An Assessment of the U.S. Recycling System: Financial Estimates to Modernize Material Recovery Infrastructure

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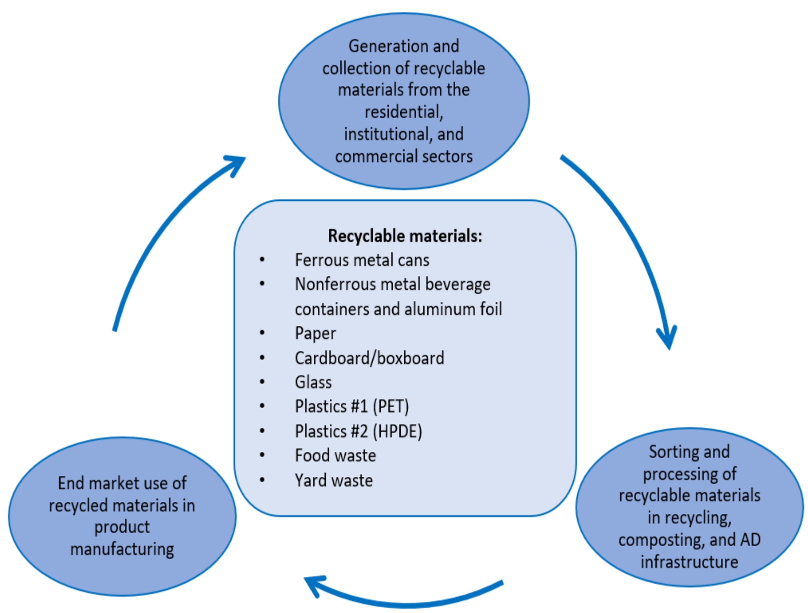
Executive Summary

As part of the Fiscal Year (FY) 2021 appropriations bill passed in December 2019, House Report 116-448 directs the Environmental Protection Agency (referred to as "EPA" or "the Agency" for the remainder of this report) to "develop estimates of the infrastructure investment required to modernize the Material Recovery infrastructure…[and] develop estimates for the amounts of investment needed to provide all citizens with access to recycling services on par with access to disposal."[1] In direct response, EPA developed estimates of the total infrastructure investment required to modernize recycling infrastructure, improve consumer recycling education, and provide all residents with equivalent access to recycling services (i.e., opportunities to recycle are on par with trash disposal services, such as residents having access to both curbside trash and curbside recycling services). The goal of these investments is to achieve consistent collection across the nation and maximize the efficient recovery of materials.

The U.S. recycling system faces significant challenges in improving recycling. A U.S. Government Accountability Office (GAO) report published in December 2020 flagged several key challenges in improving recycling in the U.S., which include the contamination of recyclables, low recycling collection rates, limited market demand for recycled materials, low profitability for operating commercial recycling programs, and limited information to support decision-making about recycling.[2] In 2021, Congress passed the Infrastructure Investment and Jobs Act, also known as the Bipartisan Infrastructure Law (BIL), to fund improvements to post-consumer materials management, infrastructure, and recycling programs through the Solid Waste Infrastructure for Recycling (SWIFR) grant program.[3]

Exhibit ES-1. Scope of Infrastructure Investment Assessment



To delineate the analysis scope, summarized in **Exhibit ES-1**, EPA focused on quantifying and assessing the level of investment needed to provide all residents access to recycling services on par with access to

[1] U.S. House of Representatives. 2021. House Report 116-448. Accessed online Sept. 2022: https://www.congress.gov/congressional-report/116th-congress/house-report/448

[2] U.S. Government Accountability Office. 2020. Recycling: Building on Existing Federal Efforts Could Help Address Cross-Cutting Challenges. Accessed online Sept. 2021: https://www.gao.gov/products/gao-21-87

[3] U.S. Congress H.R.3684 - 117th Congress, 2021. Infrastructure Investment and Jobs Act. Congress.gov, Library of Congress. Accessed online Jan. 2024: https://www.congress.gov/bill/117th-congress/house-bill/3684.

trash disposal, using the nation's 2030 50 percent recycling goal as a framework to measure success of recycling investments. Specifically, EPA focused its analysis on:

- Packaging and organic recyclable materials as the combined tonnages of these materials account for 82 percent of the municipal solid waste stream (MSW) and are therefore essential targets in providing communities with access to recycling services on par with access to trash disposal.[4]
- Proven, existing technologies to recycle these materials at a national level. This includes mechanical technologies that process commonly-recycled materials (e.g., metals, plastics, paper, and glass) through Material Recovery Facilities (MRFs) and biological technologies that process organic materials (e.g., food waste and yard waste) as livestock feed and through composting and anaerobic digestion facilities.[5]

Methodology

To develop investment estimates, EPA:

- Assessed the current stock of U.S. recycling infrastructure and identified associated gaps within the recycling system that must be addressed to modernize infrastructure and provide all residents with access to recycling services on par with access to trash disposal.
- Determined the level of investment needed to fill such gaps using secondary sources and a thorough literature review of 125 documents published between 2015 and 2021 that focus on key improvements and associated costs of improving the U.S. recycling system. Cost information relies primarily on data from The Recycling Partnership's *Paying It Forward* report[6], the Institute for Local Self-Reliance's (in partnership with the National Recycling Coalition and Zero Waste USA) *American Recycling Infrastructure Plan*,[7] ReFED's *Roadmap to 2030* report,[8] and ReFED's *Insights Engine*.[9] EPA did not collect any primary data for this report.
- Conducted a series of interviews with U.S. recycling system stakeholders and experts to verify research findings and refine cost estimates.

Summary of Infrastructure Investment Estimates

Based on available information, an estimated total investment of **$36 to $43 billion**, summarized in **Exhibit ES-2**, would improve curbside collection, drop-off, and processing infrastructure (i.e., MRFs, packaging material specific recycling facilities, composting, AD, and livestock infrastructure) by 2030. This level of investment, which would leverage combined funding and financing mechanisms from stakeholders across the entire recycling system including federal, state, and municipal governments, the private sector, hybrid public-private partnerships, and fee-based programs, could lead to the potential

[4] U.S. EPA. 2022. Guide to the Facts and Figures Report about Materials, Waste and Recycling. Accessed online Aug. 2022: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/guide-facts-and-figures-report-about

[5] The report scope does not include recovery technologies that are not yet used at scale (e.g., plastics chemical recycling, which transforms recycled plastic into a virgin-like resin).

[6] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

[7] Institute for Local Self-Reliance (ISRI). 2021. "Recycling Infrastructure Plan Released." Accessed online May 2022: https://ilsr.org/recycling-infrastructure-plan-released/

[8] ReFED. 2021. Roadmap to 2030: Reducing U.S. Food Waste by 50% and the ReFED Insights Engine. Accessed online May 2022: https://refed.org/uploads/refed_roadmap2030-FINAL.pdf.

[9] ReFED. 2022. ReFED Insights Engine. Accessed online May 2022: https://insights.refed.org/?_ga=2.257273867.1212413126.1660677635-778134506.1657051175.

recovery of an additional **82 to 89 million tons** of packaging and organic waste, a 91 percent increase in recovery over current levels. This increased tonnage of recovered material could increase the nation's recycling rate from its current level of **32 percent to 61 percent**, allowing the U.S. to surpass the national recycling goal of 50 percent set by EPA.[10]

Exhibit ES-2. Summary Education, Outreach, and Infrastructure Investment Cost Estimates.

Cost Category	Low-End Estimate	High-End Estimate
Packaging Materials		
Curbside Collection	$19,900,000,000	$21,500,000,000
Glass Separation (Curbside)	$2,900,000,000	$2,900,000,000
Drop Off	$1,900,000,000	$3,400,000,000
Deposit Redemption System	$100,000,000	$100,000,000
Curbside + Dropoff	***$21,800,000,000***	***$24,900,000,000***
Curbside + Dropoff + Deposit Redemption System	***$21,900,000,000***	***$25,000,000,000***
Curbside + Dropoff + Glass Separation	***$24,700,000,000***	***$27,800,000,000***
Curbside + Dropoff + Glass Separation + Deposit Redemption System	***$24,800,000,000***	***$27,900,000,000***
Organic Materials		
At-Home Composting	$380,000,000	$380,000,000
Community Composting	$4,700,000,000	$4,700,000,000
Centralized Composting	$8,700,000,000	$9,400,000,000
Centralized Anaerobic Digestion	$422,000,000	$436,000,000
Water Resource Recovery Facility (WRRF) Anaerobic Digestion	$77,000,000	$96,000,000
Animal Feed	$449,000,000	$504,000,000
Organics Total	***$14,700,000,000***	***$15,500,000,000***
Total Recycling Investment	**$36,000,000,000**	**$43,000,000,000**
Note: *Low-end and high-end estimates are driven by various factors. For packaging, the low-end estimates assume that facilities will not receive the latest technology upgrades (e.g., optical sorters, robotic arms, etc.) while the high-end estimates assume that facilities will be upgraded or modernized with the latest technology, resulting in higher capital costs. Technology upgrades would work to reduce contamination and improve recycling output quality. For organics, the low-end estimates assume that not all existing facilities are operating at full capacity and could intake a portion of the potentially recoverable materials, resulting in reduced capital costs. The high-end estimate assumes that facilities will not operate any closer to full capacity and that comparatively more facilities will need to be built, which will result in higher capital costs. Cost estimates do not factor in benefits associated with recycling, including potential revenue from the sale of recycled commodities, GHG emissions and pollutant reduction, conservation of landfill space, etc.*		

[10] U.S. EPA. 2018. National Overview: Facts and Figures on Materials, Wastes and Recycling. Accessed online Aug. 2022: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#:~:text=The%20recycling%20rate%20(including%20composting,person%20per%20day%20for%20recycling.

Cost Category	Low-End Estimate	High-End Estimate
Estimated using: (1) Eunomia. 2021. The 50 States of Recycling. Prepared for the Ball Corporation. (2) U.S. Census Bureau. 2022. 2019 American Community Survey. (3) State waste management reports. (4) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. (5) U.S. EPA Office of Resource Conservation and Recovery. 2020. 2019 Wasted Food Report. (6) U.S. Census Bureau. 2022. 2019 American Community Survey. (7) Natural Resources Defense Council. 2017. Estimating Quantities and Types of Food Waste at the City Level. Accessed online May 2022: https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf. (8) ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf. (9) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/ (10) U.S. Composting Council. 2021. "Organics Bans and Mandates." Accessed online May 2022: https://www.compostingcouncil.org/page/organicsbans. (11) U.S. Composting Council. The Case for Centralized Compost Manufacturing Infrastructure. Accessed May 2022. (12) U.S. EPA. 2021. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). Accessed online May 2022: https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf. (13) Interviews with industry experts.		

To modernize recycling infrastructure, improve consumer recycling education, and provide all residents with equivalent access to recycling services, the investments would need to address identified gaps in recycling infrastructure across all stages in the U.S. recycling system:

- **Generation and collection:** Currently, access to recycling services is not equivalent to that of trash disposal services. Roughly 40 percent of households do not have access to recycling services for packaging materials equivalent in quality to trash disposal services and roughly 91 percent of households do not have access to recycling services for organic materials equivalent in quality to trash disposal services (e.g., residents have curbside trash collection but must take packaging materials/organic materials to a drop-off center to be recycled).[11, 12]
- **Sorting and processing:** The current U.S. packaging and organic materials sorting and processing universe includes approximately 10,000 facilities that currently recycle 65 million tons of material.[13] While some facilities have been recently updated with the latest sorting and processing technology and have expanded capacity, many facilities still require technological updates to streamline the sortation process and more efficiently address contamination of incoming materials. In addition, there are many regions of the U.S. with few or no recycling facilities.
- **End markets:** A successful recycling system requires robust end markets to accept processed materials. The U.S. recycling market currently includes around 200,000 facilities that can directly use the end product produced from the recycling process for input in material manufacturing or operations.[14] Currently, few existing policies and economic incentives exist to encourage the use of recycled materials in production and operation and support end market development.

In addressing the identified gaps in the recycling system, investments in education, collection, and processing capacity should be made simultaneously, along with policies to disincentivize landfilling materials (e.g., pay-as-you-throw programs) and to promote the use and sale of recycled material (e.g.,

[11] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

[12] GreenBlue. 2022. Mapping Urban Access to Composting Programs. Accessed online May 2022: https://greenblue.org/work/compostingaccess/.

[13] U.S. EPA. 2022. Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

[14] U.S. EPA. 2022. Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

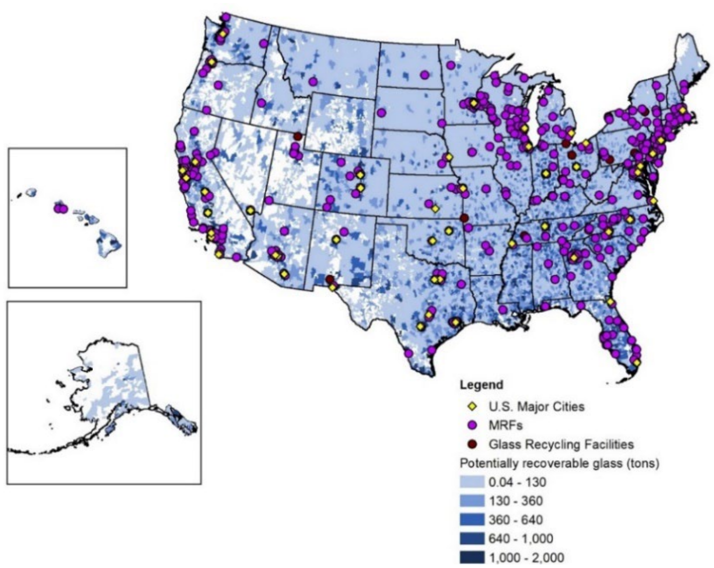
minimum post-consumer recycled content mandates). Recycling programs across the U.S. can leverage financing mechanisms such as private equity, public-private partnerships, and government grants to fund investment in such recycling projects and programs.

Considerations

While the expansion of recycling infrastructure is needed nationwide, there are select regions, specifically the South, Southwest, and Rocky Mountains, with high rates of potentially recyclable material and a general lack of recycling infrastructure.[15] It may be beneficial to focus initial investments, including investments in education and outreach to motivate behavior change, in these areas using proven technology and infrastructure as they represent high-need, high-reward regions. **Exhibit ES-3** shows opportunities for potentially high glass recovery in dark blue. (Additional packaging materials maps can be found in **Appendix A**.) **Exhibit ES-4** shows opportunities for organics recycling, shown in dark green.

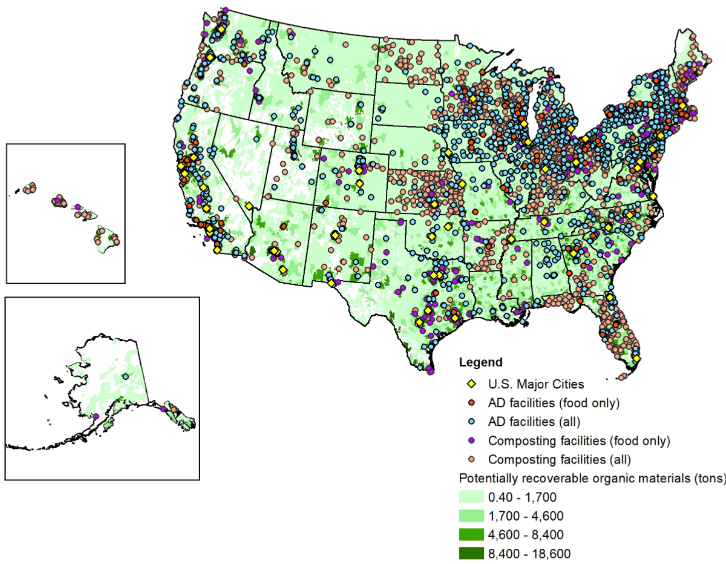
Beyond 2030, recycling assessments will need to expand to include materials beyond conventionally recycled packaging and organics, such as electronics, textiles, and plastics #3 to #7. These assessments should include thoughtful consideration of how to maximize source reduction and promote reuse, as well as how best to upgrade and integrate infrastructure required for recycling. In addition, future analyses should align with circular economy considerations. Currently, the U.S. has a linear material supply chain involving extraction, use, and disposal. A more circular economy would provide more meaningful and lasting waste reduction as it recaptures waste and uses it as a valuable input for manufacturing. This type of system is not only oriented toward lifecycle impacts of materials but also would focus on waste elimination through alternative materials use and design to reuse, restore, and even regenerate materials, maintaining value for as long as possible.

Exhibit ES-3. Example Geographic Prioritization of Investment: Potentially Recyclable Glass[16]



[15] Note that areas in the South, Southwest, and Rocky Mountains currently lack the critical infrastructure to process additional packaging and organic materials for a variety of legislative, policy, and administrative reasons.
[16] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

Exhibit ES-4. Geographic Prioritization Analysis for Organics Recycling Investment Opportunities.[17]



[17] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

Section 1: Introduction

1.1 Report Purpose

> **Report Purpose:** EPA developed this report at the request of Congress. This report summarizes estimates of the total infrastructure investment required to modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal.

The U.S. recycling system faces significant challenges to improve recycling. Changes in the international trade of municipal solid waste (MSW) recyclables have impacted the domestic recycling system by limiting U.S. recycling exports, a constraint that appears to have exposed weak points in the aging U.S. system. A U.S. Government Accountability Office (GAO) report published in December 2020 flagged several key challenges in improving recycling in the U.S.:[18]

1. Contamination of recyclables;
2. Low recycling collection rates;
3. Limited market demand for recycled materials;
4. Low profitability for operating commercial recycling programs; and
5. Limited information to support decision-making about recycling

House Report 116-448, as part of the Fiscal Year (FY) 2021 appropriations bill passed in December 2019, directs EPA to "develop estimates of the infrastructure investment required to modernize the Material Recovery infrastructure…[and] develop estimates for the amounts of investment needed to provide all citizens with access to recycling services on par with access to disposal."[19] In direct response, EPA developed estimates of the total infrastructure investment from stakeholders across the recycling system that would modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal, with the goal of achieving consistent collection across the nation and maximizing the efficient reuse of materials.

EPA focused its analysis on those materials with proven technologies already used to process materials at scale and that have established recycling end markets. The materials of focus are packaging and organic materials, which together account for 82 percent of the municipal solid waste stream and are therefore essential targets in providing residents with access to recycling services on par with access to trash disposal.

As an initial step in developing investment estimates, EPA identified existing proposals, reports, case studies, and secondary data that evaluate the financial gaps and needs in and of the U.S. recycling system. Building from that effort, EPA used the identified data and reports, along with interviews with recycling experts, to analyze the current state of the U.S. recycling infrastructure stock and infrastructure gaps, estimate the cost to fill those gaps, and finally, examine the potential financial mechanisms to address such gaps.

1.2 Scope of Assessment and Key Definitions

To delineate the scope of this analysis, EPA focused on quantifying and assessing the level of investment needed to provide all residents with access to recycling services on par with access to trash disposal, using the nation's

[18] U.S. Government Accountability Office. 2020. Recycling: Building on Existing Federal Efforts Could Help Address Cross-Cutting Challenges. Accessed online Sept. 2021: https://www.gao.gov/products/gao-21-87

[19] U.S. House of Representatives. 2021. House Report 116-448. Accessed online Sept. 2022: https://www.congress.gov/congressional-report/116th-congress/house-report/448

2030 50 percent recycling goal as a framework to measure the success of recycling investments.[20] EPA directed its efforts toward identifying near-term opportunities for increasing effective recycling across the nation's existing recycling system (e.g., collection, sortation, processing, etc.) within a 2030 timeframe for recycling technologies that are already used to process materials at scale and that have established recycling end markets (i.e., recycled materials are traded and sold in commodity markets nationwide).

To effectively target achievable investments in the 2030 timeframe**, the analysis focuses specifically on MSW packaging material and organic materials with established recycling end markets**. The primary materials of interest include ferrous metal cans, nonferrous metal beverage containers, aluminum foil, paper, cardboard/boxboard, glass, plastics #1, plastics #2, and organic material (i.e., food waste and yard waste). Packaging and organic materials account for 82 percent of the municipal solid waste stream and are therefore essential targets in providing residents with access to recycling services on par with access to trash disposal.[21]

The plastic numbering system, or **Resin Identification Code (RIC)** is a set of symbols included on plastic products that identify the plastic resin out of which the product is made. Plastics are labeled with numbers #1-7:

- **Plastics #1:** PET typically used for beverage bottles (e.g., water bottles)
- **Plastics #2:** HDPE typically used for milk jugs and laundry detergent bottles
- **Plastics #3:** PVC typically used for pipes
- **Plastics #4:** LDPE typically used for shrink wrap or other flexible plastic packaging
- **Plastics #5:** PP typically used for straws and single-use food ware
- **Plastics #6:** PS typically used for packing peanuts
- **Plastics #7:** Miscellaneous

Other materials such as textiles, electronics, and plastics #3 to #7 are equally important and require thoughtful consideration of how best to upgrade and integrate infrastructure required for recycling, as well as how to develop end markets. However, these materials are not included in the scope of the current assessment due to material flow and cost data limitations as well as a lack of demonstrated, wide-scale, and proven (or feasible) recovery technologies and established end markets. As more data on these materials become available, EPA will consider updating the assessment accordingly.

Key terms that frame the assessment scope are defined below:

- **Anaerobic digestion (or co-digestion)** – the breaking down of organic material with bacteria in the absence of oxygen (i.e., anaerobic). This process generates biogas and nutrient-rich matter. Co-digestion refers to the simultaneous anaerobic digestion of food and other organic material in one digester. This process includes fermentation (i.e., converting carbohydrates – such as glucose, fructose, and sucrose – via microbes into alcohols) in the absence of oxygen to create products such as biofuels.
- **Composting** – the process of breaking down organic material with bacteria in oxygen-rich (aerobic) environments. Composting produces organic material that can be used as a soil amendment.
- **Equivalent access** – refers to when opportunities to recycle are on par with trash disposal services (i.e., opportunities to recycle are on par with trash disposal services, such as residents having access to both curbside trash and curbside recycling services).

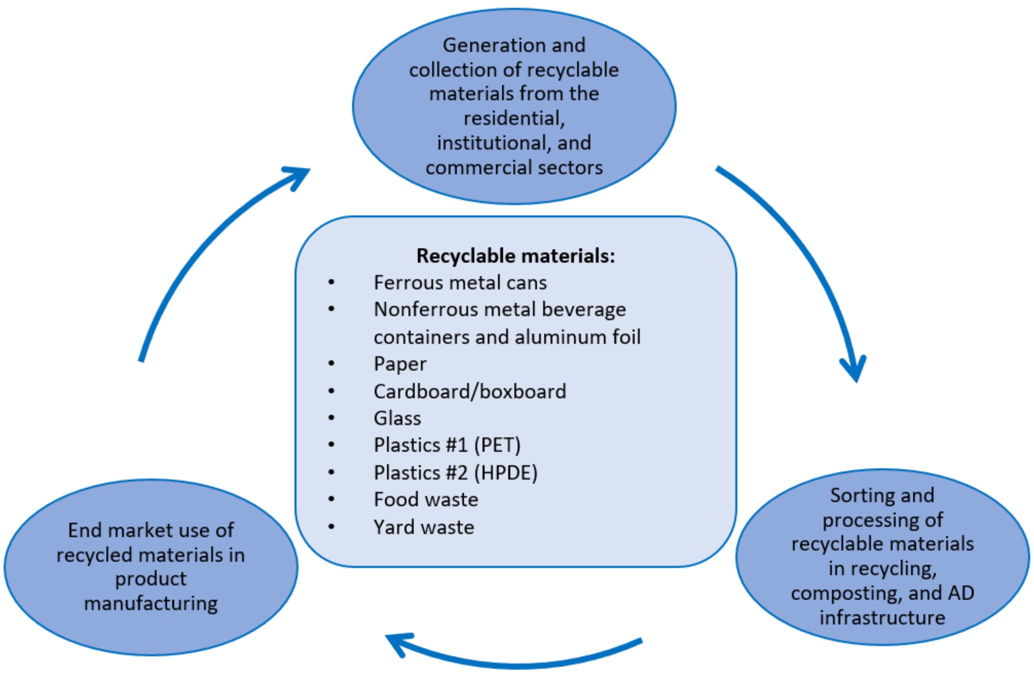
[20]U.S. EPA. 2022. Guide to the Facts and Figures Report about Materials, Waste and Recycling. Accessed online Aug. 2022: https://www.epa.gov/recyclingstrategy/us-national-recycling-goal

[21] U.S. EPA. 2022. Guide to the Facts and Figures Report about Materials, Waste and Recycling. Accessed online Aug. 2022: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/guide-facts-and-figures-report-about

- **Organic materials** – refers to food waste (e.g., fruits and vegetables, grains, coffee grounds, etc.) and yard waste (e.g., leaves, sticks, grass clippings, etc.).
- **Packaging materials** – refers to ferrous and nonferrous metal cans and foil, paper, cardboard/boxboard, glass containers (e.g., bottles and jars), and plastic containers used to package both solid and liquid products (including plastics #1 and #2).
- **Recycling** – refers to the series of activities by which discarded or used materials, products, or substances are collected, sorted, processed, and/or converted into feedstock for use in the manufacture of new products.
- **Recycling infrastructure and technology** – infrastructure that encompasses the general recycling process as it currently exists in the U.S., beginning with generation, collection, sortation, processing, and finally, end market use of recycled materials (e.g., product manufacturing).

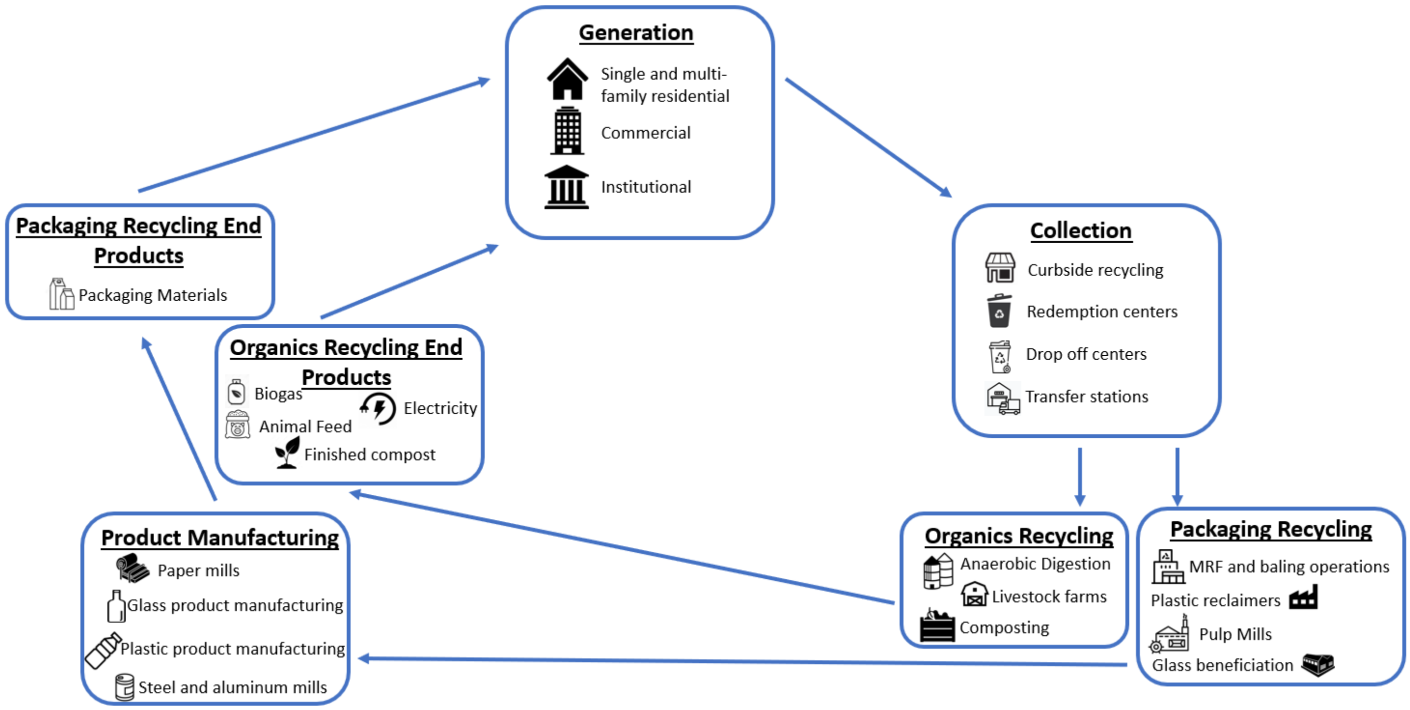
Exhibit 1-1 depicts the scope of this report and **Exhibit 1-2** visually depicts the recycling system for packaging and organic materials in the U.S.

Exhibit 1-1. Scope of Infrastructure Investment Assessment*



**Note: This assessment focuses on existing infrastructure to collect and process materials that have proven, existing technologies for recycling as well as known end markets for the recycled products at a national level. This includes mechanical technologies that process commonly-recycled materials (e.g., metals, plastics, paper, and glass) through Municipal Recovery Facilities (MRFs) and biological technologies that process organic materials (e.g., food waste and yard waste) as livestock feed and through composting and anaerobic digestion facilities. The report scope does not include recovery technologies that are not yet used at scale (e.g., plastics chemical recycling, which transforms recycled plastic into a virgin-like resin).*

Exhibit 1-2. U.S. Recycling System for Packaging and Organic Materials



In alignment with existing federal efforts to improve the recycling system, EPA also developed this report keeping parallel recycling initiatives in mind. These initiatives include:

- the Agency's current *National Recycling Strategy* and subsequent documents in EPA's Circular Economy series;
- a nationwide information collection request for recycling data (e-ICR);
- two grant programs authorized by the Bipartisan Infrastructure Law focused on improving the nation's recycling infrastructure, decreasing contamination, standardizing measurement, increasing data collection, and expanding consumer recycling education and outreach; and
- concerted efforts to bolster the recycling market through the creation of supporting tools and maps.

This assessment focuses on existing recycling infrastructure to collect and process materials with known end markets for recycled products at a national level and focuses on proven, existing technologies to recycle these materials. The report scope does not include recovery technologies that are not yet used at scale.

The remainder of this report provides more detail on the financial estimates to modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal. This report is organized as follows:

- **Section 2:. Financial Assessment and Estimates for Packaging Materials** describes the current recycling infrastructure and infrastructure gaps for packaging materials, provides a breakdown of financial investments needed to address identified gaps, and details geographic priorities for investment.

