (Figure 5-7).

By removing textiles in the top 25% of microfiber shedding rates, we modeled a 49% decrease in the shedding rate of synthetic microfibers. Of the individual policies modeled, reducing the shedding rate of microfibers through design changes achieves the greatest decrease in pollution (-49%) relative to BAU. This points to the potential for textile manufacturing processes to reduce microfiber shedding during the use phase. By comparison, banning biosolid application to agricultural land reduces pollution by 33%, and installing filters reduces pollution by 15%.

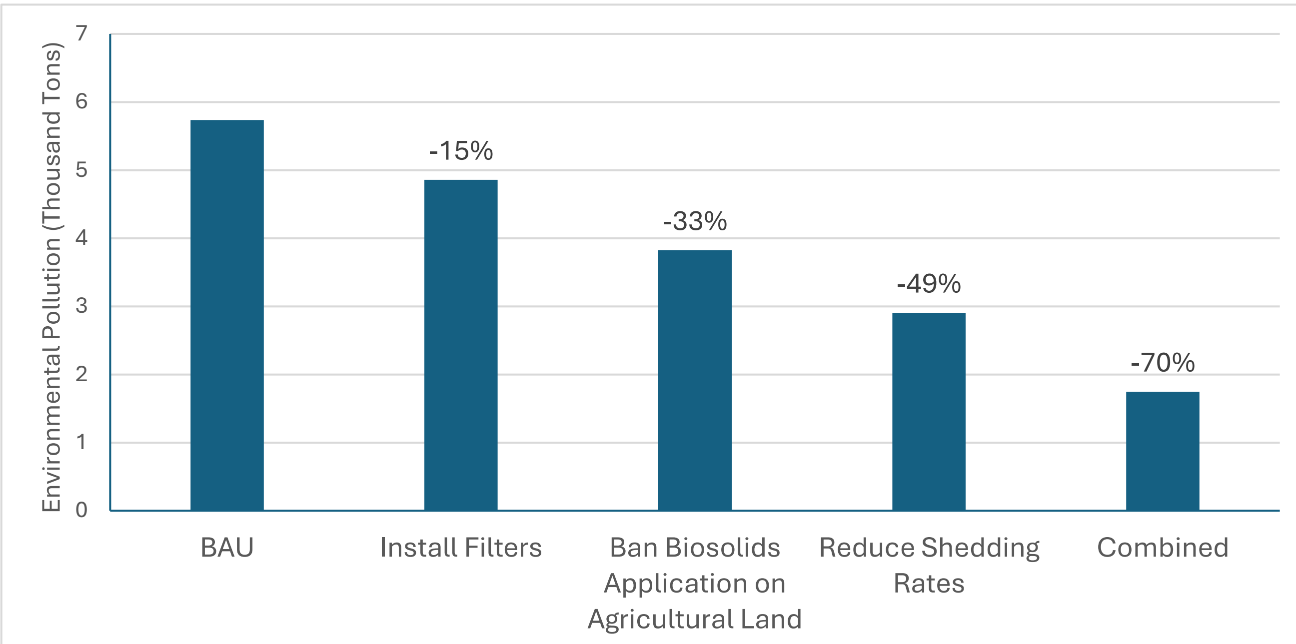
Banning the application of biosolids on agricultural land may result in increased fertilizer use or increased GHG emissions from other waste management options for biosolids, such as via landfills or incineration (Xue et al., 2025). Policies will need to factor in these trade-offs for effective biosolids management.

In this model, biosolids application to land is the only pathway through which textiles become terrestrial pollution. Research in California's San Francisco Bay found higher numbers of microfibers in urban stormwater than in wastewater, which suggests that there are other pathways for microfibers on land (Sutton et al., 2019). Therefore, our results underestimate terrestrial pollution from microfibers and overstate the impact of banning biosolids application to agricultural lands on overall terrestrial pollution.

Installing external filters on washing machines reduced microfiber pollution by 15%, capturing microfibers for the fraction of washing machines with filters. While our modeling analysis assumed that two-thirds of households will install filters by 2040 with half of the captured microplastics being properly managed, another modeling analysis showed that installing filters on 100% of washing machines in California and disposing all captured microplastics through landfill or incineration would lead to a 79% decline in terrestrial pollution (Geyer et al., 2022). Though the methodologies differ, both studies show that installing filters on washing machines can capture microfibers; however, the effectiveness of this policy depends on the scale of adoption and public education to ensure proper waste management of collected microfibers.

Figure 5-7. Textile microplastic pollution under the BAU scenario and under each textile microplastic policy scenario, 2040

Labels above the policy bars indicate the percentage change in pollution under the policy relative to BAU.



5.2.2 Tires Scenario Results

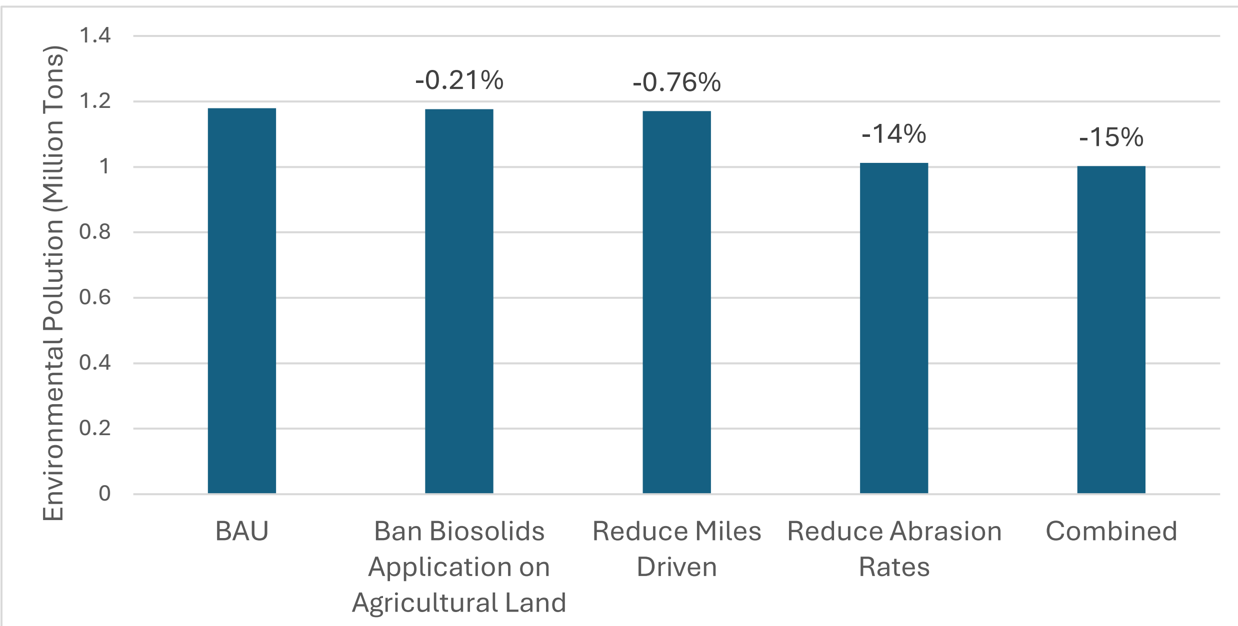
Under BAU, 1.2 million tons of tire wear particles are released into the environment by 2040. Under the combined policy scenario, which includes all three policies (reducing tire abrasion rates, reducing passenger vehicle miles driven, and banning biosolids application on agricultural lands), microplastic pollution from tires is reduced by 15% by 2040 relative to BAU (Figure 5-8).

By removing tires with the top 25% of abrasion rates for all vehicles except airplanes, we modeled the following reductions by vehicle type: 18% for heavy-duty vehicles, 15% for motorcycles, 12% for light commercial vehicles, and 9% for passenger vehicles. Of the individual policies modeled, reducing tire abrasion rates through changes in tire design achieves the greatest decrease in pollution (-14%) relative to BAU. This scenario targeted tires used by a variety of vehicle types, including motorcycles, passenger cars, and light- and heavy-duty vehicles. In modeling potential abrasion limits in EU, Giechaskiel et al. (2024) found that reducing tire abrasion yielded net cost savings from avoided pollution. Although we do not model the costs of microplastic policy scenarios, reducing abrasion rates could have additional benefits beyond the scope of this modeling analysis.

The scenario reducing passenger vehicle miles driven achieved a small reduction in pollution (-0.76%) primarily due to the assumption that growth in public transportation would lead to a 2% decrease in miles driven for passenger vehicles only. Banning the application of biosolids on agricultural lands had a similarly small impact on tire microplastic pollution (-0.21%), since most of the country is connected to separate sewage systems that do not process surface water runoff and any tire wear particles caught in the runoff.

Figure 5-8. Tire microplastic pollution under the BAU scenario and under each tire microplastic policy scenario, 2040

Labels above the policy bars indicate the percentage change in pollution under the policy relative to BAU.



6. Summary of Key Findings

The results of this analysis align with those from comparable studies, which indicate that plastic waste and pollution in the United States will continue to rise unless comprehensive interventions are implemented to reverse current trends. This chapter summarizes the key findings associated with the BAU and policy scenarios, including how the policies could reduce waste and pollution from plastic packaging and microplastics, and what the corresponding impacts might be in terms of costs, jobs, and GHG emissions. Here we present key findings tied to the high targets for plastic packaging policy scenarios; data on low targets is provided in Section 7.8.2.

These findings and the information provided in this report can be used by local, state, and federal agencies to support evidence-based decision-making around policies to reduce plastic waste and pollution in the United States.

6.1 Plastic MSW Key Findings

- ***Under BAU, an additional 1 billion tons of plastic waste will be generated in the U.S. between 2025 and 2040, leading to over 30 million tons of plastic pollution in U.S. lands and waters.***
- ***Managing the plastic waste generated in 2040 under the BAU scenario—including capital and operating expenditures associated with collection and sorting, recycling, landfilling, and incineration—is estimated to cost $40 billion annually, of which an estimated $37 billion is borne by taxpayers***.[7] Approximately 60% of these costs are associated with collection and sorting, and 28% with disposal through incineration and landfilling. Recycling (both mechanical open-loop and closed-loop recycling and chemical conversion) represents only 6.5% of annual waste management costs under the BAU scenario.

6.2 Plastic Packaging MSW Key Findings

Key findings on the BAU scenario

Plastic packaging makes up 54% of the plastic material found in both MSW and in plastic pollution in 2025. Under the BAU scenario, it will pose an increasingly difficult challenge for U.S. waste management systems.

- ***Under BAU, annual plastic packaging waste is projected to increase by 31% from 2025 to 2040, from 30 million to 39 million tons per year.*** This is equivalent to over 215 pounds of plastic packaging waste generated per person in 2040, or over half a pound each day.
- ***Flexible packaging makes up 50% of plastic packaging waste by mass under BAU and is one of the least recycled plastic packaging materials.*** It also makes up 50% of total

[7] Costs to taxpayers include the costs of formal collection, sorting, incineration, and landfilling. See Section 7.8.1 for detail.

plastic packaging pollution by mass. Flexible packaging poses a unique challenge for collection, sorting, and recycling processes, which is reflected in its low recycling rate in the United States, estimated at 0.25% under BAU. This is in part because flexible materials have been found to get caught in recycling facilities' sorting machinery, and the recyclate produced from flexible packaging is typically of low value and in limited demand.

Key findings on the policy scenarios

Combining all of these policies aimed at addressing plastic packaging waste and pollution can lower plastic packaging waste generation by 29% and reduce plastic packaging pollution by 35%—a greater decrease than can be achieved by each individual policy scenario on its own. Each policy targets different parts of the plastic value chain and together they yield substantial reductions in plastic packaging waste, pollution, and disposal needs.

- ***Relative to the BAU scenario, every policy scenario reduces the amount of plastic packaging waste that is landfilled or incinerated.*** By 2040, each individual policy scenario decreases the mass of plastic packaging waste disposed of via landfill or incineration by 10% to 20%. Under the Combined policy scenario, it is reduced by 44% by 2040.
- ***Phasing out PS/EPS and PVC and reducing plastic use in packaging by 20% reduces both plastic waste generation and pollution by 20% by 2040 and makes plastic packaging more recyclable.*** In addition to reducing annual packaging waste by 20% and reducing annual pollution by 20% relative to BAU (the most of any policy scenario evaluated except the combined policy scenario), the Phaseout and Optimize scenario yields corresponding 20% decreases in the mass of plastic packaging waste that gets landfilled and incinerated. The policy also results in an increase in the recycling rate, because plastic is shifted away from PS/EPS and PVC to more recyclable materials. Given the reduction in waste generation and the elimination of unnecessary plastic, costs and jobs associated with the waste management system decrease by 11% relative to BAU 2040. These decreases are driven predominantly by reduced collection. GHG emissions also decrease by 11%, driven by the reduction in waste incineration.
- ***In the Reuse scenario, a 30% market share for beverage bottles and 10% market share for all other packaging reduces plastic packaging waste by up to 11% and pollution by 12% by 2040 relative to business as usual.*** Currently, reuse systems for plastic packaging are very limited in the United States; a shift toward reuse at scale represents a departure from BAU. Shifting 30% of beverage bottles and 10% of all other single-use packaging to reusable packaging (equivalent to an overall 13% shift of single-use plastic packaging to reusable plastic, glass, and metal) reduces annual costs to taxpayers associated with packaging waste management by more than $1 billion. While jobs in the waste management sector decrease by 4% under a reuse scenario due to less waste being managed, this is offset by the creation of jobs that are also safer than waste management and recycling jobs (OSHA, n.d.-a; U.S. Bureau of Labor Statistics, n.d.). Additionally, with such a reuse policy, GHG emissions decline by 3%.

- ***Quadrupling the regional collection rate and limiting sorting losses of plastic packaging waste to 10% in the Collect and Sort scenario increases the national plastic packaging recycling rate from 6.3% to 19% by 2040, while also reducing plastic packaging landfilling by 17% and incineration by 18%.*** These improvements will require more than $21 billion in capital and operating expenses over the next 14 years and increase employment in the recycling sector by more than 17,000 jobs. While these interventions increase the quantity of material sent to recycling and increase GHG emissions from the waste management sector by 6.6%, this is offset by using recycled material, which has lower GHG emissions than primary plastic.
- ***The DRS scenario substantially increases beverage bottle recycling rates, minimizes regional recycling rate disparities, and reduces the amount of waste that must be managed through landfilling or incineration.*** While the DRS policy targets a 90% collection rate for PET and HDPE beverage bottles only, it raises the national plastic packaging recycling rate from 6.3% to 15% by 2040 and reduces the disparity in recycling rates across regions relative to BAU. By creating economic incentives for consumers to return beverage bottles, this policy reduces the amount of plastic bottle waste incinerated or sent to landfills and reduces annual plastic bottle pollution by 41% relative to BAU.
- ***None of the policy scenarios appreciably address waste generation or pollution from flexible packaging.*** Under the Combined policy scenario, flexible packaging continues to make up over 50% of plastic packaging waste and pollution in 2040. While under this scenario, the recycling collection rate for flexible plastic packaging increases to 9.6% from 2.4% under BAU, the recycling rate remains low, at just 3%, suggesting that different strategies are needed to improve the circularity of these materials.
- ***Combining policies amplifies their impact due to the cascading benefits of upstream policies on downstream parts of the value chain.*** Relative to the BAU projection for 2040, the Combined scenario reduces plastic packaging waste generation by 29% and plastic packaging pollution by 35%, bringing both below 2025 levels. The benefits of waste reduction achieved by the upstream policies of Phaseout (shifting mass of PVC and PS/EPS to other plastic categories) and Optimize (20% reduction by mass across all plastic types) and reuse (30% market share for beverage bottles and 10% market share for all other packaging) cascade through the downstream stages of the value chain, reducing the mass of plastic packaging disposed via landfills, reducing incineration by 44%, and increasing the mass recycled by 140%.
- ***The Combined policy scenario increases the number of jobs in the waste management sector and reduces the costs of managing plastic waste.*** The combined scenario shifts jobs away from landfilling, incineration, and P2F chemical conversion into mechanical recycling, increasing overall jobs by 2%. Furthermore, while not estimated in this analysis, costs could be further reduced by systems like DRS and reuse sharing infrastructure,

increasing the scale of reuse, and using standardized packaging with high return rates in reuse systems.

