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The Waste Diversion

Benefits of Expanding

STUART MALEC

PROGRESSIVE POLICY INSTITUTE
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Contents

EXECUTIVE SUMMARY 03

INTRODUCTION 04

LANDSCAPE ASSESSMENT 05

Recycling Rates in the U.S. 06

Key Barriers to Effective Recycling 09

Efforts to Improve U.S. Recycling Rates 09

National Recycling Strategy 09

State and Regional Recycling Programs 10

Voluntary Standards and Credit Programs 12

ADVANCED RECYCLING CAPACITY POTENTIAL 14

Announced Projects 14

Deployment Scenarios 15

DIVERSION ANALYSIS 17

Methodology 17

National Results 18

State-Level Results 19

Diverted Plastic 19

Municipal Landfill Cost Savings 23

Case Study: Los Angeles, CA and Harris County, TX 23

CONCLUSIONS 24

APPENDIX 26

The Waste Diversion Benefits of Expanding

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EXECUTIVE SUMMARY

Advanced recycling offers a unique potential solution to the problem of plastic waste. Conventional mechanical recycling is limited by technological and logistical issues, particularly the inability to process plastic waste contaminated by food or oil residue. Mechanical recycling is also not designed to recycle the millions of tons of flexible plastics (e.g., shopping bags and plastic films) generated each year, which means those plastic products must be sent to landfills. Existing recycling initiatives have shown promise, but not at the scale required to meaningfully reduce the amount of plastic waste that ends up in landfills.

A distinct advantage of advanced recycling over mechanical recycling is that, through chemical processes like pyrolysis, advanced recycling facilities can reduce plastics down to the molecular level. This means that a broader range of plastics, including flexible plastics, can be recycled at advanced recycling facilities compared to mechanical ones. Advanced recycling facilities are complementary to existing mechanical recycling facilities: together, both types of facilities form an “all-of-the-above” solution to recycling plastic waste.

In addition to broadening the types of plastic materials that can be recycled, advanced recycling expands the geographical extent of recycling efforts. Advanced recycling technology can be added to oil refineries, integrating plastic waste into their processes as a feedstock. Many existing oil refineries are located in states that historically have had low recycling rates, such as Louisiana, which currently has an estimated total plastic recycling rate of just 6%.

Advanced recycling could deliver economic benefits to municipalities beyond the benefits of plastic waste diversion. Landfills charge a “tipping fee” per ton of waste collected. Because recycling diverts plastic waste away from landfills, advanced recycling could save between $230 million and $328 million in tipping fees per year for municipalities across the U.S. For example, Los Angeles County, CA, could save between $3 to $6 million in tipping fees while Harris County, TX, could save up to $22 million. The estimated potential benefits of advanced recycling are summarized below in Table 1.

TABLE 1: TOTAL POTENTIAL BENEFITS OF ADVANCED RECYCLING IN THE U.S.

SCENARIO	ADVANCED RECYCLING FACILITIES	ADDITIONAL PLASTIC RECYCLED (MILLION TONS)	ESTIMATED SAVINGS (2024 $ MILLIONS)	U.S. PLASTIC RECYCLING RATE
CURRENT	N/A	N/A	N/A	9%
SHORT-TERM	44	3.7	$229.7	19%
MEDIUM-TERM	74	4.7	$301.2	22%
LONG-TERM	98	5.1	$327.5	23%

Despite the potential environmental and economic benefits of advanced recycling technology, the advanced recycling industry lacks the regulatory framework necessary for a robust market for plastic waste to form. Absent strong economic incentives to collect, sort, and transport waste to advanced recycling facilities, the scale of the industry and its realized benefits will be constrained.

INTRODUCTION

Advanced recycling, or technologies that break down used plastics into their chemical building blocks to be used as feedstocks for new products, offers new solutions to improving recyclable material recovery and reducing landfilled waste.[1] By complementing existing recycling systems, advanced recycling can play a key role in strengthening the circular economy and improving the sustainability of plastic waste management.

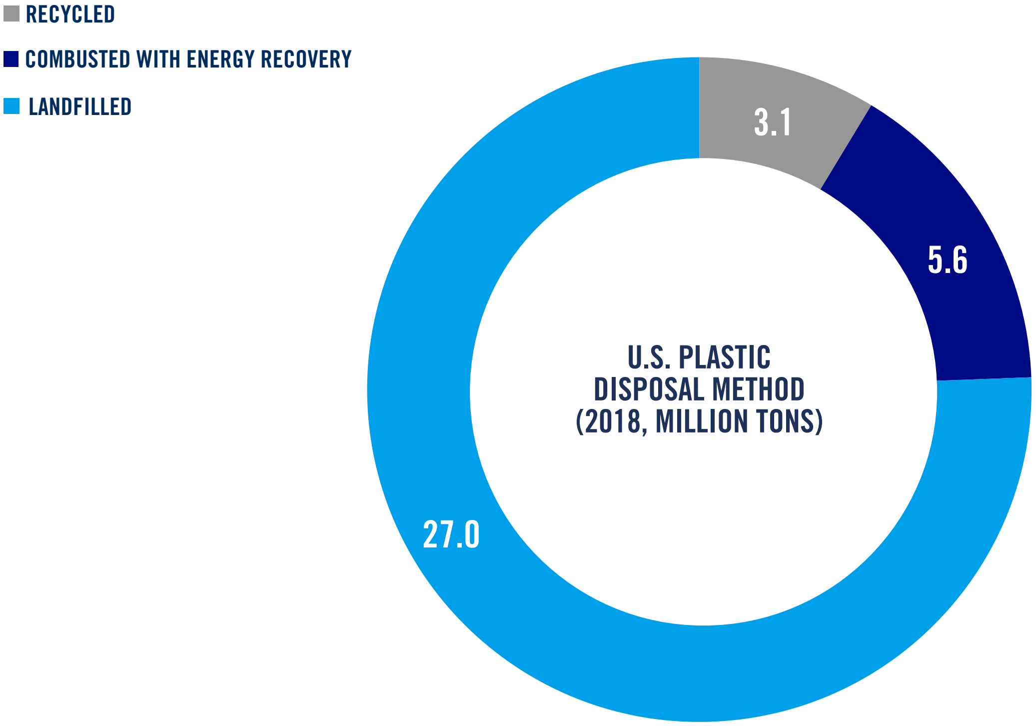
Through advanced recycling technologies, common and hard-to-recycle plastics are often converted into polymers under high heat or pressure in the absence of oxygen. The plastic polymers can then be further broken down into monomers, and contaminants can be removed. The resulting material can be remade into plastics or used as fuel.[2] Advanced recycling technologies may also use solvents or other processes to break down plastic waste. This technology has the potential to address structural gaps in the U.S. recycling system by recovering plastics that traditional methods cannot process. By strengthening domestic plastic processing capacity and reintroducing durable economic incentives to collect and process plastic waste, advanced recycling can help improve long-term recycling performance.

This assessment explores the potential benefits of expanding advanced recycling in the U.S. The study begins with a review of existing recycling standards, programs, and performance. Next, we detail announced advanced recycling projects and estimate the advanced recycling capacity that could potentially be added to existing refinery infrastructure. We then develop advanced recycling deployment scenarios using this data and analyze the amount of plastic waste that could be diverted from landfills. Finally, we conclude with a discussion of potential benefits and cost savings for municipalities across the country.

LANDSCAPE ASSESSMENT

Recycling programs across the U.S., especially those designed to manage plastic waste, are underperforming. The majority of the nation's plastic waste is either landfilled or incinerated, as shown in Figure 1, highlighting structural limitations in traditional waste management. Traditional mechanical recycling struggles with contamination issues, separating mixed plastics, inconsistent program rules, insufficient community education, and lost export markets.