- **Section 3**:**. Financial Assessment and Estimates for Organic Materials** describes the current recycling infrastructure and infrastructure gaps for organic materials, provides a breakdown of financial investments needed to address identified gaps, and details geographic priorities for investment.
- **Section 4**:**. Financial and Resource Support** describes the financial mechanisms that could be considered to address the investments identified to upgrade the nation's recycling infrastructure and provide all residents with access to recycling services on par with access to trash disposal.
- **Section 5**:**. Additional Materials for Future Consideration** describes considerations in improving the nation's recycling system for other materials outside of the assessment scope, such as textiles, plastics #3 to #7, and electronics.
- **Section 6**:**. Summary and Beyond 2030** provides a summary of the investments needed to modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal and summarizes considerations to improve recycling beyond 2030.
- **Appendix A** provides maps of existing recycling infrastructure for packaging materials and potentially recyclable material tonnage across the U.S.
- **Appendix B** provides maps of existing recycling infrastructure for organic materials and potentially recyclable material tonnage across the U.S.
- **Appendix C** provides documented case studies and project examples highlighting specific real-world and place-based applications of recycling solutions.

Section 2: Financial Assessment and Estimates for Packaging Materials

2.1 Introduction and Overview

An investment of **$22 to $28 billion** is needed to recycle the 38 to 45 million tons of currently potentially recyclable packaging material (i.e., glass bottles, aluminum/steel cans, paper, cardboard, and plastics #1 and #2). An investment of this scale would require funding from stakeholders across the entire recycling system, including federal, state, and municipal governments, the private sector, hybrid public-private partnerships, and fee-based programs. This would increase the nation's recycling rate from 32 percent to approximately 45 to 47 percent.

The current U.S. recycling system diverts several commonly-recycled packaging materials from the municipal solid waste stream. EPA estimates that the nation generates around 96 million tons of packaging materials waste and recycles 39 percent of this waste. This analysis estimates that an additional 38 to 45 million tons of packaging material could be recycled by expanding recycling access and infrastructure (e.g., more collection trucks, more recycling carts, etc.).[22]

This expansion of the U.S. recycling infrastructure would require an investment of $22 to $28 billion for improvements to curbside collection, drop-off, and processing infrastructure (i.e., material recovery facilities, or MRFs). This level of investment from cities, states, private companies, public-private partnerships, and the federal government through legislation such as the Bipartisan Infrastructure Law would provide households with equivalent access to packaging material recycling as trash disposal services and **could increase the nation's overall recycling rate to approximately 45 to 47 percent, close to EPA's nationwide goal of 50 percent**. This report details the following below:

- Discusses EPA's methodology to estimate the investment required to modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal;
- Describes gaps within the existing packaging materials recycling system;
- Estimates the investment needed to improve infrastructure and address identified gaps; and
- Discusses logistical considerations such as investment timing, geographic focus, and policy environments required to make lasting change.

2.2 Methodology

To estimate the level of investment needed to modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal, EPA identified strategies for expanding U.S. residential recycling infrastructure, from ensuring equivalent access to curbside collection and drop-off stations to developing glass separation and deposit redemption systems. The National Recycling Goal, which is to attain a national recycling rate of 50 percent by 2030, serves as a framework to measure the success of identified recycling investments.

The scope of packaging materials focuses on those with proven technologies to process materials at scale and have established recycling end markets. Only packaging materials from the residential sector are included in this analysis; commercial and industrial recycling are out of scope. The list of packaging materials comprises ferrous metal cans, nonferrous metal beverage containers, aluminum foil, paper, cardboard/boxboard, glass, plastics #1 (polyethylene terephthalate, or PET), and plastics #2 (high-density polyethylene, or HDPE). Textiles, electronics, and plastics #3 through #7 are excluded from this analysis

[22] This estimate assumes no source reduction, no major changes in processing technology, some level of contamination, and participation rate of 78.6 percent, consistent with the participation rate used by The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/.

because they are not widely accepted for residential recycling, rely on emerging recycling technologies, or lack a robust end market.[23] **Exhibit 1-1** illustrates the full scope of this report.

The model for packaging materials makes several assumptions to develop investment estimates, address information gaps, and account for scarce national-level data on materials, infrastructure, and MRF capacity and throughput. These are highlighted throughout the report, but three key assumptions are outlined below:

1. With the investments outlined in this report, the participation rate for packaging materials for both single-family and multi-family households would be 78.6%.[24] This means that even with investments to make recycling accessible to all residents and to improve the overall recycling system, not everyone who has access to recycling services will choose to recycle.
2. The increase in residential recycled materials will require either constructing new MRFs or upgrading the design and capacity of existing MRFs to improve utilization. Low-end estimates assume that existing facilities are operating at less than 100% capacity and can manage an increase in materials, while high-end estimates assume that facilities are operating at or near 100% capacity and must be upgraded or modernized with the latest technology, such as optical sorters or robotic arms.
3. All urban households are assumed to recycle packaging materials via curbside collection and all rural households are assumed to recycle packaging materials via drop-off services. Urban households will not recycle via drop-off and curbside is assumed to be unavailable for rural households. The reason for this simplified assumption is because in previous studies, there was a delineation between curbside collection and drop-off based on the type of recycling program listed on the municipality's website.

Generation and recycling tonnage estimates used per capita rates from the Ball Corporation's *50 States of Recycling* report from 2021 applied to state-level population data from the 2019 American Community Survey. [25, 26] EPA estimated the tonnage of potentially recyclable packaging material using an approach consistent with the *50 States of Recycling* report, subtracting the quantity of recovered material from the total amount of material generated for each type of packaging material in each state. Data for paper generation and recycling were unavailable for most states, so EPA estimated missing values using the difference between average per capita generation and recycling for select states reporting paper data, applied to the same state-level population data. It is important to note that the state paper generation data are self-reported, not independently verified, collected at irregular intervals, and contain varying levels of detail about community recycling programs.

In addition, this report quantifies the existing infrastructure stock and estimates the total number of additional MRFs needed to address identified gaps in the U.S. recycling system, using information from

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[23] Interviews with industry experts suggest there are developing end markets for plastics #4 (LDPE) and #5 (PP). Plastic #7 is sometimes used in manufacturing but is not recycled widely. The Pew Charitable Trusts report indicates no existing or anticipated end markets for plastics #3 (PVC) and #6 (PS). Source: Pew Charitable Trusts. 2020. Breaking the Plastic Wave. Accessed online Sept. 2021: https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/breaking-the-plastic-wave-top-findings

[24] This value is derived from TRP's estimate of increased recycling access for single family households in the U.S. (additional single-family households served/total U.S. single-family households). It is also applied to multifamily households because the goal is equivalent access, or recycling service on par with trash disposal services. Multifamily households stand to benefit considerably from improvements to recycling collection.

[25] Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.* Accessed online Oct. 2021: https://www.ball.com/sustainability/real-circularity/50-states-of-recycling

[26] U.S. Census Bureau. 2022. 2019 American Community Survey. Accessed online May 2022: https://www.census.gov/programs-surveys/acs

EPA's Recycling Infrastructure and Market Opportunities map, which provides data for MRFs and materials-specific processing facilities.[27] EPA identified key costs (e.g., equipment for collection and processing, operation, education, etc.) for both infrastructure expansion and new infrastructure.

Both the e-ICR and Solid Waste Infrastructure for Recycling (SWIFR) grant program funded through the Bipartisan Infrastructure Law (BIL) serve as unique opportunities to collect recycling data on a community level and verify or adjust current, national-level estimates; if possible, these may be incorporated in future recycling infrastructure needs analyses. **Exhibit 2-1** summarizes generation, recycling, and potentially recyclable packaging material by type.

Exhibit 2-1. Packaging Material Generation, Recycling, and Potentially Recyclable Material (2019).

Packaging Material	Generation (Tons)	Recycling (Tons)	Potentially Recyclable Material (Tons)
PET Bottles	3.3 million	764,000	2.5 million
PET Rigid	766,000	45,000	721,000
HDPE Bottles	2.2 million	499,000	1.7 million
Aluminum	1.5 million	553,000	950,000
Steel	1.8 million	562,000	1.2 million
Cardboard	34.2 million	18.3 million	15.9 million
Paper	42.3 million	12.5 million	29.8 million
Glass	9.9 million	4.1 million	5.8 million
Total	**96 million**	**37.3 million**	**58.6 million**

Estimated using:
(1) Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.*
(2) U.S. Census Bureau. 2022. 2019 American Community Survey.
(3) State waste management reports.

Furthermore, EPA conducted a thorough review of available recycling infrastructure literature: 125 documents focused on key improvements and associated costs of expanding the aging U.S. recycling system (published between 2015 and 2021). (A complete list of references can be found in the **References** section of this report). Cost information relies primarily on data from The Recycling Partnership's *Paying It Forward* and the Institute for Local Self-Reliance's (in partnership with the National Recycling Coalition and Zero Waste USA) *American Recycling Infrastructure Plan* for the Recycling is Infrastructure Too Campaign.[28, 29] Estimates also integrate findings from interviews with experts in the domestic recycling system:

- Container Recycling Institute
- EPA's Office of Resource Conservation and Recovery
- EPA's Tribal Waste Management Program
- Environmental Research and Education Foundation

[27] U.S. EPA. 2022. Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.
[28] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/
[29] Institute for Local Self-Reliance (ISRI). 2021. "Recycling Infrastructure Plan Released." Accessed online May 2022: https://ilsr.org/recycling-infrastructure-plan-released/

- Northeast Recycling Council
- Southeast Recycling Development Council
- Solid Waste Association of North America
- The Recycling Partnership
- Sustainable Packaging Coalition

EPA was not able to locate existing data regarding collection/drop-off equipment and operation needs, processing, and end markets in tribal communities prior to the publication of this report, so tribal community needs are discussed qualitatively throughout.

Finally, EPA conducted a high-level spatial analysis, identifying geographic areas within which to prioritize investment. This work leverages EPA's Recycling Infrastructure and Market Opportunities map where generation, recycling, and uncaptured recycling quantities, by material type, are mapped against existing recycling infrastructure.[30] The existing recycling infrastructure includes MRFs, material specific recycling facilities (e.g., plastics recycling facilities, metal recycling facilities, etc.), and potential end markets (e.g., paper mills, smelters, etc.). The map is used to identify the geographic distribution of residential recycling infrastructure stocks and gaps and to consider region-specific needs. Additionally, the report goes one step further by overlaying data from EPA's EJScreen tool to review and discuss how environmental justice factors must be incorporated into proposals to upgrade the U.S. recycling system.[31]

2.3 Summary of Identified Infrastructure Stock and Gaps

In developing investment estimates, EPA first identified the existing infrastructure stock and gaps that need to be filled to expand residential curbside collection and drop-off programs, and to aggregate and process more materials through existing and new MRFs. An overview of the infrastructure stock and gaps for packaging materials, organized by recycling system stage follows below.[32]

2.3.1 Generation and Collection

Residential packaging material waste is either recycled or managed through landfilling or incineration. [33] This assessment focuses on two main types of recycling collection:

- Curbside collection, where a municipal or private hauler drives through communities to pick up carts of recycled material and brings it to a transfer station, and
- Drop-off, where residents bring their own household packaging material waste to a "convenience center" (i.e., a drop-off station).

Currently, 6 percent of homes across the U.S. do not have access to any recycling services such as curbside recycling collection through the municipality, options for subscription-based service (whereby customers pay a recurring fee for their recycling to be picked up on a regular basis), or drop-off locations within the municipal boundary. Additionally, roughly 40 percent of households do not have access to recycling services equivalent in quality to trash disposal (e.g., residents have curbside trash collection but must take

[30] U.S. EPA. 2022. Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

[31] U.S. EPA. 2023. EJScreen: Environmental Justice Screening and Mapping Tool. Accessed online January 2023: https://www.epa.gov/ejscreen.

[32] Note that insufficient materials management infrastructure in the U.S. to collect and process recycling is a documented issue. State and local governments have made significant efforts to divert waste from landfills. These efforts have been documented in a number of published reports and case studies. **Appendix C** provides some specific real-world and place-based applications of recycling solutions.

[33] The scope of this report is limited to generators in the residential sector only. Commercial and industrial generation and collection is considered out of scope for this assessment of infrastructure stocks and gaps.

packaging materials to a drop-off center to be recycled).[34, 35] Multi-family units are at a particular disadvantage: 12 percent of multi-family units do not have access to any recycling services.[36, 37] Equivalent access to curbside collection and drop-off, where recycling services are as accessible as trash disposal services, is an important starting place for the analysis of infrastructure gaps.[38] Equivalent access would require adjustments to the following:

- **Curbside collection:** 81 percent of single-family households have access to curbside collection (i.e., through their municipality or through a private subscription service), while only 27 percent of multi-family households have on-property collection.[39] By contrast, 14 percent of single-family households and 61 percent of multi-family households have access to drop-off stations. While many urban municipalities have some form of drop-off station or convenience center for drop-off in addition to municipal or subscription curbside collection services, multi-family buildings are often left out of curbside collection altogether, leaving off-site drop-off as their only option. Multi-family buildings' recycling collection needs are similar to commercial collection needs (e.g., they require an aggregation bin and possibly a different type of truck for pickup). In some states, multi-family properties over a certain size are considered businesses, and therefore not eligible for municipally-run curbside programs. Multi-family building owners may either choose to contract with recycling collection services and increase unit rental rates to accommodate the cost of the service or leave it up to households to transport their recycling to a drop-off station. In either case, recycling access for a majority of multi-family households are not on par with trash disposal.
- **Drop-off collection:** Drop-off recycling is a sole option for many rural communities, and though this technically constitutes "access" to recycling services for households,[40] convenience stations (i.e., residential trash and recycling drop-off locations) may be more than 20 miles away, across town lines, or some distance away from public transportation routes. No matter the travel required, drop-off recycling access is not considered equivalent unless it is on-par with trash disposal (i.e., households must transport both trash and recycling to a "convenience station" because curbside pickup is not available through their municipalities or subscription services).
- **Education:** Curbside collection and drop-off program expansion require an investment for household education to help reduce contamination at the source (i.e., the household). Source contamination issues identified by industry expert interviewees range from improper disposal (e.g., bagged recyclables) to food residues on the insides of plastic containers, and inclusion of material that is not actually recyclable (e.g., broken furniture). Universally accessible educational

[34] The Recycling Partnership. 2020. 2020 State of Curbside Recycling Report. Accessed online Sept. 2021: https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2020/02/2020-State-of-Curbside-Recycling.pdf

[35] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

[36] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

[37] Multi-family buildings are defined as buildings with 5 or more housing units.

[38] Equivalent access to recycling is defined throughout this report as access to recycling equivalent to access to garbage disposal. It is a measure that harmonizes the recycling needs of urban and rural communities that have different design priorities for effective recycling, and it is consistent to "equitable access" definitions used by The Recycling Partnership in their reports. The terminology is different here, but the measure is the same.

[39] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

[40] Sustainable Packaging Coalition. 2021. 2020 to 2021 Centralized Study on Availability of Recycling. Accessed online Oct. 2021: https://sustainablepackaging.org/spc-releases-comprehensive-update-of-its-centralized-availability-of-recycling-study/.

materials to reach populations with varying languages, knowledge of acceptable materials, and/or cultural contexts is crucial to a well-functioning system.

As part of this analysis, EPA also looked at recycling programs in tribal communities. While tribal recycling and waste management is tribe-specific (i.e., with different resources, priorities, governance, etc.), many federally recognized tribes receive funding from EPA's Indian Environmental General Assistance Program (GAP) to manage their own solid waste. GAP grants fund for activities like developing integrated solid waste management plans, implementing curbside collection, and educating tribal citizens on recycling. Through GAP, many tribes have the funding to support a single environmental program staffer who must juggle multiple competing environmental program interests (e.g., air quality monitoring, water quality monitoring, and above-ground tank inspections). As a result, these positions often experience regular turnover, making it difficult to consistently staff and manage recycling programs. Service agreements and/or contracts with haulers are also identified as an area of need for tribes. EPA recently held a listening session for the design of the SWIFR Tribal Grant Program where commenters identified that they need technical assistance to negotiate recycling pick up in rural areas with low population density, as affordable collection services are difficult to secure given the geographically remote nature of many communities. Due to lack of quantitative data, EPA did not develop estimates for recycling infrastructure in tribal communities, but considerations for infrastructure expansion will be discussed qualitatively in **Section 2.4**.

The expansion of curbside recycling programs to areas that presently have drop-off centers would require investment in collection bins, carts, and trucks, as well as aggregation bins (e.g., compacting roll-offs or front-end containers) for multi-family buildings. This investment would convert to curbside collection some proportion of urban single and multi-family homes that currently have access to drop-off recycling only, thereby lowering a barrier to recycling participation. Expanding drop-off programs in rural areas would require investment in containers or compacters, supporting infrastructure like signage, tools (e.g., pitchforks or small forklift vehicles), and staffing. No matter the specific features of the recycling program, ultimately the expansion of recycling collection programs requires accessibility considerations such as the provision of recycling services on par with trash disposal services.

2.3.2 Sorting and Processing

The current U.S. material sorting and processing universe includes a total of 5,863 facilities designed to recover packaging material waste, including: [41]

- 421 MRFs that process multiple types of packaging material
- 83 glass recycling and beneficiation facilities (secondary processing facilities that address contamination by crushing, cleaning, and sorting glass into cullet)
- 5,099 metals recycling facilities that process either aluminum or steel[42]
- 57 paper recycling facilities
- 203 plastics recycling facilities.

[41] Data for plastic, paper, glass, and MRFs come from EPA's Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

[42] Data for metal recovery facilities come from the National Disaster Debris Recovery Facilities (EPA) point data layer, filtered to include only "metals" and "recovery" facilities. Source: U.S. EPA. 2022. US EPA Disaster Debris Recovery Tool. Accessed online Aug. 2022: https://services.arcgis.com/cJ9YHowT8TU7DUyn/arcgis/rest/services/EPA_Disaster_Debris_Recovery_Data/FeatureServer

As a whole, these facilities process more than 37 million tons of recoverable material. While some facilities have been recently updated with the latest sorting and processing technology and expanded capacity (e.g., Waste Management facilities), many of these facilities still require technological updates.[43] Technological updates can include upgrades to sortation and conveyance equipment, such as optical sorters, picker robots, and additional storage bunker capacity. Additionally, MRF operations data suggest that a majority of MRFs are not operating at full capacity. Currently, utilization data and recycling experts suggest that on average,[44] MRFs operate at a throughput capacity of just 56 percent, leaving an average unused throughput capacity of 44 percent. In addition, there are many regions of the U.S. with few or no MRFs.[45] (See **Appendix A** for maps of existing recycling infrastructure by material type processed.)

Currently, utilization data and recycling experts suggest that on average, MRFs operate at a throughput capacity of just 56 percent, leaving an average unused throughput capacity of 44 percent.

Regardless of location or daily throughput capacity, all MRFs are currently struggling with inbound contamination from the generation and collection of materials for recycling, which affects operating efficiency, residual contamination, and end-product quality.[46] Key sources of contamination include:

- Glass breakage
- Complex packaging labeled as “recyclable” but requiring consumers to disassemble pieces or remove labels before placing in recycling bins
- Black carbon plastic (optical scanners cannot process this material)
- Materials that are not widely accepted such as plastics #3, #6, and #7 [47]

While interviews with packaging recycling industry experts suggest that a change from single stream to dual stream collection would improve the quality of recycled material through reduced inbound contamination, interviewees also suggested that this would be a cost-prohibitive challenge. Interviewees identified glass separation as a possible middle path, reducing inbound contamination through the source separation of the largest contaminating material (glass). MRF operators reportedly do not prefer to process glass because glass is abrasive and grinds down equipment over time, increasing maintenance costs. Glass also breaks easily, and crushed glass shards or dust may get into bales of other recycled material such as paper. For this reason, glass is often sent to landfills as alternative daily cover (i.e., protection against animal scavenging, fire prevention, odor and pollution control). Combining glass with other materials during collection also reduces the quality and value of the glass waste stream itself. Markets for recycled glass highly value source-separated beverage containers (e.g., through deposit return programs); interviews with industry experts suggest that values and reuse options for mixed glass are typically more constrained.

[43] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/
[44] While the data are from U.S. MRFs, the data are limited to a small subset of MRFs reporting their throughput capacity.
[45] Note: This analysis examines regional patterns in MRF siting and generation of potentially recyclable material in **Section 2.5**.
[46] Inbound contamination is the contamination of materials collected by haulers from residential sources. Residual contamination refers to post-processing contamination at MRFs.
[47] According to multiple industry experts interviewed, plastic #4 film is often collected at grocery stores and sold directly to end market users, while plastic #5 is becoming a more widely accepted material.

Two additional areas where change is needed to bring about more effective and efficient recycling include 1) consistent messaging about the materials accepted by recycling and glass separation programs in differing jurisdictions, and 2) materials alignment with MRF processing equipment. While consistent messaging for collection is contingent on the acceptance of similar materials by MRFs, interviews with industry experts suggest that guidelines across neighboring municipalities often differ, even in cases where collected materials are sent to the same MRF. To further add to the confusion, lists of materials accepted at MRFs for recycling change periodically. The Recycling Partnership's 2019 State of Curbside Survey found that roughly one-third of surveyed programs made changes to the list of materials they collect or accept in the past two years.[48] A significant second component contributing to recycling ineffectiveness is that the types of items accepted in collection programs and the types of items that are targeted for recycling by materials management facilities may be misaligned. For instance, a community may engage and contract with a waste hauler stipulating that a certain material must be accepted for collection (e.g., clean pizza boxes). While the hauler is contractually obligated to collect certain items, the recycling facility that eventually receives these items may not sort or process them (e.g., recycling facilities may not process pizza boxes due to historic trends with contamination associated with food residue and grease). This misalignment may happen in both directions: items listed as acceptable in a collection program may not be sorted and sold by the receiving MRF and items listed as being prohibited in a collection program may indeed be sorted and sold by the receiving MRF. Alignment of municipal recycling guidelines with MRF-accepted materials is a clear way to reduce contamination and inefficiency in any recycling system.

In total, the effective expansion of recycling infrastructure requires targeted investment to address capacity, technology, labor, contamination, and staff education needs across MRFs and facilities with a range of operating conditions. Similarly, the expansion of sorting and processing infrastructure requires equity considerations such as siting and limiting operational disruption (e.g., traffic) to surrounding communities.

2.3.3 Recycling End Markets

A successful recycling system requires robust recycling end markets to accept processed materials. The U.S. recycling market currently includes around 1,000 end market facilities that can directly use the end product produced from the recycling process for input in material manufacturing (e.g., glass container manufacturers, smelters, foundries, paper mills, etc.).[49]

Currently, few existing policies and economic incentives support end market development by encouraging the use of recycled materials in products. In addition, contamination stemming from the generation and collection stage affects commodity quality and prices for most materials. Interviews with recycling industry experts suggest that a reduction in contamination from glass specifically would improve commodity quality and prices for all other packaging materials.

Ultimately, the expansion of recycling end markets would require investment to bolster domestic markets for recycled commodities as well as improve and/or ensure the quality of recycled commodities. Since

[48] The Recycling Partnership, "2020 State of Curbside Recycling Report," February 13, 2020. Available here: https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2020/02/2020-State-of-Curbside-Recycling.pdf

[49] U.S. EPA. 2022. Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

China's National Sword policy was enacted in 2018,[50] MRF operators have already increased investments in sorting equipment, purchasing robotic pickers and optical sorters as a means of increasing processing throughput and quality.[51] Technology improvements and automation with artificial intelligence and robotics continue to be an important investment trend in the recycling industry to strengthen the quality of recycled commodities. In addition, while consumers may be the driving source of contamination in the residential recycling stream, producers also have the capacity and responsibility to design packaging materials to support the reduction of consumer contamination (e.g., eliminating or reformatting large shrink sleeve labels, a contaminant, from PET bottles for improved capture rates).[52]

2.4 Assessment of Financial Estimates

Research identified several priorities for investment in future opportunities to capture packaging materials. An investment focused on materials with existing end markets would ensure: a) equivalent access to curbside and drop-off collection on par with trash disposal, b) options for reducing contamination by separating glass, and c) goal achievement by 2030. A summary of the investment estimates for two recycling scenarios – single stream and glass separation – organized by recycling system stage: generation and collection, sorting and processing, and end markets is provided below, in **Exhibit 2-2**. Within each of these scenarios, the analysis also considers a national-level bottle bill add-on scenario.

Exhibit 2-2. Summary Investment Cost Estimates for Packaging Materials.

System Component	Cost Category	Low-End Estimate	High-End Estimate
Curbside Collection	Capital (Deposit Redemption System only)	$100,000,000	$100,000,000
	Capital (without Deposit Redemption System)	$6,900,000,000	$8,500,000,000
	Operating (excludes MRFs)	$13,000,000,000	$13,000,000,000
	Subtotal	***$19,900,000,000***	***$21,500,000,000***
Glass Separation (Curbside)	Capital	$2,700,000,000	$2,700,000,000
	Operating (processing and trucking)	$225,000,000	$240,000,000
	Subtotal	***$2,900,000,000***	***$2,900,000,000***
Drop Off	Capital	$602,000,000	$2,100,000,000
	Operating (MRFs only)	$1,300,000,000	$1,300,000,000
	Subtotal	***$1,900,000,000***	***$3,400,000,000***
ALL	**Curbside + Dropoff**	**$21,800,000,000**	**$24,900,000,000**
	Curbside + Dropoff + Deposit Redemption System	**$21,900,000,000**	**$25,000,000,000**
	Curbside + Dropoff + Glass Separation	**$24,700,000,000**	**$27,800,000,000**

[50] China's National Sword Policy bans the import of most plastics and other materials from foreign sources. For more information see: https://www.epa.gov/smm/sustainable-materials-management-smm-web-academy-webinar-chinas-green-sword-impacts-state-and

[51] Quinn, M. (2022, Sept. 14) "National Sword kicked off a wave of MRF investments. 5 years later, tech and funding continue to advance." *Waste Dive.* Accessed online Nov. 2022: https://www.wastedive.com/news/national-sword-five-years-mrf-robotics-recycling-investment/630731/

[52] Goldsberry, C. (2014, May 7). "Recycling issues continue to plague shrink sleeve labels." *Plastics Today*. Accessed online Aug. 2022: https://www.plasticstoday.com/recycling-issues-continue-plague-shrink-sleeve-labels

System Component	Cost Category	Low-End Estimate	High-End Estimate
	Curbside + Dropoff + Glass Separation + Deposit Redemption System	**$24,800,000,000**	**$27,900,000,000**
Note: *The low-end estimates assume that facilities will not receive the latest technology upgrades (e.g., optical sorters, robotic arms, etc.) while the high-end estimates assume that facilities will be upgraded or modernized with the latest technology, resulting in higher capital costs. Technology upgrades would work to reduce contamination and improve recycling output quality.*			
Estimated using: (1) Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.* (2) U.S. Census Bureau. 2022. 2019 American Community Survey. (3) State waste management reports. (4) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. (5) Cost values from interviews with industry experts.			

2.4.1 Generation and Collection

To improve recycling, an expansion of residential curbside and drop-off collection opportunities is needed. Expansion of residential curbside collection, particularly to multi-family units, is a critical step in improving the U.S. recycling system in both volume and equity. Expansion of drop-off collection is important to providing access to recycling services for rural households. Expansion of curbside and drop-off collection will improve participation among currently non-participating households and provide access to recycling services for multi-family building residents and other households without current access. Currently, households without access to recycling services on par with trash disposal must either transport their recycling to a drop-off facility or trash their recyclables.

In addition, there is room for improving collection within the subset of households that already participate in curbside recycling – they can receive carts to ease the transport of recyclable material between their dwelling or garage, and households that currently use bags to collect materials for recycling could receive bins. (Bags are often disposed with the recycling and contaminate the recyclable materials with plastic film.)

Education. An investment in packaging recycling infrastructure includes education efforts to reduce contamination at the source, prior to collection. Using household-level cost information from The Recycling Partnership ($10/household), EPA estimates that a total investment of **$1.2 billion** for U.S. household education is needed to develop materials that are universally accessible to educate communities on which packaging materials are accepted locally, with an emphasis on simple messaging conveyed primarily with graphics and images (e.g., Do's and Don'ts with examples of what can and cannot be recycled), as well as translations where needed (both language and culturally-relevant examples). Importantly, this investment also includes temporary cart-tagging programs to support urban communities with particularly low recycling rates or high contamination rates (i.e., loss).

2.4.1.1 Curbside Collection

EPA estimates that capital improvements to curbside collection in urban areas in the U.S. would cost between $6.9 billion and $8.5 billion, including the costs associated with collection bins, education, trucks, etc.[53] These capital cost estimates are closely linked with the total count of households, and much of the capital cost relates to household education and equipment (e.g., bins, carts). **Exhibit 2-3** has an example model of accepted packaging materials messaging from a recycling program in Beaufort, North Carolina.

[53] The Ball Corporation 2021 *50 States of Recycling* report describes urban residents as a proportion of the total population in a state. EPA subtracted from 100% to back out the corresponding rural proportion. Source: Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.* Accessed online Oct. 2021: https://www.ball.com/getattachment/na/Vision/Sustainability/Real-Circularity/50-States-of-Recycling-Eunomia-Report-Final-Published-March-30-2021-UPDATED-v2.pdf.aspx?lang=en-US&ext=.pdf

Exhibit 2-3. Accepted Materials Messaging from Beaufort, North Carolina.[54]

All of the curbside collection capital cost estimates assume new MRF construction to process the additional curbside material, along with improved utilization of existing MRF design capacity.[55] The low-end estimates assume that facilities will not receive the latest technology upgrades (e.g., optical sorters, robotic arms, etc.) while the high-end estimates assume that facilities will be upgraded or modernized with the latest technology, resulting in higher capital costs. Technology upgrades would work to reduce contamination and improve recycling output quality. Total annual collection operations are estimated to cost $13 billion, which includes administration, transportation and fuel,[56] and salary for recycling service employees. Investment estimates vary between single-family and multi-family:

[54] Town of Beaufort, NC. 2022. Solid Waste and Recycling Guidelines. Accessed online Sept 2022: https://www.beaufortnc.org/community/page/solid-waste-recycling-guidelines

[55] Existing MRFs operate at an average of 50 – 60 percent of total capacity, leaving 40 – 50 percent capacity unused.

[56] Transportation does not include new trucks, as this would be considered a capital cost.

- **Single-family urban**: Using the methodology described in **Section 2.2**, EPA estimates an investment of $38.2 million for urban in-home bins ($8/bin), $1.3 billion for carts ($50/cart), and $798 million for household level education for single family households ($10/household).[57] Assuming that 78.6 percent of single-family households are served by these changes in the recycling system,[58] this investment would increase curbside recycling by 24.1 million tons.
- **Multi-family urban:** EPA estimates that an investment of $10.1 million for urban multi-family in-home bins and $335 million for carts is needed to improve material recycling so that it is on par with trash disposal opportunities.[59] Multi-family buildings also require larger bins to aggregate materials from the entire building (i.e., all the contents from individual units' in-home bins). EPA estimates $1.2 billion is needed for aggregation bins. An additional $210 million for household level education is needed to ensure that multi-family building residents collect only appropriate materials and clean them effectively. Assuming that 78.6 percent of multi-family households are served by these changes in the recycling system,[60] this investment would increase curbside recycling by 6.2 million tons.