- ***Incineration generates the most GHG emissions of all waste management pathways, totaling 16 $MtCO_2e$ in the BAU scenario in 2040; the combined scenario achieves the greatest reduction in emissions associated with incineration.*** All the policy scenarios reduce the annual emissions from incineration, with the combined policy scenario achieving a substantial 20% reduction in annual incineration emissions by 2040 (-3.2 $MtCO_2e$). The combined policy scenario generates higher emissions associated with recycling, relative to BAU, because the collect and sort and DRS policies increase the recycling rate. However, these increases are more than offset by reductions in emissions associated with primary plastic production avoided.

6.3 Microplastic Key Findings

Our analysis focused on only two microplastic sources in 2025 and under BAU in 2040, yet the pollution from these sources is on par with that of plastic packaging. This underscores the importance of additional research on microplastic generation from other sources to better understand the scale of pollution. The policies modeled in this analysis included both upstream policies aimed at reducing microplastic generation at the source and downstream policies aimed at improving management of microplastics after they are generated.

- ***Under the BAU scenario, in 2040 the annual mass of microplastic pollution from textiles and tires in 2040 is equal to the estimated pollution from plastic packaging.*** The combined policy scenarios for microplastics reduce the mass of pollution from textiles and tires relative to BAU. However, the resulting mass of pollution for combined policy scenarios for microplastics still exceeds the combined policy scenario for plastic packaging.

- ***For microplastics generated from textiles and tires, combining upstream and downstream policies were most effective at reducing microplastic pollution relative to the BAU scenario.*** When policies are evaluated individually, those that target design are most effective for reducing microplastic pollution from textiles and tires as they prevent microplastic generation at the source (e.g., via manufacturing standards for textiles or minimum tire wear standards for tires). For tire wear particles, almost all are lost to the environment once they are generated. For textile microfibers generated through washing, installing washing machine filters can reduce the discharge of textile microplastics into the environment. However, once textile microfibers and tire wear particles enter the environment, it is difficult to remove them, underscoring the importance of preventing their release in the first place.

7. Technical Appendix

7.1 Pathways Tool

The Breaking the Plastic Wave Pathways Tool (“Pathways”) is based on the Plastics-to-Ocean (P_2O) model developed by Pew and Professor Richard Bailey of the University of Oxford (Lau et al., 2020). It is a data-driven coupled ordinary differential equation (ODE) model that calculates the flow of mass through predefined waste systems. For this analysis, ICF and Pew compiled updated data on U.S. plastic inventories, flows, and impacts and organized them in an SQL database. The database contains individual tables for each set of relevant information, along with bibliographic information and data pedigree scores to inform uncertainty analysis (see Section 8.2).

ICF processed and analyzed the data in R (version 4.4.2) to transform, combine, and format the baseline inputs. The files created through this coding process contained the 45 flow values for each year in a time series (2017 to 2040) for each of the 41 plastic types for each of the six regions. The baseline inputs were then run in Pathways. The R code includes notes documenting any changes made to the raw data housed in the SQL database to allow for transparency in our methodological process and reproducibility of our modeling results.

The data for this analysis are published on Zenodo and publicly available at this link: https://doi.org/10.5281/zenodo.17880491

7.2 Uncertainty

Due to variability in data availability, quality, and uncertainty across the plastic system, it was essential to incorporate quantitative measures of uncertainty of all input variables to the model that could then inform statistical resampling of the inputs over an ensemble simulation (Monte Carlo, MC, simulation). Following the methods used in Lau et al. (2020), we assigned scores to each data source entered into the SQL database across a four-attribute matrix, taking into account key data quality measures including sample size, uncertainty, accuracy and reliability, and date of publication (Table 7-1). The scores for each row of the matrix were then summed to yield a total data quality score (Table 7-2). Sources with a lower summed score indicate higher data quality, whereas sources with higher summed scores indicate lower data quality.

Table 7-1. Data pedigree scoring matrix

Score	1	2	3	4
Sample size	Representative	Representative under certain conditions and/or in some scenarios	Limited representation: Only representative under a specific condition or in one scenario	Unknown
Uncertainty	Uncertainty is measured and reported (e.g., standard deviation, confidence interval, interquartile range, mean, error bars)	Uncertainty is not measured or reported, but all assumptions are stated and the impacts of assumptions on results are discussed	Assumptions are stated, but no reference is made to the impact of assumptions on results	Uncertainty and assumptions are neither measured nor discussed
Accuracy and reliability	Verified based on empirical measurements and/or direct-to-source interviews (e.g., cost data quoted directly from a recycling facility will be graded as 1 in this category)	Verified data based on empirical measurements and/or direct-to-source interviews with some assumptions and/or estimates to fill data gaps	Nonverified data based on estimates and/or assumptions including qualified estimates (e.g., expert opinion)	Nonverified and/or nonqualified data
Date of publication	Less than 5 years ago	6-10 years ago	11-15 years ago	More than 15 years ago and/or unknown

We assigned each data source a score of 1 to 4 for each of the criteria in Table 7-1 with 1 representing the highest data quality level and 4 representing the lowest data quality level. For data points that were calculated using multiple sources, we assigned the highest, most uncertain, data quality score across those sources to determine the uncertainty of the flow. The sources with the highest data quality (i.e., lowest score based on those in Table 7-1) were assigned an uncertainty level of +/- 10%. The lowest-quality data sources were assigned an uncertainty level of +/- 50%. Expert assumptions were always assigned an uncertainty level of +/- 50%.

In the selection of data sources for use in the analysis, preference was given to those with lower data pedigree scores indicating higher data quality and lower uncertainty. However, data sources with higher data pedigree scores were not immediately excluded from the analysis if they met a particular need for the analysis, such as the lack of another available data source for a particular flow or impact, lack of a more recent data source, or the data source provided other attributes, such as disaggregation by region/state or by specific plastic types. In addition, while older datasets gathered from literature sources increased the data pedigree scoring for those particular sources, this did not necessarily equate with the data being of poor quality; older data still have relevance as certain measurements may not change much over time or an older study could have a more robust methodology, making it preferable to a newer data source.

Table 7-2. Uncertainty assignments per total data pedigree score

Score	1-5	6-8	9-12	13-16
Data quality	High-quality data, high certainty and/or minimal impact on result(s)	Likely good quality data with minimal impact on results	Data quality may be outdated and/or imprecise, but impact on results is insignificant and/or data have low sensitivity toward results of the model	Poor data quality with a high impact on results
Uncertainty	+/- 10%	+/- 20%	+/- 35%	+/- 50%

Uncertainty values represent the upper and lower boundaries of a uniform distribution for each input parameter. The uncertainty was propagated through model output using Monte Carlo (MC) simulation by randomly sampling input parameters within these bounds. A total of 200 MC simulations were performed for plastic packaging flows, costs, jobs, GHG emissions, and microplastics. For reproducibility, all Monte Carlo simulations were run using a fixed random seed.

7.3 Modeling Scope

7.3.1 Material Types

The analysis includes plastic found in U.S. MSW, including packaging and nonpackaging plastic. Nonpackaging plastic includes durable plastics (e.g., plastic toys and furniture) and nondurable plastics (e.g., plastic plates and cups). We disaggregated plastic MSW waste by polymer and format based on data from Milbrandt et al. (2022). This disaggregation resulted in 41 polymer-plastic type combinations in the baseline, with five other material types used in the policy scenarios (DRS plastic and reusable materials). We assumed that the Milbrandt categories “bottles/containers” and “mixed plastic packaging” represented rigid packaging, “durable” and “non-durable” represented rigid nonpackaging, “film/wrap/bags” represented flexible packaging and flexible nonpackaging, and “remainder/composite plastic” represented multimaterial packaging and multimaterial nonpackaging.

We separately identify bottles from the packaging category because bottles tend to have the highest recovery rates for recycling. In the model, flexible plastic are defined as monomaterial films, wraps, or bags, which may be single- or multilayer. Multimaterial plastic are defined as products composed of more than one material.

Table 7-3. Material types included in the MSW plastic analysis

Material Type	Polymer	Application	Format	Product Type
1	HDPE	Packaging	Rigid	Beverage bottle
2	HDPE	Nonpackaging	Flexible	NA
3	HDPE	Packaging	Flexible	NA
4	HDPE	Nonpackaging	Multimaterial	NA
5	HDPE	Packaging	Multimaterial	NA
6	HDPE	Packaging	Rigid	Nonbeverage bottle
7	HDPE	Nonpackaging	Rigid	NA
8	HDPE	Packaging	Rigid	NA
9	LDPE_LLDPE	Nonpackaging	Flexible	NA
10	LDPE_LLDPE	Packaging	Flexible	NA
11	LDPE_LLDPE	Nonpackaging	Multimaterial	NA
12	LDPE_LLDPE	Packaging	Multimaterial	NA
13	LDPE_LLDPE	Nonpackaging	Rigid	NA
14	LDPE_LLDPE	Packaging	Rigid	NA
15	Other	Nonpackaging	Multimaterial	NA
16	Other	Packaging	Multimaterial	NA
17	Other	Nonpackaging	Rigid	NA
18	PET	Packaging	Rigid	Beverage bottle
19	PET	Nonpackaging	Multimaterial	NA
20	PET	Packaging	Multimaterial	NA
21	PET	Packaging	Rigid	Nonbeverage bottle
22	PET	Nonpackaging	Rigid	NA
23	PET	Packaging	Rigid	NA
24	PP	Nonpackaging	Flexible	NA

Material Type	Polymer	Application	Format	Product Type
25	PP	Packaging	Flexible	NA
26	PP	Nonpackaging	Multimaterial	NA
27	PP	Packaging	Multimaterial	NA
28	PP	Nonpackaging	Rigid	NA
29	PP	Packaging	Rigid	NA
30	PS	Nonpackaging	Flexible	NA
31	PS	Packaging	Flexible	NA
32	PS	Nonpackaging	Multimaterial	NA
33	PS	Packaging	Multimaterial	NA
34	PS	Nonpackaging	Rigid	NA
35	PS	Packaging	Rigid	NA
36	PVC	Nonpackaging	Flexible	NA
37	PVC	Packaging	Flexible	NA
38	PVC	Nonpackaging	Multimaterial	NA
39	PVC	Packaging	Multimaterial	NA
40	PVC	Nonpackaging	Rigid	NA
41	PVC	Packaging	Rigid	NA
42	HDPE	DRS eligible	Rigid	NA
43	PET	DRS eligible	Rigid	NA
44	Plastic	Reuseable material	NA	NA
45	Glass	Reuseable material	NA	NA
46	Metal	Reuseable material	NA	NA

7.3.2 Geographic Scope

We initially sought to disaggregate the geographic scope into urban and rural archetypes, as in Lau et al. (2020), however, sources indicated that the differences may not be meaningful. For instance, Milbrandt et al. (2022) notes that the difference in waste composition between urban versus rural communities in a state is about 1% to 2%, which is captured in state average rates. In addition, with the exception of urban and rural residential recycling data received from Burman (2024) and The Recycling Partnership (2024), urban and rural data were unavailable for the other flows. While waste composition can vary between urban and rural areas, the state average rate, which is the percentage composition of waste materials averaged across various locations within a state, compensates for these minor differences (Milbrandt et al., 2022).

7.4 Detailed Methods for Modeling the Business-as-Usual Scenario

In the following sections, we provide more detailed information to supplement the methods described in Section 2. Except for the values for Arrow Y1 (plastic waste generated) and Arrow Z1 (imported waste), which are in tonnage units[8] in the baseline files input into Pathways, the other flows (i.e., arrows) are in percentage units. When more than one arrow flows out of a box, one of the flows is considered a “plug” flow calculated as the residual from the other flows.

7.4.1 Plastic Categories and Format Shares by Polymer

We used various studies to estimate the share of each plastic category and format that makes up the total waste generated by polymer. We first estimated polymer and product disaggregation from Milbrandt et al. (2022). That study organizes plastic waste into seven categories: PET #1 bottles/containers, HDPE #2 bottles/containers, mixed plastic packaging #3 to #7, PS/EPS products, film/wrap/bags, durable plastic products, and remainder/composite plastic. Because waste composition is similar across regions, we calculated the national estimate for each plastic category (Milbrandt et al., 2022). Supplemental information for Milbrandt et al. (2022), shown in Table 7-4, was used to disaggregate mixed plastic packaging #3 to #7, film/wrap/bags, durable plastic products, and remainder/composite plastic by polymer.

Table 7-4. Share of polymer types in plastic waste categories

Plastic Waste Materials	PET	HDPE	LDPE/ LLDPE	PP	PS/ EPS	PVC	Other
Mixed plastic packaging #3 - #7 (MP)	-	-	10%	65%	22.5%	2.5%	-
Film/wrap/bags (FWB)	-	17%	69%	10%	2.7%	1.3%	-
Durable plastic products (DP)	4.6%	11.4%	15%	33.6%	5.7%	1.8%	27.9%
Remainder/composite plastic (RC)	8%	12%	18%	30%	9%	3.6%	19.4%
Source: Adapted from Milbrandt et al. (2022), Table S1							

To distinguish between flexible packaging and flexible nonpackaging for the film/wrap/bags category by polymer (Table 7-5), we used the American Chemistry Council’s 2021 Resin Review (ACC, 2021) of plastic production to apply the proportions of flexible packaging and flexible products produced to the Milbrandt et al. (2022) estimates for LDPE/LLDPE, HDPE, and PVC. For PP and PS, we used the 2021 Washington Statewide Waste Characterization Study (State of Washington Department of Ecology, 2021). Flexible packaging and nonpackaging of unknown polymer makeup was used as a proxy for PP and PS.

[8] Inputs to the model are in metric tons. The results were converted into U.S. (short) tons for this report.

Milbrandt et al. (2022) categorizes PET and HDPE as “bottle/container.” Nisticò (2020) and Smithers (2020) present the breakdown of PET packaging by sector (water, carbonated soft drinks, all other drinks, food, nonfood, and thermoforming). For beverages, the average between the two sources results in an estimate of 72% of PET packaging as beverage bottles. The remaining plastic are nonbeverage bottles and containers. To further disaggregate between nonbeverage bottles and containers, state-level data on PET bottles and PET other rigid packaging from Eunomia (2021) was summed at the national level to calculate the mass of total PET packaging. Assuming 72% of PET packaging was beverage bottles, the mass of beverage bottles was subtracted from the mass of PET bottles to obtain the mass of nonbeverage bottles. The mass of nonbeverage bottles was divided by the total mass of PET packaging to calculate the percentage contribution of nonbeverage bottles in total PET packaging. For HDPE, we used the American Chemistry Council (2021) Resin Review to disaggregate HDPE bottle/container by beverage bottle, nonbeverage bottle, and nonbottle rigids.