FIGURE 1: U.S. PLASTIC DISPOSAL METHOD (2018, MILLION TONS)[3]



Source: EPA[4]

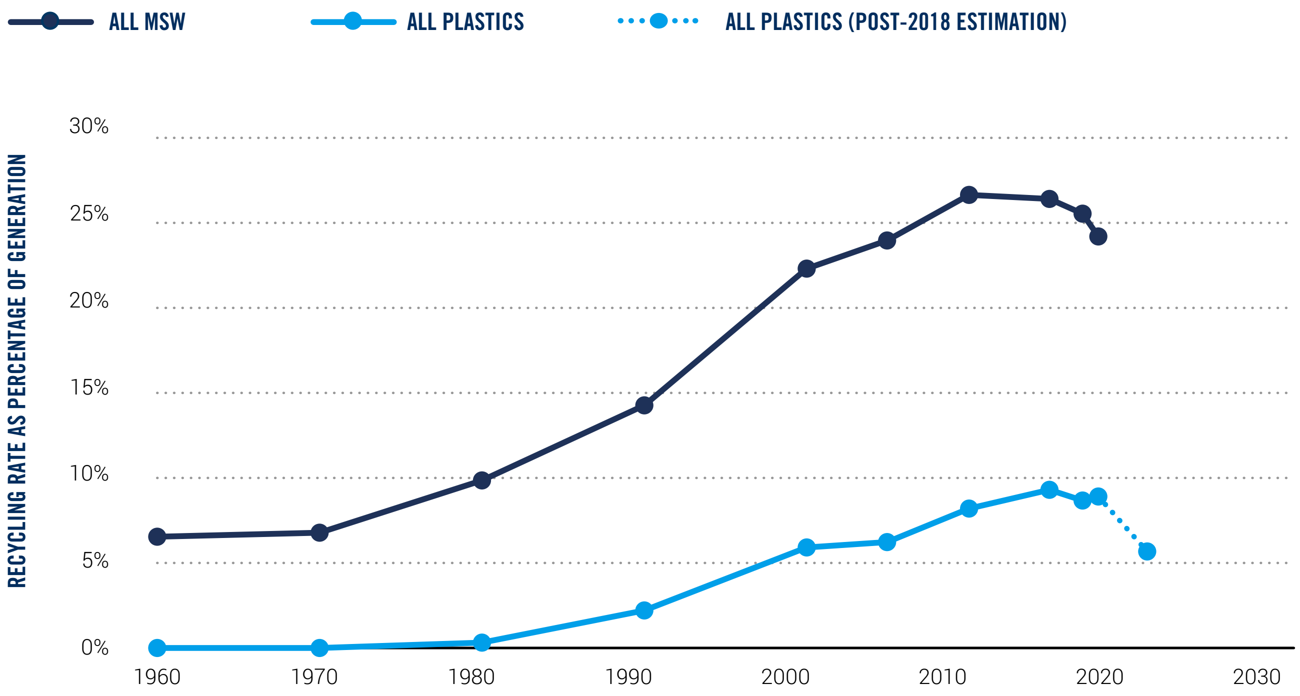
The U.S. generates nearly 35.7 million tons of plastic waste each year, according to the latest comprehensive national-level data released by the U.S. Environmental Protection Agency ("EPA") in 2018. As shown above in Figure 1, just 8.7% of this plastic waste generated is currently recycled using traditional mechanical recycling, with the vast majority ending up in landfills (75.6%). Plastic recycling performance varies across the world, but in total, global plastic production exceeded 400 million tons in 2022, with most waste ending up in landfills or the ocean.[5]

Recycling Rates in the U.S.

The potential value of advanced recycling has only grown since 2018, the last year with comprehensive recycling data, as the U.S. recycling rate has declined and more plastic waste is sent to landfills each year. As such, estimates of potential plastic waste available for diversion via advanced recycling in this analysis should be considered conservative. The national recycling rate for plastics was negligible from 1960 through 1980 and then steadily increased to about 2% in 1990, 6% in 2000 and 2005, 8% in 2010, reaching a peak of 9% in 2015, and then falling slightly to around 8.7% in 2018. Recycling rates then began to decline further after 2018, likely due to China's "National Sword Policy" and its cascading effects on the U.S. recycling system depicted in Figure 2.[6] Under this policy, China banned imports of many common plastic recyclables and established a strict 0.5% contamination limit for the materials that it would continue to accept. As China had been a primary importer of U.S. recyclables, U.S. exports fell dramatically following the implementation of this policy. With fewer end markets available, U.S. recyclers faced substantially higher costs and stricter quality demands, leading to more material being landfilled instead of exported for processing.

With the enactment of the 2021 amendments to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal, also called the Basel Convention, markets for the export of U.S. plastics waste were further constrained. Under the Basel Convention, the trade of plastic waste can only occur between countries that have ratified the Convention. The U.S. has not ratified the convention and thus cannot trade with Convention parties without a predetermined agreement between other countries. The U.S. currently has agreements with OECD members, but some countries still have restrictions on transboundary movements of plastic waste.[7] Limited U.S. exports of plastic waste have increased the importance of U.S.-based technological solutions to the problem of plastic waste, such as advanced recycling. Because even 2018 data does not capture the negative effect of the 2021 Basel Convention amendment on U.S. recycling rates, advanced recycling's potential contribution to U.S. recycling capacity could be even more dramatic if more recent baseline recycling data were available.

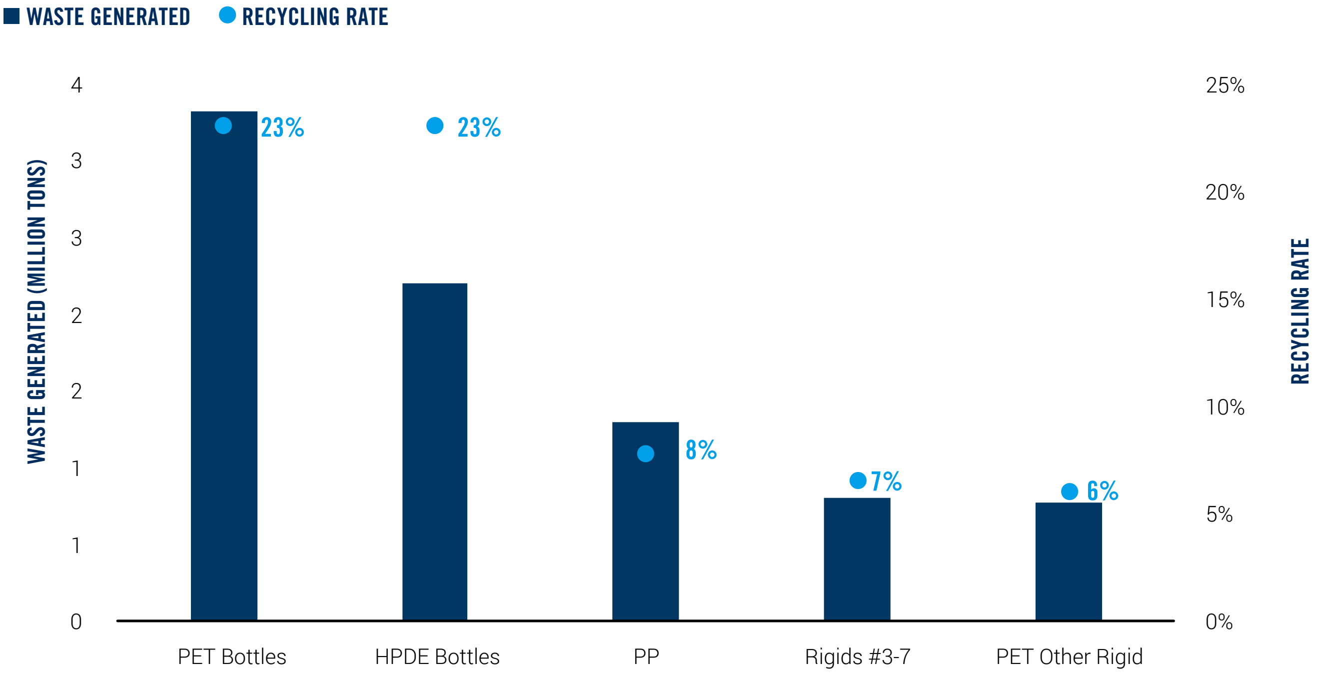
FIGURE 2: U.S. MATERIALS RECYCLED (1980-2021)