The low-end estimates assume that facilities will not receive the latest technology upgrades (e.g., optical sorters, robotic arms, etc.) while the high-end estimates assume that facilities will be upgraded or modernized with the latest technology, resulting in higher capital costs. Technology upgrades would work to reduce contamination and improve recycling output quality.

Investments in single-family and multi-family urban curbside collection could result in 30.2 million tons of potentially recyclable material, or a recycling rate of 42 percent.

Bottle Deposit Programs. Currently, 10 states have deposit programs: California, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont. Deposit programs collect the following bottle-format packaging materials: aluminum, PET plastic, and glass. A 2021 report by Reloop identifies that beverage container landfilled waste can be up to 79 percent lower in jurisdictions with bottle deposit redemption systems, when compared to jurisdictions that do not host such programs. (Source: Reloop Platform. 2021. What we waste. Accessed online May 2022: https://www.reloopplatform.org/wp-content/uploads/2021/04/What-We-Waste-Reloop-Report-April-2021-1.pdf)

EPA also explored the possible impact of a nationwide deposit redemption system (DRS) to provide economic incentives to recycle and also ensure higher-quality materials recycling for specific containers. The Institute for Local Self Reliance's 2021 *Recycling Infrastructure Plan* estimated an initial cost of $100 million to implement a nationwide bottle deposit program, where consumers are charged a deposit for their beverage container

57 Cost assumptions are from The Recycling Partnership's 2021 *Paying it Forward* Report and confirmed via interview.
58 This value is derived from TRP's estimate of increased recycling access for single family households in the U.S. (additional single-family households served/total U.S. single-family households).
59 The estimate for multi-family carts is imprecise. Many multi-family buildings may not need carts because residents can walk down to the parking lot to empty their in-home bins into a larger aggregating bin; however, others may choose to have a cart (or more) for floor-level collection for the building manager or superintendent to wheel down to the aggregation bin.
60 This value is derived from TRP's estimate of increased recycling access for single family households in the U.S. (additional single-family households served/total U.S. single-family households); however, we apply it for multifamily households as well, because the goal is equivalent access, or recycling service on par with trash disposal services. Multifamily households stand to benefit considerably from improvements to recycling collection.

purchases, to be refunded upon return of the container (bottle redemption).[61] EPA assumes DRS diversion rates consistent with industry data: 40 percent of aluminum (298,000 tons),[62] 28 percent of glass (1.9 million tons),[63] and 25 percent of PET bottles (839,000 tons).[64] The additional material from DRS would increase the total collection of packaging material by more than 3 million tons, which would result in a recycling rate of 43 percent when combined with curbside collection. Using this total tonnage, the initial capital cost of $100 million breaks down to $33/ton of deposit-eligible material.

Exhibit 2-4. Investment Cost Estimates for Curbside Collection with Deposit Redemption System.

Cost Category	Low-End Estimate	High-End Estimate
Capital (with Deposit Redemption System)	$100,000,000	$100,000,000
Capital (without Deposit Redemption System)	$6,900,000,000	$8,500,000,000
Operating[65]	$13,000,000,000	$13,000,000,000
Total	**$19,900,000,000**	**$21,500,000,000**
Note: *The low-end estimates assume that facilities will not receive the latest technology upgrades (e.g., optical sorters, robotic arms, etc.) while the high-end estimates assume that facilities will be upgraded or modernized with the latest technology, resulting in higher capital costs. Technology upgrades would work to reduce contamination and improve recycling output quality.*		
Estimated using: (1) Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.* (2) U.S. Census Bureau. 2022. 2019 American Community Survey. (3) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. (4) Cost values from interviews with industry experts.		

2.4.1.2 Glass separation

Recycling industry experts who were interviewed suggested that glass separation is a viable strategy for reducing contamination at the source (i.e., curbside pickup or drop-off) while preserving the overall simplicity of single-stream recycling. Glass separation would parse out a contaminant of concern for MRFs, reducing their maintenance costs while simultaneously improving the quality of the remaining material they sell to end markets.

EPA estimates a total cost of approximately $3 billion would be required to implement a glass separation program for urban households across the U.S. (single-family and multi-family). Rural drop-off facilities often already have source separation capacity (i.e., a separate bin for glass), so they are assumed to require no updates. Capital cost represents 92 percent of the total investment, or $2.7 billion. As with curbside collection, capital cost assumptions for urban residential glass separation include in-home bins

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[61] Institute for Local Self-Reliance. 2021. "Recycling Infrastructure Plan Released." Accessed online May 2022: https://ilsr.org/recycling-infrastructure-plan-released/.
[62] Container Recycling Institute. 2022. "Aluminum Facts & Statistics." Accessed online May 2022: https://www.container-recycling.org/index.php/factsstatistics/aluminum.
[63] Container Recycling Institute. 2022. "Aluminum Facts & Statistics." Accessed online May 2022: https://www.container-recycling.org/index.php/factsstatistics/aluminum
[64] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/
[65] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

and carts. EPA assumes no additional education investment for a glass separation program (i.e., this cost is built-in to the cost of collection/drop-off education for households). In-home bin cost is estimated to be $48 million, because EPA assumes that the cost applies only to the fraction of households requiring a second bin for glass separation. Cart cost is assumed to be $1.9 billion (individual cost of $60/cart, $10 higher than the base cost described above because of the dual separation bin design). Capital cost for trucks is estimated to be $775 million ($250,000/truck).

> **Project Example: Thetford Recycling Center.** To reduce contamination of recyclables, the Thetford Recycling Center in Vermont, a transfer station which serves around 2,700 residents with drop-off services, requests glass be separated from the rest of recyclables. In 2021, the program collected 43.4 tons of glass, which was transported to New London, NH and crushed for road and construction projects. (Source: Northeast Recycling Council. 2022. Successful Glass Recycling in Rural Communities. Webinar accessed June 2022).

Interviews with industry experts suggested a cost of $45/ton to operate a glass separation program, resulting in a processing cost between $163 million and $172 million. The final estimated range of a recycling program including glass separation is $2.9 billion to $3.0 billion. Glass separation can be expected to increase recycled glass by 3.6 million to 3.8 million tons, which has a market value of $36 million to $38 million (assuming an average market price of $10 per ton of glass cullet).[66, 67] Adding glass separation to curbside collection would result in a national recycling rate of 44 percent.

Exhibit 2-5. Investment Cost Estimates for Glass Separation in Curbside Collection.[68]

Cost Category	Low-End Estimate	High-End Estimate
Capital	$2,700,000,000	$2,700,000,000
Operating[69]	$225,000,000	$237,000,000
Total	**$2,900,000,000**	**$2,900,000,000**
Note: *Low-end estimates are driven by a 95 percent glass recovery assumption, high-end estimates assume 100 percent glass recovery.*		
Estimated using: (1) Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.* (2) U.S. Census Bureau. 2022. 2019 American Community Survey. (3) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. (4) Cost values from interviews with industry experts.		

2.4.1.3 Drop-off programs

Subject matter experts widely acknowledged that rural communities need improved access to functioning recycling drop-off systems. One expert interviewee identified that for some households in states with low population density, such as Wyoming, the nearest drop-off station can be up to 300 miles away.[70] At such a distance, it is neither time nor cost-effective for rural households to drop off their recycling. For the present infrastructure investment assessment, EPA assumes that all rural households would be eligible for

[66] The lower end of this range assumes 95 percent capture, the average practice yield at a MRF. Source: Glass Recycling Coalition. 2017. Glass Recycling Benefits Calculator. Accessed online July 2022: https://www.glassrecycles.org/industry-tools-1/benefits-calculator/

[67] ScrapMonster. 2022. Glass Cullet Prices in the U.S. and Canada. Accessed online Aug. 2022: https://www.scrapmonster.com/scrap-yard/price/glass-cullet/335

[68] Dropoff collection operations are assumed to be $13 billion for collection identified in Exhibit 2-3. As such, listing the operations cost here would be duplicative.

[69] Source: Recycling industry expert interviews. This value includes trucking costs (fuel and operation).

[70] This statistic was cited by an interviewee from EPA OLEM.

drop-off access that establishes options for drop-off at locations equivalent to trash disposal locations, rather than curbside collection. Additionally, urban households are assumed to not participate in drop-off programs.[71]

EPA estimates that capital investment between $602 million and $2.1 billion will be needed to improve recycling drop-off stations and supporting hub-and-spoke infrastructure. Similar to curbside collection capital cost, this estimate includes the cost for bins, collection stations, and education (e.g., flyers and ancillary signage). Capital cost for drop-off stations is estimated to be $102 million (including trucks needed to transport materials to MRFs), with another $59 million for supporting hub-and-spoke infrastructure. Education cost for rural households (single and multi-family) is estimated at $240 million. Operating costs are assumed to be linked to MRF operating costs, $1.3 billion. These costs together bring the total cost of nationwide drop-off system improvements to between $1.9 billion and $3.4 billion. Investment in expanded drop-off infrastructure would result in an additional 7.6 million tons of potentially recyclable packaging materials, and a national recycling rate of 35 percent. When combined with the previously described investment in curbside collection, the potential national recycling rate climbs to 45 percent.

Exhibit 2-6. Investment Cost Estimates for Drop-off.

Cost Category	Low-End Estimate	High-End Estimate
Capital	$602,000,000	$2,100,000,000
Operating	$1,300,000,000	$1,300,000,000
Total	**$1,900,000,000**	**$3,400,000,000**
Note: *The low-end estimates assume that facilities will not receive the latest technology upgrades (e.g., optical sorters, robotic arms, etc.) while the high-end estimates assume that facilities will be upgraded or modernized with the latest technology, resulting in higher capital costs. Technology upgrades would work to reduce contamination and improve recycling output quality.*		
Estimated using: (1) Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.* (2) U.S. Census Bureau. 2022. 2019 American Community Survey. (3) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. (4) Cost values from interviews with industry experts.		

2.4.1.4 Tribal communities

In terms of infrastructure for tribal communities, robust recycling programs require investment for in-home bins, collection trucks and drop-off stations (depending on how spatially dispersed the community is), security, and education (e.g., signage). Operations would require station employees as well. During a recent tribal feedback listening session for EPA's SWIFR grant program, EPA heard from several tribal Nation representatives that illegal dumping, limited access to transportation and recycling processing

[71] Importantly, this is a simplifying assumption. Urban and suburban households in many municipalities have access to a drop-off station in addition to a curbside collection subscription service. Many families opt out of the subscription option in favor of the lower-cost or even free drop-off option provided by the municipality's waste management program.

infrastructure, and a lack of end markets for recycled materials are key issues that need to be addressed on tribal lands.

2.4.2 Sorting and Processing

For improvements to collection to be successful, simultaneous capital investment in collection trucks/haulers and material recovery facilities is necessary. EPA uses The Recycling Partnership's estimate of $930 million for the capital cost of new trucks to collect and transport the potentially recyclable packaging material to the processers (without glass separation). Based on the methodology described in **Section 2.2**, the Agency estimates that the capital cost of upgrading existing recycling facilities with improved sorting equipment to both reduce contamination and ensure ability to process larger volumes would be $3.1 billion. The cost of expanding capacity and building new recycling facilities is estimated to be $5.4 billion, while the annual MRF operating cost is estimated at $1.3 billion, as summarized in **Exhibit 2-7**. Importantly, these values are all integrated into the curbside collection and drop-off estimates discussed above but are included here for completeness.

Exhibit 2-7. Investment Cost Estimates for Sorting and Processing.

Cost Category	Without Glass	With Glass
MRF Capital (New Construction + Upgrades)	$5,400,000,000	$5,400,000,000
MRF Capital (Upgrades)	$3,100,000,000	$3,100,000,000
Trucks Capital	$930,000,000	$1,700,000,000
Operating	$1,300,000,000	$1,400,000,000
Total	**$10,700,000,000**	**$11,600,000,000**
Note: *Low-end and high-end estimates are driven by the exclusion/inclusion of glass processing and transportation infrastructure, as well as higher glass operating costs.*		
Estimated using: (1) Eunomia. 2021. The 50 States of Recycling. *Prepared for the Ball Corporation.* (2) U.S. Census Bureau. 2022. 2019 American Community Survey. (3) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. (4) Cost values from interviews with industry experts.		

EPA's estimate for the total number of MRFs needed to accommodate expanded access to recycling services diverges from The Recycling Partnership's published values. State-level packaging waste generation numbers drive EPA's estimate for total number of MRFs needed to process the potentially recyclable material (by dividing total potentially recyclable packaging material by an average annual MRF throughput of 60,640 tons).[72] This analysis estimates the total number of new MRFs needed (476) by subtracting existing MRF underutilized capacity (20.2 million tons per year total) from MRF capacity needs estimated at the state level (58.7 million tons per year total) and then dividing by the average annual MRF throughput. Existing MRFs are assumed to have additional underutilized capacity.[73]

[72] MRF capacity is estimated using the average tons per day design (i.e., nameplate plant capacity) and the average tons per day (actual average throughput, or 182 tons per day). Tons per year is estimated using 333.34 operational days, which stems from the textbook 8,000 operating hours/year assumption used by engineers in calculating plant capacity (see for example Sinnott, R.K. (2005) Coulson & Richardson's Chemical Engineering Design. Elsevier Coulson & Richardson's Chemical Engineering Series, 6, 231, 477).

[73] The excess MRF capacity (an average throughput of 203 tons per day) is a value identified by RTI in an interview. Extrapolated to tons per year using the same assumptions outlined in FN 65.

Lack of MRF data is a key limitation for the present analysis. Without robust data on facility throughput capacity, the present analysis of where new and upgraded MRFs are needed and thresholds for material distances traveled to MRFs falls short of providing precise information about where these facilities should be constructed, or which MRFs should be upgraded. While MRF opportunities are discussed further in **Section 2.5** and mapped by individual material in **Appendix A**, the present assessment is limited by the data available. A feasibility study is needed to set a regional limit on how far materials can travel to target specific regions where new MRFs should be constructed, and existing MRFs upgraded. Distance traveled to MRFs should be informed by material weight, types of materials accepted by nearby processing facilities, trucking load weight restrictions (tonnage values differ by state), and existing nearby MRF processing capacity. The present analysis handles these limits on spatial information by assuming an average processing capacity and treating existing facilities as if they could all be upgraded to improve efficiency and capture underutilized capacity.

Another key limitation of this analysis is that fire insurance costs for MRFs are not included in the operating cost estimates due to a lack of data. As such, the annual MRF operating cost in **Exhibit 2-7** may be an underestimate. Battery fires are a growing issue for MRFs and may result in facility damage and/or increased insurance cost. Previous EPA research indicates that MRF fire insurance is a changing landscape, and as insurers leave the recycling and waste management market, some facilities are turning to self-insurance (which may require up to tens of millions of dollars).[74, 75] Education for consumers to reduce contamination through removal of batteries prior to recycling and policies for standardized and clear product labels indicating the presence of batteries and instructions for how to recycle are required to reduce the risk of battery-caused facility fire.[76] It is important to note that pursuant to the Bi-Partisan Infrastructure Law, EPA is required to develop a battery collection best practices report, and labelling guidelines and education materials to improve battery recycling.

Recycled Material Commodity Prices. The blended commodity price for single stream recovered materials with residuals is $169.75, and $180.73 without residuals. Based on these commodity prices, the total additional recoverable material from curbside collection alone has a potential value ranging from **$5.1 to $5.4 billion**. The potential value from additional material tonnage from improved drop-off ranges from **$1.5 to $1.6 billion**. (Source: Northeast Recycling Council (NERC), 2022. NERC Recycling Markets Value Reports. Accessed online Aug. 2022: https://nerc.org/news-and-updates/nerc-recycling-markets-value-reports)

Finally, the financial estimates above do not address cost, energy, and resource savings associated with recycling packaging materials. The following are some examples of possible savings from the use of recycled material inputs:

- Revenue from the sale of recycled packaging materials;
- Energy savings and associated GHG emission savings through use of recycled (rather than virgin) materials;
- Resource savings, such as reduced water use, use of raw materials, mining waste, and fossil-fuel based chemicals; and
- Reduced burden on existing landfills.

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[74] U.S. EPA. 2021. An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling. *Prepared by the Office of Resource Conservation and Recovery.* EPA 530-R-21-002. Accessed online Jul. 2022: https://www.epa.gov/system/files/documents/2021-08/lithium-ion-battery-report-update-7.01_508.pdf.

[75] Taylor, B. 2018. After the fire, a new alarm is sounded. *Waste Today.* Published 2018, December 7. Accessed online Aug. 2022: https://www.wastetodaymagazine.com/article/lithium-ion-battery-waste-mrf-fires-insurance/

[76] Institute for Local Self Reliance (ISRI), Solid Waste Association of North America (SWANA), and the National Waste and Recycling Association (NWRA). 2020. *Guide for Developing Lithium Battery Management Practices at Materials Recovery Facilities.* Accessed online Aug. 2022: https://www.isri.org/docs/default-source/default-document-library/mrf-lithium-battery-guidance.pdf?sfvrsn=2

2.5 Summary and Investment Considerations

EPA estimates that an investment of **$22 to $28 billion** is needed to modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal for packaging materials. This level of investment would result in an additional 38 to 45 million tons of recycled packaging material, increasing the U.S. recycling rate from 32 percent to 45 to 47 percent, close to the Agency's goal of increasing nationwide recycling to 50 percent by 2030.[77]

To be effective, investment in collection and drop-off infrastructure should be aligned with investment in expanded processing infrastructure (MRFs and material-specific facilities) and education. MRF processing capacity needs to be increased in concert with curbside and drop-off collection because the distribution of these facilities may not be optimal to handle the increased volume of potentially recyclable packaging material. Packaging recycling expert interviewees recommended targeting locations with very little infrastructure (e.g., Wyoming), as well as locations where MRF capacity is not being fully utilized. As described in **Section 2.4**, many MRFs typically operate between 50 to 60 percent of their total capacity,[78] so some initial increases to total nationwide processing capacity may simply require hiring more full-time employees to operate on a second or third shift and capture the underutilized but existing capacity.

Comparison with Existing Estimates. Several recent estimates have been developed for the investment needed to promote equitable access to curbside collection and drop-off and correspondingly expand MRF capacity. A popular study is **The Recycling Partnership's 2021 *Paying it Forward*** report.

The Recycling Partnership estimates that $28 billion is needed to provide some form of recycling access for all U.S. households by 2025 (excluding flexible plastics and film). This value falls at the higher end of EPA's estimated total cost range: $22 billion to $28 billion. EPA's estimate includes a lower bound due to the consideration of a variety of infrastructure solutions, including curbside collection and drop-off only, glass separation, and a national deposit redemption system. EPA's lower bound estimates do not include MRF upgrades or modernization, resulting in a reduced capital cost.

A key factor missing from this analysis is the impact to end market prices from an increased supply of recycled materials. Estimating the price impact for end markets is out of scope for the present analysis. Qualitatively, increased recycled material supply linked with access to collection equivalent to trash disposal services and increased MRF processing capacity could lead to an overall decrease in market prices for recycled materials for which demand is low. Alternatively, where producers have an appetite for more recycled feedstock, a change in the availability of recycled content could result in industry decisions to expand manufacturing capacity. An anticipated decrease in market prices for recycled material could be combated somewhat by policies encouraging higher recycled material content in manufacturing.

Policies to reduce packaging materials at the source by encouraging the use of recycled feedstock in product manufacturing are important. President Biden's Executive Order 14057 on *Catalyzing Clean Energy Industries and Jobs through Federal Sustainability* can be leveraged for this exact purpose. Under Section 208, it directs the federal government, the largest purchaser in the world, to purchase sustainable

[77] U.S. EPA. 2018. National Overview: Facts and Figures on Materials, Wastes and Recycling. Accessed online May 2022: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#:~:text=The%20recycling%20rate%20(including%20composting,person%20per%20day%20for%20recycling.

[78] This statistic was cited in an interview with RTI International.

products, and specifically mandates purchasing products that contain recycled content.[79] The Executive Order further directs government agencies to purchase sustainable products and services recommended by EPA. EPA maintains *Recommendations on Specifications, Standards, and Ecolabels for Federal Purchasing* to identify credible standards and ecolabels and facilitate purchasing of sustainable products. Recycled content criteria are specified by recommended standards and ecolabels for most product categories.[80] EPA's purchasing recommendations are also used outside of the federal space by state and local governments, companies, and other institutional purchasers. For example, EPA established a Comprehensive Procurement Guideline (CPG) Program in the 1990s, coordinated through the Agency's Sustainable Materials Management initiative.[81] The CPG Program provides a public-facing product supplier directory, as well as a list of designated products that meet certain criteria for recovered, post-consumer, or bio-based content to encourage the use of recycled materials. In response to H.R. 5376 – Inflation Reduction Act of 2022 (introduced September 2021),[82] EPA is working on guidelines for Environmental Product Declarations as well (i.e., improved standards and more transparent labeling for product claims of reduced carbon impact).[83]

Policies are also needed to require clear labels and reduce consumer confusion about what is and is not recyclable to improve recycling of packaging materials. For instance, the Climate Leadership and Environmental Action for our Nation's Future Act (H.R. 1512 – CLEAN Future Act, introduced in March 2021) aims to establish a national bottle deposit redemption program and standards for recycled content.[84] The Act also calls for a pause in permitting for new plastics manufacturing facilities and directs the National Academy of Sciences to study the impact of single-use plastic bans. Finally, the act charges EPA with developing grants for a host of waste reduction initiatives, including recycling education, source reduction and zero waste initiatives. To the extent that this and other related policies pass, EPA, legislators, and other key policymakers may wish to revisit the infrastructure investment assessment as source reduction can significantly reduce the generation of packaging waste, and consequently the regional infrastructure and financial investment needed to address potentially recyclable packaging materials.

Where policy is crucial to improving packaging recycling at a national level, a more regional approach is needed to focus infrastructure investments. There are several U.S. regions with both a substantial generation of potentially recyclable packaging material waste and a notable lack of recycling infrastructure. EPA mapped existing MRFs, material-specific recycling facilities, and potentially recyclable material tonnage across the U.S. to develop a list of priority regional areas for recycling infrastructure

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[79] EO 14057 Section 208 states: "Agencies shall reduce emissions, promote environmental stewardship, support resilient supply chains, drive innovation, and incentivize markets for sustainable products and services by prioritizing products that can be reused, refurbished, or recycled; maximizing environmental benefits and cost savings through use of full lifecycle cost methodologies; purchasing products that contain recycled content, are biobased, or are energy and water efficient, in accordance with relevant statutory requirements; and, to the maximum extent practicable, purchasing sustainable products and services identified or recommended by the Environmental Protection Agency (EPA)." https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/

[80] EPA *Recommendations on Specifications, Standards, and Ecolabels for Federal Purchasing* are available at: https://www.epa.gov/greenerproducts/recommendations-specifications-standards-and-ecolabels-federal-purchasing

[81] U.S. EPA. 2022. Comprehensive Procurement Guideline Program. Accessed Nov. 2022: https://www.epa.gov/smm/comprehensive-procurement-guideline-cpg-program#content

[82] 117th Congress. 2022. House Bill 5376: Inflation Reduction Act of 2022. Accessed online Nov. 2022: https://www.congress.gov/bill/117th-congress/house-bill/5376/text/rh

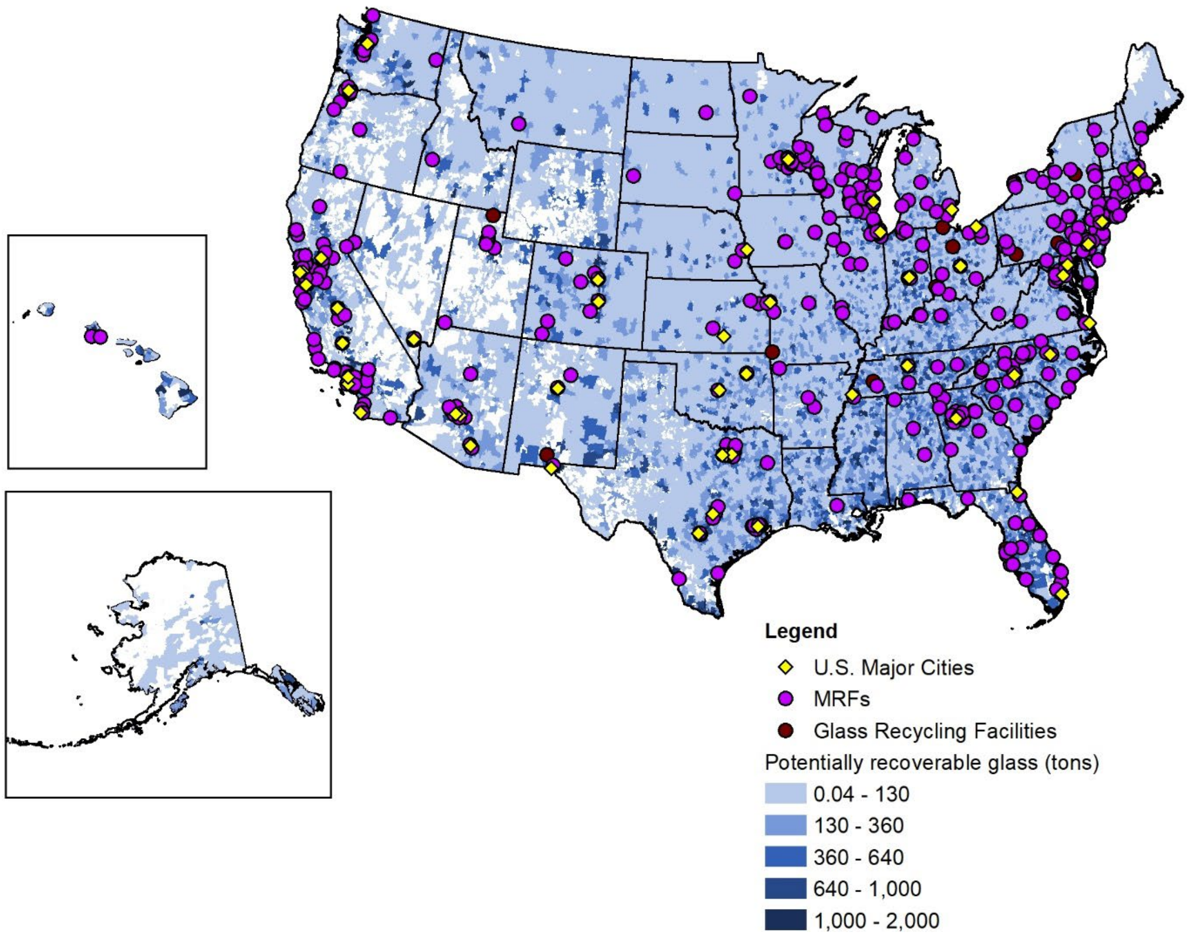
[83] U.S. EPA. 2022. Inflation Reduction Acy Non-Regulatory Dockets for Public Input. Accessed online Nov. 2022: https://www.epa.gov/air-and-radiation/inflation-reduction-act-non-regulatory-dockets-public-input

[84] 117th Congress. 2021. House Bill 1512: Climate Leadership and Environmental Action for our Nation's Future Act or the CLEAN Future Act. Accessed online Sept. 2022: https://www.congress.gov/bill/117th-congress/house-bill/1512.

investment. Using this qualitative geographic analytical approach, EPA identified opportunities in the following regions (opportunities for glass are shown in **Exhibit 2-8,** additional packaging materials maps can be found in **Appendix A**):[85]

- South (in particular, parts of Kentucky, Louisiana, Mississippi, Alabama, Georgia)
- Southwest (in particular, Texas, Arizona, and New Mexico)
- Rocky Mountains (in particular, Wyoming, Montana, Colorado, Idaho, Nevada)

Exhibit 2-8. Example Geographic Prioritization of Investment: Potentially Recyclable Glass[86]



Furthermore, the specific recycling needs of communities with environmental justice concerns, such as those with low-income, high unemployment, large populations of people of color, and other factors, must be considered in a way that is sensitive to the unique challenges those communities face. While the literature review yielded few results on the intersection of environmental justice and recycling, policymakers must pay close attention to the needs of disadvantaged and marginalized populations that may be disproportionately affected by changes to and impacts from the recycling system and municipal

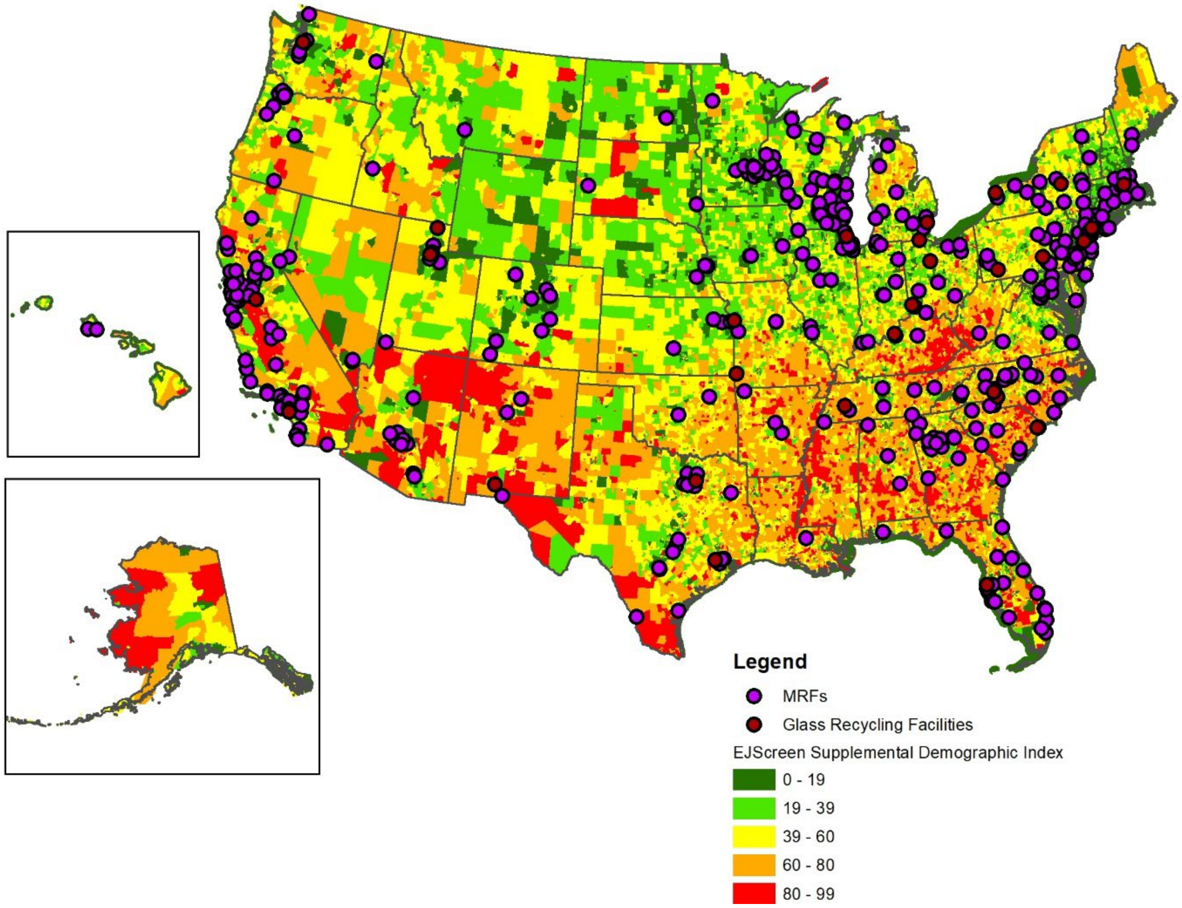
[85] Note that areas in the South, Southwest, and Rocky Mountains currently lack the critical infrastructure to process additional packaging materials for a variety of legislative, policy, and administrative reasons.
[86] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

solid waste management in general, particularly relating to the development of new waste management facilities. For example, communities near MRFs may be adversely affected by health impacts resulting from MRF operations, including noise, harmful emissions, and exposure to harmful or toxic chemicals. These communities may also have unique concerns when accessing recycling services that must be accounted for when pursuing equivalent access across the country.