These approaches allowed us to obtain the proportions of plastic formats within each polymer (Table 2-1) and the split of film/wrap/bags packaging and nonpackaging by polymer (Table 7-5).

Table 7-5. Estimated packaging versus product film/wrap/bags proportions

Polymer	Film/Wrap/Bags Proportion Packaging	Film/Wrap/Bags Proportion Nonpackaging
PET	-	-
HDPE	33%	67%
PVC	87%	13%
LDPE/LLDPE	66%	34%
PP	87%	13%
PS/EPS	87%	13%
Other	-	-

The Milbrandt data used as the basis for this study’s input data closely aligns with Flow 3, formal collection of waste. We back calculated total plastic waste generated (Flow 42) by region and plastic type using estimates on the amount of plastic waste that is informally collected (Flow 4) and the amount of plastic waste that is not collected (Flow 2). In our modeling, 100% of the plastic waste collected is formally collected (Flow 3) except for PET and HDPE beverage bottles. For these plastic types, we estimated that 99.9% is collected formally, while a small amount is collected by the informal sector (Sure We Can, 2023).[9] Escaped trash, or waste that is intentionally or unintentionally lost to the environment throughout the plastic life cycle, is represented by Flow 2. This includes litter, uncollected trash from households that is “managed by the household” (i.e., via

[9] Independent recyclers, also known as “canners,” contribute to the collection of recyclable plastic. There is a lack of data on the contribution of canners to plastic recycling. Sure We Can (2023) estimated up to 8,000 canners in New York City, comprising about 0.1% of the population.

open burning or dumping as described by National Academies of Sciences (2022)), and trash that escapes the waste management system (such as trash falling off waste collection vehicles). We estimated that the escaped trash rate across the United States is 3% (Jambeck, 2025). The portion of waste not lost as litter is calculated in Flow 1 as the complement flow of Flow 2.

Calculations used for these boxes and flows are shown here.

$$FormalCollect_{tr} = CategoryPortion_{pc} \times ManagedWaste_{p} \times PopShare_{r}$$

Where…

t is the plastic type (1-41)

r is the region

p is the polymer of the plastic type

c is the plastic category (rigid nonpackaging, beverage bottle, etc.)

$ManagedWaste_{p}$ and $CategoryPortion_{pc}$ were obtained from Milbrandt et al. (2022) and $PopShare_{r}$ was estimated using state-level population projection data (University of Virginia, 2024).

$$TotalCollect_{tr} = \frac{FormalCollect_{tr}}{Flow\ 3_{t}}$$

Where…

$Flow\ 3_{t}$ is 1 for all plastic types except for beverage bottles (types 1 and 18). For beverage bottles, Flow 3 is 0.999.

$$WasteGenerated_{tr} = \frac{TotalCollect_{tr}}{Flow\ 1}$$

$WasteGenerated_{tr}$ is the input to this model (Flow 42 input). Pathways then calculates virgin plastic waste generated (Flow 42 output) based on the mass entering Box A from the recycling flows (Flows 19 and 22).

Table 7-6. Flow 42 inputs (million metric tons)

Plastic Type	Polymer	Application	Format	Product Type	Midwest		Northeast		Pacific		Rocky Mountain		Southeast		Southwest	
					2025	2040	2025	2040	2025	2040	2025	2040	2025	2040	2025	2040
1	HDPE	Packaging	Rigid	Beverage bottle	0.21	0.26	0.20	0.26	0.17	0.22	0.05	0.07	0.27	0.36	0.14	0.19
2	HDPE	Nonpackaging	Flexible	NA	0.53	0.66	0.50	0.64	0.42	0.55	0.13	0.18	0.68	0.89	0.35	0.48
3	HDPE	Packaging	Flexible	NA	0.26	0.32	0.25	0.31	0.21	0.27	0.06	0.09	0.33	0.44	0.17	0.23
4	HDPE	Nonpackaging	Multi	NA	0.14	0.17	0.13	0.17	0.11	0.14	0.03	0.05	0.18	0.23	0.09	0.12
5	HDPE	Packaging	Multi	NA	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	0.02	0.01	0.01
6	HDPE	Packaging	Rigid	Nonbeverage bottle	0.18	0.23	0.17	0.22	0.15	0.19	0.04	0.06	0.23	0.31	0.12	0.16
7	HDPE	Nonpackaging	Rigid	NA	0.17	0.22	0.17	0.21	0.14	0.18	0.04	0.06	0.22	0.30	0.11	0.16
8	HDPE	Packaging	Rigid	NA	0.33	0.42	0.32	0.41	0.27	0.35	0.08	0.11	0.43	0.57	0.22	0.30
9	LDPE	Nonpackaging	Flexible	NA	1.03	1.29	0.99	1.25	0.83	1.08	0.25	0.35	1.32	1.75	0.68	0.93
10	LDPE	Packaging	Flexible	NA	1.98	2.48	1.90	2.41	1.59	2.08	0.49	0.68	2.55	3.38	1.31	1.80
11	LDPE	Nonpackaging	Multi	NA	0.18	0.22	0.17	0.22	0.14	0.19	0.04	0.06	0.23	0.30	0.12	0.16
12	LDPE	Packaging	Multi	NA	0.02	0.02	0.02	0.02	0.01	0.02	0	0.01	0.02	0.03	0.01	0.01
13	LDPE	Nonpackaging	Rigid	NA	0.22	0.27	0.21	0.26	0.17	0.23	0.05	0.07	0.28	0.37	0.14	0.20
14	LDPE	Packaging	Rigid	NA	0.08	0.10	0.08	0.10	0.06	0.08	0.02	0.03	0.10	0.14	0.05	0.07
15	Other	Nonpackaging	Multi	NA	0.30	0.38	0.29	0.37	0.24	0.32	0.07	0.10	0.39	0.52	0.20	0.28
16	Other	Packaging	Multi	NA	0.01	0.01	0.01	0.01	0	0.01	0	0	0.01	0.01	0	0.01
17	Other	Nonpackaging	Rigid	NA	0.41	0.51	0.39	0.50	0.33	0.43	0.10	0.14	0.53	0.70	0.27	0.37
18	PET	Packaging	Rigid	Beverage bottle	0.93	1.16	0.89	1.13	0.75	0.97	0.23	0.32	1.20	1.58	0.61	0.84
19	PET	Nonpackaging	Multi	NA	0.08	0.09	0.07	0.09	0.06	0.08	0.02	0.03	0.10	0.13	0.05	0.07

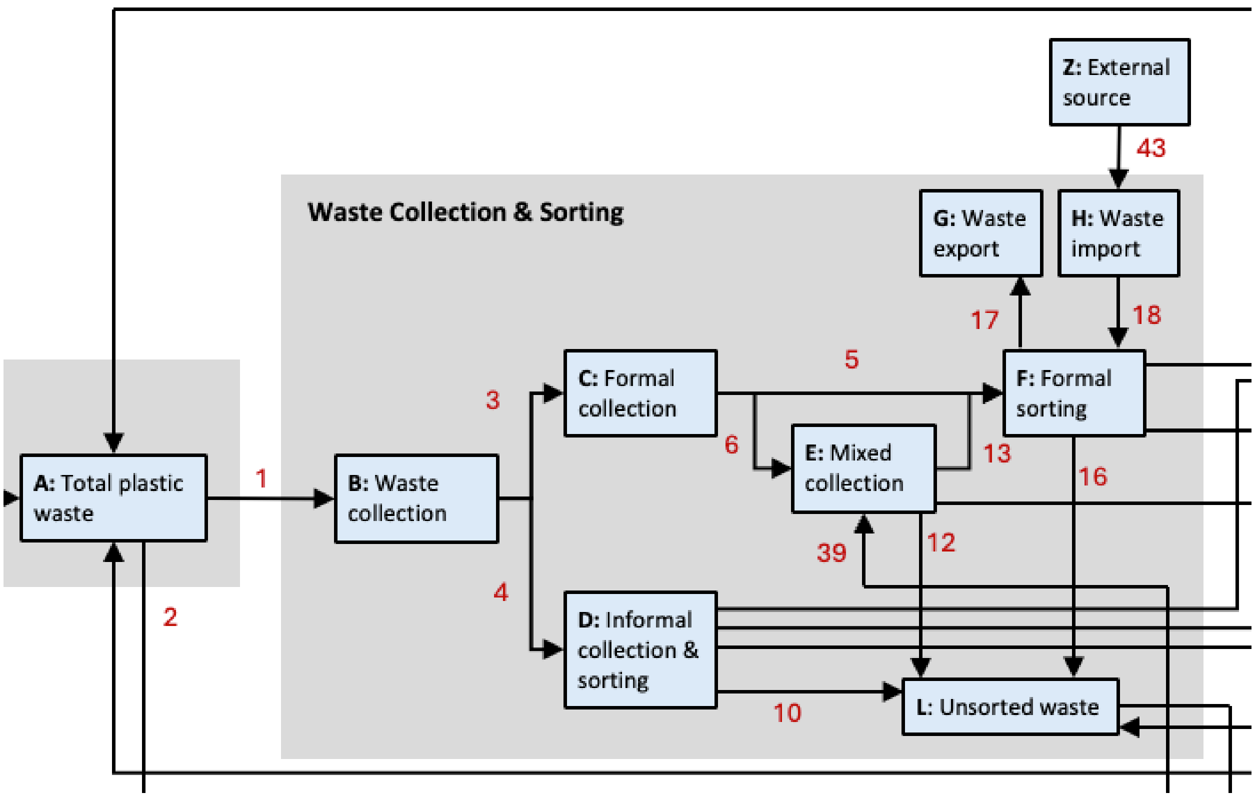
Plastic Type	Polymer	Application	Format	Product Type	Midwest		Northeast		Pacific		Rocky Mountain		Southeast		Southwest	
					2025	2040	2025	2040	2025	2040	2025	2040	2025	2040	2025	2040
20	PET	Packaging	Multi	NA	0.01	0.02	0.01	0.01	0.01	0.01	0	0	0.02	0.02	0.01	0.01
21	PET	Packaging	Rigid	Nonbeverage bottle	0.10	0.12	0.09	0.12	0.08	0.10	0.02	0.03	0.12	0.16	0.06	0.09
22	PET	Nonpackaging	Rigid	NA	0.08	0.10	0.08	0.10	0.07	0.09	0.02	0.03	0.11	0.14	0.05	0.07
23	PET	Packaging	Rigid	NA	0.19	0.24	0.19	0.24	0.16	0.20	0.05	0.07	0.25	0.33	0.13	0.18
24	PP	Nonpackaging	Flexible	NA	0.06	0.07	0.06	0.07	0.05	0.06	0.01	0.02	0.08	0.10	0.04	0.05
25	PP	Packaging	Flexible	NA	0.39	0.49	0.38	0.48	0.31	0.41	0.10	0.13	0.50	0.67	0.26	0.36
26	PP	Nonpackaging	Multi	NA	0.39	0.48	0.37	0.47	0.31	0.41	0.10	0.13	0.50	0.66	0.26	0.35
27	PP	Packaging	Multi	NA	0.02	0.02	0.02	0.02	0.01	0.02	0	0.01	0.02	0.03	0.01	0.01
28	PP	Nonpackaging	Rigid	NA	0.50	0.63	0.48	0.61	0.40	0.53	0.12	0.17	0.65	0.86	0.33	0.46
29	PP	Packaging	Rigid	NA	0.54	0.68	0.52	0.66	0.43	0.57	0.13	0.19	0.70	0.92	0.36	0.49
30	PS	Nonpackaging	Flexible	NA	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	0.02	0.01	0.01
31	PS	Packaging	Flexible	NA	0.06	0.08	0.06	0.08	0.05	0.07	0.02	0.02	0.08	0.11	0.04	0.06
32	PS	Nonpackaging	Multi	NA	0.05	0.06	0.05	0.06	0.04	0.05	0.01	0.02	0.06	0.08	0.03	0.04
33	PS	Packaging	Multi	NA	0	0	0	0	0	0	0	0	0	0.01	0	0
34	PS	Nonpackaging	Rigid	NA	0.48	0.60	0.46	0.59	0.39	0.51	0.12	0.17	0.62	0.82	0.32	0.44
35	PS	Packaging	Rigid	NA	0.11	0.14	0.11	0.13	0.09	0.12	0.03	0.04	0.14	0.19	0.07	0.10
36	PVC	Nonpackaging	Flexible	NA	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.01	0.02	0.01	0.01
37	PVC	Packaging	Flexible	NA	0.06	0.08	0.06	0.07	0.05	0.06	0.01	0.02	0.08	0.10	0.04	0.05
38	PVC	Nonpackaging	Multi	NA	0.03	0.04	0.03	0.04	0.02	0.03	0.01	0.01	0.04	0.05	0.02	0.03
39	PVC	Packaging	Multi	NA	0.01	0.01	0.01	0.01	0	0.01	0	0	0.01	0.01	0	0.01
40	PVC	Nonpackaging	Rigid	NA	0.03	0.04	0.03	0.04	0.03	0.03	0.01	0.01	0.04	0.05	0.02	0.03
41	PVC	Packaging	Rigid	NA	0.02	0.03	0.02	0.03	0.02	0.03	0.01	0.01	0.03	0.04	0.02	0.02

Note: All values are rounded to two significant figures.

7.4.2 Waste Collection and Sorting Module

Figure 7-1 depicts the boxes and flows comprising the waste collection and sorting module. In this module, we calculate the mass of plastic flowing through formal and informal collection pathways, collection for recycling, collection and sorting for unsorted waste, and the import and export of plastic waste.

Figure 7-1. Waste collecting and sorting module



Formal collection for recycling

Flow 5 represents the share of plastic waste that is formally collected for recycling. After the sorting stage (Box F), during which some material is lost to unsorted waste (Box L), a portion of plastic waste is sent to closed-loop mechanical recycling (Box I) and open-loop mechanical recycling (Box J). Our estimates of the share of plastic waste sent to recycling differ depending on the format and polymer of plastic waste.

We estimated the share of plastic collected for recycling using data from Eunomia (2021), Eunomia (2023), Stina (2021), and Stina (2024). Eunomia (2021, 2023) provides region-level plastic waste generation quantities and recycling rates for rigid packaging plastic. These Eunomia studies define the recycling data as "the quantity of material that is actually recycled and re-incorporated into a new product." In our analysis, these quantities correspond to the flows exiting the recycling module rather than the flows entering them as waste sent to recycling. We adjusted these data to account for the losses coming out of the sorting and recycling boxes (see Table 7-8), as well as the mass of plastic waste exported (Stina, 2024) (see Table 7-7). These masses were then calculated as a share of the plastic waste collected by region for each polymer and product from Eunomia (2023).

For nonpackaging rigid plastic, we began with data from Stina (2021). They report the quantities recovered for recycling by polymer type for nonbottle rigids and films at the national level. We used Milbrandt et al. (2022) to distribute these "nonbottle rigids" into rigid packaging and rigid nonpackaging to align with our modeled plastic types. Because this is data on mass being sent to recyclers, we adjusted them only for sorting losses (Table 7-8). We then calculated these masses as a share of total waste collected by polymer and product from Milbrandt et al. (2022). We assume the collection for recycling rate for nonpackaging rigid plastic is the same for each region.