Source: EPA[8]

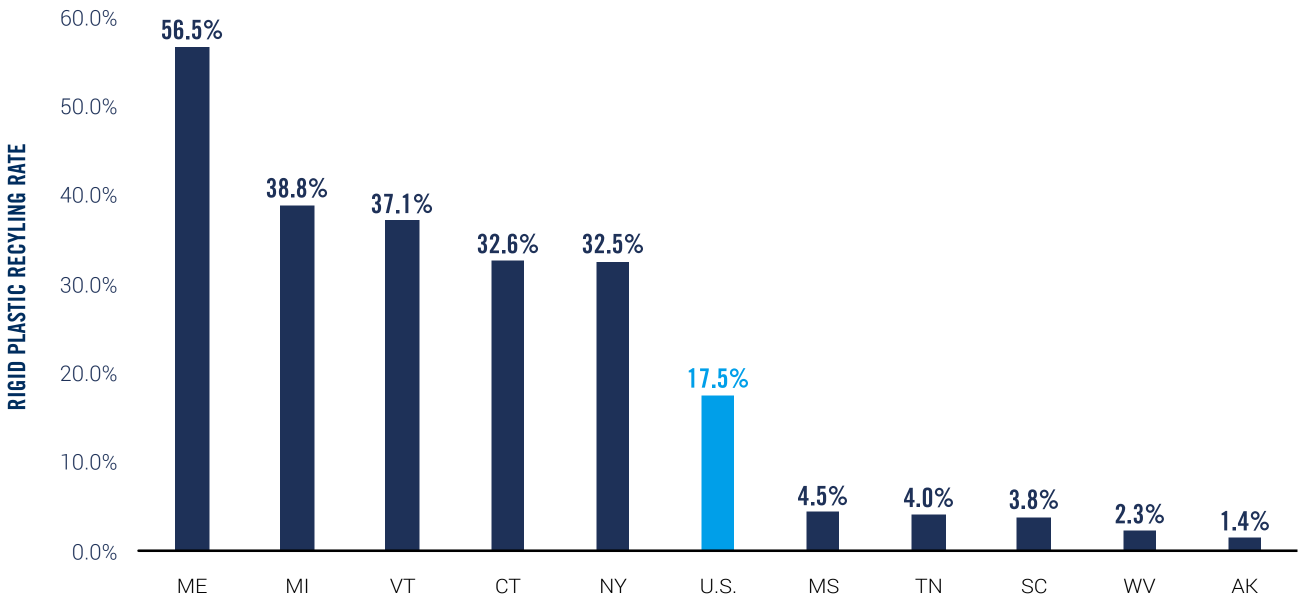
U.S. plastic recycling rates remain low, with recovery largely focused on a few types of commonly used rigid plastics. Recent estimates show that polyethylene terephthalate ("PET"), typically used for beverage containers, is the most commonly recycled plastic, followed by high-density polyethylene ("HDPE"), typically used for sturdier liquid containers for products like shampoo and detergents.[9] Other materials, such as polypropylene ("PP") that is often used for bottle caps, yogurt containers, and other thin, but rigid plastics, and polystyrene ("PS"), generally used as Styrofoam cups or plastic cutlery, have much lower recycling rates due to weak commodity values, sorting and contamination challenges, and quality degradation during processing and re-manufacturing.[10]

FIGURE 3: RIGID PLASTIC WASTE GENERATION AND RECYCLING RATES, BY TYPE[11]



Recent data presented in Figure 4 shows significant variation in combined rigid plastic recycling rates across states. The national average recycling rate for these plastics is just 17.5%. While one state, Maine, has a recycling rate greater than 50%, 17 states have rigid plastic recycling rates lower than 10%.

FIGURE 4: RIGID PLASTICS RECYCLING RATE (2018), TOP AND BOTTOM FIVE STATES[12]



High recycling rates for some states are driven by PET bottle recycling that is incentivized by deposit return systems.[13] On the other hand, low recycling rates in certain states may be caused by several reasons, including poor recycling infrastructure and a lack of regulations to encourage recycling, such as those that create access to recycling programs, manage single-use plastics, and require extended producer responsibility.[14] Recycling rates in some of these states could be improved by enhanced recycling infrastructure, such as access to advanced recycling facilities, that would create an incentive to collect plastic waste for processing.

Key Barriers to Effective Recycling

Current recycling infrastructure in the U.S. presents struggles to effectively manage plastic waste generation. Most plastics in the U.S. are recycled via mechanical recycling, whereby plastic waste is sorted, ground into small pieces, and melted into pellets that can then be made into new plastic items.[15] Mechanical recycling facilities typically accept PET and HDPE plastics.[16] Other types of plastic products, such as those that are contaminated with grease, oil, or other products, or those that have multiple layers, cannot easily be recycled via mechanical recycling and therefore often end up in landfills.[17] In fact, non-acceptable materials constitute a leading driver of contamination in single-stream recycling systems. Food and liquid residue, including soiled containers, food-contaminated paper, and leftover liquids, can cause entire recycling loads to be rejected and sent to landfills. The single-stream collection method itself, while convenient for consumers, may lead to contact between recyclable and non-recyclable materials, thereby elevating contamination levels throughout the system.

Inconsistent program rules throughout the U.S. mean that whether or not specific types of plastics are accepted varies significantly by locality, leading to potential misunderstandings among consumers about what materials are actually recyclable in their communities. Limited public education combined with the phenomenon of “wish-cycling,” where consumers, lacking clear guidance, place non-recyclables or food-contaminated materials into recycling bins hoping they will be recycled, increases rejection rates and undermines system efficiency.[18]

The recycling of flexible plastics, such as food packaging and shopping bags, presents an additional major barrier to comprehensive plastics recycling in the U.S. It is estimated that only about 5-6% of flexible plastic waste generated in the U.S. is recycled.[19] These types of plastics are generally not accepted in curbside recycling as they can easily cause jams in mechanical recycling equipment at municipal facilities.[20] Additionally, many flexible plastic products are made of multiple and cannot be easily separated by mechanical recycling equipment.[21]

Efforts to Improve U.S. Recycling Rates

Throughout the U.S., several national, state, and regional efforts are underway to improve recycling rates, with varying degrees of maturity and success.

National Recycling Strategy

In 2020, the administrator of the EPA announced the National Recycling Goal to increase the U.S. recycling rate to 50% by 2030, including plastics, aluminum, paper, and other materials. The National Recycling Strategy, established as a parallel effort to identify objectives and actions needed to create a stronger recycling system, aims to build a more coherent, efficient, and circular recycling system in the U.S.

The National Recycling Strategy emphasizes the development of standard recycling definitions and measurement standards to improve data transparency so that progress towards improved recycling rates can be better tracked. Simultaneously, these initiatives aim to strengthen markets for recyclable materials by establishing procurement standards and minimum content requirements. Public education is also viewed as integral in order to reduce improper disposal and maintain material quality throughout the collection and processing chain. Infrastructure improvements and expanding access to recycling are also incorporated in the Strategy through the modernization of material recovery facilities ("MRFs") and regional materials management infrastructure to handle contemporary waste streams more effectively. Finally, the Strategy will work to advance extended producer responsibility ("EPR") and other policies to support circularity in materials management, as well as aligning federal, state, and local policies to improve program consistency and effectiveness across jurisdictions.[22]

EPA is still in the process of working collaboratively with stakeholders to develop an implementation for the National Recycling Strategy.[23] However, the initial actions that EPA is taking to work towards this vision of a more circular economy include establishing grant programs and initiatives to provide funding to states and municipalities to improve their waste management practices, collaborating with other federal agencies to implement shared priorities around waste management, and leveraging existing EPA programs related to achieving a circular economy.[24]

State and Regional Recycling Programs

Many states and regions have implemented independent recycling programs designed to strengthen and modernize recycling systems within their communities. These programs take various forms and have demonstrated varying degrees of success in improving recycling rates and reducing waste.