Exhibit 2-9 displays current material recovery facilities and glass recovery facilities overlayed with the Supplemental Demographic Index from EPA's EJScreen.[87] This index is based on the average of five socioeconomic indicators; low-income, unemployment, limited English, less than high school education, and low life expectancy. This map illustrates how communities that are higher on the Supplemental Demographic Index (indicated by orange or red) are more likely to be located in areas that lack adequate recycling infrastructure (e.g., the South, Southwest, and Rocky Mountains) and have a high rate of potentially recoverable glass, as shown in **Exhibit 2-8**. This analysis serves only as a foundational framework for incorporating environmental justice considerations into recycling, but they must be equally analyzed when determining opportunities to finance these investments.

[87] U.S. EPA. 2022. EJ and Supplemental Indexes in EJScreen. Accessed online January 2023: https://www.epa.gov/ejscreen/ej-and-supplemental-indexes-ejscreen#what-supplemental

Exhibit 2-9. Example Geographic Prioritization with Environmental Justice Considerations: Potentially Recyclable Glass[88]



[88] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

Section 3: Financial Assessment and Estimates for Organic Materials

3.1 Introduction and Overview

Organic materials can be recycled across the nation through a variety of proven management methods, such as composting, anaerobic digestion (AD), rendering, and as livestock feed. Currently, EPA estimates that the nation generates more than 101 million tons of organic waste and recycles approximately 28 percent of this organic waste. EPA estimates that an additional 44 million tons could be recycled through an expansion of composting, AD, and livestock feed infrastructure.[89]

A total investment of **$14 to $16 billion** is needed to improve organics recycling access (e.g., composting, anaerobic digestion, and livestock feed) for food waste and yard waste so that it is on par with access to trash disposal. This would increase the nation's recycling rate from 32 percent to approximately 47 percent. Similar to packaging materials, an investment of this scale would require funding from stakeholders across the entire recycling system.

This expansion of U.S. organics recycling infrastructure, which is fundamentally and structurally different from the packaging materials recycling infrastructure discussed in **Section 2**, would **require an investment of $14 to $16 billion for improvements to curbside collection, drop-off, and processing infrastructure so that access to organics recycling services is on par with access to trash disposal**. This level of investment from cities, states, private companies, public-private partnerships, and the federal government through legislation such as the Bipartisan Infrastructure Law **could increase the nation's overall recycling rate from its current level of 32 percent to 47 percent, close to EPA's nationwide goal of 50 percent**. This report details the following below:

- Discusses EPA's assumptions and methodology to estimate the investment that would modernize recycling infrastructure, improve consumer recycling education, and provide all residents with access to recycling services on par with access to trash disposal;
- Describes gaps within the existing organics recycling system;
- Details the investment estimates to improve infrastructure and address identified gaps; and
- Provides logistical considerations such as investment timing, geographic focus, and policy environment required to make lasting change.

3.2 Methodology

To develop an estimated level of investment needed to improve organics recycling to be equivalent in access to trash disposal, EPA first identified proven technologies that could recycle current quantities of organic materials at scale. Using available information from EPA's Excess Food Opportunities map, which provides a comprehensive list of organics recycling facilities in operation, EPA analyzed the current organics recycling infrastructure stock and estimated how much additional infrastructure would be needed to facilitate equivalent access for organics recycling.[90] EPA then identified key costs (e.g., equipment for collection and processing, operation, education, etc.) for infrastructure expansion for both capacity expansion and new infrastructure construction.

Similar to the assessment on packaging materials, the National Recycling Goal of attaining a national recycling rate of 50 percent by 2030 serves as a framework to measure the success of identified

[89] This estimate assumes no source reduction and no major changes in processing technology. In addition, investment estimates throughout this report do not consider the expansion of rendering infrastructure due to limited cost and material volume data. To the extent that this information becomes available in the future, EPA may consider updating this analysis.
[90] U.S. EPA. 2022. Excess Food Opportunities Map. Accessed online May 2022: https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map.

investments needed for organics recycling. The scope of organic materials includes food and yard waste from the residential, commercial, and institutional sectors; this differs from the assessment on packaging materials, which considers only residential sources. The change in scope between the two material types is based on the availability of data; national-level data on packaging materials focused primarily on the residential sector whereas data sources for organic materials combined the residential, commercial, and institutional sectors. **Exhibit 1-1** illustrates the full scope of this report.

The model for organic materials makes several assumptions to develop investment estimates and account for national-level information and data gaps, all of which are highlighted throughout the report. Four key assumptions are outlined below:

1. While food and yard waste are critical materials in the waste stream, there is no known current national participation rate for organics recycling; therefore, this report uses the same participation rate for organic materials as packaging materials (78.6%). Providing equal access to both organics recycling and packaging recycling relies on the assumption that both material types will be recycled at a similar rate. Even with investments to make recycling accessible to all residents and improve the overall recycling system, not everyone who has access to recycling services will choose to recycle.
2. The increase in materials collected via curbside systems will require either constructing new organics recycling facilities, such as composting or anaerobic digestion facilities, or upgrading the design and capacity of current organics recycling facilities to improve utilization. Low-end estimates assume that existing facilities are operating at less than 100% capacity and can manage an increase in materials, while high-end estimates assume that facilities are operating at or near 100% capacity and must be upgraded or modernized.
3. Source reduction for organic materials is outside the scope of this assessment, as organics recycling is the primary material management pathway of consideration.
4. All urban households, including multi-family units, are assumed to have access to curbside organic waste pickup, and all rural residents are assumed to have access to either organic waste drop-off services or at-home composting opportunities. Additionally, composting facilities are assumed to only process residential organic waste while anaerobic digestion facilities are assumed to only process commercial and institutional waste.

Food waste generation and recycling tonnages were obtained from the Agency's 2019 wasted food report, which include tonnages of food waste generated and recycled by sector and by management pathway.[91] To arrive at national level estimates of yard waste generation and recycling tonnages, EPA obtained yard waste data from available state waste management reports and calculated per capita generation and recycling rates for reporting states. EPA then calculated an average per capita generation and recycling rate from the available data and applied it to state-level population data to arrive at national estimates.[92] It is important to note that these state data are self-reported, not independently verified, collected at irregular intervals, and contain varying levels of detail about community recycling programs. Both the e-ICR and SWIFR grant program funded through the Bipartisan Infrastructure Law (BIL) serve as unique opportunities to collect recycling data on a community level and verify or adjust current, national-level

[91] U.S. EPA Office of Resource Conservation and Recovery. 2022. 2019 Wasted Food Report. https://www.epa.gov/system/files/documents/2023-03/2019%20Wasted%20Food%20Report_508_opt_ec.pdf.
[92] U.S. Census Bureau. 2022. 2019 American Community Survey. Accessed online May 2022: https://www.census.gov/programs-surveys/acs

estimates and may be incorporated in future recycling infrastructure needs analyses. **Exhibit 3-1** summarizes the tonnage of organic material currently generated and recycled.

Exhibit 3-1. Current Organic Material Generation and Recycling (2019).

Organic Material	Tonnage Generated	Tonnage Recycled	Current Recycling Rate
Food waste	66 million	7.5 million	11%
Yard waste	35 million	20.7 million	59%
Total	**101 million**	**28.2 million**	**28%**

Estimated using:
(1) U.S. EPA Office of Resource Conservation and Recovery. 2022. 2019 Wasted Food Report. https://www.epa.gov/system/files/documents/2023-03/2019%20Wasted%20Food%20Report_508_opt_ec.pdf.
(2) State waste management reports.
(3) U.S. Census Bureau. 2022. 2019 American Community Survey.

EPA developed investment estimates using a thorough review of recycling infrastructure literature: 125 documents focused on key improvements and associated costs of expanding the aging U.S. recycling system (published between 2015 and 2021). (A complete list of references can be found in the **References** section of this report.) Cost information for organic materials was drawn primarily from ReFED's *Roadmap to 2030* report and *Insights Engine*.[93, 94] Estimates also integrate findings from interviews with experts in the domestic recycling system:

- American Biogas Council
- BioCycle
- Environmental Research and Education Foundation
- EPA's AD Funding Opportunity Program
- EPA's Office of Resource Conservation and Recovery
- EPA's Tribal Waste Management Program
- Institute for Local Self-Reliance
- Northeast Recycling Council
- ReFED
- Resource Recycling Systems
- U.S. Composting Council
- Waste Management

EPA was not able to locate existing data regarding collection/drop-off equipment and operation, processing, and end markets in tribal communities prior to the publication of this report. As a result, tribal community needs are discussed qualitatively throughout this assessment.

Finally, EPA conducted a high-level spatial analysis, identifying geographic areas within which to prioritize investment. This work leverages EPA's Recycling Markets and Opportunities map where generation, recycling, and potentially recyclable materials, by organic material type, are mapped against existing

[93] ReFED. 2021. Roadmap to 2030: Reducing U.S. Food Waste by 50% and the ReFED Insights Engine. Accessed online May 2022: https://refed.org/uploads/refed_roadmap2030-FINAL.pdf.
[94] ReFED. 2022. ReFED Insights Engine. Accessed online May 2022: https://insights.refed.org/?_ga=2.257273867.1212413126.1660677635-778134506.1657051175.

recycling infrastructure.[95] The existing recycling infrastructure includes industrial composters, community-scale composters, and anaerobic digestors. Similar to the packaging materials section, the report goes one step further by overlaying data from EPA's EJScreen tool to review and discuss how environmental justice factors must be incorporated into proposals to upgrade organics recycling within the U.S.[96]

3.3 Summary of Identified Infrastructure Stock and Gaps

To determine the investment necessary to improve the U.S. recycling system so that access to organics recycling is equal to access to trash disposal, EPA first identified the existing infrastructure stocks and gaps within the generation and collection, sorting and processing, and end market stages of the organics recycling system for the residential, commercial, and institutional sectors.[97] An overview of infrastructure stock and gaps for organic materials, organized by recycling system stage, is provided below.

3.3.1 Generation and Collection

Like packaging materials, organic waste is collected through either curbside pick-up or drop-off programs. For food waste, only 27 percent of the U.S. population currently has access to recycling services (although actual participation rates are unknown), in which food waste is either picked up through a curbside service or dropped off:[98]

- Around 19 percent of the total U.S. population has access to food waste curbside collection programs either through their municipality or through a private subscription service.
    - Around 3 percent of the total U.S. population has equivalent access to food waste curbside collection as they do to trash disposal.
- Around 8 percent of the total U.S. population has access to drop-off programs that accept food waste.
    - Around 6 percent of the total U.S. population has equivalent access to food waste drop-off programs as they do to trash disposal.

Yard waste collection services are more readily available in comparison to food waste. There are currently 27 states with yard waste landfill bans. The 56 percent of the nation's population that reside in these states have access to either curbside or drop-off yard waste recycling services, depending on municipal program offerings; however, details of these offerings are not known on a city-level nor are details on yard waste collection offerings in states without bans due to limited publicly available information.

It is important to note that much like recycling for packaging materials, access to organic recycling services for multi-family residents differ from single-family residents. For example, while a municipality may offer curbside organics collection, in some states, as with packaging recycling, multi-family properties over a certain size are considered businesses, and therefore are not eligible for municipally-run curbside programs. In addition, depending on the program, privately-run curbside composting programs may or may not be available to multi-family properties.

[95] U.S. EPA. 2022. Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.
[96] U.S. EPA. 2023. EJScreen: Environmental Justice Screening and Mapping Tool. Accessed online January 2023: https://www.epa.gov/ejscreen.
[97] Note that insufficient materials management infrastructure in the U.S. to collect and process recycling is a documented issue. State and local governments have made significant efforts to divert waste from landfills. These efforts have been documented in a number of published reports and case studies. **Appendix C** provides some specific real-world and place-based applications of recycling solutions.
[98] GreenBlue. 2022. Mapping Urban Access to Composting Programs. Accessed online May 2022: https://greenblue.org/work/compostingaccess/.

Currently, there is a need for additional infrastructure to expand organics recycling services to the approximate 91 percent of the nation that do not have equivalent access to organics recycling as they do to trash disposal. The successful expansion of collection services would have to include the following:

- **Curbside collection:** Investment in collection bins, collection staff, and trucks, as well as on-property aggregation bins (e.g., compacting roll-offs or front-end containers). In particular for multi-family units, recycling collection needs are similar to commercial collection needs (e.g., they require a latched aggregation bin and possibly a different type of truck for pickup).
- **Drop-off programs:** Investment in centralized collection areas, staffing, containers, and supporting infrastructure like signage and tools (e.g., pitchforks or small forklift vehicles). Equity considerations, such as accessibility, also need to be considered, particularly for those whose access is limited to drop-off programs but do not have the means to transport their collected organic materials to centralized drop-off locations.
- **Education:** Both curbside collection and drop-off program expansion also require an investment for household education to help reduce contamination at the source and alert communities of the availability of local organics recycling services. For instance, a recent survey conducted by the Institute for Local Self-Reliance found that approximately half of its 200 members noted unawareness from the local community of existing composting programs as a key challenge in successful recycling operations.[99] One member noted that customers were still landfilling compostable items even though organics collection is included in the price of trash/recycling collection. Universally accessible education materials to reach populations with varying languages, knowledge of acceptable materials, and/or cultural contexts are crucial to a well-functioning system.

For tribal communities in particular, feedback sessions indicate that much like recycling for packaging materials, transportation cost is one of the largest expenses to rural communities, especially tribal nations, given the geographically remote nature of many communities.[100] In some territories, like the Commonwealth of the Northern Mariana Islands, communities experience both high transportation costs and dependance on few shippers. This issue is particularly serious for food waste because it is heavier than most discarded materials due to its moisture retaining properties.

3.3.2 Sorting and Processing

The U.S. currently hosts infrastructure to recycle organic waste, which includes, approximately:

- 3,000 composting facilities in the U.S. (not including at-home, residential composting, community composting sites, or drop-off sites) that manage food and/or yard waste, which vary in size from large-scale centralized composting operations to smaller-scale composting operations;[101]
- 275 AD facilities that manage food waste, which vary in operation from stand-alone to on-farm digesters focusing on food waste to large-scale co-digestion with biosolids at wastewater treatment plants; and[102]

[99] Institute for Local Self-Reliance. 2022. Challenges Facing Community Composters: Community Composter Census Data.
[100] U.S. EPA. 2022. Tribal Communities: Feedback Specific to Stakeholder Types. Accessed May 2022.
[101] U.S. EPA. 2022. Excess Food Opportunities Map. Accessed online May 2022: https://www.epa.gov/sustainable-management-food/excess-food-opportunities-map.
[102] U.S. EPA. 2022. Anaerobic Digestion Facilities Processing Food Waste in the United States (2019). Accessed online May 2022: https://www.epa.gov/anaerobic-digestion/anaerobic-digestion-facilities-processing-food-waste-united-states-survey.

- 1.5 million farms, spanning 671 million acres, located in 40 states that do not have prohibitions on food waste for animal feed.[103] While there is no data on how many farms accept food waste as animal feed, recent data suggest that 14 percent of excess food is sent to feed animals, most coming from pre-consumer generators, such as grocery stores and wholesalers.[104]

These facilities collectively process around 28.3 million tons of organic waste from the residential, commercial, and institutional sectors, which represents 28 percent of total organic waste generated.[105] While some of these facilities are not operating at full capacity, the need still exists for additional organics recycling processing infrastructure. The successful construction and operation of additional facilities will have to address the same challenges that current facilities struggle with, which are detailed below:

- **Feedstock contamination:** Contamination of organic material, typically with glass, food service packaging, and produce stickers, affects operating efficiency and overall compost quality. While screening and depackaging equipment can capture large inert materials, this equipment can be expensive and reduce the cost-effectiveness of organics recycling operations.
- **Land constraints:** Organic waste, in the form of food waste, is heavy and therefore expensive to transport. For cost-effectiveness, facilities should be located within communities (e.g., at community gardens, local farms, public parks, and schools) to reduce transportation needs. However, the availability of land in population-dense areas is often limited. Furthermore, if land is available, the surrounding community may still oppose the construction of organics recycling infrastructure due to perceived concerns related to odor and pest management.
- **Labor and equipment:** Composting requires a manual labor workforce in its operations (e.g., to screen for contaminants or to turn the compost) and AD requires technical labor to load feedstock and monitor digestion systems. For tribal communities and small-scale community programs, in particular, it is often difficult to obtain enough technical labor for cost-efficient operations. While equipment can be used in place of labor, equipment can be costly to purchase and small-scale operations may not have the available upfront capital. This challenge was emphasized as a key barrier for tribal communities in national feedback listening sessions for EPA's SWIFR grant program hosted for Tribal Nations.[106]
- **Permitting:** The permitting process differs depending on the volume of organic material managed, feedstock accepted, and type of operation. While some states have a streamlined permitting process for organics recycling, others have a more complicated and time-intensive process. A recent survey conducted by the Institute for Local Self-Reliance found that some states took 14 months to approve composting license applications.[107]
- **Market Factors:** Depending on the state, tipping fees for landfills and incineration may be lower than tipping fees for organics recycling infrastructure. Low landfill and incineration tipping fees

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[103] USDA. 2022. Farms and Land in Farms 2021 Summary. Accessed online May 2022: https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0222.pdf. Harvard Law School Center for Health Law and Policy Innovation. 2016. Leftovers for Livestock: A Legal Guide for Using Food Scraps as Animal Feed. Accessed online May 2022: https://chlpi.org/wp-content/uploads/2013/12/Leftovers-for-Livestock_A-Legal-Guide_August-2016.pdf.

[104] U.S. EPA Office of Resource Conservation and Recovery. 2020. 2018 Wasted Food Report. Accessed online May 2022: https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf.

[105] Estimated using: (1) U.S. EPA Office of Resource Conservation and Recovery. 2020. 2019 Wasted Food Report; (2) State waste management reports; and (3) U.S. Census Bureau. 2022. 2019 American Community Survey.

[106] U.S. EPA. 2022. Tribal Communities: Feedback Specific to Stakeholder Types. Accessed May 2022.

[107] Institute for Local Self-Reliance. 2022. Challenges Facing Community Composters: Community Composter Census Data.

make it difficult for recycling organics infrastructure to compete in the materials management market cost-effectively.

- **Education:** Education is particularly important as participating residents, institutions, and businesses need detailed training materials and resources to understand which organic waste types to recycle.

The expansion of organics recycling infrastructure would require investment to address the challenges listed above as well as equity considerations such as siting and limiting operational disruption (e.g., traffic) to surrounding communities.

3.3.3 Recycling End Markets

Recycling organics produces end products with existing market value and distribution systems. The composting process produces finished compost, which can serve as a fertilizer, landscaping, or engineering material. The current global composting market is valued at $5.6 billion in 2020 and is expected to increase by 33.9 percent and reach $7.5 billion by the end of 2027.[108] In the U.S., there are over 200,000 landscaping companies and public garden spaces and 1.5 million farms that can use and apply finished compost.[109, 110] The anaerobic digestion process can produce either biogas (for use as fuel in alternative vehicles) or electricity and digestate, which can also serve as a fertilizer, landscaping, or engineering material. Annual revenue from electricity generation at anaerobic digestion facilities typically ranges between $300,000 to $400,000 per facility.[111] This range is highly variable and depends on local energy market conditions.

Despite this forecasted increase, there are gaps in the U.S. recycling market that must be addressed to promote a robust end market for organics recycling. Currently, there is a lack of policies and economic incentives to encourage the use of organic recycled materials on the local, state, and federal level. Interviews with organics recycling experts noted that the market price of synthetic fertilizer can be less expensive than compost; the price of synthetic fertilizer, however, does not reflect the costs to the environment associated with its use. For synthetic fertilizers that are over-applied, excess nutrients can run-off into surrounding waterways, causing algae blooms and negatively impacting water quality. In addition, excessive use of synthetic fertilizers can lead to issues such as soil degradation, nitrogen leaching, soil compaction, reduction in soil organic matter, and loss of soil carbon. Conversely, compost and digestate are natural materials and provide a slow release of the appropriate amount of nutrients needed, improving soil quality and avoiding adverse water quality impacts. Policies that limit the use of synthetic fertilizer, educate the market on the negative externalities associated with synthetic fertilizers, and encourage the use of compost and digestate through post-consumer content mandates (e.g., requiring municipal landscaping and green infrastructure projects use a certain percentage of finished compost or digestate) would help to bolster the existing end market for recycled organic products.

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108 GlobeNewswire. 2022. "Compost Market 2022." Accessed online May 2022: https://www.globenewswire.com/en/news-release/2022/01/13/2366344/0/en/Compost-Market-2022-Revenue-USD-7516-5-mn-Growth-Prospects-Price-Trends-Share-Forecast-by-2027-Report-by-Absolute-Reports.html#:~:text=Market%20Analysis%20and%20Insights%3A%20Global,3.9%25%20during%202021%2D2027.

109 U.S. EPA. 2022. Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

110 USDA. 2022. Farms and Land in Farms 2021 Summary. Accessed online May 2022: https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0222.pdf.

111 Cowley, Cortney and B. Wade Brorsen. 2018. "Anaerobic Digester Production and Cost Functions." Ecological Economics, Vol. 152. Accessed online May 2022: https://www.sciencedirect.com/science/article/abs/pii/S0921800918305500?fr=RR-2&ref=pdf_download&rr=7425f313c8f03b94.

For anaerobic digestion, the current categorization of biogas in the renewable fuels market can affect the financial viability of many anaerobic digestion facilities. To enhance markets for renewable fuel, EPA developed the Renewable Fuel Standard, a trading and enforcement program whereby refiners or importers of gasoline or diesel fuel are required to comply with renewable fuel volume obligations by either blending renewable fuels into conventional transportation fuels or obtaining credits, called renewable identification numbers (RINs). RINs can fall into a number of different categories based on the feedstocks and/or processes used to produce the renewable fuel. Each RIN category carries a different market value to incentivize the use of certain feedstocks or production processes. EPA is currently re-examining the RINs classification for biogas from anaerobic digestion and is expected to announce changes by the end of the year that could greatly improve the economics of operating anerobic digestion facilities (i.e., the profit margins could be three times higher for biogas producers under the anticipated new RIN classification). [112]

3.4 Assessment of Financial Estimates

Improved infrastructure for recycling pathways including composting, anaerobic digestion, and livestock feed can provide equivalent access to organics recycling and successfully capture potentially recyclable organic materials.[113] **Exhibit 3-2** summarizes the investment estimates for recycling organic material. Details on the investment estimates, organized by infrastructure type, are included below.

Exhibit 3-2. Summary Investment Cost Estimates for Recycling Organic Material.

Organics Recycling Method	Cost Category	Low-End Estimate	High-End Estimate
At-Home Composting	Education & Outreach	$92,000,000	$92,000,000
	Collection	$0	$0
	Capital	$290,000,000	$290,000,000
	Operating	$0	$0
	Subtotal	***$380,000,000***	***$380,000,000***
Community Composting	Education & Outreach	$1,200,000,000	$1,200,000,000
	Collection	$1,600,000,000	$1,600,000,000
	Capital	$1,100,000,000	$1,100,000,000
	Operating	$710,000,000	$710,000,000
	Subtotal	***$4,700,000,000***	***$4,700,000,000***
Centralized Composting	Education & Outreach	$1,000,000,000	$1,000,000,000
	Collection	$5,900,000,000	$5,900,000,000
	Capital	$1,200,000,000	$2,000,000,000
	Operating	$530,000,000	$530,000,000
	Subtotal	***$8,700,000,000***	***$9,400,000,000***
Centralized Anaerobic Digestion	Education & Outreach	$8,400,000	$8,400,000
	Collection	$160,700,000	$160,700,000

112 BioCycle. 2017. 101 for RINs. Accessed online May 2022: https://www.biocycle.net/101-for-rins/#:~:text=A%20key%20difference%20between%20D3,of%20the%20solid%20waste%20industry.

113 Note: EPA's estimates of the percentage of organic waste managed by each organics recycling method is aligned with how organic materials are currently managed. The percentage breakdown is detailed here: U.S. EPA Office of Resource Conservation and Recovery. 2020. 2018 Wasted Food Report. Accessed online May 2022: https://www.epa.gov/sites/default/files/2020-11/documents/2018_wasted_food_report-11-9-20_final_.pdf

Organics Recycling Method	Cost Category	Low-End Estimate	High-End Estimate
	Capital	$135,200,000	$149,500,000
	Operating	$117,600,000	$117,600,000
	Subtotal	***$421,900,000***	***$436,200,000***
WRRF Anaerobic Digestion	Education & Outreach	$8,400,000	$8,400,000
	Collection	$0	$0
	Capital	$48,000,000	$67,000,000
	Operating	$20,000,000	$20,000,000
	Subtotal	***$77,000,000***	***$96,000,000***
Animal Feed	Education & Outreach	$0	$0
	Collection	$310,000,000	$350,000,000
	Capital	$66,000,000	$75,000,000
	Operating	$75,000,000	$84,000,000
	Subtotal	***$450,000,000***	***$500,000,000***
	Total	**$14,700,000,000**	**$15,500,000,000**

Note: *Low-end and high-end estimates are driven by the count and capacity of new and upgraded recycling facilities. The low-end estimates assume that not all existing facilities are operating at full capacity and could intake a portion of the potentially recoverable materials, resulting in reduced capital costs. EPA's high-end estimate assumes that facilities will not operate any closer to full capacity and that comparatively more facilities will need to be built, which will result in higher capital costs.*

Estimated using:
(1) U.S. EPA Office of Resource Conservation and Recovery. 2020. 2019 Wasted Food Report.
(2) State waste management reports.
(3) U.S. Census Bureau. 2022. 2019 American Community Survey.
(4) Natural Resources Defense Council. 2017. Estimating Quantities and Types of Food Waste at the City Level. Accessed online May 2022: https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf.
(5) ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf.
(6) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/
(7) U.S. Composting Council. 2021. "Organics Bans and Mandates." Accessed online May 2022: https://www.compostingcouncil.org/page/organicsbans.
(8) U.S. Composting Council. The Case for Centralized Compost Manufacturing Infrastructure. Accessed May 2022.
(9) U.S. EPA. 2021. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). Accessed online May 2022: https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf.
(8) Interviews with industry experts.

The investment estimates for organics are based on several core assumptions:

1. At a minimum, all urban residents (including multi-family units) will have access to curbside organic waste pickup.
2. At a minimum, all rural residents will have access to organic waste drop-off services or at-home composting opportunities.
3. While organics recycling programs will be available to all so that recycling services are on par with trash disposal services, 78.6 percent of the eligible population will participate in organics recycling,

mirroring the current participation rate in recycling programs for communities with equal access to trash and recycling services.[114]

4. Commercial and institutional sectors will participate in organic recycling programs.
5. Anaerobic digestion does not process residential waste and only processes commercial and institutional waste.

3.4.1 Composting

Composting is a natural process of recycling organic material into a rich soil amendment. Composting can serve as a viable option to divert organic wastes such as food waste and yard waste from landfills. These materials can be collected then composted to produce a valuable material (i.e., compost). Compost can then be distributed to landscapers, farmers, and other businesses and residents as a valuable soil amendment. This soil amendment can be used to promote agricultural productivity, further supporting the growth of more food and plants and reducing the need for synthetic fertilizer and topsoil. The soil amendment can also be used for engineering purposes (e.g., erosion control and stormwater management).

Successful composting requires a healthy balance of both food and yard waste. Composting requires a balanced mix of materials that are rich in nitrogen or protein (also known as "greens") and materials that are rich in carbon or carbohydrate (also known as "browns"). The success of any compost project relies on the existence of naturally occurring microorganisms to break down organic waste and convert the waste into compost. "Greens" help the microorganisms grow and multiply quickly while the "browns" serve as a food source for the microorganisms and allow air to filter through. Materials such as food, wood, and grass and leaf clippings serve as valuable sources of "greens" for a compost pile while materials such as wood waste, e.g., tree branches and woody debris, serve as valuable sources of "browns." (Source: Hu, Sheila. 2020. "Composting 101." Natural Resources Defense Council. Accessed online May 2022: https://www.nrdc.org/stories/composting-101.)

There are three types of composting models considered in the estimates: at-home composting, community composting, and centralized composting:

- **At-home composting** entails single-family households composting food and yard waste in backyard settings through the use of tumblers or piles that are routinely turned.
- **Community composting** also entails composting through tumblers or piles that are routinely turned, but at a larger scale (approximately 2,500 tons per year) at community gardens, local farms, public parks, schools, etc.[115] Community composting operations usually involve the community, typically through volunteer opportunities to manage the compost, and compost is kept and used within the community.[116] Organic waste is typically collected through drop-off services for community composting, although curbside hauling services do exist for select programs.
- **Centralized composting**, also known as industrial composting, involves large-scale composting facilities that process commercial, residential, and institutional food waste, in facilities with approximately 50,000 tons per year or more of processing capacity.[117] These facilities are typically

[114] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

[115] ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf.

[116] Institute for Local Self-Reliance. 2019. Community Composting Done Right: A Guide to Best Management Practices. Accessed online May 2022: https://ilsr.org/composting-bmp-guide/.

[117] U.S. Composting Council. The Case for Centralized Compost Manufacturing Infrastructure. Accessed May 2022.

managed by a private compost companies or solid waste agencies and organic waste is typically collected through curbside pick-up or drop-off.