For flexibles, we used mass estimates of film recovered for recycling at the national level from Stina (2021). We used data from Milbrandt et al. (2022) to distribute this mass to the polymer and sector level (packaging versus nonpackaging). Similar to the methods for nonpackaging rigid plastic, we adjusted this mass by our estimated sorting losses for flexibles (see Table 7-8). We then calculated these masses as a share of film collected from Milbrandt et al. (2022). We assume the collection for recycling rate for flexibles is the same for each region.

The percentage of formally collected plastic that flows to mixed collection (Flow 6) is the complement of Flow 5. We assumed that these values remain constant over the modeling period.

$$Flow\ 6 = 1 - Flow\ 5$$

From mixed collection, plastic may flow directly to chemical conversion (Flow 11), to formal sorting for mechanical recycling (Flow 13) or unsorted waste (Flow 12). The approach for Flow 11 is discussed in the Recycling Module. We assumed that the share of plastic collected in mixed waste going to formal sorting (Flow 13) is 0% and that this remains constant over the modeling period. We calculated the share of plastic in mixed waste going to unsorted waste (Flow 12) as 100% minus Flow 11 and Flow 13. The share of plastic in mixed waste that goes to unsorted waste decreases over time as the share of plastic sent to chemical conversion increases.

$$Flow\ 12 = 1 - Flow\ 11 - Flow\ 13$$

Imports and exports of plastic waste

Flow 43 in the waste collection and sorting module represents plastic waste imports. Import tonnage data were obtained for PE, PET, PVC, and other plastic scrap imports from ICIS (2024). We used additional sources on end markets for imports to distribute the polymer-specific import data into the modeled plastic categories. We used information on the end markets for PET imports (fiber, sheet and film, strapping, food and beverage bottles, nonfood bottles, other) from the National Association for PET Container Resources (NAPCOR, 2021) to split PET imports into plastic types. We assumed the proportion of food and beverage bottles will be imported as beverage bottles, nonfood bottles as nonbeverage bottles, sheet and film as flexible packaging, and strapping, fiber, and other as nonpackaging rigids. According to Stina (2024), end uses for nonbottle rigid plastic are automotive products, crates, buckets, pallets, lawn and garden products, railroad ties and other relatively thick-walled, injection-molded products. A small portion of the nonbottle rigid plastic recovered is used in plastic lumber and other extruded products. For ethylene, PVC, and Other, we assumed that plastic scrap is recycled into nonpackaging rigid plastic. We assumed styrene is recycled into PS or EPS, that ethylene is recycled into HDPE and LDPE, and that plastic scrap imports is the same as the split of HDPE and LDPE nonpackaging rigid plastic that is waste. The CAGR for Flow 43 was obtained directly from ICIS (2024) as the rate of growth in plastic scrap imports from 2022 to 2023. We assumed this growth rate is the same for all the plastic types and regions.

Plastic flows out of formal sorting in four ways: closed-loop recycling, open-loop recycling, exported waste, and unsorted waste. For exported waste (Flow 17), we used the Stina (2024) export data to calculate the shares recovered for recycling that were exported both overseas and to other North American countries (12% for PET and HDPE bottle formats, 16.5% for rigid packaging and rigid nonpackaging plastic, and 13.7% for flexibles). We assumed 0% export rate for multimaterial formats because domestic reclamation capacity, as per MORE Recycling (2020), focuses on dry PE film or single resin material, thus multimaterial flexible plastic are not collected for recycling. As Stina (2024) does not report on the export of “other” (polymer) plastic, we assumed other plastics were not exported. Stina (2024) relies on surveys; therefore, exports may be underreported, and consequently our export rates and plastic types may be an underestimate.

Table 7-7. Estimated plastic waste exported internationally

Plastic Type	Percent Exported
Beverage and nonbeverage bottles	12%
Nonbottle rigids (both packaging and nonpackaging)	16.5%
Flexibles (all polymers)	13.7%
Multimaterial	0%
Note: Calculated with data reported in Stina (2024) and MORE Recycling (2020).	

Sorting losses

Sorting losses (Flow 16) refer to the share of plastic that is not exported or recycled and therefore result in unsorted waste. For losses from formal plastic sorting, we used the sorting loss rate values presented in Table 7-8 from Eunomia (2023) for PET bottles, PET other rigid, HDPE bottles, PP, and rigids #3-#7. We assumed HDPE nonbottle rigids have the same loss rates as HDPE bottles. For flexibles, we used the 60% loss rate from The Recycling Partnership (2024). We assumed that these values remain constant over the modeling period.

The shares sent from formal sorting to closed-loop mechanical recycling (Flow 14) and to open-loop mechanical recycling (Flow 15) are addressed in the Recycling Module.

Table 7-8. Sorting and recycling losses

Polymer	Sorting Loss Rate	Recycling Loss Rate
PET bottles (beverage and nonbeverage)	13%	14%
PET other rigids (packaging and nonpackaging)	47%	21%
HDPE rigids (packaging, nonpackaging, beverage bottles, and nonbeverage bottles)	21%	7%
PVC, LDPE/LLDPE, PS/EPS, Other (rigid packaging and nonpackaging)	35%	9%
PP (rigid packaging and nonpackaging)	35%	6%
Flexibles	60%	60%
Multimaterial*	0%	0%

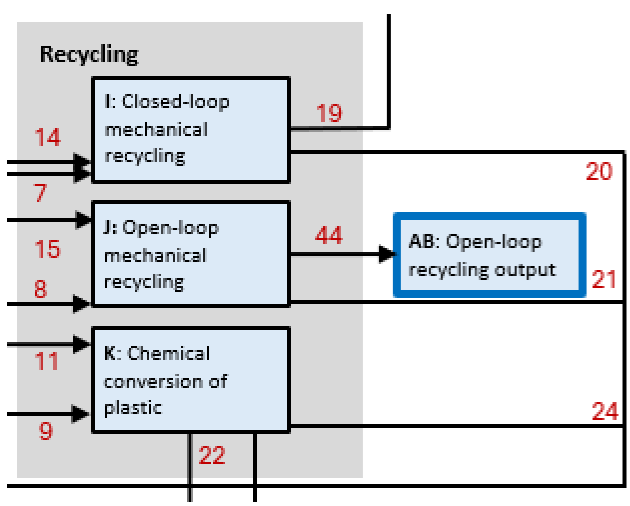
Sources: Eunomia (2023), with loss rates for rigids #3-#7 assumed for PVC, LDPE/LLDPE, PS, and other; The Recycling Partnership (2024) providing the loss rates for flexibles

* Multimaterial products are not collected for recycling, so they are not assigned sorting loss rates or recycling loss rates.

7.4.3 Recycling Module

Figure 7-2 displays the recycling module, which includes the estimates for mechanical recycling (both open-loop and closed-loop) and chemical conversion (both plastic-to-plastic, or P2P, and plastic-to-fuel, or P2F).

Figure 7-2. Recycling module



Plastic waste enters the recycling module from both formal collection and sorting (Flows 14, 15, and 11) and informal collection and sorting (Flows 7, 8, and 9). We calculated the share of informally collected plastic that is sent to closed-loop recycling (Flow 7) by taking the weighted average of values used in Lau et al. (2020) for this flow and their share of the plastic mix in Lau et al. (2020) for the high-income urban archetype (Table 7-9). We assumed that the share of informally collected plastic going to open-loop recycling (Flow 8) is 25%, based on Lau et al. (2020). We assumed that none of the plastic collected via informal collection is sent to chemical conversion, also based on Lau et al. (2020). We assumed that these values remain constant over the modeling period.

Table 7-9. Share of informally collected waste sent to closed-loop recycling by format

Format	Flow 7
Rigid	70%
Flexible	10%
Multimaterial	0%
Source: Lau et al., 2020	

We calculated the share of formally collected plastic waste sent to chemical conversion (Flow 11) by summing the rated processing capacity tonnages for operating and partially operating U.S.-based chemical conversion facilities and dividing by the total plastic waste managed nationally from Milbrandt et al. (2022). This yields an estimate of 0.6% when plants are operating at capacity. We assumed that chemical conversion plants are operating at capacity. We also assumed that this value will have a compound annual growth rate of 4.9% from 2021 to 2040, representing ongoing investment in chemical conversion infrastructure (Grand View Research, 2025). We assumed that this is the same for all plastic types.

We calculated the share of formally collected plastic waste sent to closed-loop mechanical recycling (Flow 14) using Eunomia (2023) recycling rates and their estimated share of open- versus closed-loop recycling.[10] Due to lack of data specific to HDPE rigid packaging, we apply the closed-loop recycling rate for HDPE bottles to HDPE rigid packaging. The recycling rates from Eunomia (2023) do not account for exports and sorting losses, so we adjusted the Flow 14 estimates to account for these flows (Table 7-2). We assume that the share of formally sorted waste sent to closed-loop mechanical recycling does not vary by region and that the rates remain constant over the modeling period. Flow 15 (the share of formally sorted waste sent to open-loop mechanical recycling) is the complement of Flows 14, 16, and 17.

To estimate the loss rates from mechanical recycling (Flows 20 and 21), we assume recycling losses are the same between closed- and open-loop recycling. We rely on recycling loss rate estimates

[10] See Figure 2.6 in Eunomia (2023), which provides the “retained value: of collected material from recycling” for the closed-loop recycling rates and the sum of “quality loss to non-circular packaging” and “quality loss to low grade” for the open-loop recycling rates.

from Eunomia (2023) for rigid plastic packaging types, presented in Table 7-8. We apply the same rates to nonpackaging plastic due to lack of data. We applied the rigids #3-#7 processing loss rate to LDPE, PS, PVC, and other packaging categories, and used the HDPE bottle loss rate for HDPE rigid packaging. For flexibles, we assume a 60% loss rate based on estimates from The Recycling Partnership (2024) that formal sorting capture rates for films and flexibles is 40%. We estimate the loss rate for chemical conversion (Flow 24) at 33% based on the reported 67% depolymerization yield from Closed Loop Partners (2021).

Flows 19, 44, and 22 represent the share of plastic recycled via closed-loop recycling, open-loop recycling, and chemical conversion, respectively. Flows 19 and 44 are the residual shares that are not lost from the mechanical recycling process, as shown here. Flow 44 does not reenter the waste stream the same way as Flow 19 does because it represents mass that is recycled into different plastic types and the model cannot capture that shift.

$$Flow\ 19 = 1 - Flow\ 20$$

$$Flow\ 44 = 1 - Flow\ 21$$

We calculate Flow 22, the share of mass converted to plastic (P2P), using estimates of capacity tonnage and operating capacity from Bell and Gitlitz (2023) and ExxonMobil (2024). Based on these studies, we estimated that Flow 22 is 5.8%. Flow 23, the share of chemically converted mass that becomes fuel, is the complement of Flow 22 and Flow 24, as shown below (Table 7-10). We assume that these values remain constant over the modeling period.

$$Flow\ 23 = 1 - Flow\ 22 - Flow\ 24$$

Table 7-10. Chemical conversion flow values

Flow Name	Flow Value
Flow 22: Share of mass converted to plastic (P2P)	5.8%
Flow 23: Share of mass converted to fuel (P2F)	61.2%
Flow 24: Losses from chemical conversion	33%

Table 7-11. Share of formally sorted plastic waste sent to closed-loop recycling for all plastic types (Flow 14)

Plastic Type	Polymer	Application	Format	Product Type	Flow 14
1	HDPE	Packaging	Rigid	Beverage bottle	0.44
2	HDPE	Nonpackaging	Flexible	NA	0
3	HDPE	Packaging	Flexible	NA	0
4	HDPE	Nonpackaging	Multi	NA	0
5	HDPE	Packaging	Multi	NA	0

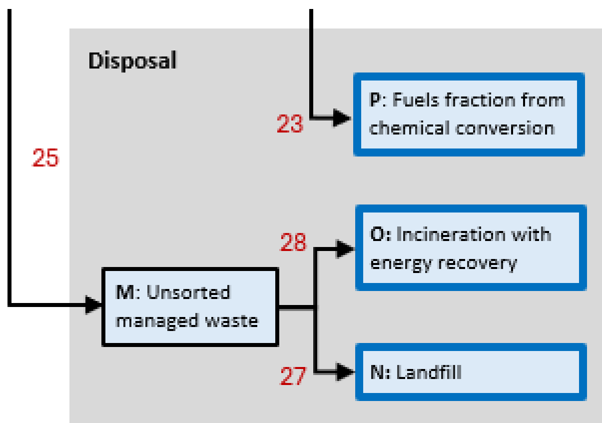
6	HDPE	Packaging	Rigid	Nonbeverage bottle	0.44
7	HDPE	Nonpackaging	Rigid	NA	0
8	HDPE	Packaging	Rigid	NA	0.41
9	LDPE	Nonpackaging	Flexible	NA	0
10	LDPE	Packaging	Flexible	NA	0
11	LDPE	Nonpackaging	Multi	NA	0
12	LDPE	Packaging	Multi	NA	0
13	LDPE	Nonpackaging	Rigid	NA	0
14	LDPE	Packaging	Rigid	NA	0.056
15	Other	Nonpackaging	Multi	NA	0
16	Other	Packaging	Multi	NA	0
17	Other	Nonpackaging	Rigid	NA	0
18	PET	Packaging	Rigid	Beverage bottle	0.50
19	PET	Nonpackaging	Multi	NA	0
20	PET	Packaging	Multi	NA	0
21	PET	Packaging	Rigid	Nonbeverage bottle	0.50
22	PET	Nonpackaging	Rigid	NA	0
23	PET	Packaging	Rigid	NA	0.22
24	PP	Nonpackaging	Flexible	NA	0
25	PP	Packaging	Flexible	NA	0
26	PP	Nonpackaging	Multi	NA	0
27	PP	Packaging	Multi	NA	0
28	PP	Nonpackaging	Rigid	NA	0
29	PP	Packaging	Rigid	NA	0.062
30	PS	Nonpackaging	Flexible	NA	0
31	PS	Packaging	Flexible	NA	0
32	PS	Nonpackaging	Multi	NA	0
33	PS	Packaging	Multi	NA	0
34	PS	Nonpackaging	Rigid	NA	0
35	PS	Packaging	Rigid	NA	0.056
36	PVC	Nonpackaging	Flexible	NA	0
37	PVC	Packaging	Flexible	NA	0

38	PVC	Nonpackaging	Multi	NA	0
39	PVC	Packaging	Multi	NA	0
40	PVC	Nonpackaging	Rigid	NA	0
41	PVC	Packaging	Rigid	NA	0.056
Note: All values are rounded to two significant figures.					

7.4.4 Disposal Module

Figure 7-3 depicts the boxes and flows that make up the disposal module, which includes incineration, landfills, and plastic-to-fuel (Section 7.4.3). In this component, unsorted managed waste flows to engineered landfills or incineration plants (with energy recovery). As in Lau et al. (2020), dump sites or unmanaged landfills are not included in the disposal module because they are considered mismanaged waste.