Beverage container deposit programs, also known as Deposit Return Systems ("DRS"), have proven particularly effective as they offer an economic incentive for consumers to responsibly manage plastic waste. States with DRS consistently achieve higher overall recycling rates than those without such programs. Notably, nine of the top ten highest states for PET bottle recycling displayed in Table 2 have DRS programs in place.

TABLE 2: RECYCLING RATES OF STATES WITH DEPOSIT RETURN SYSTEMS[25]

BOTTLE BILL STATES	PET BOTTLES RECYCLING RATE	TOP 10 RECYCLING STATE?
MAINE	78%	Yes
OREGON	69%	Yes
MICHIGAN	57%	Yes
CALIFORNIA	57%	Yes
NEW YORK	54%	Yes
VERMONT	51%	Yes
CONNECTICUT	47%	Yes
HAWAII	44%	Yes
MASSACHUSETTS	38%	Yes
IOWA	30%	No

Landfill bans and mandatory recycling represent another category of state and local policies aimed at increasing recycling rates, reducing landfilled waste, and supporting more robust recycling markets. These bans, however, often target specific materials including food scraps, electronics, yard waste, and other commercial recyclables, requiring their diversion from landfills to more sustainable management pathways.

Education programs have emerged as critical tools for improving recycling system performance. One such program, Recycle Smart MA, seeks to improve recycling quality and consistency by focusing on reducing contamination in single-stream recycling through teaching residents what can and cannot be recycled.[26] The program provides tools and resources including the Smart Recycling Guide and Recyclopedia database for accepted materials and common contaminants. Similarly, Michigan's Recycling Raccoon Squad provides educational resources to help residents recycle correctly and reduce contamination in their local systems.[28]

Recycling market development and infrastructure initiatives represent another important category of state programs. For example, New Jersey's Recycling Market Development Council aims to advance recycling in the state and support environmental and economic goals.[29] This program works to provide recommendations to reduce contamination of collected recyclables and investigate ways to stimulate end-market demand for recycled content products. The council has provided numerous recommended potential changes to laws, rules, or regulations to support these efforts.[30]

Extended producer responsibility ("EPR") represents a targeted policy approach that places the responsibility for end-of-life management of packaging waste on the manufacturers. Under EPR frameworks, producers are accountable for the collection, recycling, and safe disposal of their products and packaging. This approach seeks to encourage manufacturers to design and sell more environmentally friendly product packaging and ensure their ultimate disposal is handled properly, creating incentives for sustainable design at the source.[31] As of early 2026, California, Colorado, Maine, Maryland, Minnesota, Oregon, and Washington have enacted or are planning to enact EPR laws.[32] Companies doing business in these states are currently or will be responsible for reporting the amount of packaging waste generated by their product sales in the state and paying a fee that goes to support waste management initiatives.[33]

Federal and state grants provide crucial financial support for recycling infrastructure development. The Solid Waste Infrastructure for Recycling ("SWIFR") grant program is a leading grant program in the U.S. focused on strengthening recycling systems nationwide.[34] The program provides approximately $275 million in funding from 2022 to 2026, with grants provided annually to recipients to support recycling infrastructure and materials management improvements. The EPA has awarded two rounds of funding to date. In October 2023, 25 grants were awarded totaling $72.9 million, representing approximately just 9% of the funding requested by applicants.[35]

One SWIFR grant recipient, EcoMaine, was awarded $2,000,000 to promote single-sort recycling in multi-family dwelling units through targeted outreach to residents and property owners across Maine. EcoMaine provides access to recycling to more than 70 communities in the state, including operating a waste-to-energy plant, a waste sorting facility, a landfill, and publishing educational materials on recycling. EcoMaine aims to divert more recyclable materials from landfills and increase local recycling participation.[36] Similarly, Chaffee County, Colorado, was awarded nearly $4,000,000 to create a recyclables transfer station and MRF on its landfill site in order to increase diversion rates and create drop-off access to recycling for county residents who are not serviced by or could not afford curbside recycling services. Caffee County estimates that this transfer station and MRF will be capable of processing 90,000 U.S. tons of material per year and divert 50% of all material received from being landfilled.[37]

Voluntary Standards and Credit Programs

Prior to the implementation of China's National Sword policy in 2018 and the Basel Convention amendments in 2021, economic incentives to collect recyclable plastics were driven largely by the ability to export these waste products to China and other countries that have historically processed plastic waste. While there are voluntary programs that provide an economic value for collecting plastic waste via tradeable credits, these programs are not enforceable. As such, the credits are only worth as much as potential buyers are willing to pay. Several market standards have been established to provide verification and credibility for these efforts.

Verra's Plastic Waste Reduction Standard ("PWRS") represents one such framework. In an effort to reduce overall plastic waste, Verra established a system for accounting for and crediting plastic waste collection and recycling. The program established an auditing system to ensure meaningful reductions in plastic waste are properly accounted for and provides verified standards to track and quantify plastic collection, recycling, and diversion. Projects meeting the standard can generate tradable credits for companies seeking to offset plastic waste impacts.[38] Zero Plastic Oceans' Ocean-Bound Plastic ("OBP") standard focuses on preventing plastic from entering oceans by targeting high-risk areas near waterways. The standard establishes verification and reporting requirements for collected ocean-bound plastic and provides certifications verifying that collected ocean-bound plastic is managed responsibly, with commercially recyclable waste traceable to the final product and non-recyclable waste properly handled through verified, traceable credits.[39]

Plastic neutrality and offset platforms have emerged as mechanisms to create economic incentives for plastic waste reduction. For example, rePurpose Global operates as a global plastic crediting system aiming to help companies manage and reduce their plastic waste footprint. The platform provides a marketplace to direct funding to verified plastic collection and recycling projects worldwide, creating financial incentives for waste reduction activities that might not otherwise be economically viable.[40] Similarly, TONTOTON establishes credits specifically for non-recyclable plastics, addressing a gap in existing programs. The platform aims to empower local communities to serve as "Community Barriers," preventing plastic pollution at its source, particularly in areas with limited waste management infrastructure where traditional recycling systems may not be viable or accessible.[41] Finally, Plastic Bank functions as a global plastic bottle deposit program that monetizes the collection of plastic waste, providing digital plastic credit tokens to track and verify collected plastic. Since its inception in 2013, the program has gathered the equivalent of over 9 billion plastic bottles; however, this only represents 205,000 tons of diverted plastic, or less than 1% of the total plastic generated in the U.S. in 2018.[42, 43]

Market-based platforms are also used to facilitate the trading of plastic credits. For example, Plastic Credit Exchange and BVRio's Circular Credits Mechanism have introduced marketplaces that facilitate the buying and selling of verified plastic credits. This market-based approach allows private capital to be channeled into options for plastic collection and recovery projects.[44] Material-specific programs offer another approach to addressing plastic waste challenges. For example, NexTrex operates a targeted program focused on collecting and recycling plastic bags and film, using community-based collection models and reward incentives.[45] These types of programs highlight how collected targeted material types can be aggregated and scaled, potentially expanding the supply options for advanced recycling systems given proper incentives. To date, however, their impact has been minimal relative to the overall amount of plastic that could potentially be recycled in the U.S. using advanced recycling technologies.

ADVANCED RECYCLING CAPACITY POTENTIAL

Advanced recycling could significantly expand U.S. plastic recycling capacity. Our scenario-based analysis projects a national advanced recycling capacity between 2.4 and 3.8 million tons of plastic per year at existing refineries and an additional 1.3 to 2.8 million tons of plastic per year at standalone facilities.