EPA estimates an investment of $13.8 to $14.5 billion is needed to modernize composting infrastructure. This investment would result in an additional 38 million tons of organics recycled, increasing the national recycling rate to 45 percent. **Exhibit 3-3** below provides a breakdown of investment estimates for composting.

Exhibit 3-3. Investment Cost Estimates for Composting Food Waste and Yard Waste.

Composting Model	Cost Category	Low-End Estimate	High-End Estimate
At-Home Composting	Education & Outreach	$92,000,000	$92,000,000
	Collection	$0	$0
	Capital	$290,000,000	$290,000,000
	Operating	$0	$0
	Subtotal	***$380,000,000***	***$380,000,000***
Community Composting	Education & Outreach	$1,200,000,000	$1,200,000,000
	Collection	$1,600,000,000	$1,600,000,000
	Capital	$1,100,000,000	$1,100,000,000
	Operating	$710,000,000	$710,000,000
	Subtotal	***$4,700,000,000***	***$4,700,000,000***
Centralized Composting	Education & Outreach	$1,000,000,000	$1,000,000,000
	Collection	$5,900,000,000	$5,900,000,000
	Capital	$1,200,000,000	$2,000,000,000
	Operating	$530,000,000	$530,000,000
	Subtotal	***$8,700,000,000***	***$9,400,000,000***
	Total	**$13,800,000,000**	**$14,500,000,000**

Note: *Low-end and high-end estimates are driven by the count and capacity of new and upgraded recycling facilities. The low-end estimates assume that not all existing facilities are operating at full capacity and could intake a portion of the potentially recoverable materials, resulting in reduced capital costs. EPA's high-end estimate assumes that facilities will not operate any closer to full capacity and that comparatively more facilities will need to be built, which will result in higher capital costs.*

Estimated using:
(1) Natural Resources Defense Council. 2017. Estimating Quantities and Types of Food Waste at the City Level. Accessed online May 2022: https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf.
(2) ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf.
(3) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/
(4) U.S. Composting Council. 2021. "Organics Bans and Mandates." Accessed online May 2022: https://www.compostingcouncil.org/page/organicsbans.
(5) U.S. Composting Council. The Case for Centralized Compost Manufacturing Infrastructure. Accessed May 2022.
(6) Interviews with industry experts.

EPA's composting estimates assume that:

- 45.6 percent of participating rural households will compost at-home while the remaining 54.4 percent will drop-off their organic material at community composters,[118]
- In addition to managing organic material from 54.4 percent of participating rural households, community composters will manage 50 percent of organic material from urban households[119]
- Centralized composters will manage all other organic materials from commercial entities, institutional entities, and the remaining 50 percent of urban households (both single and multi-family households) not served by community composting.[120]

Equity Benefits of Community Composting. Community composting serves as a valuable resource to rural households, as rural households are typically not served by curbside programs due to lack of density. However, community composting, which may offer pick-up services, can provide rural residents, in particular those who do not have the means to easily transport their organic waste or cannot physically compost at-home, access to organic recycling services.

To avoid odor and pest issues, it is further assumed that at-home and community composting can only compost vegetative waste (e.g., fruit and vegetable scraps), which represents 78 percent of generated food waste. [121] The analysis assumes that community compost operations cannot take food waste such as meat and fish; liquids, oil, and grease (FOG); and dairy and eggs, though centralized composting operations can accept all types of food and yard waste as part of curbside programs. Centralized composting operations can process all types of food waste as these facilities have specialized industrial equipment that can quickly compost organic material, reducing the potential for odor and pest issues typically associated with composting non-vegetative organic material.

Tribal Community Project Example: Composting at the Ho-Chunk Nation. For over 15 years, the Ho-Chunk Nation has diverted over 50,000 pounds of food waste annually from its local Majestic Pines Casino. Created with the help of a Solid Waste Management Assistance Grant from the U.S. EPA's Region 5 office, the composting program is operated by the Nation's Health Office staff and distributes the finished compost first to gardens in the Nation's communities and then to individual members. (Source: Jerome Goldstein. 2008. Tribal Composting Projects Across The U.S. BioCycle. Accessed online Aug. 2022: https://www.biocycle.net/tribal-composting-projects-across-the-u-s/.)

EPA's low-end and high-end estimates are driven by assumptions made on existing capacity for centralized composting. EPA's low-end estimates assume that around 204 new centralized composting facilities will need to be built as states with existing yard waste bans can retrofit existing yard waste collection piles to include food waste composting.[122] EPA's high-end estimates assume that states with existing yard waste bans cannot

[118] EPA assumes that of all the participating rural households, 54.4 percent will compost via community centers and 45.6 percent will compost at home. Since evidence-based data on rural composting participation and breakdown rates are not available, this assumption is based on the percentage of the rural population living within metro areas as a proxy. Source: U.S. Census Bureau. 2016. Life Off the Highway: A Snapshot of Rural America. Accessed Oct 2022: https://www.census.gov/newsroom/blogs/random-samplings/2016/12/life_off_the_highway.html#:~:text=Over%20half%20(54.4%20percent)%20of,population%20lives%20in%20rural%20areas Based on feedback from the U.S. Composting Council, rural areas that are fairly close to a metropolitan area will likely have ample community composting programs and will likely not be posed with prohibitively long distances to organic waste drop off sites while rural areas that are not located close to a metropolitan area will likely face prohibitively long distances to travel to an organic waste drop off site and therefore, would likely compost at home.

[119] U.S. Composting Council. The Case for Centralized Compost Manufacturing Infrastructure. Accessed May 2022.

[120] U.S. Composting Council. The Case for Centralized Compost Manufacturing Infrastructure. Accessed May 2022.

[121] Natural Resources Defense Council. 2017. Estimating Quantities and Types of Food Waste at the City Level. Accessed online May 2022: https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf.

[122] U.S. Composting Council. 2021. "Organics Bans and Mandates." Accessed online May 2022: https://www.compostingcouncil.org/page/organicsbans.

retrofit existing yard waste collection piles to include food waste composting so that approximately 450 new centralized composting facilities will need to be built, resulting in higher capital costs.

For **investments in collection**, EPA's estimate assumes that for centralized composting, collection costs cover the costs of collection bins (e.g., kitchen top collection bins and secure toters for curbside pick-up) and fuel to collect and transport organic waste from generators to a surrounding centralized composting facility. EPA's estimate assumes that for community composting, collection costs cover the costs of collection bins (e.g., kitchen top collection bins), but organic waste generators drop-off the organic waste at existing local infrastructure such as farmers markets, transfer stations, or directly at community composting sites. Due to the variability of community composting programs that offer and do not offer collection services, the cost of these pick-up services for community composting programs is not included in the national level estimate. In addition, given the on-site nature of at-home composting, EPA has assumed no associated collection costs.

Capital costs for at-home and community composting operations include small scale equipment such as rakes, shovels, and bins to turn and store the compost. For centralized composting, capital costs include large-scale equipment such as trucks for collection, front-end loaders, bulldozers, compost turners, brush chippers, and tub grinders. Both community and centralized composting capital costs include equipment such as magnets and screens to address and reduce possible contamination. For centralized composting, additional start-up costs, such as land acquisition, site prep, and permitting are included in estimates for new construction.

Operating costs for community and centralized composting include the associated equipment and labor costs for operations. While at-home composting requires residents to devote time to maintaining their own compost piles, EPA has not included the time costs associated with management of residential compost piles.

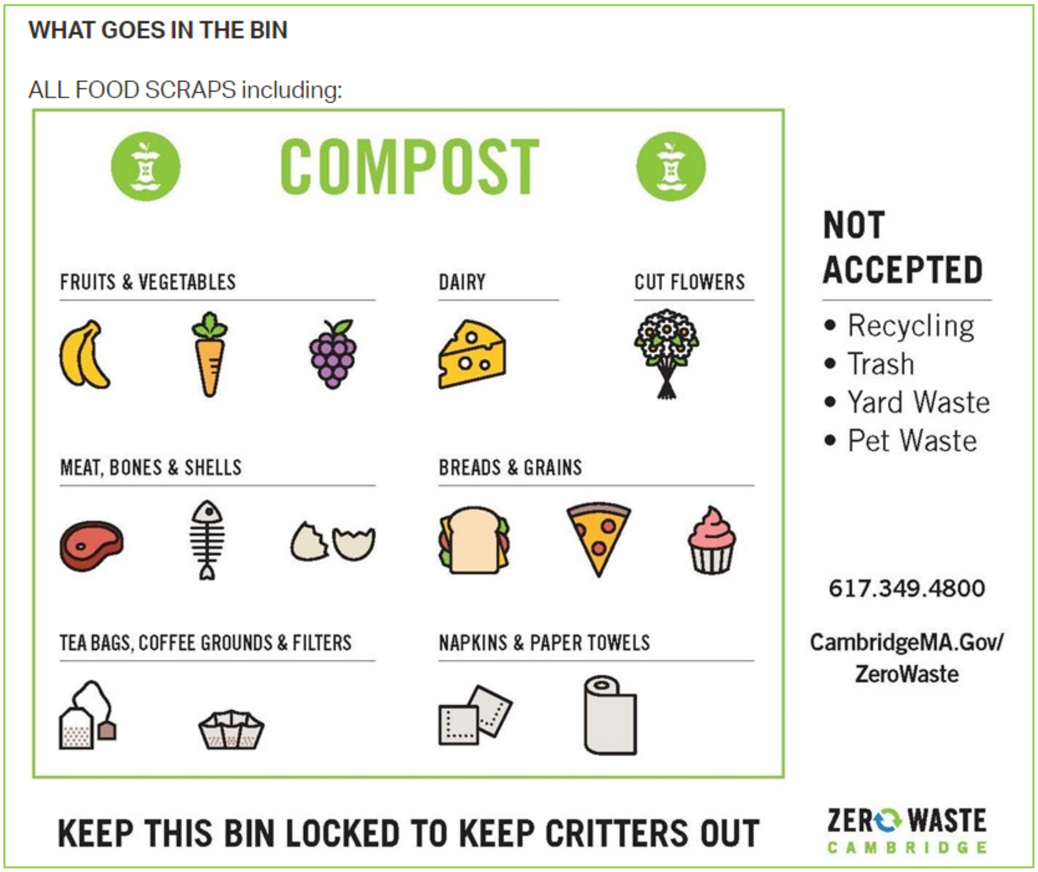
Key to all three composting operations is education. All three composting models consider the cost of educating residents and applicable businesses and institutions on the availability of composting programs and how and what to compost. Education and outreach costs are around $10 per household per year for centralized and community models and likely take the form of flyers, infographics, and other written announcements on public platforms (e.g., town websites, social media, etc.).[123] **Exhibit 3-4** has an example model of accepted composting materials messaging from an organics recycling program in Cambridge, Massachusetts. Education for at-home composting is much more involved and is assumed to be $36 per household per year as

Project Example: At-Home Composting Education in Orlando, Florida. The City of Orlando hosts a robust residential composting program. Residents living in single-family homes are able to request a free composter from the Solid Waste Division office. The office delivers the composter along with in-depth, step-by-step materials on how to start composting. The city's composting website also hosts publicly available videos on how to start, maintain, and harvest compost along with a phone line to call if residents need help troubleshooting their own composting bins. As of October 2019, more than 6,500 residents have participated in the city's at-home composting program. (Source: City of Orlando. 2022. Food Waste Drop-Off. Accessed online Aug. 2022: https://www.orlando.gov/Our-Government/Departments-Offices/Executive-Offices/CAO/Sustainability-Resilience/Green-Works-Focus-Areas/Zero-Waste/Food-Waste-Drop-off & City of Orlando. 2022. Request a Free Composter. Accessed online Aug. 2022: https://www.orlando.gov/Trash-Recycling/Request-a-Free-Composter)

[123] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/

at-home composting requires hands-on or virtual training sessions to educate residents on how to compost properly.[124]

Exhibit 3-4. Example Composting Messaging from the Cambridge, Massachusetts Composting Program.



Finally, it is important to note that the financial estimates above do not incorporate any benefits associated with cost savings or revenue from the use and sale of finished compost as different models accrue these benefits in different forms and thus cannot be easily modeled. Composting can produce potential benefits, which include but are not limited to:

- Revenue for community and centralized composters, who can sell the produced compost to landscapers, gardeners, farmers, and state and federal agencies (e.g., Department of Transportation). The current price for compost ranges between $13 to $35 per cubic yard (the price varies by feedstock material and finished product quality).[125] Revenue from the sale of compost can fund and compensate labor, supporting local jobs within communities.
- Cost savings incurred by residents and farmers, who can reduce the amount spent on synthetic fertilizers from the use of compost.

[124] ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf.
[125] Waste360. 2004. "Doing the Dirty Work." Accessed online May 2022: https://www.waste360.com/composting-and-organic-waste/doing-dirty-work.

- Cost savings to all at-home and community composters, who can save money on garbage disposal costs through food waste and yard waste diversion.
- Resource savings (e.g., fuel and water) and GHG emissions savings associated with avoided production of synthetic fertilizers.
- Ecosystem-wide benefits from avoided water pollution and soil degradation issues usually associated with the use of synthetic fertilizers.

Equity Benefits. Composting locally, either through community composting or at-home composting, yields many equity benefits. Such benefits include but are not limited to:

- Greener neighborhoods and improved local soils,
- Enhanced food security and fewer food deserts, and
- Less truck traffic from hauling garbage.

Community composting in particular also leads to:

- Social inclusion and empowerment through hands on volunteer and education opportunities, and
- More local jobs and technical training.

Source: (Institute for Local Self-Reliance. 2014. State of Composting in the U.S. Accessed online May 2022: https://cdn.ilsr.org/wp-content/uploads/2014/07/state-of-composting-in-us.pdf?_gl=1*4fxke0*_ga*MTczNjE0MTc4LjE2NTY2MzgyNDk.*_ga_M3134750WM*MTY2MTI1OTc1Mi44LjEuMTY2MTI1OTc2Mi4wLjAuMA..&_ga=2.211537365.1967080789.1661184465-173614178.1656638249.)

3.4.2 Anaerobic Digestion

Anaerobic digestion is a process through which bacteria break down organic matter, such as animal manure, wastewater biosolids, and food wastes, in the absence of oxygen. Anaerobic digestion for biogas production takes place in a sealed vessel called a reactor, which is designed and constructed in various shapes and sizes specific to the site and feedstock conditions. Anaerobic digestion produces two valuable outputs: biogas and digestate. The energy in biogas can be used like natural gas to provide heat, generate electricity, and power cooling systems, among other uses. Biogas can also be purified to generate renewable natural gas (RNG). This can be sold and injected into the natural gas distribution system, compressed and used as vehicle fuel, or processed further to generate alternative transportation fuel, energy products, or other biochemicals and bioproducts. Digestate is the residual material left after the digestion process. With appropriate treatment, digestate can be used as a soil amendment or fertilizer.

There are two types of anaerobic digestion models considered in the report's estimates: centralized anaerobic digestion and anaerobic digestion co-located with water resource recovery facilities (WRRF). Centralized anaerobic digesters include standalone facilities located in industrial, commercial, or on-farm settings, and food waste is typically trucked to these facilities. WRRF anaerobic digestion involve anaerobic digestion operations at water resource recovery facilities (i.e., wastewater treatment plants) that process both food waste and sludge simultaneously. Typically, food waste is delivered to these facilities through in-sink disposals and sewage lines, but it can also be trucked.

Tribal Community Project Example: Anaerobic Digestion at the Forest County Potawatomi Community. Since 2013, the Forest County Potawatomi Community has diverted 16 million gallons of food waste annually to its 2-megawatt anaerobic digester. The biogas produced is used to generate electricity, which is sold to the local utility and used to power approximately 1,600 homes in the community. Excess heat is recovered and beneficially reused. (Source: U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. 2022. Renewable Energy Deployment Projects for Forest County Potawatomi Community. Accessed online Aug. 2022: https://www.energy.gov/eere/technology-to-market/renewable-energy-deployment-projects-forest-county-potawatomi-community.)

EPA estimates an investment of $499 million to $532 million is needed to modernize anaerobic digestion infrastructure and facilitate equivalent access to organics recycling. This investment would result in an additional 2.1 million tons of organics recycled, increasing the national recycling rate to 33 percent. **Exhibit 3-5** below provides a breakdown of investment estimates.

Exhibit 3-5. Investment Cost Estimates for Anaerobically Digesting Food Waste.

Anaerobic Digestion Model	Cost Category	Low-End Estimate	High-End Estimate
Centralized Anaerobic Digestion	Education & Outreach	$8,400,000	$8,400,000
	Collection	$160,700,000	$160,700,000
	Capital	$135,200,000	$149,500,000
	Operating	$117,600,000	$117,600,000
	Subtotal	***$421,900,000***	***$436,200,000***
WRRF Anaerobic Digestion	Education & Outreach	$8,400,000	$8,400,000
	Collection	$0	$0
	Capital	$48,000,000	$67,000,000
	Operating	$20,000,000	$20,000,000
	Subtotal	***$77,000,000***	***$96,000,000***
Total		**$499,000,000**	**$532,000,000**

Note: *Low-end and high-end estimates are driven by the count and capacity of new and upgraded recycling facilities. The low-end estimates assume that not all existing facilities are operating at full capacity and could intake a portion of the potentially recoverable materials, resulting in reduced capital costs. EPA's high-end estimate assumes that facilities will not operate any closer to full capacity and that comparatively more facilities will need to be built, which will result in higher capital costs.*

Estimated using:
(1) ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf.
(2) U.S. EPA. 2021. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). Accessed online May 2022: https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf.
(3) U.S. EPA Office of Resource Conservation and Recovery. 2020. 2019 Wasted Food Report.
(4) Interviews with industry experts.

In terms of specific pathways, EPA's estimates assume that:

- Of MSW food waste, only commercial and institutional food waste gets managed by anaerobic digestion, due to the need for consistent feedstock as noted by the recycling experts interviewed; residential food waste does not typically meet requirements for consistency. (Currently, only 1 percent of MSW food waste from the residential sector is managed by anaerobic digestion.)[126]
- 86 percent of food waste quantities available for anaerobic digestion is managed by centralized anaerobic digestion facilities while the remaining 14 percent is managed by WRRF anaerobic digestion.[127]

[126] U.S. EPA Office of Resource Conservation and Recovery. 2020. 2019 Wasted Food Report.
[127] U.S. EPA. 2021. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). Accessed online May 2022: https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf.

For centralized anaerobic digestion, EPA's low-end and high-end estimates are driven by assumptions related to existing capacity. There are currently 275 anaerobic digesters in operation. [128] EPA's low-end estimates assume that around 13 new AD facilities will need to be built because not all existing anaerobic digestion facilities are operating at full capacity.[129] EPA's high-end estimates assume that all existing AD facilities will not operate any closer to full capacity and that around 25 new AD facilities will need to be built to manage MSW generated food waste, resulting in higher capital costs. (Note that these estimates for newly constructed AD facilities only cover new AD construction to manage MSW food waste through anaerobic digestion. For efforts to capture food waste from non-MSW sources, such as food manufacturers, the total number of AD facilities needed will likely be higher. Currently, 97 percent of food waste managed by anaerobic digestion stems from non-MSW sources, such as food manufacturers and processors.) [130]

For **collection**, EPA's estimate assumes that for centralized anaerobic digestion, collection costs cover the costs of collection bins (e.g., secure toters for curbside pick-up from commercial and institutional settings) and fuel to collect and transport food waste from generators to a surrounding centralized anaerobic digestion facility. EPA assumes no collection associated with WRRF anaerobic digestion as food waste managed by water resources recovery facilities are delivered to the facilities through in-sink disposals and existing sewer lines.

EPA's estimate of **capital costs** for anaerobic digestion includes infrastructure and equipment costs such as anaerobic vessels and monitoring equipment. Additional start-up costs, such as land acquisition, site prep, and permitting are included in estimates for new construction. For WRRF anaerobic digestion in particular, capital costs are only assumed for the food waste anaerobic digestion portion of new WRRFs and does not include capital costs associated with general wastewater treatment.[131] **Operating costs** include the associated equipment and labor costs for operations and maintenance.

Finally, given the need for consistent, non-contaminated feedstock, centralized anaerobic digestion estimates also include investment estimates for **education and outreach**. Education and outreach costs are around $10 per commercial and institutional establishment per year and likely take the form of distributing flyers and infographics.[132]

The financial estimates above do not incorporate any benefits associated with cost savings or revenue from the use and sale of biogas and digestate produced from anaerobic digestion operations. Anaerobic digestion can produce potential benefits, which include but are not limited to:

Additional benefits from fleet electrification. As waste management providers look to electrify fleets, the production of electricity from anaerobic digestion could be possibly used to power collection vehicles for anaerobic digestion facilities. This could provide added benefits for emissions and pollution reduction and noise reduction from waste collection.

[128] U.S. EPA. 2022. Anaerobic Digestion Facilities Processing Food Waste in the United States (2019). Accessed online May 2022: https://www.epa.gov/anaerobic-digestion/anaerobic-digestion-facilities-processing-food-waste-united-states-survey.
[129] U.S. EPA. 2021. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). Accessed online May 2022: https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf.
[130] U.S. EPA Office of Resource Conservation and Recovery. 2022. 2019 Wasted Food Report.
[131] Due to data limitations, EPA's estimates do not consider expanding anaerobic digestion systems to current WRRFs, although this option may be technologically feasible.
[132] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/.

- Revenue for operators, who can sell the produced biogas and digestate.
- Cost savings to all participating institutional and commercial customers, who can save money on garbage disposal costs through food waste diversion.
- Resource (e.g., fuel and water) and GHG emissions savings associated with avoided production of synthetic fertilizers and energy from fossil fuels.
- Ecosystem-wide benefits from the production of renewable energy in place of fossil fuel-derived energy.

3.4.3 Livestock Feed

Food waste that is no longer edible to humans but still safe for animals can be re-purposed and recycled into livestock feed. Typically, vegetative wastes are fed to cows, sheep, goats, and poultry while vegetative and meat wastes are fed to swine. EPA estimates an investment of $450 million to $500 million is needed to modernize livestock feed infrastructure and facilitate equivalent access to organics recycling. This investment would result in an additional 3.9 to 4.4 million tons of organics recycled, increasing the national recycling rate to 33 to 34 percent. **Exhibit 3-6** below provides a breakdown of investment estimates.

Exhibit 3-6. Investment Cost Estimates for Recycling Food Waste as Animal Feed.

Cost Category	Low-End Estimate	High-End Estimate
Collection	$310,000,000	$350,000,000
Capital	$66,000,000	$75,000,000
Operating	$75,000,000	$84,000,000
Total	**$450,000,000**	**$500,000,000**

Note: *EPA's low-end and high-end estimates are driven by how much food waste is potentially recycled as livestock feed. For low-end estimates, estimates assume that states with any restrictions on livestock feed will not participate in recycling food waste into livestock feed. The higher-end estimates assume that states with select feed restrictions regarding meat as livestock feed will not participate in recycling food waste into livestock feed.*

Estimated using:
(1) Natural Resources Defense Council. 2017. Estimating Quantities and Types of Food Waste at the City Level. Accessed online May 2022: https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf.
(2) ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf.
(3) U.S. EPA Office of Resource Conservation and Recovery. 2020. 2019 Wasted Food Report.

EPA's low-end and high-end estimates are driven by how much food waste is potentially recycled as livestock feed. To prevent disease outbreaks associated with animal feed (e.g., mad cow disease, also known as foot-and-mouth disease in swine and bovine spongiform encephalopathy), several existing federal and state laws and regulations limit how much food waste can be recycled as livestock feed. Some states have feed restrictions on using both meat and vegetative waste for livestock feed, while other states have feed restrictions on using meat waste as livestock feed but do allow for using vegetative waste as livestock feed. EPA's low-end estimate assumes 3.9 million tons of food waste is available for recycling as livestock feed while EPA's high-end estimate assumes that 4.4 million tons of food waste is available for recycling as livestock feed. EPA's low-end estimate assumes that the states with any type of restriction (e.g., meat waste only or both meat and vegetative waste) on feeding food waste to livestock will not recycle food waste as livestock feed. [133] EPA's high-end estimate assumes that all states will recycle food waste as livestock feed except for the states that currently have restrictions on feeding meat waste to livestock (i.e., states that only restrict meat waste will still recycle vegetative waste in the high-end scenario).[134]

EPA's estimate assumes that collection costs cover the costs of fuel to collect and transport animal feed from food waste generators to surrounding livestock farms. Given the need for consistent, large volume, and unprocessed food waste as livestock feed, EPA assumes that only commercial entities such as grocery stores (as opposed to other generators like the residential sector) are likely to use livestock feed as an organics recycling method. Capital costs include the purchase of heat treatment and dehydration equipment to comply with existing federal livestock feed regulations and reduce the weight of food waste to minimize transport costs. Operating costs include the costs associated with operating the food waste treatment equipment and distributing and feeding the food waste to livestock.

It is important to note that the financial estimates above do not incorporate any cost savings associated with recycling food waste into livestock feed. Recycling food waste into livestock feed can produce potential benefits and associated cost savings, which include, but are not limited to:

- Cost savings incurred by farmers, who can use food waste to supplement costly animal feed.
- Cost savings to food waste generators, who can save money on garbage disposal costs through food waste diversion.
- Resource savings (e.g., fuel, water, etc.) and GHG emissions savings associated with the avoidance of growing and distributing food specifically as animal feed.

3.5 Summary and Investment Considerations

EPA estimates that an investment of **$14 to $16 billion in composting, AD, and livestock infrastructure** by 2030 could potentially recover an additional 44 million tons, **increasing the nation's overall recycling rate from its current level of 32 percent to 47 percent, close to EPA's nationwide goal of 50 percent**. Notably, investment estimates in this report do not factor in source reduction and its effect on existing food waste generation quantities. Upcoming grants (such as grant programs under the Bi-Partisan Infrastructure Law), legislation enacted by Congress (such as the Bill Emerson Good Samaritan Food Donation Act and the Food Donation Improvement Act), and proposed legislation (such as the Healthy Meals, Healthy Kids Act and the Zero Food Waste Act) all work to reduce or prevent food waste by increasing opportunities for food rescue, reallocating surplus food, and

Comparison with Existing Estimates. There are currently other estimates publicly available on the level of investment needed to expand recycling infrastructure opportunities for organic materials. A popular study is ReFED's *Roadmap to 2030* report, which estimates that an investment of $14 billion is needed to reduce and recycle food waste by 2030. EPA provides a higher bound estimate for several reasons:

- ReFED assumes that source reduction will serve as the driving factor behind food waste reduction, avoiding the need for unnecessary infrastructure. EPA's estimates assume that food waste will continue at the same rate of generation at present levels. Investment in source reduction is typically cheaper than that for infrastructure on a per ton basis.
- The ReFED model does not include cost estimates for yard waste. EPA's estimate includes costs for recycling food and yard waste together.
- The ReFED model does not include cost estimates associated with collection bins, large-scale outreach and education, land acquisition, site preparation, permitting, etc.

[133] These states include Alabama, Delaware, Idaho, Illinois, Kansas, Kentucky, Louisiana, Mississippi, Nebraska, North Dakota, Oregon, South Carolina, South Dakota, Texas, Vermont, and Wisconsin.
[134] These states include Alabama, Illinois, Kansas, Kentucky, Louisiana, Mississippi, North Dakota, Oregon, South Dakota, and Wisconsin.

restricting the disposal of food waste.[135,136, 137, 138] To the extent that Congress enacts currently pending legislation, EPA may wish to revisit the infrastructure investment assessment as source reduction can significantly reduce the generation of food waste and, consequently, the regional infrastructure and financial investment needed to address potentially recyclable organic materials.

For successful capture of potentially recyclable organics waste, investments in collection, education, and building organics recycling processing capacity should be made simultaneously. Multiple organics recycling experts interviewed recommend recycling providers and municipalities to work together first to assess local interest in participating in recycling programs, the availability of organics for recycling, the availability of land for recycling infrastructure, and available financing options (including grants), then expand or build new infrastructure accordingly (see **Section 4** for more information on financing mechanisms). To avoid situations with multiple service providers overbuilding capacity for the expected volume of organic feedstock in a specific region, experts advise local permitting departments to be included in initial assessment conversations as permitting officials will have deep knowledge on local proposed infrastructure projects and possible sites that meet permitting requirements for recycling infrastructure expansion.

> Investment estimates do not factor in the growing complexity associated with **compostable packaging and serviceware**. As the use of compostable packaging becomes mainstream, issues associated with increased contamination arise as compostable packaging and non-compostable packaging can appear to be very similar, confusing consumers. Replacing all packaging with compostable packaging may ultimately work to increase the quantity of material available for organics recycling and reduce contamination. However, the uptake of compostable packaging is currently unknown as research in the intended and unintended impacts of compostable packaging is currently in its early stages.
>
> For instance, initial research suggests that compostable packaging may lead to an increase in microplastics, remnants of plastics from coatings found in packaging, in finished compost. Once land applied, these microplastics can enter the ecosystem, potentially exposing wildlife and humans to dangerous concentrations of chemicals found in microplastics, such as PFAS and dioxins. However, the exact impacts of compostable packaging are currently unknown and not yet widely researched. Currently, many composting facilities do not accept BPI-certified compostable packaging and serviceware as it does not break down well in facilities and results in contamination. As more information on compostable packaging becomes available, EPA may consider updating the analysis and estimates accordingly. (Source: Woods End Laboratories and Ecocycle. 2018. Microplastics in Compost. Accessed online May 2022: https://www.ecocycle.org/files/pdfs/microplastics_in_compost_summary.pdf.)

Policies to promote the use and sale of recycled organic material should also be made concurrently with other investments to spur the demand and investment for organics recycling infrastructure. Policies such as pay-as-you-throw programs, where landfills charge residents and businesses for the collection of MSW based on the amount thrown away, or organic waste landfill bans could help to disincentivize the landfilling of organic materials and instead lead to recycling such materials. For instance, five states now have landfill food waste bans. Massachusetts's landfill ban on commercial food waste, implemented in 2014, increased annual food rescue and organics recycling from a baseline of 100,000 tons in 2010 to more than 270,000 tons in

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[135] 42 U.S.C. 1791. Bill Emerson Good Samaritan Food Donation Act. Accessed online Nov. 2024 https://uscode.house.gov/view.xhtml?req=(title:42%20section:1791%20edition:prelim)%20OR%20(granuleid:USC-prelim-title42-%20section1791)&f=treesort&edition=prelim&num=0&jumpTo=true

[136] 117th Congress. 2021. Senate Bill 3281: Food Donation Improvement Act of 2021. Accessed online Aug. 2022: https://www.congress.gov/bill/117th-congress/senate-bill/3281.

[137] 117th Congress. 2022. House Bill 8450: Healthy Meals; Healthy Kids Act. Accessed online Aug. 2022: https://www.congress.gov/bill/117th-congress/house-bill/8450/actions?r=1&s=1.