Figure 7-3. Disposal module



Unsorted waste exiting the waste collection and sorting module that is "managed" flows via Flow 25 into the disposal module and ends up in either incineration (Box O) or landfill (Box N). For these flows, we rely on data from Milbrandt (2024a) and Milbrandt (2024b), which provide state-level incineration and landfilling data by polymer. We aggregate that data to the regional level, applying the Milbrandt et al. (2022) polymer-plastic type proportions to arrive at the total amount of plastic waste that is either landfilled or incinerated by plastic type and region. We convert these into percentages for the inputs to the model, as shown below. These rates vary by polymer and region, but not by format or product type (Table 7-12). We assumed these rates remain constant over the modeling period.

$$Flow\ 28 = \frac{Incin_{Milbrandt}}{Landfill_{Milbrandt} + Incin_{Milbrandt}}$$

$$Flow\ 27 = 1 - Flow\ 28$$

Table 7-12. Incineration rates (Flow 28) by polymer

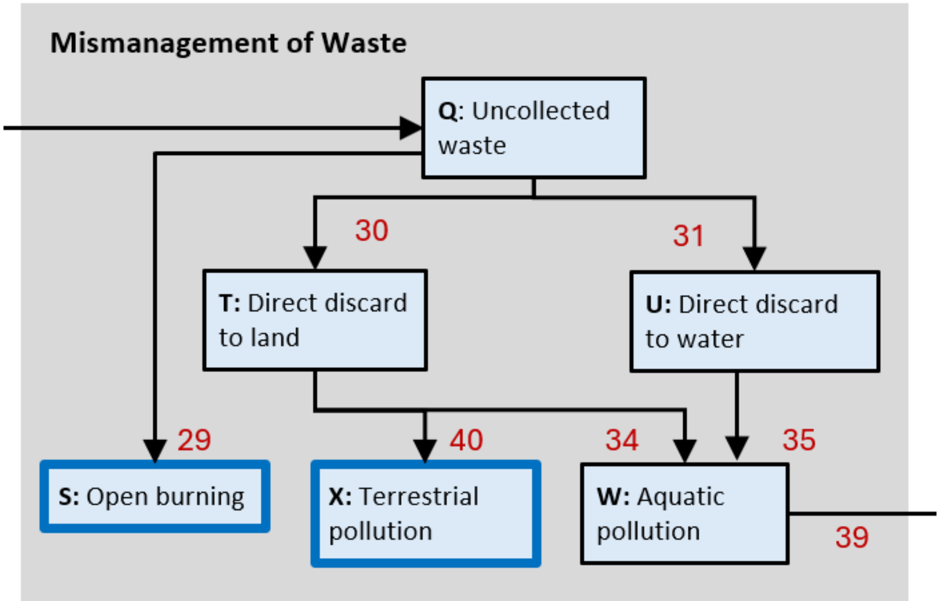
Polymer	Midwest	Northeast	Pacific	Rocky Mountain	Southeast	Southwest
HDPE	0.03	0.33	0.03	0	0.11	0.01
LDPE	0.03	0.34	0.03	0	0.11	0.01
Other	0.03	0.32	0.03	0	0.11	0.01
PET	0.02	0.33	0.03	0	0.13	0.01
PP	0.03	0.35	0.03	0	0.10	0.01
PS	0.02	0.30	0.03	0	0.11	0
PVC	0.03	0.34	0.03	0	0.11	0.01
Note: All values are rounded to two significant figures.						

7.4.5 Mismanaged Waste Module

Figure 7-4 depicts the boxes and flows included in the mismanagement of waste module. This module calculates the mass of plastic that is uncollected and littered (Flow 2) and the mass of plastic that is collected but, due to losses at various stages of the waste management system, ultimately becomes mismanaged (Flow 26). The module calculates the shares of each of these flows that ultimately become aquatic and terrestrial pollution. Due to data limitations for U.S.-specific data, all estimates of losses from littering and throughout the waste management system are rolled into the loss rate represented by Flow 2. Flow 26 is assumed to be zero in this model, and therefore all flows coming from Box R (collected mismanaged waste) are zero

All single-use plastic products are assumed to have a litter rate (Flow 2) of 3%. For materials with a DRS and reuse materials, we scaled this litter rate down to 1.5%. This is based on a study done by Keep America Beautiful (2021) that showed that states with bottle bills experience approximately half the litter rate per capita of states without bottle bills.

Figure 7-4. Mismanaged waste module



Waste enters the mismanagement of waste module only through Flow 2. For Flow 29, we assume that 10% of all uncollected waste is openly burned in the United States (Wiedinmyer et al., 2014; Jambeck, 2025). For Flows 30 and 31, we used the values for these flows from Lau et al. (2020) and scaled them to account for our assumption that 10% of waste entering Box Q is openly burned.

Once waste flows to the water, it moves to aquatic pollution (Flow 35). Once the plastic flows to land, it may then move to terrestrial pollution (Flow 40) or aquatic pollution (Flow 34). Flow 35 is set at 100% because it is the only flow leaving the direct discard to water box. We calculate 15% for Flow 34 using the EPA's Escaped Trash Risk Map (U.S. EPA, 2025b). Flow 40 is the complement of Flow 34.

$$Flow\ 40 = 1 - Flow\ 34$$

Flow 39, the collection of plastic waste from aquatic sources, was calculated from a preliminary Pathways run when Flow 39 was defined as an absolute flow (tons per year) as opposed to a relative flow. The initial tons per year value calculation is described below. Those mass values are now used as constraints on the flows. After Pathways was run with the preliminary values, we divided the resulting mass flows by the amount of mass entering the aquatic pollution box. We converted this flow to a relative flow because it allows for more flexibility in the system.

Constraint for Flow 39/preliminary run values for Flow 39: We calculated this by multiplying state-level tonnage from the Ocean Conservancy (2022), aggregated to the regional level, by the regional polymer percentage managed by the polymer-plastic type proportions from Milbrandt et al. (2022). We assumed that 50% of total collected waste is plastic in each region according to De Frond (2024). This is shown with the following formula.

$$Flow\ 39 = Regional\ tonnage\ (Ocean\ Conservancy, 2022) * regional\ polymer\ managed\ \%\ (Milbrandt\ el\ al., 2022) *\ Y1\ proportions$$

7.4.6 BAU Plastic Packaging MSW Growth Rates

Given that all but two of the flows are in percentage units and their shares are unlikely to change markedly over the modeling period, we have kept those flow values constant (i.e., the percentage flow values will not change over the time series), with the exception of Flow 11, which grows with the projected growth in the chemical conversion industry (see the Recycling Module). However, the mass flowing through those flows will increase along with the growth in waste generation and growth in imports.

We included in the modeling CAGR values for the two tonnage flows—Flow 42 (waste generation) and Flow 43 (import of plastic waste). The CAGR value for Flow 42 was calculated as follows:

$$Flow\ 42\ CAGR = (\left(\frac{35{,}680{,}000\ short\ tons\ plastic\ waste\ generated\ in\ 2018}{32{,}070{,}000\ short\ tons\ of\ plastic\ waste\ generated\ in\ 2012}\right)^{\frac{1}{6}} - 1) * 100$$

Where the plastic waste generated tonnage comes from U.S. EPA (2024c), which was identified as one of the few sources that provided such historical information for the United States over a time series.

The Flow 43 CAGR was estimated as 5% for all imported plastic types and calculated based on ICIS (2024) as the rate of growth in plastic scrap imports 2022 to 2023.

7.5 Detailed Methods for Modeling Impacts

Impacts detailed in the section include GHG emissions, CAPEX and OPEX, and jobs. We also present a summary of an additional analysis of potential revenues from recycling and incineration processes.

7.5.1 Greenhouse Gas Emissions

Table 7-13 provides a summary of the data sources identified for GHG impacts, measured in carbon dioxide (CO_2) equivalent units, at each stage of the value chain. Following is additional detail on how we used the data sources.

- For closed- and open-loop mechanical recycling, incineration, and landfilling, we used the GHG emissions estimates from the Waste Reduction Model (WARM), Version 16, documentation (U.S. EPA, 2023b). WARM provides emission estimates for PET, HDPE, PP, LDPE, LLDPE, PVS, PS/EPS, and mixed plastic in metric tons of carbon dioxide equivalent units per short ton ($MTCO_2e$/short ton). For recycled estimates, we summed the process energy and transport energy emission components and similarly converted to arrive at estimates in $MTCO_2e$/metric ton. For incineration, we summed the transport to combustion and CO_2 from combustion emission component estimates. For landfilling, we included the transport to landfill and equipment operation emissions. In the use of the WARM emission factors, we excluded the utility emissions offsets as that was outside the boundaries of this analysis.

- For formal and informal collection and formal sorting, we took emissions data from Lau et al. (2020), which are reflective of the global high-income urban geographic archetype.
- For chemical conversion (P2P and P2F) emissions estimates, we used data from Uekert et al. (2023) for pyrolysis by averaging the estimates reported in that study in Table S29 for PET, HDPE, and LDPE, and Lau et al. (2020) for PP, and applying to all plastic.

Table 7-13. GHG emissions data and sources

Phase	Specified Material	Data Sources Used	Data Year	Emissions Factor ($MTCO_2e/yr/ton$)	Geographic Scope & Notes
Formal collection	All plastic	Lau et al., 2020	2015	0.01736	Global high-income urban archetype
Formal sorting	All plastic	Lau et al., 2020	2015	0.04838	Global high-income urban archetype
Closed-loop MR	All plastic	U.S. EPA, 2023b	2023	PET: 0.91492 HDPE: 0.54013 PP: 0.51808 LDPE/LLDPE: 0.76059 PVC: 0.76059 PS/EPS: 0.76059 other: 0.76059	U.S.
Open-loop MR	All plastic	U.S. EPA, 2023b	2023	PET: 0.91492 HDPE: 0.054013 PP: 0.51808 LDPE/LLDPE: 0.76059 PVC: 0.76059 PS/EPS: 0.76059 other: 0.76059	U.S.
Chemical conversion P2P	PET, HDPE, LDPE, and PP	Uekert et al., 2023	2017	PET: 15.34 HDPE: 15.34 LDPE: 15.34 PP: 15.34 PVC: 15.34	U.S.

Phase	Specified Material	Data Sources Used	Data Year	Emissions Factor ($MTCO_2e$/yr/ton)	Geographic Scope & Notes
				PS/EPS: 15.34 other: 15.34	
Chemical conversion P2F	PET, HDPE, LDPE, and PP	Uekert et al., 2023	2017	PET: 15.34 HDPE: 15.34 LDPE: 15.34 PP: 15.34 PVC: 15.34 PS/EPS: 15.34 other: 15.34	U.S.
Incineration	All plastic	U.S. EPA, 2023b	2023	2.59	U.S.
Engineered landfills	All plastic	U.S. EPA, 2023b	2023	0.02204	U.S.

7.5.2 CAPEX and OPEX

Table 7-14 provides a summary of the data sources identified for capital and operational expenditures. Most of these data come from Lau et al. (2020). The table provides the raw cost data gathered for this report. All costs have been adjusted for inflation from their original dollar year to 2024 U.S. dollars using the Bureau of Labor Statistics' consumer price index.

Table 7-14. CAPEX/OPEX data and sources

Phase	Expenditure	Data Sources Used	Original Dollar Year	$/Weight/Year	Geographic Scope & Notes
Formal collection	OPEX	Lau et al., 2020	2016*	$202/metric ton	Global high-income urban archetype
Formal collection	CAPEX	Lau et al., 2020	2016*	$86/metric ton	Global high-income urban archetype
Informal collection and sorting	OPEX	Lau et al., 2020	2016*	$315/metric ton	Global high-income urban archetype
Informal collection and sorting	CAPEX	Lau et al., 2020	2016*	$0/metric ton	Global high-income urban archetype

Phase	Expenditure	Data Sources Used	Original Dollar Year	$/Weight/Year	Geographic Scope & Notes
Formal sorting	OPEX	The Recycling Partnership, 2021	2020	$82/metric ton	U.S.
Formal sorting	CAPEX	The Recycling Partnership, 2021	2020	$272/metric ton	U.S.
Closed-loop mech recycling	OPEX	Lau et al., 2020	2016*	$569/metric ton	Global high-income urban archetype
Closed-loop mech recycling	CAPEX	Lau et al., 2020	2016*	$160/metric ton	Global high-income urban archetype
Open-loop mech recycling	OPEX	Lau et al., 2020	2016*	$410/metric ton	Global high-income urban archetype
Open-loop mech recycling	CAPEX	Lau et al., 2020	2016*	$120/metric ton	Global high-income urban archetype
Chemical conversion P2P	OPEX	Lau et al., 2020	2016*	$402/metric ton	Global high-income urban archetype
Chemical conversion P2P	CAPEX	Lau et al., 2020	2019	$153/metric ton	Global high-income urban archetype
Chemical conversion P2F	OPEX	Lau et al., 2020	2019	$402/metric ton	Global high-income urban archetype
Chemical conversion P2F	CAPEX	Lau et al., 2020	2019	$153/metric ton	Global high-income urban archetype
Incineration	OPEX	Kaza et al., 2018	2018	$44-$55/metric ton	U.S.
Incineration	CAPEX	Kaza et al., 2018	2016	$600-$830/metric ton	U.S.
U.S. landfills (assume all engineered)	OPEX	EREF, 2024	2023	$51.60/metric ton	U.S.

Phase	Expenditure	Data Sources Used	Original Dollar Year	$/Weight/Year	Geographic Scope & Notes
Engineered landfills	CAPEX	Lau et al., 2020	2016*	$23/metric ton	Global high-income urban archetype
*For many Lau et al. (2020) cost factors, no dollar year was provided in the original documentation. We assume the dollar year is 2016 based on the publication dates of some of the sources provided in the documentation.					

7.5.3 Jobs

Table 7-15 provides a summary of the data sources identified for jobs. While we use U.S. data where possible, most of these data come from Lau et al. (2020). The U.S.-specific values from the Tellus Institute were developed using a combination of existing studies and survey tools to gather data.

Table 7-15. Jobs data and sources

Phase	Specified Material	Data Sources Used	Data Year	Jobs/Metric Ton/Year	Geographic Scope & Notes
Formal collection	Plastic	Tellus Institute, 2011	2008	0.0015	U.S.
Informal collection	Recyclables	Adapted from Lau et al., 2020	2019	0.08[11]	Global value adapted for U.S. context
Formal sorting	Plastic	Lau et al., 2020	2015	0.0017	EU-28
Closed-loop MR	Plastic	Lau et al., 2020	2015	0.003	EU-28
Open-loop MR	Plastic	Lau et al., 2020	2015	0.003	EU-28
Chemical conversion P2P	Plastic	Lau et al., 2020	2015	0.0013	EU-28
Chemical conversion P2F	Plastic	Lau et al., 2020	2015	0.0013	EU-28
Incineration	MSW	Tellus Institute, 2011	2008	0.0001	U.S.

[11] This value is based on the assumption that the informal sector collects 0.1% of beverage bottles (we assume fraction of canners is equivalent to fraction of bottles collected based on data from Eunomia on New York City canners). We than apply the formal/informal jobs ratio from Lau et al. (2020) to estimate informal jobs in the United States.

Phase	Specified Material	Data Sources Used	Data Year	Jobs/Metric Ton/Year	Geographic Scope & Notes
Engineered landfills	MSW	Tellus Institute, 2011	2008	0.0001	U.S.

The original value (0.015 jobs/1,000 metric tons) was converted from jobs per 1,000 metric tons of plastic waste displaced to jobs per 1,000 metric tons of reuse material used—embodying all of the cycles that reuse materials go through before being discarded.

7.6 Detailed Methods for Modeling the Policy Scenarios

This section provides reference tables associated with development of the policies modeled in this analysis.

7.6.1 Plastic Types Covered by Each Policy Scenario

The table below summarizes plastic types covered under each policy lever that make up the policy scenarios.