Announced Projects

Developers have announced advanced recycling projects as either additions to existing refineries or as standalone facilities. Based on public reporting, we identified 14 announcements for standalone facilities and 4 announcements for facilities that will be integrated with existing refineries. Most standalone facilities are planned near existing refineries along the Gulf Coast and throughout the Midwest, as shown in Table 3. All types of advanced recycling, whether at standalone facilities or at refineries, can help improve waste diversion rates and keep plastics out of landfills.

TABLE 3: LIST OF ANNOUNCED STANDALONE PROJECTS BY PLASTIC INPUT CAPACITY

COMPANY	PLASTIC INPUT CAPACITY (U.S. TONS)	CITY	STATE
BRIGHTMARK	400,000	Thomaston	GA
FREEPOINT	193,125	Eloy	AZ
PURECYCLE	140,000	Augusta	GA
EASTMAN CHEMICAL COMPANY	121,254	Longview	TX
EASTMAN CHEMICAL COMPANY	121,254	Kingsport	TN
BRIGHTMARK	100,000	Ashley	IN
FREEPOINT	90,000	Hebron	OH
PURECYCLE	54,750	Ironton	OH
NEXUS CIRCULAR AND BRASKEM	33,069	Chicago	IL
NEXUS CIRCULAR AND DOW	28,660	Dallas	TX
ALTERRA/NESTE	21,900	Akron	OH
NEXUS CIRCULAR	15,000	Atlanta	GA
BRAVEN ENVIRONMENTAL	12,000	Zebulon	NC
BRAVEN ENVIRONMENTAL	N/A	Texarkana	TX

Standalone facilities can use pyrolysis to break down plastic into pyrolysis oil.[46] In some cases, this pyrolysis oil is then sent to separate facilities to be processed into recycled plastic products. These facilities tend to be smaller and more purpose-built. On the other hand, large refinery complexes can integrate advanced recycling technologies with existing operations. For example, an integrated facility can refine crude oil into derivatives that can be sent via pipeline to adjacent refining and chemical processing facilities and turned into plastic pellets for plastic manufacturers.

Advanced recycling technology can be used at integrated refinery complexes to break down plastics into raw materials such as pyrolysis oil that can be fed directly into the existing chemical processing facilities and used to produce new plastic on site or for a number of other applications. Smaller refineries without exiting polymer production facilities on site may also be able to add advanced recycling technology to their facilities, but they may use the resulting pyrolysis oil in a different application or transport it to a different facility for further processing.

Deployment Scenarios

We structured our potential advanced recycling deployment scenarios into a multi-stage analysis across three broad time horizons: Short-Term, Medium-Term, and Long-Term. These time horizons do not correspond to specific years and are intended to represent general deployment scenarios. Because each time horizon introduces gradually relaxed assumptions about which facilities decide to invest in advanced recycling technology, each should be viewed independently instead of stages comprising a single analysis.

Refineries were sorted into two groups based on the likelihood that they would install advanced recycling equipment. We assumed that larger refineries, based on crude oil processing capacity, will be more likely to install advanced recycling equipment, as owners of larger facilities may have sufficient capital. We also assumed that facilities with high-pressure and/or high-temperature processes are more likely to install advanced recycling equipment. For a conservative sample of refineries, we included only refineries with either catalytic cracking or catalytic hydrocracking equipment. Table 4 below summarizes the criteria for each group and notes how many existing refineries meet the criteria. In total, 84 existing refineries were considered in our deployment scenario analysis out of the 132 total refineries included in the database.[47]

TABLE 4: REFINERY DEPLOYMENT CRITERIA

METRIC	GROUP 1	GROUP 2
CRUDE OIL CAPACITY (BPD)	>=100,000	50,000-99,999
INCLUDES EQUIPMENT?	Yes	Yes
QUALIFIED REFINERIES	60	24

A staggered deployment timeline for advanced recycling facilities co-located with refineries reflects a gradual technological adoption pathway whereby early adopters establish a sizeable market for plastic waste to be sent to advanced recycling facilities, which creates opportunities for smaller refineries to adapt a proven technology to their facilities.

We based our estimate of refinery plastic feedstock capacity on announced advanced recycling capacity of ExxonMobil's facility at Baytown, TX (250 million pounds of plastic per year) relative to total crude oil processing capacity published by the EIA.[48, 49] We then applied this ratio to each existing refinery's crude oil capacity to estimate the amount of plastic that could potentially be processed at each remaining facility. In total, the 84 facilities included in all scenarios could process up to roughly 3.8 million tons of plastic per year.

In the Short-Term, we assume half of the refineries in Group 1 develop advanced recycling capabilities. In the Medium-Term, we assume the remaining half of Group 1 is deployed.
In the Long-Term, the remaining Group 2 facilities begin advanced recycling operations. The number of refineries with an advanced recycling facility in each scenario, along with the cumulative plastic recycling capacity in each scenario, is detailed in Table 5 below.

TABLE 5: ADVANCED RECYCLING REFINERY FACILITY GROWTH FORECAST

METRIC	SHORT-TERM	MEDIUM-TERM	LONG-TERM
REFINERIES ADDING ADVANCED RECYCLING	30	60	84
POTENTIAL PLASTIC RECYCLING CAPACITY (US TONS)	2,397,668	3,416,282	3,803,968

For standalone facilities, we assume that all 14 announced projects would be operational in the Near Term, and that in more optimistic scenarios, additional standalone facilities would gradually come online as the market for plastic waste strengthens.

DIVERSION ANALYSIS

Methodology

Expanding the number of advanced recycling facilities operating in the U.S. has the potential to divert significant amounts of plastic waste away from landfills. To estimate the unrecycled plastic waste that could be sent to advanced recycling facilities, we combined data on the amount of unrecycled plastic by zip code with the locations and estimated plastic recycling capacities of advanced recycling projects.

This advanced recycling diversion analysis is distinct from the advanced recycling capacity forecast analysis because additional standalone recycling capacity aside from the 14 announced projects is excluded; however, all other data inputs, including the estimated plastic recycling capacity at existing refineries, remain the same. Our diversion analysis uses the geographic location of all facilities in the model, and reasonable assumptions about the geographic location of unannounced future standalone advanced recycling facilities cannot be determined.

Currently, most recycled plastics are made up of a few particular resins. PET, used in plastic beverage containers, and HDPE, used for sturdier liquid containers such as shampoo bottles, are the most common types of plastic recycled in our data and are both examples of “rigid” plastics. Flexible plastics, on the other hand, are generally not recycled because of technological limitations.[50] Plastic bags, for example, slow or halt recycling plant operations by getting caught in process machinery. Issues with contamination, where food or other residues remain on recycled containers, also hinder conventional recycling efforts.

The EPA published a data set that contains estimates of the amount of unrecycled plastic by zip code, broken out by specific types of rigid plastics in 2018.[51] Separately, the EPA estimated the amount of unrecycled plastic, including flexible plastics, nationally in 2018.[52] Because advanced recycling facilities, unlike traditional mechanical recycling facilities, can readily recycle flexible plastics, we estimated the amount of unrecycled flexible plastic by zip code by allocating the national estimate among zip codes by population. Our final dataset included an estimate of rigid and flexible plastic by zip code. As noted above, the problem of unrecycled plastic waste has only grown since 2018 as U.S. exports of plastic waste and the U.S. plastic recycling rate have both declined. Even though this analysis uses 2018 data, if more recent data were available, our finding that advanced recycling facilities address the problem of plastic waste through increased recycling capacity would still hold.