[138] 117th Congress. 2021. House Bill 4444: Zero Food Waste Act. Accessed online Aug. 2022: https://www.congress.gov/bill/117th-congress/house-bill/4444?s=8&r=2.

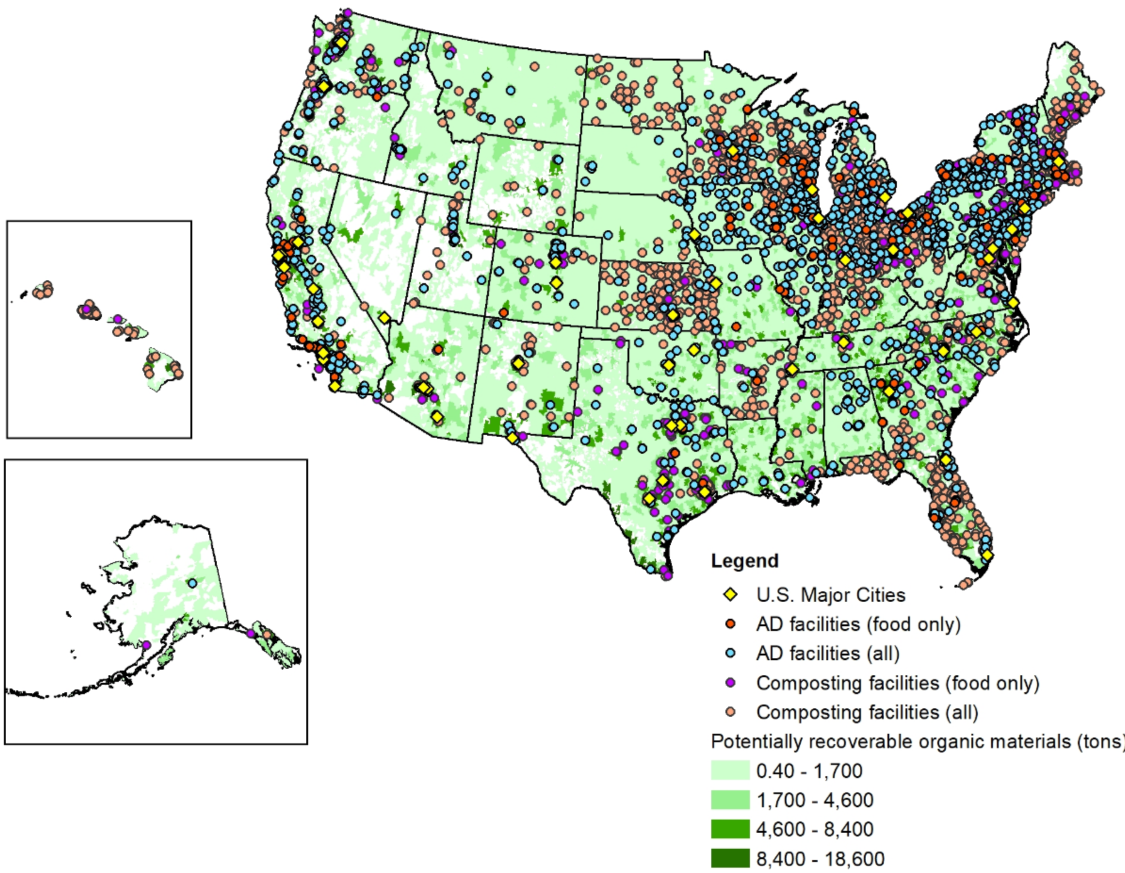
2016.[139] Currently, California has expanded its existing landfill ban on organic waste by instituting SB 1383 ("Short-Lived Climate Pollutant Reduction" law), which aims to ban organic waste from residences and businesses to ultimately divert 75 percent of organic waste from landfill by 2025.[140] A subject matter expert interviewed noted that cities with mandatory organics recycling programs were able to achieve a minimum 50 percent participation rate within the first year.[141]

A key factor missing from this analysis is the impact to end market prices from an increased supply of recycled materials. Estimating the price impact for end markets is out of scope for the present analysis. Qualitatively, increased recycled material supply linked with access to collection equivalent to trash disposal services and increased organic material processing capacity could lead to an overall decrease in market prices for finished compost/digestate for which demand is low. A forecasted decrease in market prices for finished compost/digestate could be combated somewhat by policies encouraging the use and application of recycled organic material. Policies, such as recycled purchasing mandates, could spur the market for recycled organic materials. The American Biogas Council recommends having municipalities institute specific policies to drive the market for organic recycling outputs, such as ordinances mandating finished compost and digestate be used for local landscaping projects.

While the expansion of organics infrastructure is needed nationwide, there are select regional areas with high rates of potentially recyclable organics waste and a general lack of organics recycling infrastructure; it may be beneficial to focus initial infrastructure investments in these areas first. EPA conducted a qualitative spatial needs analysis using the Recycling Infrastructure and Market Opportunities map, which maps current recycling infrastructure against existing quantities of organic waste generated. Latest available data indicate that there are geographic areas generating high volumes of potentially recyclable organics waste (denoted in **Exhibit 3-7** as dark green) and currently do not have the surrounding infrastructure to manage the tonnage of potentially recyclable organic waste.

[139] Rosengren, C. 2016. "Massachusetts Commercial Food Waste Ban Has Generated $175M in Economic Activity," WasteDive. Accessed online Sept. 2022: https://www.wastedive.com/news/massachusetts-commercial-food-waste-ban-has-generated-175m-in-economic-act/432904/
[140] Waste Management. 2021. "What is SB 1383?" Accessed online Sept. 2022: https://www.wm.com/us/en/sb1383
[141] This statistic was cited in an interview with BioCycle.

Exhibit 3-7. Geographic Prioritization Analysis for Organics Recycling Investment Opportunities.[142]



These geographic regions include the:

- South (in particular, parts of Louisiana, Alabama and Mississippi);
- Southwest (in particular, parts of Texas, Arizona, New Mexico, and Oklahoma); and
- Rocky Mountains (in particular, parts of Montana, Idaho, Colorado, and Nevada).

Investments in these geographic areas may help to rapidly capture large volumes of organic waste.[143] (See **Appendix B** for detailed maps of organic feedstock and composting and anaerobic digestion infrastructure.)

Finally, when considering equivalent access to organics recycling on par with access to trash disposal, communities with higher rates of low-income, unemployed, and other disadvantaged populations must be considered. The development of new composting or anaerobic digestion facilities may uniquely and disproportionately impact marginalized communities, such as through an increased risk of odor, noise, traffic congestion, and associated health concerns. Policymakers should pay close attention to the needs

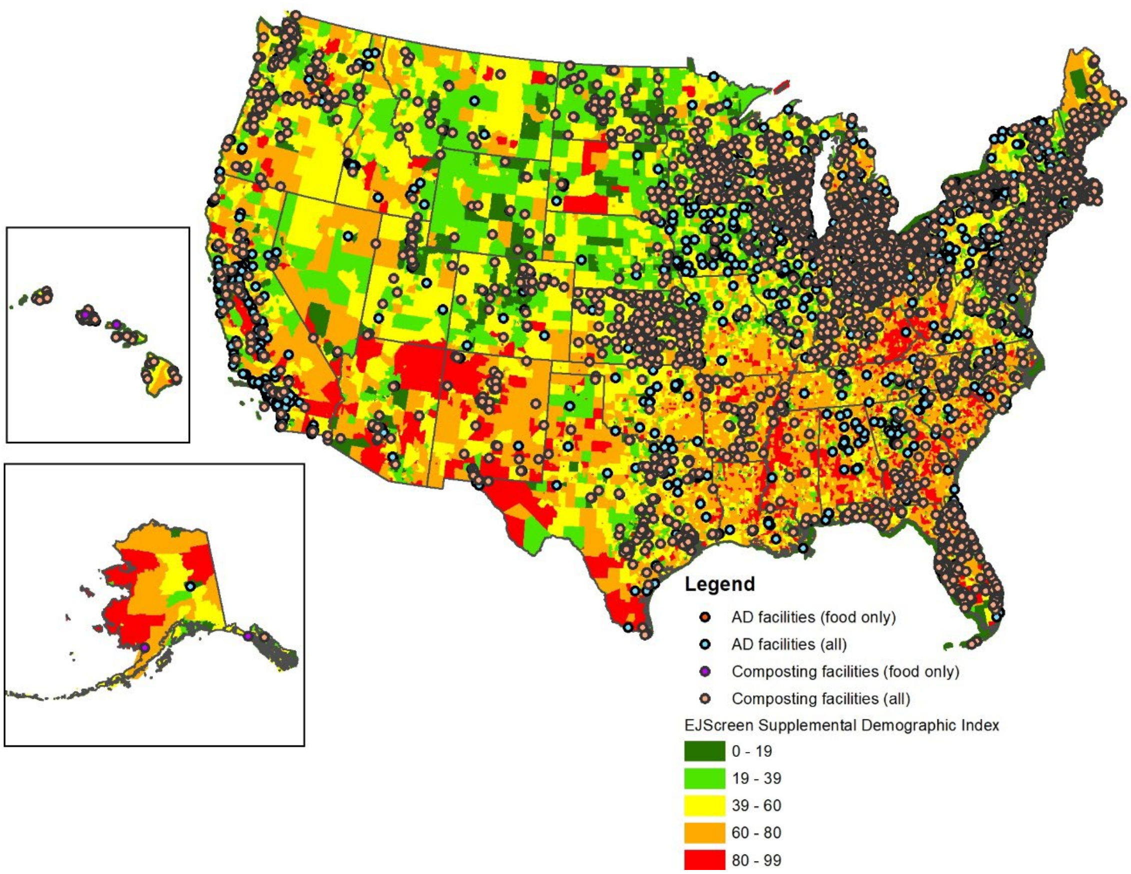
[142] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

[143] Note that areas in the South, Southwest, and Rocky Mountains currently lack the critical infrastructure to process additional organic materials for a variety of legislative, policy, and administrative reasons.

of these communities and ensure that they both have equivalent access to organics recycling services and are not unfairly affected by investments in recycling infrastructure.

Exhibit 3-8 displays several types of composting and anaerobic digestion facilities overlayed with the Supplemental Demographic Index from EPA's EJScreen.[144] This index is based on the average of five socioeconomic indicators; low-income, unemployment, limited English, less than high school education, and low life expectancy. The map below illustrates how communities that are higher on the Supplemental Demographic Index (indicated by orange or red) are more likely to be located in areas that lack adequate organics recycling infrastructure (e.g., the South, Southwest, and Rocky Mountains) and have a high rate of potentially recoverable organic waste, as shown in **Exhibit 3-7**. Similar to the environmental justice analysis on packaging materials and infrastructure, this spatial evaluation should serve only as a foundational framework for incorporating environmental justice into organics recycling, as well as to highlight the need for further consideration when determining opportunities to finance investments.

Exhibit 3-8. Geographic Prioritization Analysis with Environmental Justice Considerations for Organics Recycling Investment Opportunities[145]



[144] U.S. EPA. 2022. EJ and Supplemental Indexes in EJScreen. Accessed online January 2023: https://www.epa.gov/ejscreen/ej-and-supplemental-indexes-ejscreen#what-supplemental

[145] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

Section 4: Financial and Resource Support

Several mechanisms can be used to finance recycling infrastructure investments detailed in **Sections 2** and **3** of this report. These mechanisms include financing of different types from government, private sector, hybrid public-private partnerships, and fee-based programs, which are discussed in more detail in the sections below.

4.1 Government Financing Options

Resources are often provided by local, state, and federal governments to finance recycling programs. The most common form of government financing is grants, which typically assist recycling programs by covering a portion of total project costs. In return, grant recipients are required to provide grant programs with periodic project updates and an explanation of how funds were used. The federal government currently hosts a number of grant programs to support the construction and expansion of recycling infrastructure, some of which are detailed below:

- **EPA's Solid Waste Infrastructure and Recycling (SWIFR) Grants** - $275,000,000 ($55 million nationally/year from FY22-26). These grants support improvements to local post-consumer materials management, including state waste management planning and implementation, municipal recycling infrastructure improvements, and assist local waste management authorities in making improvements to local waste management systems. States, territories (including the District of Columbia), federally-recognized tribes, Intertribal Consortia, former reservations, and Alaskan Native Villages are also eligible. More information about the SWIFR Grants can be found on EPA's website.
- **EPA's Recycling Education and Outreach Grants** - $75,000,000 ($15 million nationally/year from FY22-26). These grants are focused on improving material recycling, recovery, management, and reduction. Projects funded through the grant program inform the public about residential or community waste prevention or recycling programs and provide information about the recycled materials that are accepted to increase collection rates and decrease contamination across the nation. More information about the SWIFR Grants can be found on EPA's website.
- **EPA's Hazardous Waste Management Grant Program for Tribes** - $300,000 in FY22. These grants support tribes or Intertribal Consortia in the development and implementation of hazardous waste management on tribal lands, including education and infrastructure to encourage recycling, reuse, and source reduction among tribal communities.
- **EPA's Indian Environmental General Assistance Program (GAP)** - $66,250,000 in FY22. GAP funds may be used to fund activities that are necessary for the tribe to plan and develop solid waste and material recovery infrastructure and provide solid waste and material recovery services on reservation lands.
- **EPA's AD Funding Opportunity** - $2,000,000 nationally/year with an individual award range of $50,000 to $200,000. These grants support diversion of food waste and organic materials from

Tribal Community Considerations. Many tribes depend on GAP to fund environmental program staff positions, and GAP comes with a host of reporting requirements unique to the grant. Due to frequent staff turnover in tribal solid waste management programs, there is a significant loss of institutional knowledge for maintaining this critical source of funding. During a recent listening session for EPA's Solid Waste Infrastructure and Recycling (SWIFR) grant, EPA heard from several commenters that capacity issues to apply for, manage, and implement grants to fund recycling programs are a problem for tribes.

landfills through the acceleration and development of new AD facilities or capacity expansion for existing AD facilities.

- **USDA's Community Compost and Food Waste Reduction Program** - $2,000,000 nationally/year. These grants support composting projects that divert organics from the landfill, including community garden and on-farm composting projects. This program will see an additional $30 million investment toward a feasibility study to support a national-level food loss and waste prevention strategy.[146]

Other forms of direct government financing include bond issuance. Federal, state, and local governments can issue bonds to raise money for public service facilities and infrastructure, such as roads, bridges, hospitals, and material management facilities. The bond issuer (i.e., state and/or local governments) sells the bond to the bond holder (i.e., the investor). The bond holder lends the bond issuer a fixed amount of funds for a certain time period in exchange for regularly scheduled interest payments, which are typically exempt from national taxes and hold a long maturity period. Bond issuers generally provide bond holders with annual financial information until they mature or are redeemed. Bonds are typically issued in situations where municipalities are unable to fully fund their own materials management operations.

Several proposed bills may increase future grant opportunities geared toward municipal recycling programs. For instance, bills such as the Realizing the Economic Opportunities and Values of Expanding Recycling Act (RECOVER) Act, will provide up to $500 million in matching federal grants for improvements to MRFs, curbside collection systems, and education programs. (Source: 117th Congress. 2021. House Bill 2357: RECOVER Act. Accessed online Aug. 2022: https://www.congress.gov/bill/117th-congress/house-bill/2357/text?r=1&s=1.)

Other bills for consideration focus on increasing recycling infrastructure in specific locations. For instance, bills such as the Recycling Infrastructure and Accessibility Act would grant between $500,000 and $15 million each for projects that make recycling services more accessible to rural and disadvantaged communities that do not have reliable or nearby access to MRFs. (Source: 117th Congress. Senate Bill 3742: Recycling Infrastructure and Accessibility Act of 2022. Accessed online Aug. 2022: https://www.congress.gov/bill/117th-congress/senate-bill/3742.)

Other bills for consideration focus on recycling more specific materials. For instance, the Cultivating Organic Matter through the Promotion of Sustainable Techniques (COMPOST) Act, currently before the House Subcommittee on Conservation and Forestry, would allocate $200 million a year through 2031 for composting infrastructure projects through grants and loan guarantees. (Source: 117th Congress. House Bill 4443: COMPOST Act. Accessed online Aug. 2022: https://www.congress.gov/bill/117th-congress/house-bill/4443.)

Another popular form of government financing is income tax credits. Federal, state, and local governments can provide tax credits that may be used as an incentive to private industry to fund projects that broadly benefit the public and use recycled content in product manufacturing to spur demand within the recycling industry. For instance, many states host state recycling tax incentive programs where recycling providers can receive a percentage-based income tax credit for the cost of recycling equipment or an employment income tax credit for each employee hired in service of incorporating recycled products into product manufacturing.[147]

[146] USDA. 2022. "USDA Announces Framework for Shoring Up the Food Supply Chain and Transforming the Food System to Be Fairer, More Competitive, More Resilient." *Press Release No. 0116.22, published on USDA.gov*. Accessed online June 2022: https://www.usda.gov/media/press-releases/2022/06/01/usda-announces-framework-shoring-food-supply-chain-and-transforming

[147] U.S. EPA. 2016. EPA Web Archive: State Recycling Tax Incentives. Accessed online May 2022: https://archive.epa.gov/wastes/conserve/tools/rmd/web/html/rec-tax.html.

For all government-based funding, it is important to note that financing mechanisms should be directed toward proven recycling technologies due to limited resource ability for municipalities to take on risk associated with new, emerging technologies.

4.2 Private Sector Financing

There are many private sector financing options with varying levels of application to different types and locations of recycling-related projects. Popular financing mechanisms include equity, in which investors provide funding toward specific materials management projects. In return, equity investors typically require a stake in the recycling operation or some other form of return for their investment. The most common form of equity investment is selling stock in publicly-owned companies; privately-owned companies may arrange similar forms of financing for specific direct investors.

> **Project example: Waste Management.** Waste Management, a comprehensive waste and environmental services company operating across the U.S., recently announced their plans to invest $800 million over the next three years in their recycling facilities. This investment is geared toward automating internal recycling processes and expanding infrastructure to underserved geographies. (Source: WasteDive. 2022. “Waste Management Planning $1.6B in ESG investments.” Accessed online Nov 2022: https://www.wastedive.com/news/waste-management-q4-2021-esg-rng-recycling-automation/618103/)

Another popular financing mechanism is debt financing, in which businesses, (i.e., recycling providers) take out loans from banks, credit unions, and other savings institutions. Typically, a bank provides the loan for a pre-determined period of time and the borrower (i.e., the materials management provider) repays the loan within the allotted time with interest.

Finally, the other source of private sector financing is own-source revenue, wherein a business uses its own funds generated from existing revenue to fund the expansion of existing or construct new infrastructure. This option is available to established recycling providers with the capital necessary to pursue construction without financing.

These options are most applicable for private sector businesses such as subscription-based collection service providers (whereby they charge a recurring fee to pick up recycling on a regular basis), recyclers, and end-market buyers, who typically see a higher return on their infrastructure investments than state, municipal, or tribal governments.

> **Project example: Atlas Organics Durham.** This 65,000 ton per year facility in Durham, NC composts yard waste, food waste, and biosolids through a public-private partnership with the City of Durham. The company has an 11-year contract with the City to process these feedstocks, ensuring a consistent source of revenue while the City is able to make gains on goals to reduce waste sent to the landfill. (Source: Atlas Organics. 2022. “Atlas Organics in North Carolina.” Accessed online May 2022: https://atlasorganics.net/locations/north-carolina/durham/.)

4.3 Public-Private Partnership

Public-private partnerships can vary considerably from project to project. In a public-private partnership, a government entity supports a private entity by subsidizing some portion of total investment costs for a service that the government entity would not otherwise be able to provide. This type of financial agreement can be particularly helpful for the recycling infrastructure sector as a private company can purchase the land, pay engineers to design the facility, operate the facility, and sell recyclable commodities to continue financing future operations. Municipalities can streamline the permitting process during the construction phase, oversee the collection of recycled materials during the operations phase, and ensure the consistent flow of recycling feedstocks.

Successful public-private partnerships require consistent collaboration between government officials, community organizations, and recycling service providers.

4.4 Fee-Based Programs

Structured fee programs also serve as a possible financing instrument. For instance, landfill tipping fees or a pay-as-you-throw fee programs can work to reflect the "true" cost of landfill disposal and provide residents with an understanding of the cost of waste. In pay-as-you-throw programs, fees are typically weight-based and capture the costs associated with the maintenance and operating costs to operate a landfill in compliance with state and federal regulations. The average tipping fee in the U.S. is $53.72 per ton and regional MSW tip fees range from $39.66 per ton in the South-Central region to $72.03 per ton in the Pacific region.[148] By internalizing the costs of landfilling through a fee, local recycling programs can fund various projects and incentivize residents and businesses to reduce reliance on landfill disposal through recovery and recycling.

Additional structure fee programs, such as bottle deposit programs (analyzed in **Section 2** of this report) can help to fund recycling programs.[149] Beverage container deposit programs require a minimum refundable deposit on beer, soft drink, and other beverage containers to ensure a high rate of recycling or reuse. This deposit is refunded when containers are returned for recycling or reuse. When consumers choose not to redeem their used beverage containers for the deposit value (either because they recycled them through curbside or other public recycling programs or threw them in the trash), the deposit money is considered "unclaimed." Depending on the state, state agencies can collect unclaimed deposit funds to fund recycling programs. Currently, eight of the 10 states with bottle deposit programs re-allocate 75 to 100 percent of unclaimed deposits to state agencies to fund and manage municipal recycling programs, educate the public on recycling programs, and promote markets for recycled material. In 2021, Connecticut, Maine, Massachusetts, Michigan, New York, and Vermont re-allocated approximately $350 million in unclaimed deposits toward state recycling programs.[150]

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[148] Environmental Research & Education Foundation. 2021. Analysis of MSW Landfill Tipping Fees — 2020. Accessed Aug. 2022: https://www.erefdn.org/product/analysis-msw-landfill-tipping-fees-2/

[149] Currently, 10 states have deposit programs: California, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont.

[150] Container Recycling Institute. 2022. Bottle Bill Resource Guide: The Fate of Unclaimed or Abandoned Deposits. Accessed Aug. 2022: https://www.bottlebill.org/index.php/about-bottle-bills/the-fate-of-unclaimed-or-abandoned-deposits

Section 5: Additional Materials for Future Consideration

EPA determined the scope of this assessment to include packaging and organic materials with established end markets and proven technology to process materials at scale; this is part of the focus on near-term investments needed to provide recycling services that are on par with disposal. As a result, materials such as electronics (including batteries), textiles, and plastics #3 to #7 are not included in this assessment. However, it is important to note that these materials are growing in significance and require thoughtful consideration of how to maximize source reduction and promote reuse, as well as how best to upgrade and integrate infrastructure required for recycling. These topics are discussed in the sections below.

5.1 Electronics

Electronics waste is a fast-growing material waste stream with unique challenges and opportunities related to disassembly and recovery of high-value components that include rare metals. While 25 states and the District of Columbia have enacted legislation establishing statewide electronics waste, or e-waste, recycling programs, recent data suggest that the U.S. generates 6.7 million tons of electronic waste and only captures 16 percent for recycling.[151, 152]

Project Example. Through its electronics extended producer responsibility policy, California charges an advanced recovery fee (i.e., a deposit) on electronics purchases, to be returned when the electronics are recycled rather than disposed, promoting diversion of electronic waste from landfills. The fee serves as a source of revenue for the government, netting tens of millions of dollars each year, which has the potential to support complementary recycling and/or consumer education programs. (Source: Gregory, J. and Kirchain, R. 2007. A Framework for Evaluating the Economic Performance of Recycling Systems: A Case Study of North American Electronics Recycling Systems. Accessed online Sept 2021: https://pubs.acs.org/doi/pdf/10.1021/es702666v.)

Product redesign is one critical strategy in the effort to reduce the landfill of electronics waste. A recent UN report notes that electronic products need to be designed for reuse, durability, and safe recycling.[153] Design elements should incorporate durability and ease of repair to ensure that devices are kept in circulation longer, reducing overall generation of electronic waste. In addition, easy disassembly should also be incorporated into the product design so that recyclable components can be seamlessly extracted and recycled at the end of the product's life.

Recycling infrastructure is needed to process and recapture potentially valuable recyclable electronic product components, which include plastics, glass, and precious metals such as silver, gold, palladium, and copper. Currently, there are 772 identified certified electronics recyclers in the U.S.,[154] as shown in **Exhibit 5-1**.

Global electronic waste generation is expected to more than double by 2050.[155] Given the rapid growth of this waste stream, investment in additional collection and processing infrastructure is needed to bolster recycling rates and capture future generation of electronics waste.

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[151] National Conference of State Legislatures. 2018. Electronic Waste Recycling. Accessed online July 2022: https://www.ncsl.org/research/environment-and-natural-resources/e-waste-recycling-legislation.aspx.

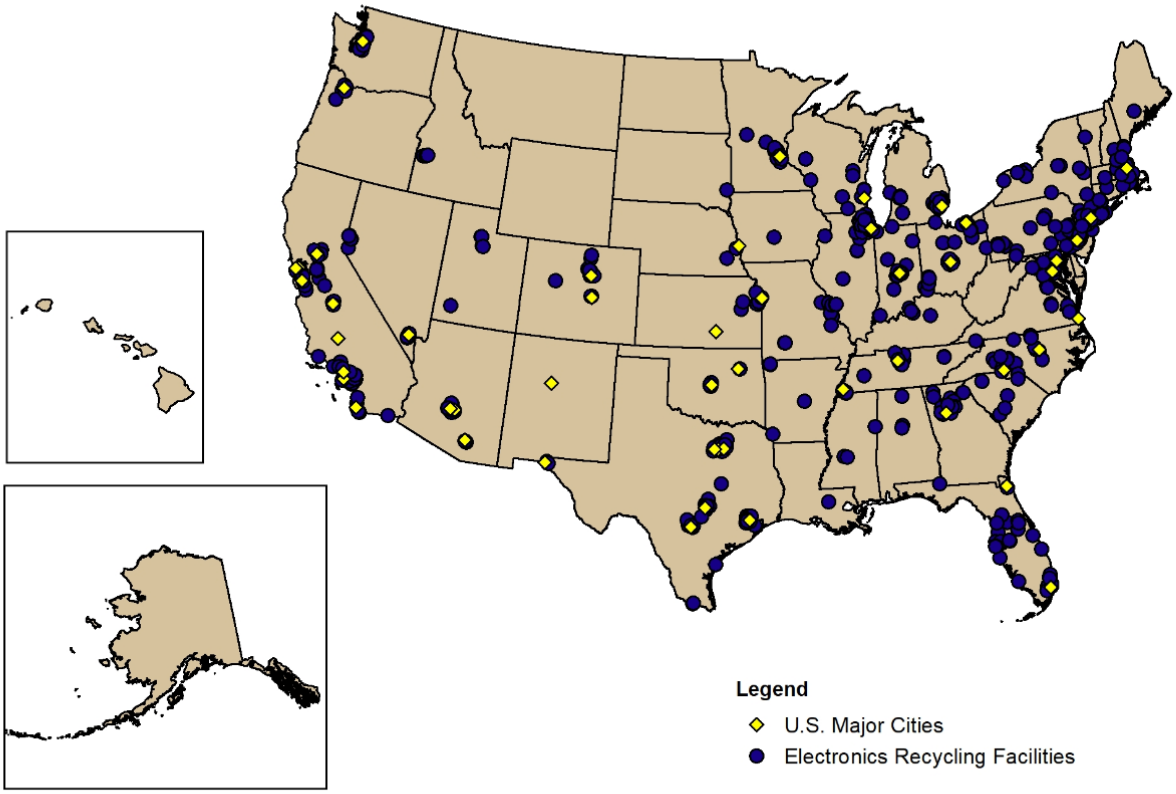
[152] The Global E-Waste Statistics Partnership. 2022. Global E-Waste Monitor Statistics. Accessed online July 2022: https://globalewaste.org/map/.

[153] World Economic Forum and Platform for Accelerating The Circular Economy. 2019. A New Circular Vision for Electronics. Accessed online July 2022: https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf.

[154] Certified electronics recyclers have demonstrated through audits and other means that they continually meet specific high environmental standards and safely manage used electronics. Once certified, continual oversight by the independent accredited certifying body holds the recycler to the particular standard.

[155] World Economic Forum and Platform for Accelerating The Circular Economy. 2019. A New Circular Vision for Electronics. Accessed online July 2022: https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf.

Exhibit 5-1. Map of Certified Electronics Recycling Facilities[156]



Currently, electronics recycling is challenged by the need for toxic material handling precautions for worker safety and pollution prevention (e.g., acid or lead and other heavy metals require personal protection and strict handling protocols). Due to the combustion potential of lithium-ion batteries in some electronic devices, fire hazard mitigation and suppression measures are also necessary.

Battery fires may result in significant facility damages and can raise insurance costs. EPA published a report in 2021 analyzing lithium-ion battery fires in MRFs and other waste management facilities.[157] The report describes facility fires with substantial MRF damage costs, ranging from hundreds of thousands of dollars to millions of dollars in direct damages. Total facility loss is also possible if the damage is extensive enough. For example, the Shoreway Environmental Center in San Carlos, California had a battery fire in 2016 that was estimated to have caused $8.5 million in damages to the facility and its equipment. Fires also create logistical problems for the recycling system. If a facility is under partial or total reconstruction

[156] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

[157] U.S. EPA. 2021. An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling. *Prepared by the Office of Resource Conservation and Recovery.* EPA 530-R-21-002. Accessed online Jul. 2022: https://www.epa.gov/system/files/documents/2021-08/lithium-ion-battery-report-update-7.01_508.pdf.

The threat of battery fire in MRFs and in collection trucks has inspired Rumpke Waste & Recycling in Cincinnati, Ohio to establish standard operating procedures for removing ignited batteries from conveyors and extinguishing fires at the MRF. (Source: U.S. EPA. 2021. An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling. Prepared by the Office of Resource Conservation and Recovery. EPA 530-R-21-002. Accessed online Jul. 2022: https://www.epa.gov/system/files/documents/2021-08/lithium-ion-battery-report-update-7.01_508.pdf)

(or lost altogether), it cannot process recovered material; e.g., packaging material waste must either be landfilled or rerouted to another facility. Lithium-ion batteries may also combust while in transit and cause the hauler/collection truck to catch fire. The total loss of a truck could cost between $250,000 to $300,000 and may introduce up to an entire truckload of recoverable material directly into the environment (putting waterways and surrounding habitats at risk for contamination). Battery fires are a growing concern as electronics waste generation increases. Policy will be necessary to address this issue and properly recover valuable trace metals from batteries.