Table 7-16. Summary of plastic types covered by each policy

<table>
<tr><th>Policy Levers</th><th>Plastic Types</th></tr>
<tr><td>Material phaseout</td><td>• Flexible packaging (PVC, PS/EPS)
• Multimaterial packaging (PVC, PS/EPS)
• Rigid packaging (PVC, PS/EPS)</td></tr>
<tr><td>Design optimization</td><td>• Beverage and nonbeverage bottles (PET, HDPE)
• Flexible packaging and nonpackaging (HDPE, LDPE/LLDPE, PP, PS/EPS, PVC)
• Rigid packaging (PET, HDPE, LDPE/LLDPE, PP, PS/EPS, PVC)
• Multimaterial packaging (HDPE, LDPE/LLDPE, PET, PP, PS/EPS, PVC, other)</td></tr>
<tr><td>Reuse</td><td>• Beverage and nonbeverage bottles (PET, HDPE)
• Rigid packaging (PET, HDPE, PP, PS/EPS)
• Flexible packaging (HDPE, LDPE/LLDPE)
• Multimaterial packaging (PET, HDPE, PP, PS/EPS, LDPE)</td></tr>
<tr><td>Collection for recycling</td><td rowspan="2">• Beverage and nonbeverage bottles (PET, HDPE)
• Rigid packaging (PET, HDPE, PP)
• Flexible packaging (HDPE, LDPE)</td></tr>
<tr><td>Sorting losses</td></tr>
<tr><td>DRS</td><td>• Beverage bottles (PET, HDPE)</td></tr>
</table>

7.6.2 Material Phaseout and Design Optimization

The table below describes how certain private sector companies have been able to reduce plastic consumption (Triodos Investment Management, 2024).

Table 7-17. Change in weight of plastic used (tons)

Company	Plastic Used	Industry	2021	2022	2023	Intensity
Danone	PET, HDPE, PS, PP, LDPE	Dairy, food, and water	750,994	762,519	693,156	9%
Henkel	Not specified	Adhesive technology and consumer brands	304,420	306,222	281,485	9%
Procter & Gamble	PE, PET, PP	Consumer goods, mainly laundry & cleaning, paper, beaty care, food and beverage, and health care	NA	776,220	712,000	8% *OR* 3% adjusted for decline in units sold

7.6.3 Collection for Recycling and Sorting Losses

This section provides reference tables in support of the collection for recycling and sorting losses policy. Table 7-18 shows the sorting and process loss rates.

Table 7-18. Collection and recycling impacts under the BAU and policy scenarios in 2040

Policy	Collection Rate for Recycling[a]	Recycling Rate[b]
BAU	11%	6%
Collect	31%	16%
Sort	11%	7%
Collect and Sort combined	31%	19%

Note: All values are rounded to two significant figures.

[a] Calculated as the mass of plastic waste collected and sent to MRFs divided by the total mass of collected plastic waste.

[b] Calculated as the mass of plastic recyclate from mechanical recycling (both open-loop and closed-loop) and chemical conversion (plastic-to-plastic) divided by waste generated.

7.6.4 Reuse

The data provided in this section comes from a landscape review of reuse policies and underpins the technical methodology.

Table 7-19. Summary of global reuse targets

Location	Target	Product	Year	Source
Austria	25%	Beverage containers	2025	"Bundesrecht konsolidiert: Gesamte Rechtsvorschrift für Abfallwirtschaftsgesetz 2002, Fassung vom 30.11.2023."
Austria	30%	Beverage containers	2030	
California	2%	Plastic packaging	2027	California Legislature, "SB-54 Solid waste: reporting, packaging, and plastic food service ware." 2022.
California	4%	Plastic packaging	2030	
Chile	30%	Beverage containers	2024	Library of the National Congress of Chile, "LEY 21368 Firma electrónica REGULA LA ENTREGA DE PLÁSTICOS DE UN SOLO USO Y LAS BOTELLAS PLÁSTICAS, Y MODIFICA LOS CUERPOS LEGALES QUE INDICA." 2021.
France	5%	Packaging	2023	Legifrance, "LOI n° 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire (1)." 2020.
France	10%	Packaging	2027	
Germany	70%	Beverage containers	2022	Bundesgesetzblatt, "Gesetz zur Fortentwicklung der haushaltsnahen Getrennterfassung von wertstoffhaltigen Abfällen." 2017.
Portugal	30%	Packaging	2030	Law No. 52/2021
Romania	5%	Packaging	2020	The Government of Romania, "ORDONANŢĂ DE URGENŢĂ nr. 74." 2018.
Romania	30%	Packaging	2025	
Sweden	20%	Packaging	2026	A study, not a bill: European Environment Agency, "Waste management country profile with a focus on municipal and packaging waste." 2025.
Sweden	30%	Packaging	2030	

Table 7-20. Reuse targets by region*

Region	Coefficient Based on Urban Population	Beverage Bottles (High Target)	All Other Packaging (High Target)	Beverage Bottles (Low Target)	All Other Packaging (Low Target)
Pacific	1.26	34%	11%	11%	6%
Rocky Mountain	1.03	31%	10%	10%	5%
Northeast	1.03	31%	10%	10%	5%
Southwest	1	30%	10%	10%	5%
Midwest	0.93	28%	9%	9%	5%
Southeast	0.89	27%	9%	9%	4%
Note: *Targets rounded to the nearest whole percentage.					

Table 7-21. Reuse product categories and reusable materials

Sustainable Packaging Coalition Best Fit Categories	Polymer	ACC Use	Format in This Analysis	Proportion of Reuse Materials		
				Plastic (Rigid)	Glass	Metal
Beverage bottles	PET	Beverage bottles	Beverage bottles	50%	50%	0%
Beverage bottles	HDPE	Beverage bottles	Beverage bottles	50%	50%	0%
Food bottles	PET	Liquid food bottles	Nonbeverage bottle	30%	70%	0%
Food service, packaged food, home and personal care products	HDPE	Liquid food bottles, household chemical bottles, pharmaceuticals, cosmetics, toiletries	Nonbeverage bottle	60%	10%	30%
Food service/packaged food	PET	Food packaging	Rigid packaging	72.5%	10%	17.5%

Food service, packaged food, home and personal care products	HDPE	Tubs and containers	Rigid packaging	80%	20%	0%
Food service/packaged food	PP	Cups and containers	Rigid packaging	70%	0%	30%
Food service/packaged food	PS/EPS	Food packaging	Rigid packaging	100%	0%	0%
Food service/packaged food	LDPE/LLDPE	Food packaging	Flexible packaging	100%	0%	0%
Food service/packaged food	HDPE	Food packaging	Flexible packaging	100%	0%	0%

Table 7-22. Weight of single use and reusable bottles

Variable	Unit	1L Beverage Bottle		
		Single-Use PET	Reusable PET	Reusable Glass
Weight—packaging	Grams	26	55	520
Source: Ellen MacArthur Foundation (2023) Technical Appendix table on Page 19				

Pathways calculates the mass of reuse material needed to shift away from single-use material by taking the share of single-use mass demand that is specified to be shifted according to the targets above, multiplying that mass by the weight ratio of the specified reuse material compared to single-use materials, and then dividing by the life-cycle ratio of the reuse material (the number of times the material is used compared to a single use). This accounts for the increased weight of reuse materials, as well as the fact that less reuse material is needed to meet the same utility as single-use materials. Within reuse systems, reuse units are not always returned. We assume a return rate of 95% in this model, which means that 95% of the reuse materials are collected to be refilled during each reuse cycle. Logistically, this means that more reuse material will need to be produced to make up for the material that is not returned. We capture this in the model by increasing the weight ratios of each reuse material by the loss rate (equal to 1 minus the return rate).

To model the transition from flexible and multimaterial packaging to reuse, we mapped the Sustainable Packaging Coalition's "best fit" product categories (Sustainable Packaging Coalition, 2019) for reuse to the plastic use categories from the American Chemistry Council (an industry trade association for U.S. chemical companies), and aligning those categories with the Pew list of plastic types (see Section 7.6.4 for more detail). We used feedback from two experts in the reuse field to determine the shift of single-use plastic packaging to reusable plastic, metal, or glass, and the split between material options if there is more than one option. There is no category for multimaterial from the ACC; therefore, we assume the polymer set for multimaterial packaging is identical to that for rigid packaging transitioning to reuse. Additionally, we use existing literature to parameterize the mass of new reuse material to substitute for single-use plastic (i.e., PET plastic, metal, glass), the return rate, and the number of reuse cycles for each reuse material.

7.7 Detailed Methods for Microplastic Modeling

7.7.1 Geographic Scope

The framework for the microplastic modeling was adapted from *Breaking the Plastic Wave* (BPW). Where possible, we updated inputs with U.S.-specific data. When U.S.-specific data were not available, we used values from BPW high-income archetype data as a proxy for the U.S. Like modeling in *Breaking the Plastic Wave*, the U.S. is represented by two income archetypes: urban and rural.

We used 2020 U.S. Census Bureau data to calculate the proportion of the U.S. that lives in urban or rural areas. According to the bureau, urban areas are composed of "a densely settled core of census blocks that meet minimum housing unit density and/or population density requirements. This includes adjacent territory containing non-residential urban land uses. To qualify as an urban area, the territory identified according to criteria must encompass at least 2,000 housing units or have a population of at least 5,000."

7.7.2 Tires

Tire wear particles are released during normal vehicle use as tires abrade against road surfaces. These particles pose environmental risks not only due to their physical form but also because of the harmful chemicals they contain. One such chemical, 6PPD-quinone, has been shown to be toxic to coho salmon. Regulatory efforts to address tire wear are expanding, particularly through the European Union's Euro 7 regulatory framework to set tire abrasion limits and through emerging initiatives in the United States.

Given the challenges posed by tire wear, our focus is on upstream interventions to reduce tire particle generation from the source.

<u>Scope</u>

We modeled microplastic emissions from motorcycles, passenger vehicles (sedans and SUVs), heavy-duty vehicles, and airplanes.

Business as Usual

Mileage

We used Federal Highway Administration (2022) Traffic Volume Trends reports from 2018 to 2022 to calculate miles traveled on the road by vehicle type. The VM-1 reports document the annual mileage for light-duty short wheelbase, light-duty long wheelbase, motorcycles, buses, single-unit trucks, and combination trucks. Light-duty short wheelbase and light-duty long wheelbase represent passenger cars, light trucks, vans, and sport utility vehicles. Federal Highway Administration (2024) projects the annual percentage growth in mileage from 2019 to 2050 for all vehicle types except buses and motorcycles. Buses were assumed to have the average growth rate between single-unit trucks; combination trucks and motorcycles were assumed to have the same growth rate as light-duty vehicles. To simplify the vehicle types for the model, light-duty short and light-duty long vehicles were summed and reclassified as passenger vehicles, and buses, single-unit trucks, and combination trucks were summed and reclassified as heavy-duty vehicles.

Following the methodology of *Breaking the Plastic Wave*, passenger vehicles are split between passenger cars and light trucks. U.S. Department of Transportation (2022) provides vehicle registration data for passenger cars and light trucks. The relative proportion of passenger cars and light trucks were used to split passenger vehicle mileage between passenger cars and light trucks.

Federal Highway Administration (2023) was used to calculate the split between urban and rural driving. To match the methodology of *Breaking the Plastic Wave*, we cross-walked the FHWA and BPW data to create four road types:

Table 7-23. Crosswalk of FHWA and BPW road categories

FHWA Road Categories	BPW Road Categories
Urban other arterial	Urban road
Other urban	
Urban interstate	Urban motorway
Rural other arterial	Rural road
Other rural	
Rural interstate	Rural motorway

The mean travel for each road type was used to calculate the proportion of annual driving that occurs on each road type.

Tire Wear Rates

Tire wear rates were collected from studies that measured the mass of tire wear released per kilometer driven. Tire wear data for passenger vehicles come from the Allgemeiner Deutscher Automobil-Club (ADAC 2021). Tire wear data from ADAC consisted of both summer and winter tires. Most tire wear data from these two data sources are from studies based in Europe. Additional data sources for all vehicles include Lee et al. (2020), Kole et al. (2017), Verschoor (2016), Magnusson et al. (2016), Aatmeeyata & Sharma (2009), Hillenbrand et al. (2005), and Luhana et al. (2004). While tires formulated in Asia and Europe may differ from those in the U.S., these data were used as a proxy for the U.S. market due to the lack of publicly available data on losses from tires produced in or for the U.S.

For tire wear losses from flights, World Bank (2021) was used for flights departing from the U.S. between 2019 and 2021. To project flights from 2022 to 2040, International Air Transport Association (2024) provides the compound annual growth rate between 2023 and 2040. The growth rate for North America (2.7%) was used as the growth rate in the U.S. We multiplied the number of flights by the tire microplastic loss rate for airplanes (Kole et al., 2017).

To calculate tire wear emissions from the road, miles were converted to kilometers and multiplied by the tire wear rates (mg/km) to get the mass of tire wear particles (mg) lost by vehicle type. For airplanes, the number of flights was multiplied by the tire wear rate per takeoff.

Wastewater Treatment

About 16% of the U.S. population is connected to combined sewage systems, which collects both municipal wastewater and stormwater runoff for treatment at wastewater treatment facilities. According to Pitt et al. (2005), 9% of pollutants released onto streets are washed into surface waters, with the remaining 91% staying on land. We assume that of the 9% of microplastics that wash into surface waters, 16% of that surface water is collected by a combined sewage system, meaning that 1% of tire microplastics are captured in wastewater treatment, 8% washed into aquatic systems, and 91% remaining on land. Our assumption for aquatic losses are in line with tire microplastic losses in the San Francisco Bay (Moran et al., 2023).

The 2022 EPA Clean Watersheds Needs Survey provides the distribution of wastewater treatment across primary, secondary, and tertiary treatment types (U.S. EPA, 2022). The treatment proportions reported in 2022 were assumed to be representative of conditions from 2019 to 2022. The survey also reports on the distribution wastewater treatment levels in 2042 based on future infrastructure investments. Between 2023 and 2040, we model a linear growth to the projected distribution of wastewater treatment levels.

The Environmental Protection Agency also provides information on biosolid use and disposal from its biosolids annual reports. Based on the 2024 report, 59.5% of biosolids are applied to land, 24.5% landfilled, 14% incinerated, and 2% under other management practices such as storage (U.S. EPA, 2025a). Of the microplastics that are applied on land, the end uses include agriculture (53%), distribution and marketing (34.5%), reclamation (1.5%), and other (11%).

7.7.3 Textiles

Synthetic microfibers are released during the use phase of a garment. While microfibers could be lost when a garment is worn, most research has been focused on microfiber losses during washing.

Both upstream and downstream solutions have been proposed to prevent microfiber losses from entering the environment. Textile design, through changes in knitting techniques and yarn choice, could reduce microfiber shedding from a garment when it is worn or washed. Filters installed in washing machines can effectively capture microfibers in wash water, helping to prevent their release into wastewater systems. This approach shifts responsibility to consumers, who must then properly dispose of the collected lint.

Business as Usual

Microfiber Losses

The fiber loss rate from washing was calculated using data compiled from 10 studies that reported losses in milligram microfiber loss per kilogram textile washed (Vassilenko et al., 2021; De Falco et al., 2020; Fontana et al., 2020; Belzagui et al., 2019; De Falco et al., 2019; Kelly et al., 2019; Vassilenko et al., 2019; De Falco et al., 2018; Hernandez et al., 2017; Pirc et al., 2016). The fabrics tested varied in polymer type and construction, with polyester being the most represented material. Differences in experimental conditions, such as whether clothing was washed with or without detergent, were also observed. The average fiber loss rate across these studies was used as the microfiber loss rate from machine washing.