We estimated the amount of unrecycled flexible plastic in each zip code in three stages. First, we reconciled the 1.5 million tons of recycled plastics in our zip code-level dataset with the 3 million tons of recycled plastics reported by the EPA overall by assuming that the 1.5 million other tons were all rigid plastics and were all recycled at the same rate as the rigid plastics in our zip code-level data.[53] This resulted in an estimated total of 17.7 million tons of rigid plastics generated and an estimated 14 million tons of unrecycled rigid plastics, assuming that all 3 million tons of recycled plastic are rigids. Second, we subtracted the estimated 17.7 million tons of rigid plastics generated from the total 35.6 million tons generated to get an estimate of 17.9 million tons of unrecycled flexible plastics. Third, we allocated the "extra" rigids and flexible plastics not captured in our zip code-level data by zip code according to population.

To model which zip codes are most likely to send plastic to advanced recycling facilities, we collected data on all the zip codes that fall within a 200-mile radius of each existing refinery or announced standalone project, based on the assumption that transportation costs within that size radius are low enough for plastic shipments to occur.[54] In our allocation algorithm, the largest facilities by plastic recycling capacity "move" first to "take" enough plastic within a 200-mile radius to meet their plastic refining capacity. Once that refinery meets its capacity, the next-largest refinery "takes" from the pool of available plastic within a 200-mile radius. The algorithm runs identically for each refinery until all refineries have met their capacity.

Refineries "decide" between zip codes based on each zip code's cost to landfill plastic. The underlying assumption for this method is that zip codes with a higher landfill cost would be more willing to send plastic to an advanced recycling facility. The cost of landfilling is commonly referred to as a "tipping fee". To simplify our analysis, we assigned each zip code their respective state-wide average tipping fees published by the EPA.[55]

This analysis was conducted separately for each of the Short-, Medium-, and Long-Term time horizon scenarios, with the corresponding facilities from Table 5 included in each analysis.

While advanced recycling facilities are notable for the ability to recycle previously unrecycled plastics, such as flexible plastics, 100% of the flexible plastics in each zip code may not be adequately collected, processed, and sent to an advanced recycling facility, owing to the added complexity of collecting flexibles relative to rigids. As such, we assume that only 50% of flexible plastics in each zip code would be "available" for recycling, meaning that half of flexible plastics would not be properly separated from other waste and instead disposed of by consumers.

National Results

At the national level, introducing advanced recycling increases the total diversion rate (i.e., including rigid and flexible plastic) in all scenarios. National results are summarized in Table 6 below.

TABLE 6: NATIONAL DIVERSION RESULTS

CATEGORY	CURRENT	SHORT-TERM	MEDIUM-TERM	LONG-TERM
RIGIDS	17%	31%	34%	35%
FLEXIBLES	0%	8%	10%	11%
TOTAL	**9%**	**19%**	**22%**	**23%**

The results from our diversion analysis indicate that advanced recycling could significantly improve national plastic diversion rates. Assuming that only 50% of flexible plastic is available to be recycled, the national recycling rate is estimated to increase from 9% to 19-23%.[56]

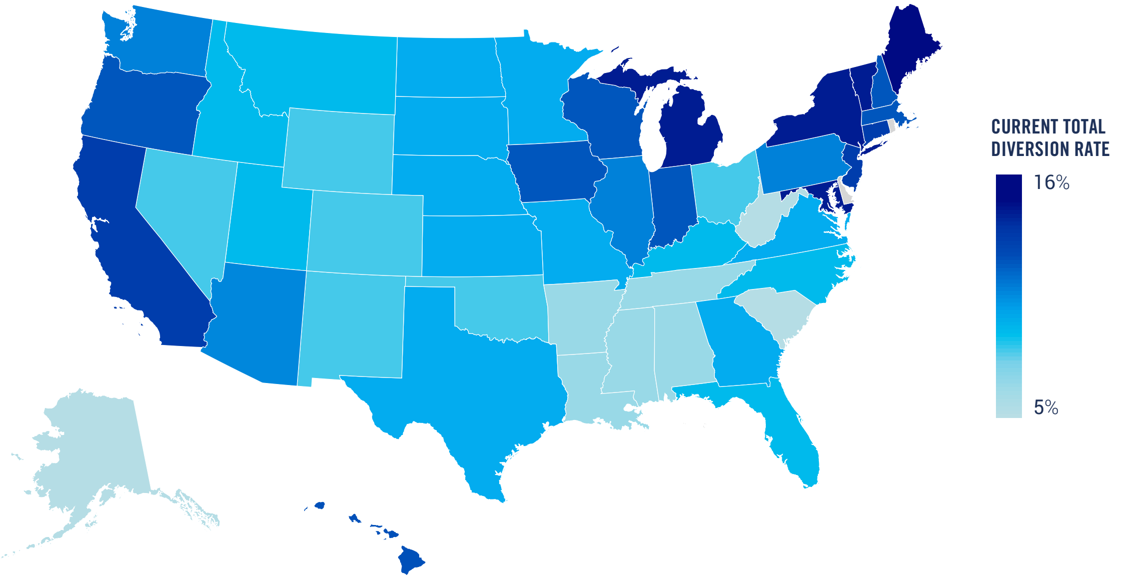
Achieving a diversion rate of between 19-23% would help the U.S. make considerable progress towards general recycling milestones. The EPA has outlined a national recycling goal for all materials of 50%, including non-plastics, by 2030.[57] While our results are not tied to specific years, this analysis demonstrates that advanced recycling has the potential to effect meaningful changes to the recycling landscape.

State-Level Results

Diverted Plastic

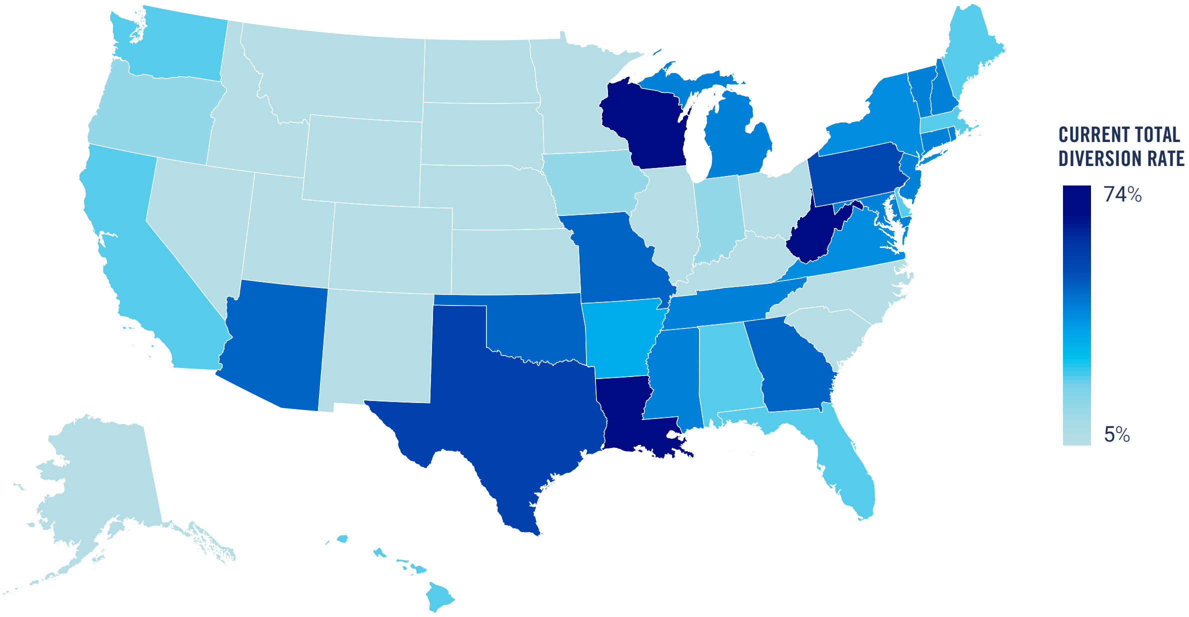
Current diversion rates differ significantly between states. As shown in Figure 5, current estimated total diversion rates across all plastics, including both rigid and flexible types, range from a maximum of 16% in Maine to a minimum of 5% in Alaska. On average, the total diversion rate in the U.S. is 9%. As noted above, current recycling rates in each state depend on regulatory environments and economic incentives to recycle. Supporting the development of a market for advanced recycling will require a regulatory framework that strengthens the economic incentives to collect plastic waste.