5.2 Textiles

Textiles are another fast-growing material waste stream. Textiles are a significant component of MSW across the U.S.; textiles comprised approximately 5 percent (13 million tons) of total U.S. MSW in 2018.[158] Approximately 15 percent of textiles generated from the residential, commercial, and institutional sectors are currently recycled.[159]

Source reduction is a critical strategy for reducing textile waste. While source reduction of textiles can be difficult due to consumer preferences and retail brand promotion of fast fashion marketing, source reduction through rent/recommerce/resale business models is growing in popularity (e.g., online thrift retail). Moreover, these models are expected to expand to impact home furnishings, upholstery, and linens markets. The *American Recycling Infrastructure Plan* proposes federal funding for reuse initiatives to be disbursed as grants for the creation of reuse and repair centers across the U.S., totaling to $250 million per year for three years.[160]

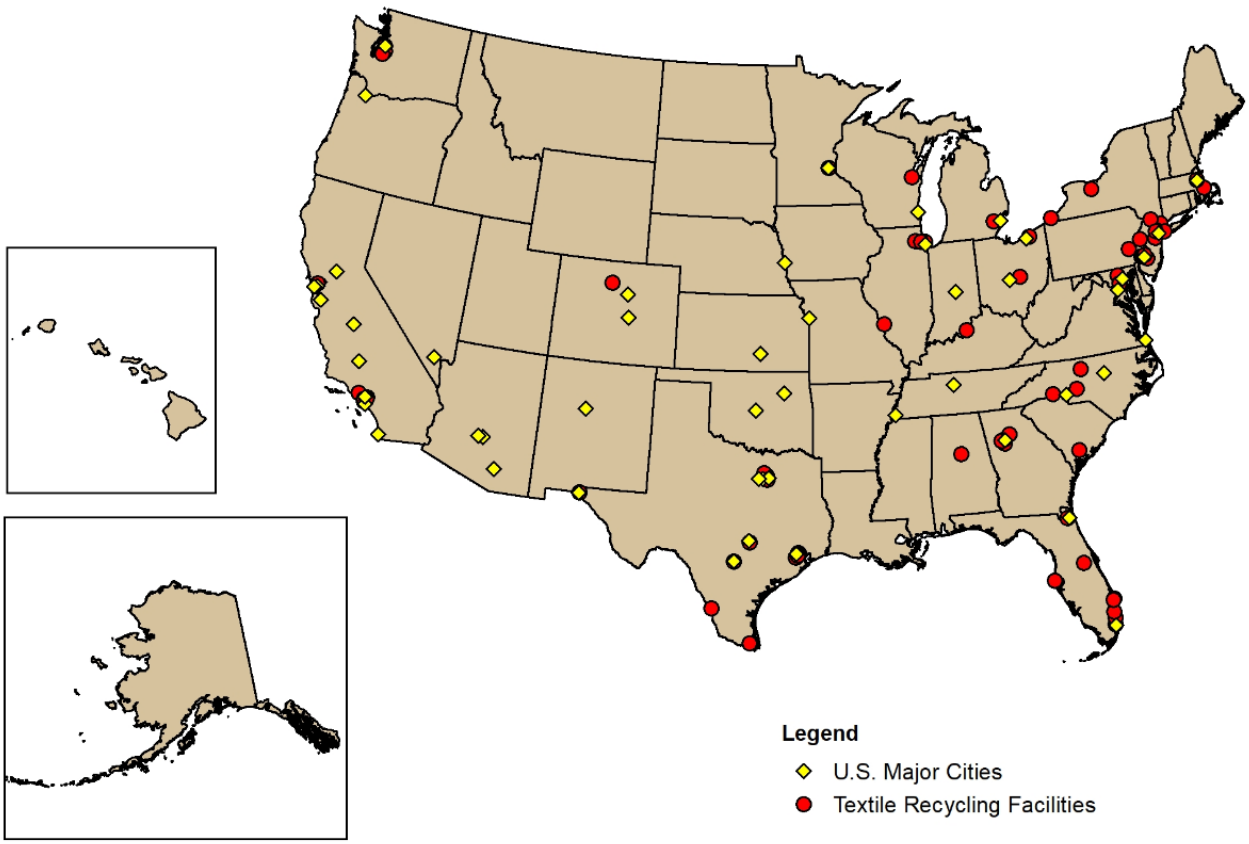
However, reuse and repair cannot absorb all textile waste.[161] Technology exists to currently recycle textiles, however, this technology is not integrated at scale. Examples include machines that automate the cleaning and color-sorting of used textiles and RFID tagging on clothing so that textile types (e.g., cotton, polyester, etc.) can be quickly identified and sorted for recycling.[162] Currently, there are approximately 77 textile facilities in operation in the U.S., as shown in **Exhibit 5-2**.

Infrastructure cost estimates for recycling textiles is not widely available. A report conducted by Metabolic for the city of Charlotte, North Carolina estimates that the annual costs of moving to a closed loop textile supply chain would cost $10,000 in investment; $30,000 in rent; $9,000 in fuel and utilities; $112,000 in employee wages; and $3,260,000 payments to third parties (though the role for third parties is unclear).[163]

[158] U.S. EPA. 2018. Advancing Sustainable Materials Management: 2018 Fact Sheet. Accessed online Oct. 2021: https://www.epa.gov/sites/default/files/2020-11/documents/2018_ff_fact_sheet.pdf
[159] U.S. EPA. 2022. Textiles: Material-Specific Data. Accessed online July 2022: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/textiles-material-specific-data#:~:text=The%20recycling%20rate%20for%20all,the%20American%20Textile%20Recycling%20Service
[160] Gedert, B., Drake, J., Liss, G. 2021. Recycling Infrastructure Plan. *Prepared for the Recycling Is Infrastructure Too Campaign.* Accessed online Oct 2021: https://resource-recycling.com/recycling/wp-content/uploads/sites/3/2021/07/Recycling-Infrastructure-Plan-Final.pdf
[161] Ellen MacArthur Foundation. 2017. A new textiles economy: Redesigning fashion's future. Accessed online Oct. 2021: http://www.ellenmacarthurfoundation.org/publications
[162] RRS. 2020. Textile Recovery in the U.S.: A Roadmap to Circularity. Accessed online Oct. 2021: https://recycle.com/white-paper-textile-recovery-in-the-us/#download-paper
[163] Metabolic. 2018. Circular Charlotte: Towards a zero waste and inclusive city. Accessed online Oct. 2021: https://www.metabolic.org/projects/circular-charlotte/

While it appears that the investment is focused on the hotel and hospital linen, towel, and uniform value chain, it is unclear how many textile recycling facilities could result from this investment, or what portion of overall textile wastes in the area would be addressed.

Exhibit 5-2. Map of Textile Recycling Facilities[164]



5.3 Plastics #3 to #7

Finally, plastic waste is a fast-growing material waste stream. Plastics comprised 18.5 percent (27 million tons) of total MSW landfilled in 2018, and 16.3 percent (5.6 million tons) of all combusted MSW.[165] In 2016, the U.S. generated more plastic waste than any other country in the world (42 million metric tons).[166] The U.S. plastics recycling rate was only 8.7 percent in 2018 (3.1 million tons).[167] Most plastics fall into the category of plastics #3-7 (24 thousand tons, or 68 percent of total U.S. plastic MSW generation), but the infrastructure to recycle these plastic types are limited. Recycling opportunities are limited for plastics #3-7 due to:

[164] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

[165] U.S. EPA. 2018. Facts and Figures about Materials, Waste and Recycling: Plastics: Material-Specific Data. Accessed online Nov. 2021: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data.

[166] National Academies of Sciences, Engineering, and Medicine 2021. Reckoning with the U.S. Role in Global Ocean Plastic Waste. Washington, DC: The National Academies Press. https://doi.org/10.17226/26132.

[167] U.S. EPA. 2018. Facts and Figures about Materials, Waste and Recycling: Plastics: Material-Specific Data. Accessed online Nov. 2021: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data.

1. A lack of available cost-effective recycling technologies to process these materials; and
2. A lack of end markets to use recycled outputs in manufacturing (although end market conditions vary by plastic resin).

In many locales, only PET and HDPE (#1-2 plastics, respectively) are collected for recycling, and only those plastic types have established recycling systems and secondary markets at a national level.[168]

Studies note that source reduction is critical to addressing the growing problem of plastic waste. Source reduction, especially for plastics #3, #6, and #7, is key because given the nature of particular resins, recycling may not be the best pathway due to lack of available end markets and lack of cost-effective means for recycling. Pew Charitable Trusts estimates that reduction and substitution of plastics can address nearly half of the plastic waste projected for 2040 (under business-as-usual conditions) by cutting it off at the source. Recommendations for encouraging source reduction include plastic elimination and consideration of product end-of-life in design (e.g., design products for reuse or optimal recycling). Producers can also redesign or replace materials to eliminate unnecessary plastic packaging. Substitution of plastics with paper or compostable material can reduce up to 1/6 of global plastics by 2040.[169] Policies such as extended producer responsibility (EPR), a policy approach under which producers are given a significant responsibility – financial and/or physical - for the treatment or disposal of post-consumer products, can support the redesign of plastic packaging. California recently enacted an EPR law aimed at single-use packaging and food service ware. The law, the Plastic Pollution Prevention and Packaging Producer Responsibility Act (Senate Bill 54), would require all covered material sold in or imported into California to be recyclable or compostable by 2032.[170]

Reports emphasize that reducing or otherwise preventing plastic release into the environment from known sources is critical. Tires, textiles, intermediate plastic pellet formats for product manufacturing, and personal care products are all sources of microplastic (< 5 mm) that can end up in waterways, oceans, and food systems, all of which can be reduced and addressed through policy. The *American Recycling Infrastructure Plan* proposes both production and use changes, including product redesign development grants (with an

The plastic numbering system, or **Resin Identification Code (RIC)** is used for identifying resins and indicating how they should be processed. Plastics are labeled with numbers #1-7:

- **Plastics #1:** PET typically used for beverage bottles (e.g., water bottles)
- **Plastics #2:** HDPE typically used for milk jugs and laundry detergent bottles
- **Plastics #3:** PVC typically used for pipes
- **Plastics #4:** LDPE typically used for shrink wrap or other flexible plastic packaging
- **Plastics #5:** PP typically used for straws and single-use food ware
- **Plastics #6:** PS typically used for packing peanuts
- **Plastics #7:** Miscellaneous

Recycling experts note that end markets are possibly developing for plastics #4 and #5, which can represent a future area of focus for which to increase recycling opportunities. A study by RRS suggests that current markets could expand to absorb an increased wholesale supply of mixed flexible film plastics #4 and #5 as inputs for plastic decking, pavers, and railroad ties. (Source: RRS. 2020. Materials Recovery for the Future: Flexible Packaging Recycling in Material Recovery Facilities Pilot. Accessed online September 2021: https://www.materialsrecoveryforthefuture.com/wp-content/uploads/MRFF-Pilot-Report-2020-Final.pdf)

[168] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/.

[169] Pew Charitable Trusts. 2020. Breaking the Plastic Wave. Accessed online Sept. 2021: https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/breaking-the-plastic-wave-top-findings.

[170] The National Law Review. 2022. California Enacts EPR Law Aimed at Single-Use Plastic Packaging and Food Service Ware. Accessed online Sept. 2022: https://www.natlawreview.com/article/california-enacts-epr-law-aimed-single-use-plastic-packaging-and-food-service-ware

annual investment of $150 million for three years) to promote industry innovation and the installation of water refill stations in National Parks and public land locations (e.g., rest areas) to replace single-use water bottles (with an annual investment of $25 million for three years).[171]

While source reduction strategies are a key method for reducing the growing generation of plastics waste, the use of plastics is fully ingrained in the material economy and recycling solutions are needed to address plastic waste produced. As noted in this report, technology systems and markets exist to effectively recycle plastics #1 and #2. Currently, plastics #3 to #7 do not have robust end markets, and some types of plastic (#3 and #6) are unlikely to see end market development due to difficulties establishing recycling technologies and components in the resins that limit options for end markets. While some companies manufacture products (e.g., luggage) with recycled plastic #5 and #7,[172] plastic #7 is not widely collected or processed for use in manufacturing.

Project Example: A pilot study at a MRF in Birdsboro, Pennsylvania focused on sortation improvements for plastic #4 flexible packaging (e.g., chip bags, pet food bags, plastic film) processing. Ten surrounding communities participated, recycling their flexible plastic packaging along with commonly recycled plastics. The facility processes this flexible plastic into a product called rFlex with the help of advanced sorting, quality control stations for contaminant removal, and other process optimization advancements. More than 50 other facilities in the U.S. were identified as possible candidates for flexible packaging MRF upgrades, with an estimated cost of $3.7 million per facility. (Source: RRS. 2020. Materials Recovery for the Future: Flexible Packaging Recycling in Material Recovery Facilities Pilot. Accessed online September 2021: https://www.materialsrecoveryforthefuture.com/wp-content/uploads/MRFF-Pilot-Report-2020-Final.pdf)

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Currently, technology exists to recycle plastics #4 and #5, but large investments would have to be made at MRFs to successfully recycle and bale these materials at scale. This would entail incorporating additional sorting mechanisms (e.g., acute air blowers for separating plastic #4 from other materials, optical sorters to identify and separate plastics #5) and more quality control steps.[174] In addition to recycling infrastructure, significant additional investment is needed to build collection systems for plastics #4 as this material would require separate collection and processing infrastructure. (Note: The collection of plastics #5 can be integrated into existing recycling collection systems, as optical sorters can be used to identify and separately process this material.) Currently, plastics #4 are viewed as a contaminant at MRFs because these film materials clog rolling conveyors and prevent the efficient movement of other materials through the MRF.

[171] Gedert, B., Drake, J., Liss, G. 2021. Recycling Infrastructure Plan. *Prepared for the Recycling Is Infrastructure Too Campaign.* Accessed online Oct 2021: https://resource-recycling.com/recycling/wp-content/uploads/sites/3/2021/07/Recycling-Infrastructure-Plan-Final.pdf.

[172] Samsonite. 2020. Our Responsible Journey: Samsonite Environmental, Social and Governance Report 2020. Accessed online Jan. 2022: https://corporate.samsonite.com/on/demandware.static/-/Sites-InvestorRelations-Library/default/dw268d8861/PDF/ESG-reports-policies/2020/E_Samsonite%202020%20ESG%20Report%20(Final%202021-05-07).pdf.

[173] RRS. 2020. Materials Recovery for the Future: Flexible Packaging Recycling in Material Recovery Facilities Pilot. Accessed online September 2021: https://www.materialsrecoveryforthefuture.com/wp-content/uploads/MRFF-Pilot-Report-2020-Final.pdf.

[174] RRS. 2020. Materials Recovery for the Future: Flexible Packaging Recycling in Material Recovery Facilities Pilot. Accessed online September 2021: https://www.materialsrecoveryforthefuture.com/wp-content/uploads/MRFF-Pilot-Report-2020-Final.pdf.

Significant efforts are also required to create a robust end market for plastics #4 and #5. At present, there are only two vendors in the U.S. that accept recycled plastics #5 as a feedstock for manufacturing products such as decking and outdoor furniture. Small quantities of plastics #4 are also currently captured and recycled into new plastic bags or combined with plastics #5 to produce plastic lumber. The Recycling Partnership estimates that $4 billion is required to expand residential recycling collection and processing to include plastics #3-7, but this amount does not address the development of end markets for each of these materials.[175]

Complexity of Current Labeling for Plastic Resins and its Impact on Recycling

Plastic manufacturers include RICs on plastic bottles and containers. The **RIC label** is designed to indicate the type of plastic, rather than the recyclability of the plastic. The existing logo has a triangle with chasing arrows, which looks like the "recycle" symbol. This and other packaging labeling inconsistencies have confused consumers according to a 2020 GAO report. (Source: U.S. Government Accountability Office. 2020. Recycling: Building on Existing Federal Efforts Could Help Address Cross-Cutting Challenges. Accessed online Sept. 2021: https://www.gao.gov/products/gao-21-87)

ASTM international, a standards organization that regularly publishes technical guidance and standards, now recommends a solid triangle icon. In 2021, California passed SB 343, The Truth in Labeling for Recyclable Materials bill, which prohibits the use of the "chasing arrows" symbol (or any other indication of recyclability) on products or packaging that are not deemed "recyclable" under criteria to be established by the California Department of Resources Recycling and Recovery. (Source: Californians Against Waste. 2022. SB 343 (Allen) Truth in Recycling. Accessed online Aug. 2022: https://www.cawrecycles.org/sb343)

Finally, in addition to investments needed to reduce plastic waste generation and build robust recycling systems and infrastructure for additional plastic resins, investment to support policy actions, such as federal requirements for product pigment, composition, and standardized labeling can reduce contamination and improve plastics recycling, including:

- Require or prevent the use of certain pigments for improved plastics capture in the MRF sorting process (e.g., eliminate carbon black, a pigment not read by optical scanners in the sortation process).[176,177]
- Tax or eliminate subsidies for virgin plastic production to encourage use of recycled plastics and/or plastics alternatives.[178]
- Incentivize the use of recycled plastics in new manufactured products to increase the demand for recycled plastics.[179,180]

[175] The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/.

[176] Closed Loop Partners. 2020. The Circular Shift: Four Key Drivers of Circularity in North America. Accessed online Sept. 2021: https://www.closedlooppartners.com/wp-content/uploads/2021/01/The-Circular-Shift_Closed-Loop-Partners-2020.pdf

[177] OECD. 2018. Improving Markets for Recycled Plastics: Trends, Prospects, and Policy Responses. Accessed online Sept. 2021: https://read.oecd-ilibrary.org/environment/improving-markets-for-recycled-plastics_9789264301016-en#page1.

[178] Rewarding Efforts to Decrease Unrecycled Contaminants in Ecosystems Act of 2021. S.2545 – 117th Congress. 2021. Accessed online Jan. 2022: https://www.congress.gov/bill/117th-congress/senate-bill/2645/titles?r=14&s=1.

[179] Gedert, B., Drake, J., Liss, G. 2021. Recycling Infrastructure Plan. *Prepared for the Recycling Is Infrastructure Too Campaign.* Accessed online Oct 2021: https://resource-recycling.com/recycling/wp-content/uploads/sites/3/2021/07/Recycling-Infrastructure-Plan-Final.pdf.

[180] Incentivizing use of recycled plastics is complex and depends heavily on the price of virgin materials (and inputs, such as crude oil, from which plastics are fabricated), quality of recycled plastic resin, which may suffer from contamination, and the demand for wholesale recycled plastic, which may drive up cost. See for more information: Roth, R. 2020. Recyclable Material Wholesaling in the United States. IBISWorld Industry Report 42393; and Brooks, B. 2021, March 11. Recycled Plastics Market Becoming More Liquid and Globalized as Demand Soars. S&P Global. https://www.spglobal.com/platts/en/market-insights/blogs/petrochemicals/031121-recycled-plastics-global-market-commoditization-standards-pricing.

- Require manufacturers to use the same polymers for all bottle components (e.g., label, cap) to improve product recyclability and produce higher-quality recycled plastic with lower rates of contamination.[181,182]
- Change the Resin Identification Code (RIC) or other recycling label to explicitly detail recycling instructions. This may reduce ambiguity for consumers who may be trying to understand which products are and are not recyclable, limiting source contamination.[183]

[181] Pew Charitable Trusts. 2020. Breaking the Plastic Wave. Accessed online Sept. 2021: https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/23/breaking-the-plastic-wave-top-findings.
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[183] United Nations Environment Programme. 2020. "Can I Recycle This?" A Global mapping and Assessment of Standards, Labels and Claims on Plastic Packaging. Accessed online Sept. 2021: https://www.consumersinternational.org/media/352255/canirecyclethis-finalreport.pdf.

Section 6: Summary and Beyond 2030

6.1 Summary of Infrastructure Investment Estimates

To modernize recycling infrastructure, improve consumer recycling education, and provide all residents with equivalent access to recycling services, EPA estimates that a total investment of **$36 to $43 billion**, summarized in **Exhibit 6-1**, is needed. This investment, which would leverage combined funding and financing mechanisms from stakeholders across the entire recycling system including federal, state, and municipal governments, the private sector, hybrid public-private partnerships, and fee-based programs, could potentially recover an additional **82 to 89 million tons** of packaging and organic waste, increasing the nation's recycling rate from its current level of **32 percent to 61 percent** and allowing the U.S. to surpass the national recycling goal of 50 percent set by EPA.[184]

Exhibit 6-1. Summary Education, Outreach, and Infrastructure Investment Cost Estimates for Packaging and Organic Materials.

Cost Category	Low-End Estimate	High-End Estimate
Packaging Materials		
Curbside Collection	$19,900,000,000	$21,500,000,000
Glass Separation (Curbside)	$2,900,000,000	$2,900,000,000
Drop Off	$1,900,000,000	$3,400,000,000
Deposit Redemption System	$100,000,000	$100,000,000
Curbside + Dropoff	***$21,800,000,000***	***$24,900,000,000***
Curbside + Dropoff + Deposit Redemption System	***$21,900,000,000***	***$25,000,000,000***
Curbside + Dropoff + Glass Separation	***$24,700,000,000***	***$27,800,000,000***
Curbside + Dropoff + Glass Separation + Deposit Redemption System	***$24,800,000,000***	***$27,900,000,000***
Organic Materials		
At-Home Composting	$380,000,000	$380,000,000
Community Composting	$4,700,000,000	$4,700,000,000
Centralized Composting	$8,700,000,000	$9,400,000,000
Centralized Anaerobic Digestion	$422,000,000	$436,000,000
Water Resource Recovery Facility (WRRF) Anaerobic Digestion	$77,000,000	$96,000,000
Animal Feed	$449,000,000	$504,000,000
Organics Total	***$14,700,000,000***	***$15,500,000,000***
Total Recycling Investment	**$36,000,000,000**	**$43,000,000,000**
Note: *Low-end and high-end estimates are driven by various factors. For packaging, the low-end estimates assume that facilities will not receive the latest technology upgrades (e.g., optical sorters, robotic arms, etc.) while the high-end estimates assume that facilities will be upgraded or modernized with the latest technology, resulting in higher capital costs. Technology upgrades would work to reduce contamination and improve recycling output quality. For organics, the low-end estimates assume that not all existing facilities are operating at full capacity and could intake a portion of the potentially recoverable materials, resulting in reduced capital costs. EPA's high-end*		

[184] U.S. EPA. 2018. National Overview: Facts and Figures on Materials, Wastes and Recycling. Accessed online Aug. 2022: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#:~:text=The%20recycling%20rate%20(including%20composting,person%20per%20day%20for%20recycling.

Cost Category	Low-End Estimate	High-End Estimate
estimate assumes that facilities will not operate any closer to full capacity and that comparatively more facilities will need to be built, which will result in higher capital costs.		
Estimated using: (1) Eunomia. 2021. The 50 States of Recycling. Prepared for the Ball Corporation. (2) U.S. Census Bureau. 2022. 2019 American Community Survey. (3) State waste management reports. (4) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. (5) U.S. EPA Office of Resource Conservation and Recovery. 2020. 2019 Wasted Food Report. (6) U.S. Census Bureau. 2022. 2019 American Community Survey. (7) Natural Resources Defense Council. 2017. Estimating Quantities and Types of Food Waste at the City Level. Accessed online May 2022: https://www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf. (8) ReFed. 2016. A Roadmap to Reduce U.S. Food Waste by 20%: Technical Appendix. Accessed online May 2022: https://refed.org/downloads/ReFED_Technical_Appendix.pdf. (9) The Recycling Partnership. 2021. Paying it Forward: How Investment in Recycling Will Pay Dividends. Accessed online Sept. 2021: https://recyclingpartnership.org/read-paying-it-forward/ (10) U.S. Composting Council. 2021. "Organics Bans and Mandates." Accessed online May 2022: https://www.compostingcouncil.org/page/organicsbans. (11) U.S. Composting Council. The Case for Centralized Compost Manufacturing Infrastructure. Accessed May 2022. (12) U.S. EPA. 2021. Anaerobic Digestion Facilities Processing Food Waste in the United States (2017 & 2018). Accessed online May 2022: https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf. (13) Interviews with industry experts.		

For successful capture of potentially recyclable packaging and organics waste, investments in collection, education, and processing capacity should be made simultaneously, along with policies to disincentivize landfilling materials (e.g., pay-as-you-throw programs) and to promote the use and sale of recycled material (e.g., minimum post-consumer recycled content mandates). Financing mechanisms, such as private equity, public-private partnerships, and government grant programs can be used to fund such projects and programs.

While the expansion of recycling infrastructure is needed nationwide, there are select regions with high rates of potentially recyclable material and a general lack of recycling infrastructure. For packaging materials recycling, these areas include the:

- South (parts of Kentucky, Mississippi, Alabama, and Georgia);
- Southwest (parts of Texas, Arizona, and New Mexico); and
- Rocky Mountains (parts of Wyoming, Montana, Colorado, Idaho, and Nevada).

For organics recycling, these areas include the:

- South (in particular, parts of Louisiana, Alabama and Mississippi);
- Southwest (parts of Texas, Arizona, New Mexico, and Oklahoma); and
- Rocky Mountains (parts of Montana, Idaho, Colorado, and Nevada).

It may be beneficial to focus initial investments, including investments in education and outreach to motivate behavior change, in these areas using proven technology and infrastructure as they represent high-need, high-reward regions.[185]

6.2 Beyond 2030

Beyond 2030, recycling assessments will have to expand to include materials beyond conventionally recycled packaging and organics, such as electronics, textiles, and plastics #3 to #7. These assessments

[185] Note that areas in the South, Southwest, and Rocky Mountains currently lack the critical infrastructure to process additional packaging and organic materials for a variety of legislative, policy, and administrative reasons.

should include thoughtful consideration of how to maximize source reduction and promote reuse, as well as how best to upgrade and integrate infrastructure required for recycling.

In addition, future analyses should align with circular economy considerations. Currently, the U.S. (and much of the rest of the world) has a linear material supply chain involving extraction, use, and disposal. A circular economy provides more meaningful and lasting waste reduction; however, circularity will require systemic change not limited to recycling. A circular economy is oriented toward systems and lifecycle impacts; focused on waste elimination through product redesign and alternative materials use; and designed to reuse, restore, and even regenerate materials, maintaining value as long as possible. A circular economy recaptures waste and uses it as a valuable input for manufacturing.

The term ''**circular economy**'' means an economy that uses a systems-focused approach and involves industrial processes and economic activities that:

- are restorative or regenerative by design;
- enable resources used in such processes and activities to maintain their highest values for as long as possible; and
- aim for the elimination of waste through the superior design of materials, products, and systems (including business models).

EPA recognizes that while some elements of circularity do exist in the U.S., the current U.S. economy is far from achieving a nationwide circular economic structure. In November 2021, EPA released the National Recycling Strategy: Part One of a Series on Building a Circular Economy that outlined the agency's vision on moving towards a circular economy. An important part of this transformation is creating a viable system for reusing and recycling materials, including those that are not traditionally seen as "recyclable." Ultimately, MRF modernization will require additional capacity and technology to process more and different types of materials which, in turn, will require thoughtful planning anticipating a more circular economy in the future.

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Appendix A. Packaging Material Recycling Opportunity Maps[186]

Exhibit A-1. Aluminum recycling tonnage and facilities (MRFs and metal recycling facilities).

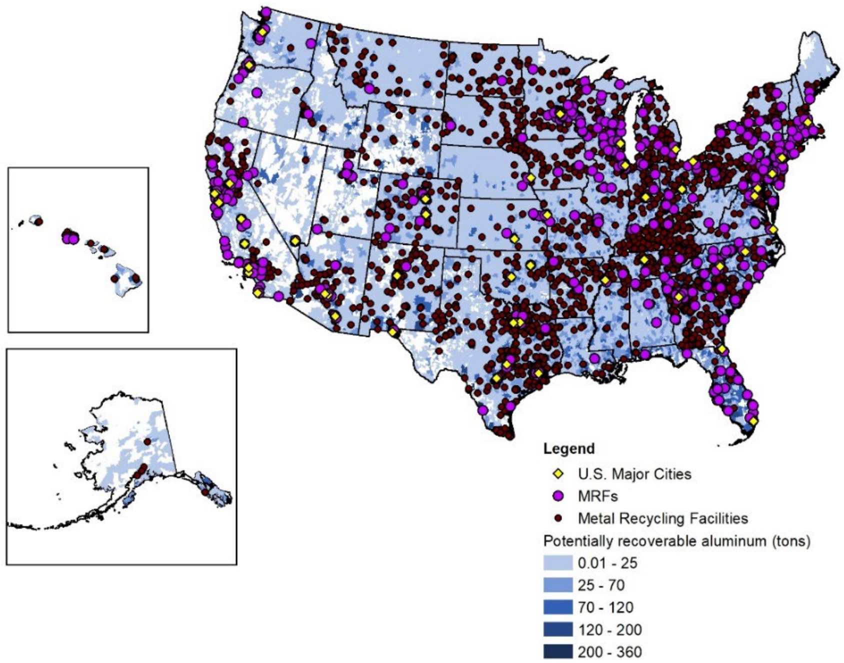
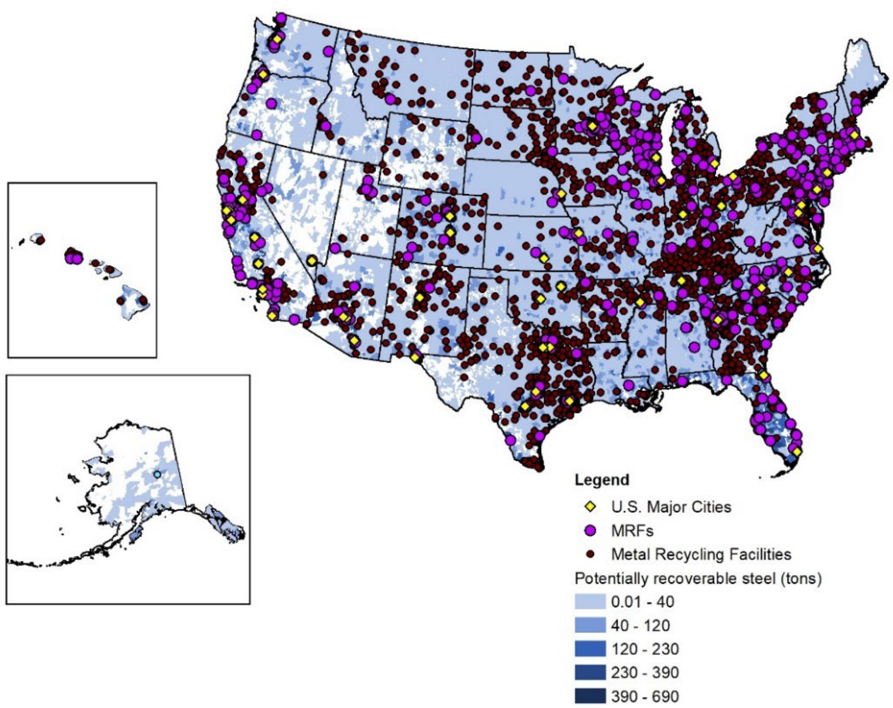


Exhibit A-2. Steel recycling tonnage and facilities (MRFs and metal recycling facilities).