Microfiber losses during the textile production encompassed both clothing and other textiles. Data on global textile production were collected from the Textile Exchange's Preferred Fiber and Materials Market Reports for 2019 to 2023. To estimate the mass of synthetic textiles, the proportion of synthetic textiles purchased by developed economies (48.2%, Boucher & Friot, 2017) was applied to global textile production values. To attribute the share of global textile production in the U.S., U.S. market share data for textiles and clothing from World Trade Organization (2020) were applied to global textile production values for 2019 to 2022 and held constant through 2040.

Microfiber losses during washing were estimated using available demographic and behavioral data. Population data from the U.S. Census were combined with household size data from United Nations Population Division (2022) to calculate the number of households in the U.S. The number of wash cycles per household and the average load size per wash were collected from Pakula and Stamminger (2010). Following Boucher & Friot (2017), it was assumed that 48.2% of textiles washed consisted of synthetic fibers. The mass of synthetic textiles washed was multiplied by the average textile loss rate from washing to estimate the total mass of synthetic microfibers shed during the washing process.

Wastewater Treatment and Disposal

According to U.S. Census Bureau (2019), it is estimated that 83% of households are connected to a public sewer. Wastewater treatment levels and the fate of biosolids collected from wastewater treatment were modeled using the same methodology applied to tire wear particles collected from wastewater treatment described in the tires methodology.

Synthetic microfibers captured in water filters were assumed to be managed in solid waste. The split between engineered landfills and incineration was based on national-level waste management data. According to Milbrandt et al. (2022), 90% of MSW plastic waste managed was landfilled and 10% was incinerated. We used the same proportions to estimate disposal of synthetic microfibers captured in filters.

7.8 Detailed Policy Scenario Results

The main report presents summary results for each policy and the combined policy scenario. For policies with both high and low targets, the main report presents results using the high targets. This section of the Technical Appendix provides additional results for the policies and combined policy scenario using the high targets and also provides results using the low targets for comparison.

7.8.1 Additional Results Using High Targets

Table 7-24. Changes in annual packaging mass (million tons) at key life-cycle stages under each policy and the combined policy scenario relative to BAU in 2040 (includes all reuse materials)

Life-Cycle Stage	BAU	Phaseout & Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Waste generation	39	-20%	0%	0%	-6.4%	-25%
Closed-loop recycling	1.5	-17%	180%	200%	3.8%	170%
Open-loop recycling	1	-19%	250%	61%	-11%	150%
Chemical conversion (plastic-to-plastic)	0.03	-20%	-22%	-13%	-10%	-47%
Chemical conversion (plastic-to-fuel)	0.32	-20%	-22%	-13%	-10%	-47%
Landfilling	32	-20%	-17%	-12%	-7.2%	-41%
Incineration	3.6	-20%	-18%	-12%	-3%	-38%
Aquatic pollution	0.23	-20%	0%	-8.4%	-12%	-35%
Terrestrial pollution	0.83	-20%	0%	-8%	-0.2%	-25%
Open burning	0.12	-20%	0%	-8.4%	-12%	-35%
Note: All values are rounded to two significant figures.						

Table 7-25. Mass of recyclate in 2040 under BAU and Collect and Sort scenarios (millions tons)

Region	BAU	Collect & Sort
Midwest	0.48	1.6 (+240%)
Northeast	0.73	1.8 (+150%)
Pacific	0.65	1.4 (+120%)
Rocky Mountain	0.087	0.37 (+330%)
Southeast	0.33	1.4 (+320%)
Southwest	0.23	0.95 (+320%)
Note: All values are rounded to two significant figures.		

Table 7-26. GHG emissions associated with waste management in 2040 (million metric tons CO_2e) with absolute and percentage change from BAU (includes all plastic and reuse materials, including plastic substitutes)

Life-Cycle Stage	BAU	Phaseout & Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Collection and sorting	1.4	-0.16 (-11%)	0.33 (24%)	0.19 (14%)	-0.052 (-3.9%)	0.057 (4.2%)
Closed-loop recycling	1.2	-0.21 (-17%)	2.1 (170%)	2.7 (220%)	0.046 (3.7%)	2.1 (170%)
Open-loop recycling	1.1	-0.16 (-14%)	2.3 (210%)	0.49 (44%)	-0.092 (-8.3%)	1.3 (120%)
Chemical conversion (plastic-to-plastic)	0.8	-0.086 (-10%)	-0.094 (-11%)	-0.055 (-6.7%)	-0.044 (-5.4%)	-0.2 (-24%)
Chemical conversion (plastic-to-fuel)	8.8	-0.91 (-10%)	-1 (-11%)	-0.58 (-6.7%)	-0.47 (-5.4%)	-2.1 (-24%)
Landfilling	1.2	-0.13 (-10%)	-0.11 (-8.8%)	-0.074 (-6.1%)	-0.045 (-3.7%)	-0.26 (-21%)
Incineration	16	-1.7 (-10%)	-1.5 (-10%)	-0.97 (-6%)	-0.26 (-1.6%)	-3.2 (-20%)
Note: All values are rounded to two significant figures.						

Table 7-27. Costs by life-cycle stage by scenario in 2040 (billions USD) with percentage change from BAU (includes all plastic and reuse materials, including plastic substitutes)

Life-Cycle Stage	BAU	Phaseout & Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Collection and sorting	26	23 (-11%)	28 (9.1%)	27 (5.5%)	25 (-3.6%)	24 (-6.8%)
Closed-loop recycling	1.3	1.1 (-17%)	3.4 (170%)	3.6 (180%)	1.3 (1%)	3.2 (150%)
Open-loop recycling	0.89	0.77 (-14%)	2.7 (200%)	1.2 (39%)	0.82 (-8.5%)	2 (120%)
Chemical conversion (plastic-to-plastic)	0.03	0.03 (-10%)	0.029 (-11%)	0.031 (-6.4%)	0.031 (-5.3%)	0.025 (-23%)
Chemical conversion (plastic-to-fuel)	0.35	0.31 (-10%)	0.31 (-11%)	0.33 (-6.4%)	0.33 (-5.3%)	0.27 (-23%)
Landfilling	4.6	4.1 (-10%)	4.2 (-8.8%)	4.3 (-6.1%)	4.4 (-3.7%)	3.6 (-21%)
Incineration	6.6	6 (-10%)	6 (-10%)	6.2 (-6%)	6.5 (-1.6%)	5.3 (-20%)
Note: All values are rounded to two significant figures.						

Table 7-28. Jobs by life-cycle stage by scenario in 2040 (thousands of jobs) with percentage change from BAU (includes all plastic and reuse materials, including plastic substitutes)

Life-Cycle Stage	BAU	Phaseout & Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Collection and sorting	130	110 (-11%)	140 (9.2%)	130 (5.6%)	120 (-3.7%)	120 (-6.9%)
Closed-loop recycling	4.6	3.8 (-17%)	13 (180%)	14 (200%)	4.6 (1.1%)	12 (160%)
Open-loop recycling	4.4	3.8 (-14%)	14 (220%)	6.2 (42%)	4 (-8.6%)	10 (130%)
Chemical conversion	0.070	0.063 (-10%)	0.062 (-11%)	0.065 (-6.7%)	0.066 (-5.4%)	0.053 (-24%)

(plastic-to-plastic)						
Chemical conversion (plastic-to-fuel)	0.74	0.67 (-10%)	0.66 (-11%)	0.69 (-6.7%)	0.7 (-5.4%)	0.57 (-24%)
Landfilling	6.1	5.4 (-10%)	5.5 (-8.8%)	5.7 (-6.1%)	5.8 (-3.7%)	4.8 (-21%)
Incineration	0.69	0.62 (-10%)	0.62 (-10%)	0.65 (-6%)	0.68 (-1.6%)	0.55 (-20%)
Note: All values are rounded to two significant figures.						

7.8.2 Results Using Low Targets

Table 7-29. Changes in annual packaging mass (million tons) at key life-cycle stages under each policy and the combined policy scenario relative to BAU in 2040 (includes all reuse materials)—low scenarios

Life-Cycle Stage	BAU 2040	Phaseout & Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Collection and sorting	39	-10%	0%	0%	-3%	-13%
Closed-loop recycling	1.5	-8.1%	100%	150%	1.5%	170%
Open-loop recycling	1	-10%	110%	44%	-4%	100%
Chemical conversion (plastic-to-plastic)	0.03	-10%	-10%	-9.4%	-4.5%	-29%
Chemical conversion (plastic-to-fuel)	0.32	-10%	-10%	-9.4%	-4.5%	-29%
Landfilling	32	-10%	-8.5%	-8.5%	-3.3%	-25%
Incineration	3.6	-9.8%	-11%	-8.3%	-1.9%	-25%
Aquatic pollution	0.23	-10%	0%	-6.1%	-5.1%	-20%
Terrestrial pollution	0.83	-10%	0%	-6%	-0.9%	-16%

Open Burning	0.12	-10%	0%	-6%	-5.1%	-20%

Note: All values are rounded to two significant figures.

Table 7-30. Mass of recyclate in 2040 under BAU and collect and sort scenarios (millions tons)—low scenarios

Region	BAU 2040	Collect & Sort
Midwest	0.48	1 (+120%)
Northeast	0.73	1.5 (+110%)
Pacific	0.65	1.2 (+87%)
Rocky Mountain	0.087	0.19 (+120%)
Southeast	0.33	0.69 (+110%)
Southwest	0.23	0.48 (+110%)
Note: All values are rounded to two significant figures.		

Table 7-31. GHG emissions associated with waste management in 2040 (million metric tons CO_2e) with absolute and percentage change from BAU (includes all plastic and reuse materials, including plastic substitutes)—low scenarios

Life-Cycle Stage	BAU	Phaseout & Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Collection and sorting	1.4	-0.076 (-5.6%)	0.16 (11%)	0.14 (10%)	-0.023 (-1.7%)	0.097 (7.1%)
Closed-loop recycling	1.2	-0.096 (-7.7%)	1.3 (100%)	2 (160%)	0.02 (1.6%)	2.2 (170%)
Open-loop recycling	1.1	-0.081 (-7.3%)	1 (90%)	0.35 (32%)	-0.033 (-3.0%)	0.78 (70%)
Chemical conversion (plastic-to-plastic)	0.8	-0.043 (-5.2%)	-0.044 (-5.4%)	-0.04 (-4.8%)	-0.019 (-2.3%)	-0.12 (-14%)
Chemical conversion (plastic-to-fuel)	8.8	-0.46 (-5.2%)	-0.47 (-5.4%)	-0.42 (-4.8%)	-0.2 (-2.3%)	-1.2 (-14%)
Landfilling	1.2	-0.063 (-5.2%)	-0.053 (-4.4%)	-0.054 (-4.4%)	-0.021 (-1.7%)	-0.16 (-13%)

Incineration	16	-0.82 (-5.1%)	-0.93 (-5.7%)	-0.7 (-4.3%)	-0.16 (-1%)	-2.1 (-13%)

Note: All values are rounded to two significant figures.

Table 7-32. Costs by life-cycle stage by scenario in 2040 (billions USD) with percentage change from BAU (includes all plastic and reuse materials, including plastic substitutes)—low scenarios

Life-Cycle Stage	BAU	Phaseout& Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Collection and sorting	26	24 (-5.5%)	27 (4.4%)	27 (4%)	25 (-1.6%)	25 (-1.5%)
Closed-loop recycling	1.3	1.2 (-7.8%)	2.6 (100%)	3 (130%)	1.3 (0.6%)	3.2 (150%)
Open-loop recycling	0.89	0.83 (-7.1%)	1.7 (88%)	1.1 (29%)	0.86 (-3.1%)	1.5 (69%)
Chemical conversion (plastic-to-plastic)	0.033	0.031 (-5.1%)	0.031 (-5.3%)	0.031 (-4.6%)	0.032 (-2.2%)	0.028 (-14%)
Chemical conversion (plastic-to-fuel)	0.35	0.33 (-5.1%)	0.33 (-5.3%)	0.33 (-4.6%)	0.34 (-2.2%)	0.3 (-14%)
Landfilling	4.6	4.3 (-5.2%)	4.4 (-4.4%)	4.4 (-4.4%)	4.5 (-1.7%)	4 (-13%)
Incineration	6.6	6.3 (-5.1%)	6.3 (-5.7%)	6.4 (-4.3%)	6.6 (-1%)	5.8 (-13%)
Note: All values are rounded to two significant figures.						

Table 7-33. Jobs by life-cycle stage by scenario in 2040 (thousands of jobs) with percentage change from BAU (includes all plastic and reuse materials, including plastic substitutes)—low scenarios

Life-Cycle Stage	BAU	Phaseout & Optimize	Collect & Sort	Deposit Return Scheme	Reuse	Combined Policy Scenario
Collection and sorting	130	120	130	130	120	120

		(-5.6%)	(4.4%)	(4.1%)	(-1.6%)	(-1.5%)
Closed-loop recycling	4.6	4.2 (-7.9%)	9.3 (100%)	11 (140%)	4.6 (0.58%)	12 (160%)
Open-loop recycling	4.4	4.1 (-7.1%)	8.4 (92%)	5.7 (30%)	4.3 (-3.2%)	7.6 (72%)
Chemical conversion (plastic-to-plastic)	0.070	0.066 (-5.2%)	0.066 (-5.4%)	0.067 (-4.8%)	0.068 (-2.3%)	0.06 (-14%)
Chemical conversion (plastic-to-fuel)	0.74	0.7 (-5.2%)	0.7 (-5.4%)	0.71 (-4.8%)	0.73 (-2.3%)	0.64 (-14%)
Landfilling	6.1	5.7 (-5.2%)	5.8 (-4.4%)	5.8 (-4.4%)	5.9 (-1.7%)	5.3 (-13%)
Incineration	0.69	0.65 (-5.1%)	0.65 (-5.7%)	0.66 (-4.3%)	0.68 (-1%)	0.6 (-13%)

Note: All values are rounded to two significant figures.

7.8.3 Monte Carlo Analysis Results for Plastic Packaging

This section summarizes data from 200 Monte Carlo simulations. We calculated the percent change between each policy scenario and BAU for each individual model run and then summarized the results using the mean and the 5th and 95th percentiles. This approach reflects the full distribution of model outcomes and captures the range of uncertainty of the model. In contrast, the main report presents percent changes based on the mean outcomes of the policy scenarios relative to BAU. These values represent point estimates and do not incorporate uncertainty across model runs. Because the technical appendix and the main report use different calculations to summarize results, the mean percent change may not match exactly; however, the overall direction and qualitative interpretation remain the same.