FIGURE 5: CURRENT TOTAL DIVERSION RATE BY STATE (2018)



The total diversion rates for each state in the least optimistic (Short-Term) and most optimistic (Long-Term) are presented in Figure 6 and Figure 7. These results should be interpreted as a finding about the general increase in recycling capacity provided by advanced recycling and the geography of announced advanced recycling facilities, rather than as projected changes to specific states' diversion rates.

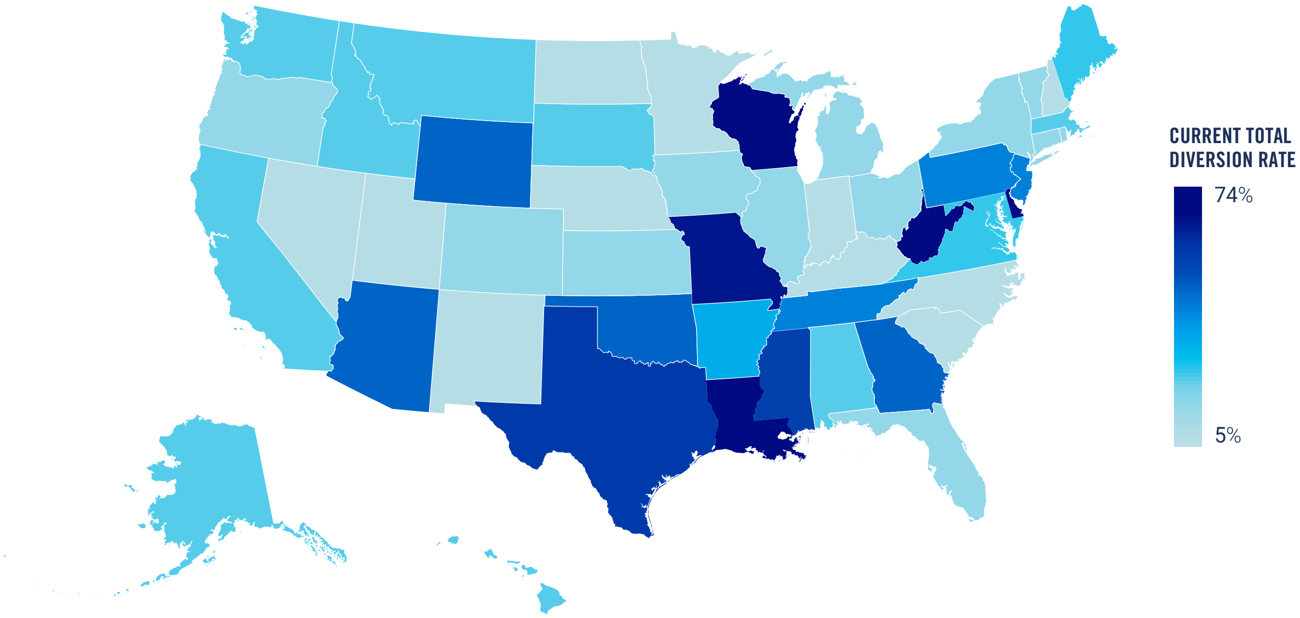
FIGURE 6: TOTAL DIVERSION RATE, SHORT-TERM



In the least optimistic scenario, advanced recycling significantly improves diversion rates in several states. Overall, the average diversion rate also doubles, increasing from 9% to 19%. In Louisiana, the diversion rate almost reaches 75%. Many of the announced standalone advanced recycled projects and refineries that may integrate advanced recycling are located along the Gulf Coast. In our model, these refineries are more likely to take plastic from nearby communities in Louisiana and Texas based on tipping fees. Louisiana also generates a relatively small amount of plastic waste each year — approximately 16% of Texas's total unrecycled plastic waste — which means the marginal impact of advanced recycling capacity on Louisiana's diversion rate is significant.

This result is based on the specific assumptions embedded in our diversion model and is not necessarily a projection of actual changes to Louisiana's plastic recycling rate. What this finding does show is that many announced advanced recycling facilities will be located in Louisiana, and that the amount of announced plastic recycling capacity could theoretically process a significant share of Louisiana's plastic waste.

FIGURE 7: TOTAL DIVERSION RATE, LONG-TERM

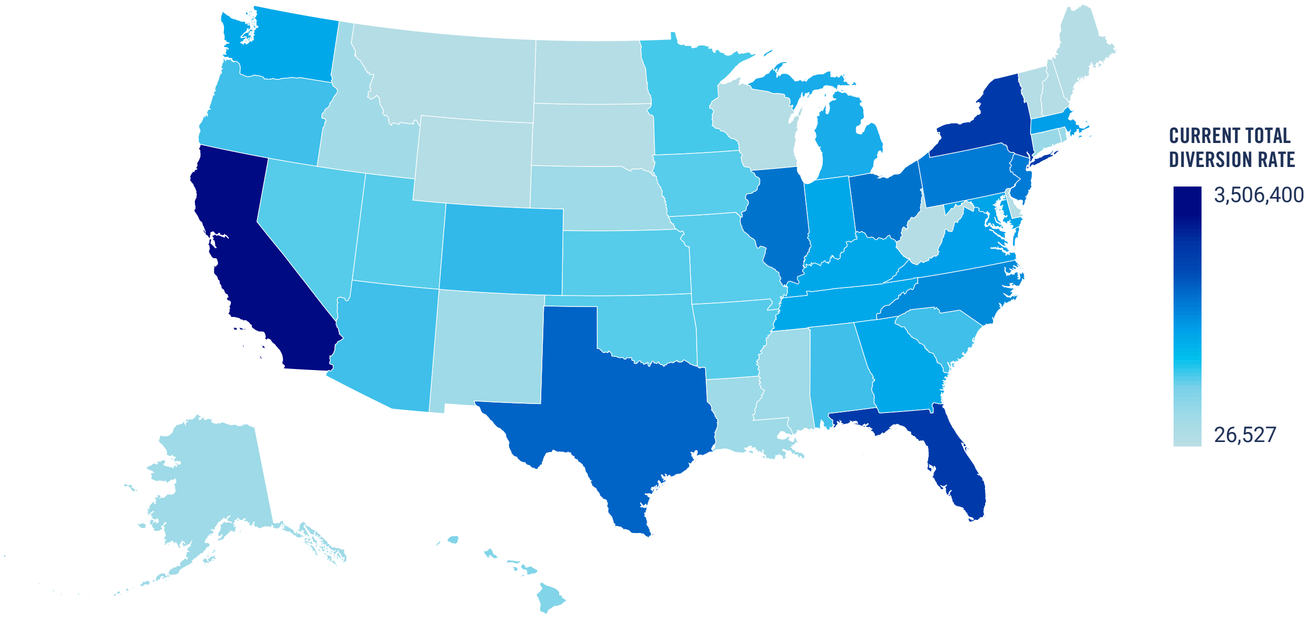


In the most optimistic scenario, the range of diversion rates throughout the U.S. does not change, although diversion rates increase substantially for specific states. For example, Delaware's diversion rate increases from 7% to 74%. Similar to Louisiana's high diversion rate, this result can be explained by the technical features of our diversion model, which determines the zip codes that send plastic to advanced recycling facilities first based on the highest tipping fees between states and geographic proximity.

The widespread deployment of advanced recycling technologies may not result in the specific state-level diversion rates observed in our results. Our results should instead be interpreted as a finding that advanced recycling has significant potential to increase overall recycling capacity writ large. Because advanced recycling facilities will either be attached to existing refineries or located near refineries, and our model makes the simplifying assumption that facilities will receive plastic from nearby areas, our results show benefits concentrated mostly in states with existing refineries. However, even if improvements to diversion rates are not concentrated in Louisiana and Delaware, our results do find that overall diversion rates could increase substantially. No matter where advanced recycling facilities source their plastic waste feedstock from, there is sufficient plastic waste throughout the U.S. that is currently being landfilled to meet potential advanced recycling capacity.

“Stranded plastic,” or plastic that remains unrecycled after accounting for potential advanced recycling facilities, remains concentrated in the populous states of California, Texas, New York, and Florida in the most optimistic scenario, as shown in Figure 8. Companies looking to identify new sites for advanced recycling facilities could consider these regions as a source of plastic feedstock.

FIGURE 8: STRANDED PLASTIC, LONG-TERM



Municipal Landfill Cost Savings

By sending plastic waste to an advanced recycling facility, municipalities avoid paying considerable tipping fees. We collected data on the average tipping fee in every state from the EPA and measured the cost savings by multiplying the amount of plastic each zip code sent to an advanced recycling facility by the average tipping fee in that zip code's state.[58] The total cost savings realized in each scenario are displayed below in Table 7.

TABLE 7: TOTAL COST SAVINGS BY SCENARIO (2024 $ MILLIONS)

SCENARIO	COST SAVINGS
SHORT-TERM	$229.7
MEDIUM-TERM	$301.2
LONG-TERM	$327.5

Case Study:
Los Angeles, CA and Harris County, TX

To illustrate the potential magnitude of the cost savings for specific counties, we identified all the zip codes within Los Angeles, CA, and Harris County, TX, and aggregated the plastic sent from those zip codes to an advanced recycling facility, as well as that zip code's avoided landfill costs, up to the county level. The results for each county are presented in Table 8 below. In total, the benefits of avoiding sending plastic to landfills range from $2.9 million to $5.6 million per year in Los Angeles County and about $21.6 million per year in Harris County.

Advanced recycling promises real economic benefits for municipalities like Harris County and Los Angeles County. Securing these potential environmental and financial gains is contingent on policies that recognize the value of advanced recycling and create appropriate mechanisms for municipalities, entrepreneurs, and households to participate in the market for recycled plastic waste.

TABLE 8: ADVANCED RECYCLING BENEFITS FOR HARRIS AND LOS ANGELES COUNTIES

TIME HORIZON	METRIC	LOS ANGELES	HARRIS
SHORT-TERM	Additional Tons Recycled	40,783	421,343
	Value (2024 $ millions)	$2.9	$21.6
MEDIUM-TERM	Additional Tons Recycled	78,656	421,343
	Value (2024 $ millions)	$5.6	$21.6
LONG-TERM	Additional Tons Recycled	78,656	421,343
	Value (2024 $ millions)	$5.6	$21.6

CONCLUSION

This report finds that advanced recycling facilities offer distinct waste diversion and economic benefits for municipalities across the U.S. According to our waste diversion model, the U.S. could increase its total plastic diversion rate from 9% to between 19 and 23%, depending on the amount of advanced recycling capacity in operation. Advanced recycling could also save communities between $230 million and $328 million in landfill tipping fees per year.

Based on the locations of announced projects, the states that stand to benefit the most from advanced recycling are those with existing oil refineries nearby. Some of these states, particularly Louisiana and Delaware, could recycle a large percentage of plastic generated in the state each year. For Louisiana, new advanced recycling could cause the state's plastic diversion rate to increase from about 6% to between 74, given the prevalence of refineries along the Gulf Coast. This result highlights the large increase in recycling capacity that advanced recycling could provide, even if the actual implementation of advanced recycling does not lead to concentrated benefits in a single state.

Conventional mechanical recycling is only one technological solution to the problem of plastic waste, which suffers from significant limitations. In contrast, advanced recycling facilities can handle a wider array of plastics and overcome some of the contamination issues that pose serious challenges for mechanical recycling facilities. Combining the capacity of conventional and advanced recycling facilities could lead to an effective large-scale solution for the large-scale problem of plastic waste. However, regulatory uncertainty limits the potential of advanced recycling facilities to develop at scale throughout the U.S. Without clear public policy that fosters strong economic incentives to collect, sort, and transport plastic waste, the advanced recycling industry will not be able to access enough plastic waste to achieve scale, making it difficult for the technology to proliferate. As a result, actual waste diversion and economic impacts would not reach the potential benefits promised by advanced recycling technology.

ABOUT THE AUTHOR

Stuart Malec is Vice President of Public Affairs at the Progressive Policy Institute (PPI), where he leads engagement with policymakers at the federal, state, and local levels. His work spans a wide range of policy issues, focusing on advancing pragmatic, pro-growth solutions and strengthening connections between policymakers and policy experts.

Stuart also oversees PPI's congressional outreach initiatives, including its staff and member delegation programs and its Congressional Fellowship program. Prior to joining PPI, Stuart spent nearly eight years working in the U.S. House of Representatives for members serving on the Energy and Commerce, Armed Services, and Homeland Security Committees.

Appendix

TABLE 9: TOTAL DIVERSION RATE BY STATE AND SCENARIO

STATE	CURRENT	SHORT-TERM	MEDIUM-TERM	LONG-TERM
ALABAMA	6%	16%	17%	19%
ALASKA	5%	5%	5%	25%
ARIZONA	8%	33%	33%	33%
ARKANSAS	6%	6%	6%	9%
CALIFORNIA	12%	16%	20%	20%
COLORADO	7%	7%	8%	13%
CONNECTICUT	12%	12%	12%	12%
DELAWARE	7%	7%	74%	74%
DISTRICT OF COLUMBIA	10%	10%	10%	10%
FLORIDA	6%	12%	12%	12%
GEORGIA	7%	37%	37%	37%
HAWAII	11%	11%	11%	24%
IDAHO	7%	7%	7%	25%
ILLINOIS	7%	7%	12%	12%
INDIANA	9%	9%	9%	9%
IOWA	9%	9%	9%	9%
KANSAS	8%	8%	12%	12%
KENTUCKY	6%	6%	6%	6%
LOUISIANA	6%	74%	74%	74%
MAINE	16%	16%	16%	16%

MARYLAND	13%	15%	15%	15%
MASSACHUSETTS	10%	18%	19%	19%
MICHIGAN	13%	13%	13%	13%
MINNESOTA	7%	7%	8%	10%
MISSISSIPPI	6%	22%	44%	50%
MISSOURI	7%	34%	51%	54%
MONTANA	7%	7%	7%	23%
NEBRASKA	8%	8%	8%	8%
NEVADA	7%	7%	7%	7%
NEW HAMPSHIRE	10%	10%	10%	10%
NEW JERSEY	11%	11%	13%	13%
NEW MEXICO	7%	7%	7%	7%
NEW YORK	13%	13%	13%	13%
NORTH CAROLINA	6%	6%	6%	6%
NORTH DAKOTA	7%	7%	7%	8%
OHIO	7%	7%	12%	12%
OKLAHOMA	6%	27%	36%	46%
OREGON	10%	10%	10%	10%
PENNSYLVANIA	9%	22%	26%	27%
RHODE ISLAND	10%	10%	10%	10%
SOUTH CAROLINA	5%	5%	5%	5%
SOUTH DAKOTA	8%	8%	8%	20%
TENNESSEE	6%	23%	24%	26%
TEXAS	7%	44%	51%	53%
UTAH	7%	7%	7%	7%

VERMONT	13%	13%	13%	13%
VIRGINIA	7%	13%	13%	13%
WASHINGTON	8%	16%	26%	26%
WEST VIRGINIA	5%	65%	65%	65%
WISCONSIN	9%	67%	73%	73%
WYOMING	7%	7%	7%	38%

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PROGRESSIVE POLICY INSTITUTE
1919 M Street NW,
Suite 300,
Washington, DC 20036

Tel 202.525.3926
Fax 202.525.3941

info@ppionline.org
progressivepolicy.org