Table 7-34. Monte Carlo mass (million tons) results by life-cycle stage (plastic packaging, including reuseable plastic)—high scenarios only

Life-Cycle Stage	2025	BAU 2040	Deposit Return Scheme	Phaseout & Optimize	Collect & Sort	Reuse	Combined Policy Scenario
Waste generated	30 (30, 30)*	39 (39, 39)*	0% (0%, 0%)	-20% (-20%, -20%)*	0% (0%, 0%)	-11% (-11%, -11%)*	-29% (-29%, -29%)*
Total recycling	2.4 (1.5, 4.1)	3.2 (2.1, 5.5)	120% (7.2%, 230%)	-11% (-62%, 61%)	170% (43%, 320%)	-21% (-68%, 52%)	110% (17%, 220%)
Closed-loop recycling	*1.5 (0.86, 2.7)*	*2 (1.1, 3.6)*	*160% (21%, 340%)*	*-8.7% (-64%, 78%)*	*150% (20%, 290%)*	*-22% (-71%, 63%)*	*100% (-5.9%, 230%)*
Open-loop recycling	*0.92 (0.52, 1.5)*	*1.2 (0.7, 1.9)*	*61% (-42%, 200%)*	*-8.2% (-60%, 89%)*	*230% (73%, 450%)*	*-15% (-66%, 71%)*	*130% (12%, 300%)*
Chemical conversion (plastic-to-plastic)	0.011 (0.0059, 0.017)	0.029 (0.016, 0.046)	0.2% (-61%, 94%)	-11% (-63%, 71%)	-12% (-59%, 67%)	0.52% (-52%, 84%)	-41% (-75%, 11%)
Chemical conversion (plastic-to-fuel)	0.12 (0.078, 0.16)	0.31 (0.21, 0.42)	-8.8% (-49%, 52%)	-18% (-54%, 32%)	-18% (-54%, 34%)	-6.7% (-49%, 45%)	-45% (-69%, -14%)

Landfill	24 (22, 25)	31 (29, 32)	-10% (-17%, -3.1%)	-20% (-26%, -13%)	-16% (-23%, -9.4%)	-10% (-17%, -3.9%)	-43% (-47%, -38%)
Incineration	2.8 (2.3, 3.2)	3.6 (2.9, 4.1)	-10% (-34%, 17%)	-20% (-38%, 0.32%)	-17% (-37%, 8.8%)	-11% (-33%, 18%)	-44% (-57%, -29%)
Total pollution	0.9 (0.74, 1.1)	1.2 (0.97, 1.4)	-6.9% (-29%, 17%)	-18% (-39%, 5.1%)	2.3% (-22%, 32%)	-10% (-33%, 13%)	-34% (-49%, -14%)
Aquatic pollution	*0.18* *(0.14, 0.23)*	*0.23* *(0.18, 0.3)*	*-6.2%* *(-33%, 24%)*	*-17%* *(-45%, 15%)*	*3.9%* *(-26%, 44%)*	*-9.5%* *(-39%, 24%)*	*-33%* *(-53%, -4.2%)*
Terrestrial pollution	*0.63* *(0.52, 0.77)*	*0.83* *(0.68, 1)*	*-6.8%* *(-31%, 17%)*	*-19%* *(-39%, 3.8%)*	*2.1%* *(-23%, 34%)*	*-11%* *(-34%, 15%)*	*-34%* *(-50%, -14%)*
Open burning	*0.089* *(0.046, 0.14)*	*0.12* *(0.06, 0.18)*	*3.5%* *(-56%, 98%)*	*-6%* *(-62%, 94%)*	*14%* *(-52%, 140%)*	*0.92%* *(-57%, 99%)*	*-26%* *(-68%, 41%)*

Note: All values are rounded to two significant figures.

**The lower and upper bounds for the Monte Carlo range for this parameter differ slightly, but the difference is not reflected when rounding to two significant figures.*

The blue highlighted rows sum to the white row above the blue highlighted rows.

Table 7-35. Monte Carlo GHG emission results by life-cycle stage (includes all plastic and reuse materialshigh scenarios only

Life-Cycle Stage	2025	BAU 2040	Phaseout & Optimize	Collect & Sort	DRS	Reuse	Combined
Collection and sorting	0.98 (0.84, 1.1)	1.3 (1.1, 1.4)	-10% (-29%, 6.6%)	25% (3.6%, 55%)	13% (-8.6%, 35%)	-3.7% (-21%, 17%)	2.9% (-15%, 24%)
Mechanical recycling	2.6 (1.4, 5.1)	3.5 (2, 7)	1.5% (-70%, 130%)	160% (7.8%, 350%)	110% (-22%, 300%)	6% (-68%, 140%)	120% (-8.7%, 290%)
Chemical conversion	3.4 (2.3, 4.6)	9.1 (6.2, 12)	-7.8% (-49%, 49%)	-6.4% (-46%, 51%)	-2.6% (-47%, 61%)	-1.1% (-46%, 56%)	-20% (-54%, 23%)
Landfilling	0.9 (0.82, 0.99)	1.2 (1.1, 1.3)	-10% (-22%, 3.1%)	-8.4% (-20%, 4.5%)	-5.5% (-17%, 6.2%)	-3.5% (-17%, 11%)	-20% (-30%, -9.3%)
Incineration	13 (9.8, 16)	16 (13, 19)	-10% (-37%, 21%)	-8% (-36%, 23%)	-4.8% (-31%, 26%)	-1.2% (-31%, 34%)	-18% (-40%, 7.8%)
Total	20 (17, 24)	31 (27, 36)	-11% (-29%, 8.9%)	6.9% (-14%, 28%)	4.9% (-15%, 29%)	-4% (-23%, 23%)	-7.3% (-24%, 15%)
Note: All values are rounded to two significant figures.							

Table 7-36. Monte Carlo cost (billions USD) results by life-cycle stage (includes all plastic and reuse materialshigh scenarios only

Life-Cycle Stage	2025	BAU 2040	Phaseout & Optimize	Collect & Sort	DRS	Reuse	Combined
Collection and sorting	19 (16, 21)	25 (21, 28)	-11% (-29%, 7.4%)	10% (-11%, 34%)	4.9% (-15%, 29%)	-2.8% (-25%, 18%)	-8% (-24%, 9%)
Mechanical recycling	2.7 (1.4, 5.7)	3.4 (1.8, 7.1)	4.5% (-72%, 150%)	160% (-1.8%, 370%)	110% (-33%, 310%)	8% (-71%, 160%)	110% (-18%, 320%)
Chemical conversion	0.15 (0.1, 0.2)	0.37 (0.25, 0.5)	-7.8% (-51%, 48%)	-6.4% (-47%, 51%)	-2.7% (-46%, 56%)	-1.2% (-48%, 62%)	-20% (-53%, 26%)
Landfilling	3.4 (3.1, 3.7)	4.5 (4.2, 4.8)	-10% (-20%, -1.5%)	-8.5% (-18%, 1.7%)	-5.3% (-16%, 6.5%)	-3.4% (-13%, 6%)	-21% (-30%, -13%)
Incineration	5.2 (3.7, 6.7)	6.6 (5, 8.4)	-11% (-42%, 33%)	-8% (-39%, 24%)	-4.7% (-37%, 39%)	0.98% (-35%, 46%)	-18% (-44%, 13%)
Total	30 (28, 33)	40 (36, 43)	-11% (-22%, 0.58%)	13% (-0.13%, 26%)	6.9% (-5.3%, 20%)	-3.7% (-15%, 8.2%)	-4.5% (-15%, 6.8%)

Note: All values are rounded to two significant figures.

Table 7-37. Monte Carlo job results (thousands of jobs) by life-cycle stage (includes all plastic and reuse materials)—high scenarios

Life-Cycle Stage	2025	BAU 2040	Phaseout & Optimize	Collect & Sort	DRS	Reuse	Combined
Collection and sorting	110 (87, 160)	150 (110, 210)	-8.9% (-43%, 39%)	12% (-30%, 61%)	9% (-33%, 76%)	-7.3% (-40%, 32%)	-12% (-41%, 20%)
Mechanical recycling	10 (5.5, 21)	14 (7.6, 28)	3.9% (-72%, 140%)	160% (3.1%, 360%)	100% (-31%, 310%)	6.4% (-71%, 150%)	120% (-11%, 290%)
Chemical conversion	0.29 (0.2, 0.4)	0.77 (0.54, 1.1)	-7.6% (-49%, 48%)	-5.6% (-46%, 52%)	-2.3% (-45%, 60%)	-0.52% (-47%, 56%)	-20% (-54%, 23%)
Landfilling	4.5 (3.9, 5.2)	5.9 (5, 6.8)	-9.4% (-28%, 7%)	-8.8% (-26%, 12%)	-5% (-24%, 17%)	-3.7% (-21%, 16%)	-20% (-36%, 1.8%)
Incineration	0.54 (0.39, 0.68)	0.68 (0.5, 0.9)	-10% (-44%, 31%)	-6.1% (-41%, 42%)	-3.4% (-37%, 43%)	0.43% (-38%, 44%)	-19% (-47%, 20%)
Total	130 (99, 180)	170 (130, 240)	-8.6% (-45%, 44%)	21% (-25%, 74%)	14% (-31%, 84%)	-6.8% (-42%, 33%)	-3.4% (-36%, 35%)
Note: All values are rounded to two significant figures.							

7.8.4 Monte Carlo Analysis Results for Microplastics

Table 7-38. Mass of tire wear particles in 2040 BAU and policy scenarios with 95% Monte Carlo ranges (5th-95th percentiles; million tons)

Stage	BAU	Reduce Abrasion	Reduce Mileage	Ban Biosolids Application to Agricultural Land	Combined
Tire wear particle generation	1.2 (0.97, 1.4)	-15% (-14%, -14%)	-0.76% (-0.76%, -0.76%)	0% (0%, 0%)	-15% (-15%, -15%)
Pollution	1.2 (0.97, 1.4)	-15% (-14%, -14%)	-0.76% (-0.76%, -0.76%)	-0.19% (-0.18%, -0.16%)	-15% (-15%, -15%)
Note: All values are rounded to two significant figures.					

Table 7-39. Mass of synthetic microfibers in 2040 BAU and policy scenarios with 95% Monte Carlo ranges (5th-95% percentiles; million tons)

Stage	BAU	Reduce Shedding	Install Filters	Ban Biosolids Application to Agricultural Land	Combined
Synthetic microfiber generation	0.008 (0.0059, 0.01)	-49% (-49%, -49%)	0% (0%, 0%)	0% (0%, 0%)	-49% (-49%, -49%)
Pollution	0.0057 (0.0041, 0.0074)	-49% (-49%, -49%)	-15% (-15%, -14%)	-33% (-38%, -31%)	-69% (-72%, -68%)
Note: All values are rounded to two significant figures.					

Glossary

CAPEX (capital expenditures): Funds used by an organization to acquire or upgrade assets such as property, buildings, technology, or equipment.

Chemical conversion: Process that breaks down polymers into individual monomers or other hydrocarbon products that can then serve as building blocks or feedstock to produce polymers again.

Circular economy: One that is restorative and regenerative by design. It looks beyond the take-make-waste extractive industrial model and aims to redefine growth, focusing on positive society-wide benefits. It is based on three principles: design out waste and pollution, keep products and materials in use, and regenerate natural systems.

Closed-loop mechanical recycling: When plastic is physically reprocessed and the material produced, called recyclate, is used to make another product in the same category, such as when PET bottles are recycled into new PET bottles.

Design for recycling: The process by which companies design their products and packaging to be recyclable.

Downstream: The postconsumer phase of a product or material life cycle, including waste management (e.g., collection, sorting, recycling, and disposal) and mismanagement (e.g., aquatic pollution, open burning, dumping).

End of life: A generalized term to describe the final fates, be they disposal, recycling, or pollution, for waste products.

Extended producer responsibility (EPR): Schemes that enable producers to contribute to the end-of-life costs of products they place on the market.

Feedstock: Any bulk raw material that is the principal input for an industrial production process.

Flexible packaging: Monomaterial films, wraps, or bags, which may be single- or multilayer.

Formal waste sector: An established system of publicly or privately managed collection and disposal, often organized or funded by local governments.

Incineration: Destruction and transformation of material to energy by combustion.

Informal waste sector: Individuals or enterprises involved in private sector recycling and waste management activities that are not sponsored, financed, recognized, supported, organized, or acknowledged by the formal solid waste authorities.

Mechanical recycling: Process for physically converting plastic waste into secondary raw materials or products without significantly changing its chemical structure, such as by crushing, shredding, washing, and extruding.

Microfibers: Microplastic released via shedding during textile production or use.

Microplastics: Plastic particles of less than 5 mm in size.

> **Primary microplastics** are intentionally produced tiny particles, such as pellets and microbeads.
>
> **Secondary microplastics** originate from the degradation of larger plastics during use or when exposed to the environment.

Mismanaged waste: Rubbish or excess material that has been intentionally or otherwise released in a place from which it can move into the natural environment such as uncontrolled landfills that do not receive daily cover to prevent their contents from interacting with the air or with surface water.

Multilayer plastics: An item, usually packaging, made of multiple plastic polymers that cannot be easily and mechanically separated.

Multimaterial: An item, usually packaging, made of plastic and nonplastic materials (such as thin metal foils or cardboard layers) that cannot be easily and mechanically separated.

Municipal solid waste (MSW): Includes all residential and commercial waste except industrial waste.

Open burning: Waste that is combusted without emissions cleaning.

Open-loop recycling: Process by which polymers are kept intact, but the degraded quality and/or material properties of the recycled material is used in applications that might otherwise not be using plastic (i.e., benches, asphalt).

OPEX (operating expenses): Costs incurred in the course of regular business, such as general and administrative costs, sales and marketing, or research and development.

Pellets: Microplastics, usually cylinders or disks, produced as a raw material and from plastic recycling for use in plastic products.

Plastic A synthetic material consisting of polymers; additives, such as plasticizers, stabilizers, and pigments; and other chemicals that are often impurities, byproducts, or breakdown products.[12]

Plastic-to-fuel (P2F): Process by which the output material of chemical conversion plants is refined into alternative fuels such as diesel.

Plastic-to-plastic (P2P): Several chemical conversion technologies are being developed that can produce petrochemical feedstock that can be reintroduced into the petrochemical process to produce primary-like plastic—a route that we define as plastic-to-plastic (P2P).

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[12] Seewoo et al., 2023

Plastic life cycle: Consecutive and interlinked stages of the life of plastic material (International Organization for Standardization (ISO)).

Plastic pollution: Plastic that ends up in the natural environment, through land, water, or air. In our modeling, this is reflected in annual mass of micro- and MSW plastic in terrestrial pollution, aquatic pollution, or opening burning.

Recyclable: For something to be deemed recyclable, the system must be in place for it to be collected, sorted, reprocessed, and manufactured back into a new product or packaging—at scale and economically. Recyclable is used here as shorthand for "mechanically recyclable."

Recycling rate: The mass of plastic waste that is processed via mechanical recycling or plastic-to-plastic chemical conversion.

Single-use plastic: A product made wholly or partly from plastic that is not conceived, designed, or placed on the market to accomplish, within its life span, multiple trips or rotations by being returned to a producer for refill or reused for the same purpose for which it was conceived.

Substitute: Alternative materials to plastic, including glass, metal, paper, and compostables.

System map: A visual illustration of the main flows and stocks of the global plastic system. For the purposes of this project, we have collected, calculated, or estimated values for each of the arrows and boxes in each of the system maps on a global level, per geographic archetype and per plastic category.

Tire dust: Microparticles released through mechanical abrasion of tires.

Upstream: The portion of the plastic life cycle that includes raw material extraction, production, and use of chemical feedstock, monomers, polymers, and products.

Value chain: Refers to a product life cycle and the activities required to create and send the product to the consumer. A circular value chain extends the traditional product life cycle by incorporating activities to minimize waste and keep materials in use, regaining value from products and materials within a closed-loop system to maximize resource use and reduce environmental impact.

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