[186] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

Exhibit A-3. Cardboard recycling tonnage and facilities (MRFs and paper recycling facilities).

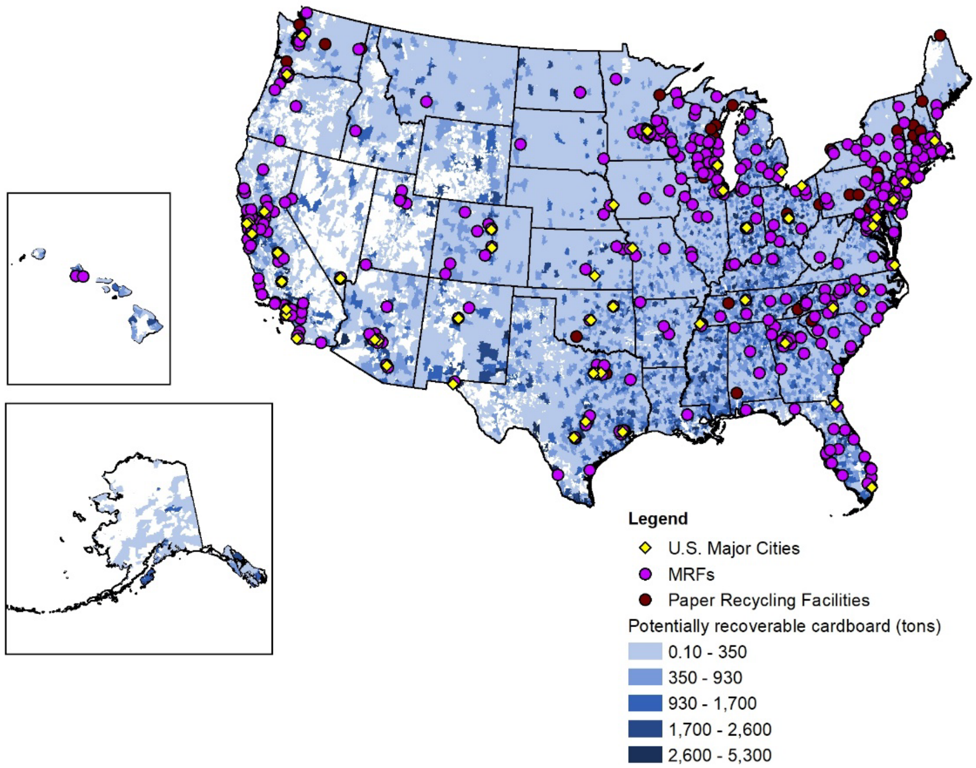


Exhibit A-4. Paper recycling tonnage and facilities (MRFs and paper recycling facilities).

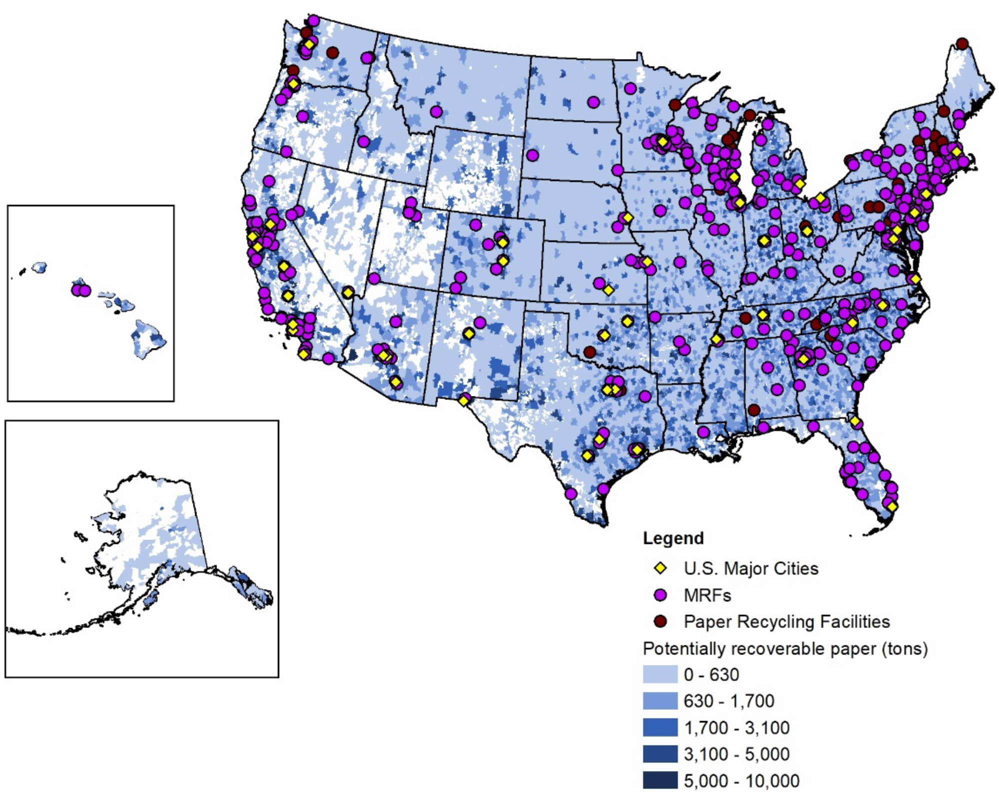


Exhibit A-4. PET bottles recycling tonnage and facilities (MRFs and plastic recycling facilities).

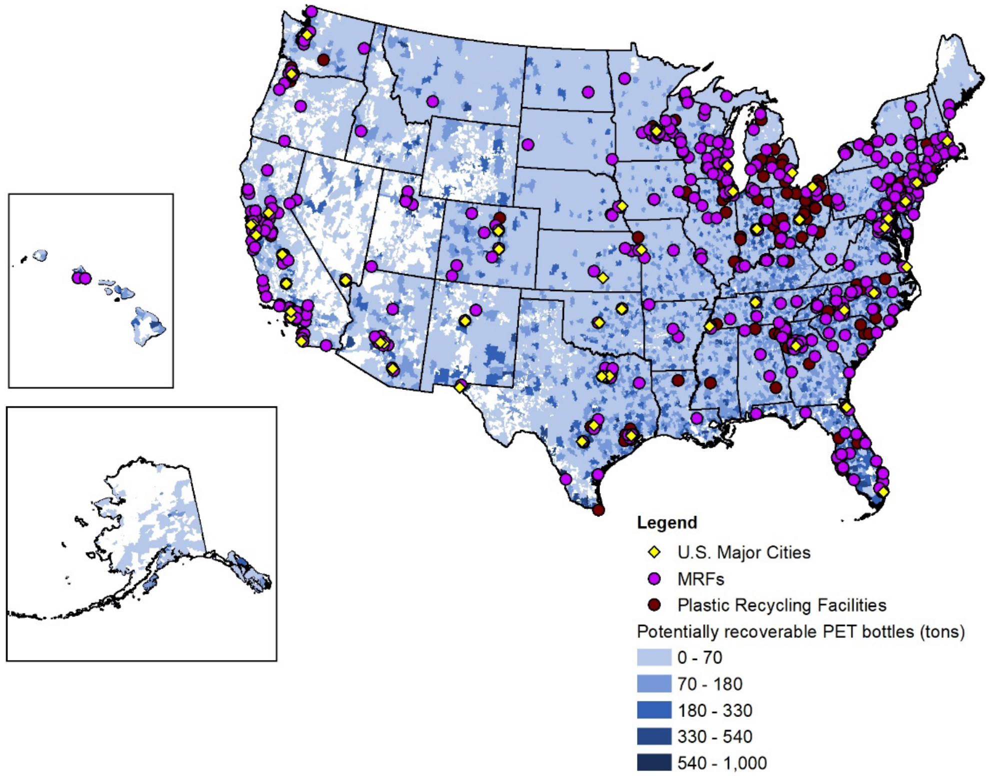


Exhibit A-5. Other PET rigid recycling tonnage and facilities (MRFs and plastic recycling facilities).

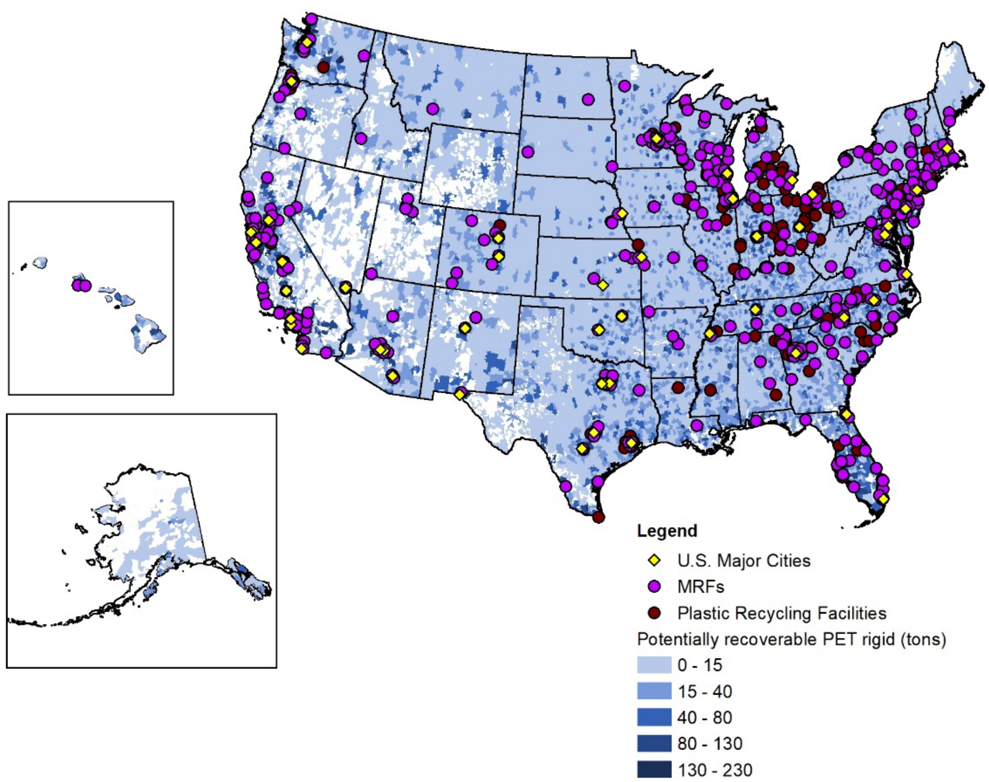
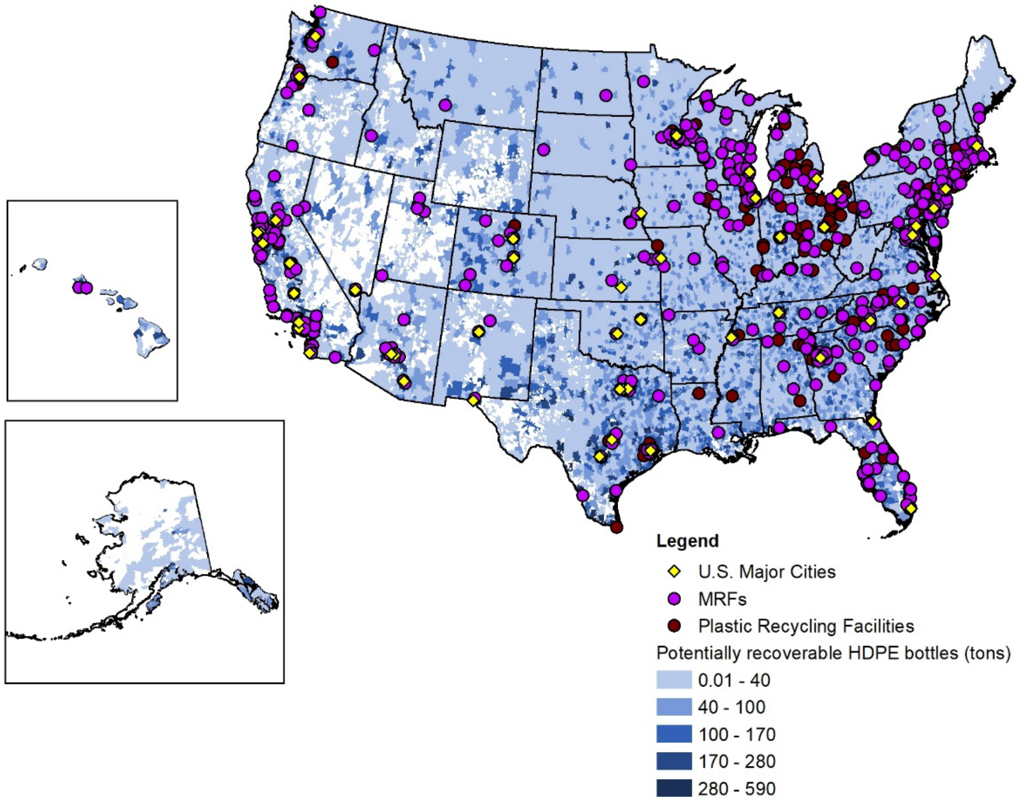
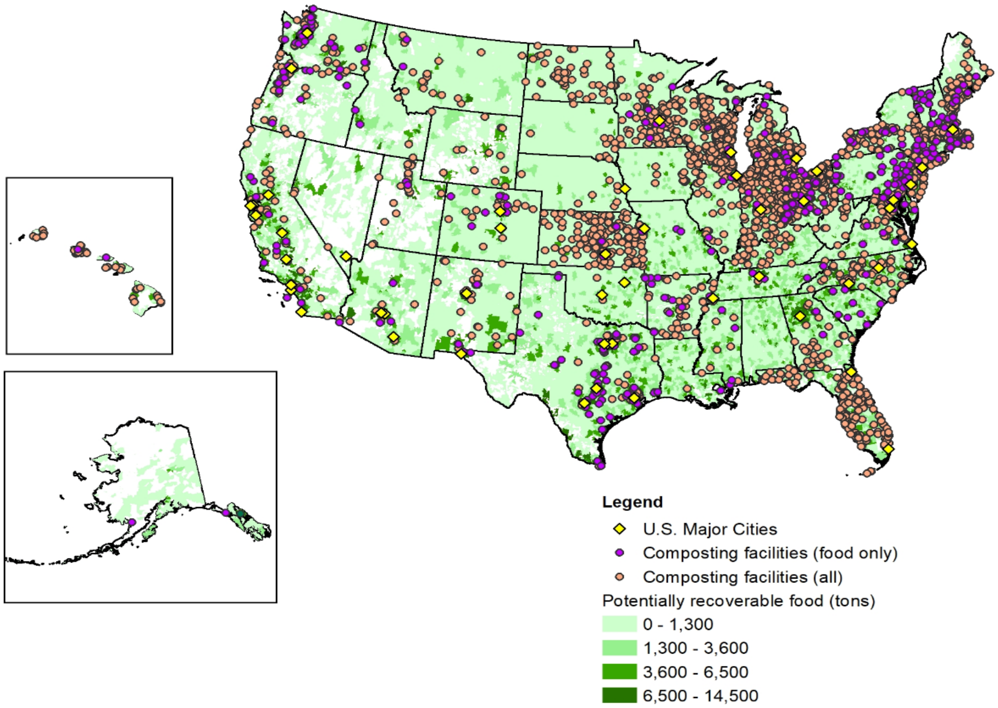


Exhibit A-6. HDPE recycling tonnage and facilities (MRFs and plastic recycling facilities).



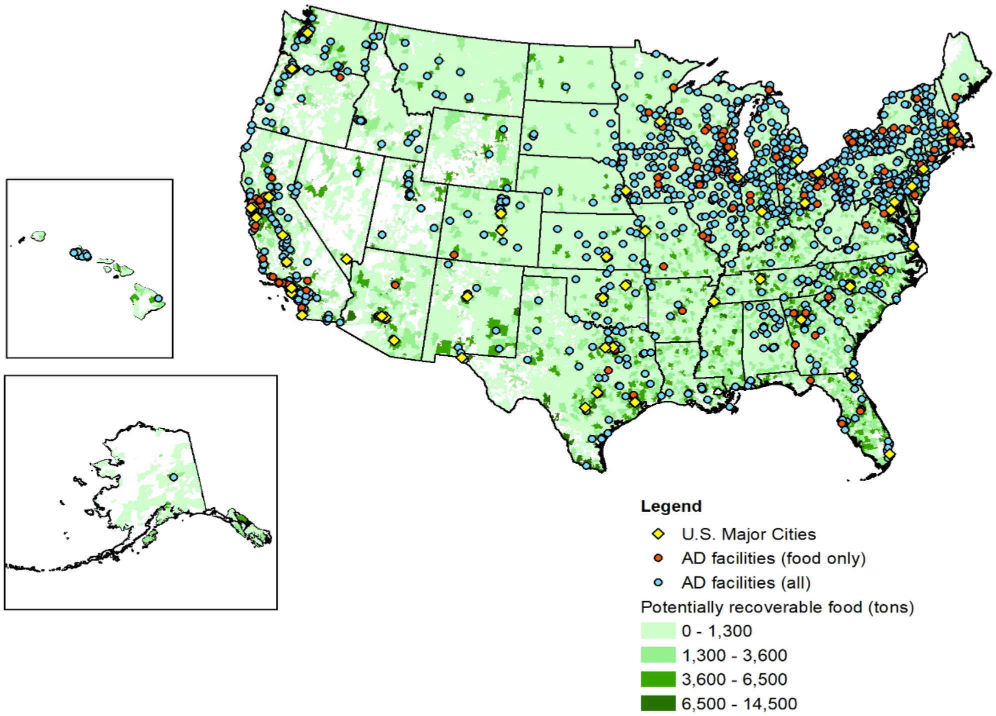
Appendix B. Organic Material Recycling Opportunity Maps[187]

Exhibit B-1. Organic material recycling tonnage and composting facilities.



[187] Data retrieved from the Recycling Infrastructure and Market Opportunities Map. https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map.

Exhibit B-2. Food waste recycling tonnage and anaerobic digestion facilities.



Appendix C. Summary of Available Case Studies

C.1 Introduction

Insufficient materials management infrastructure in the U.S. to collect and process recycling is a documented issue. State and local governments have made significant efforts to divert waste from landfills, resulting in lowered greenhouse gas emissions and air pollutants (e.g., $PM_{2.5}$), increased longevity of materials through recycling/repurposing, and increased local recycling rates.[188,189] These efforts have been documented in a number of published reports and case studies, which is defined herein as a document highlighting specific real-world and place-based applications of recycling solutions.

The following sections describe the methodology used to identify and analyze such case studies (**Section C.2**) and summarize case study contents by key attributes (**Section C.3**). **Sections C.4 – C.6** summarize case study results organized by the recommendations presented in the reports to address key needs in the current recycling system for specific materials, specific stages within the recycling process, and educational opportunities on and incentives to bolster recycling.

C.2 Methodology

EPA used Scopus, Google Scholar, and available state and local waste and materials characterization reports to identify case studies. In total, EPA reviewed 71 documents, including peer-reviewed academic journal articles (14), SWMPs (8), and other reports and articles (49). The scope of the literature search was limited to documents published between 2012 through 2021 (with a few exceptions) [190] and primarily limited to the U.S.

C.3 Overview of Case Studies

Case studies identified and reviewed differed in terms of material focus, stage in the recycling system discussed, geographic area evaluated, and year of assessment. In terms of materials discussed, general MSW is highlighted with most frequency in the case studies. Among specific materials, the largest number of case studies focus on plastics, followed by food, metal, glass, paper, and to a smaller extent, electronics waste, textiles, mattresses, and batteries. **Exhibit C-1** summarizes the material focus of reviewed case studies.

Exhibit C-1. Material Focus of Reviewed Case Studies, By Frequency and Proportion

Material Type	Count	Percentage
MSW	31	48%
Plastics	17	27%
Food	17	27%
Metal	11	17%
Glass	8	13%
Paper	7	11%

[188] Jordan, P., M. Krause, G. Chickering, D. Carson, AND T. Tolaymat. Impact of Food Waste Diversion on Landfill Emissions. Global Waste Management Symposium, Indian Wells, California, February 23 - 26, 2020.

[189] State of California (Updated: 2021, November 17). *California's Short-Lived Climate Pollutant Reduction Strategy*. CalRecycle. Retrieved November 22, 2021, from https://www.calrecycle.ca.gov/organics/slcp

[190] There are three case studies reviewed outside the 2012 through 2021 timeframe; one each from 2007, 2010 and 2011. These were identified outside of the general literature search scope as potentially relevant for electronics waste recycling, composting at a large university, and a small-scale study on infrastructure implementation and associated costs and benefits identified via references in existing reports/case studies.

Material Type	Count	Percentage
Electronics waste	3	5%
Textiles	1	2%
Mattresses	1	2%
Batteries	1	2%

*Note: Percentages do not add to 100% because most case studies mention more than one material type.

Case studies most commonly target collection (75 percent), followed by generation (25 percent), and sorting/processing (20 percent). A smaller number focus on product manufacturing (as it relates to end markets for recycled materials). Case studies targeting product manufacturing typically focus on generation of alternate products using recycled materials, and increased capacity to remanufacture recycled products while case studies focusing on generation are typically consumer-facing and emphasize source reduction. **Exhibit C-2** summarizes the stages in the recycling system discussed in reviewed case studies.

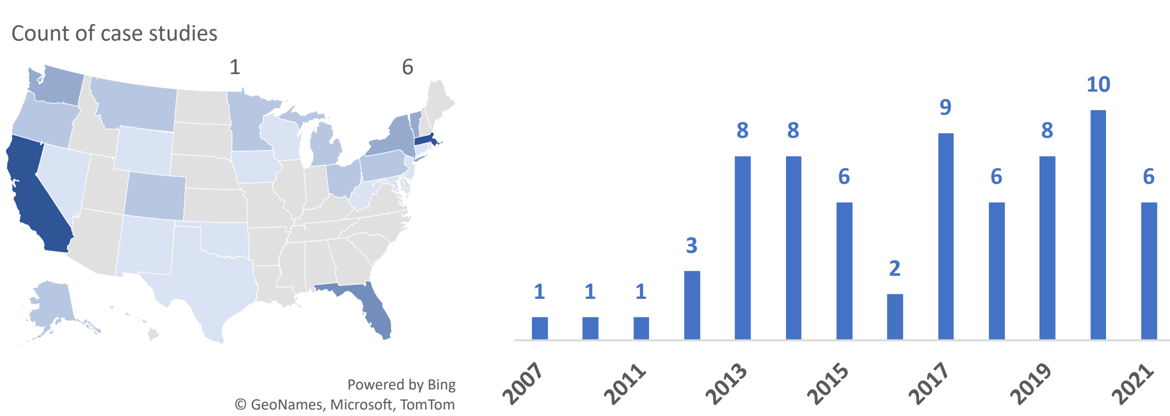
Exhibit C-2. Recycling Stages Discussed in Reviewed Case Studies, By Frequency and Proportion

Targeted Stage in Recycling System	Count	Percentage
Collection	48	75%
Generation	16	25%
Sortation and Processing	13	20%
Product manufacturing (as it relates to end markets for recycled materials)	9	14%

*Note: Percentages do not add to 100% because many case studies mention more than one stage.

Exhibit C-3 summarizes the number of case studies by state and year published.

Exhibit C-3. Case Studies Counts by U.S. State/Region and Year Published



The Southeast (EPA Region 4) is the least-covered region in terms of both case studies and reports, with the exception of Florida. The Midwest (EPA Regions 5, 7, and 8) has some representation in this sample of documents but is similarly lacking coverage. Most case studies cover the Southwest (EPA Regions 6 and 9), Northwest (EPA Region 10) and the Northeastern U.S. (EPA Regions 1 and 2). More than half the case studies (40 of 71) EPA reviewed were published between 2017 and 2021 (**Exhibit C-3**). It is important to note that the absence of case studies in a particular region or state does not necessarily imply an absence of recycling initiatives.

C.4 Addressing Needs for Specific Materials in Local Recycling Programs

As with the reports reviewed, case studies noted that significant infrastructure improvements are needed to recycle non-commonly recycled material types, such as plastics #3-7, food waste, textiles, electronics, and other materials, and point to specific successful efforts to recycle these materials. Case study results for these materials are summarized below:

- **Plastics:** A pilot study at a MRF in Birdsboro, Pennsylvania focused on sortation improvements for flexible packaging (e.g., chip bags, pet food bags, plastic film) processing.[191] Ten surrounding communities participated, recycling their flexible plastic packaging along with commonly recycled plastics. The facility processes this flexible plastic into a product called rFlex with the help of advanced sorting, quality control stations for contaminant removal, and other process optimization advancements. More than 50 other facilities in the U.S. were identified as possible candidates for flexible packaging MRF upgrades, with an estimated cost of $3.7 million per facility.
- **Food waste and organics:** The University of Michigan assessed the cost and benefits of implementing a composting program at the university.[192] The study (which recommended a $1.0 million dollar capital investment for an in-vessel composter and a $40/ton variable cost for labor, utilities, etc.), documented that the university's composting tonnages more than doubled in four years.
- **Textiles:** A study finds that 85 percent of textiles in New York State are landfilled, with the remaining 15 percent recycled through donations at clothing banks, thrift stores, etc. Eileen Fisher, a clothing brand, collected over 200,000 garments between 2009-2014 through their take-back program. The corporation offered $5 gift cards to customers for returning garments and used the textiles to repurpose into alternative garments.
- **Electronic waste:** California started charging an advanced recovery fee (i.e., a deposit) on electronics purchases, to be returned when the electronics are recycled, rather than disposed, promoting diversion of electronic waste from landfills.[193] The fee serves as a source of revenue for the government, netting tens of millions of dollars each year, which has the potential to support complementary recycling and/or consumer education programs.
- **Mattresses:** The Cambridge, Massachusetts Mattress Recycling Program was launched in 2019 to reclaim the 75 percent of mattress material that is recyclable. Residents can schedule curbside pickup online without charge. The total cost of recycling is $46 per mattress (split between the Massachusetts Department of Environmental Protection and the City of Cambridge). A total of 9,335 mattresses have been recycled since the start of the program.

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[191] RRS. 2020. Materials Recovery for the Future: Flexible Packaging Recycling in Material Recovery Facilities Pilot. Accessed online September 2021: https://www.materialsrecoveryforthefuture.com/wp-content/uploads/MRFF-Pilot-Report-2020-Final.pdf

[192] RRS, "University of Michigan: Composting Program," 2010. Available at: https://recycle.com/case-studies/university-of-michigan-composting-program/. Accessed on: Sept 2021.

[193] Gregory, J. and Kirchain, R., "A Framework for Evaluating the Economic Performance of Recycling Systems: A Case Study of North American Electronics Recycling Systems," 2007. Available at: https://pubs.acs.org/doi/pdf/10.1021/es702666v. Accessed on: Sept 2021.

C.5 Addressing Needs in the Recycling Process

The identified case studies explore funding for infrastructure development to address needs in the recycling process as a possible action step toward increasing recycling. Strategies for recycling system process improvements and infrastructure development mainly focused on collection and drop-off and are summarized below:

- A pilot study at a large southeastern university campus **increased collection areas for recyclable** bottles and cans across two campus buildings. The increase in collection points was not supplemented with consumer education or promotion of the increases. The increase in collection areas, alone, yielded a jump in volume of recycled materials by 65-250 percent at the different locations, with the cumulative effect resulting in a 130 percent increase in recycled material volume collected.[194] Increasing collection areas have shown success in tribal communities as well. For example, the Confederated Tribes of the Umatilla Indian invested $1.3 million, through the tribe's revenues and grants from various government and private agencies, to set up a community waste transfer station. This allowed the tribe to restrict open dumping and increase diversion from their landfill. Tribal members pay $22.7 per month for curbside collection.[195]
- Tribal communities have also shown that **recycling collection events** can help to improve recycling rates for materials that are not typically managed through curbside programs. For instance, Snoqualmie Indian Tribe and the City of North Bend in Washington have worked together to host an annual recycling event since 2015 to collect non-packaging items such as tires, appliances, electronics, and other household items. The event allows residents to recycle items free of charge. In 2019, the event collected over 36 tons of materials, including 188 tires and over six tons of electronics.[196]
- An environmental-economic assessment of curbside recycling in Central Florida showed that **increasing frequency of composting and recycling collection and decreasing frequency of trash collection** both lead to increased recycling rates and materials volume in the recycling stream.[197] The case study details avoided costs per ton from recyclables diversion of $40 (if diverted from landfilling) and $60-80 (from waste-to-energy). The success of increased food waste diversion with increased collection frequency is also illustrated in the case study of Berkeley, California.[198] Berkeley gradually increased the frequency of yard waste and food waste collection from monthly in 1990, to weekly in 2014. Berkeley now has a 58 percent organic waste diversion, and the participation rate has increased from 30 percent in 2007 to 70 percent in 2014.

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C.6 Addressing Recycling Knowledge and Policy

As noted in the reports, education and policy are paramount in improving the quality of recycled material through reduced contamination and incentivizing recycling. In alignment with the reports, consumer education emerged as a key case study topic, the results of which are summarized below:

- Alameda County, California's curbside compostable collection program captured 270 pounds of organics per capita and diverted more than 50 percent of the estimated total residential organic material in 2011.[199] The county attributes half the organics collection volume to their **community education programs,** which consist of regional marketing campaigns and multimedia outreach (e.g., bill inserts in pizza boxes and coffee cups and mailers to inform residents of the availability of a community composting program and what can and cannot be composted).
- Direct consumer education through **curbside inspections and tagging** can reduce contamination of recycling set out for collection. For instance, four trained inspectors in Brooklyn, Ohio in 2020 went through recycling containers left out for curbside collection and noted which items were erroneously recycled (e.g., plastic bags, food wrappers, plastic wrap, etc.) and informed residents through an "Oops" tag. By the end of the eight-week project, the recycling contamination rate for the city decreased from 38 percent to 20 percent.[200] The project was funded through a $21,000 grant provided by the state of Ohio.
- WM's Smart Truck℠ technology is a more long-term capital-driven approach to addressing source contamination: the truck has a mounted camera for tracking contamination, photographing improper recycling for customer recycling quality control, and contamination pattern recognition with AI software. WM provides **customers with feedback through bin tags or photos**, reducing contamination by 89 percent in three months during one Northern California pilot study.[201]
- WM also **educates their drivers** in recognizing contaminants, performs regular surveys to ascertain driver knowledge of recycling and common contaminants, and provide guidance to support drivers in educating customers, especially during bin tagging and enforcement campaigns. Drivers are a key resource for quality control and limiting contamination in MRFs further downstream; for example, driver education efforts reduced WM MRF contamination by 16 percent in 2020.

In addition to education, almost all case studies discussed, at some level, policy interventions that establish and/or regulate the waste collection and recycling markets, which are summarized below:

- The town of Wenham, MA instituted a **volume-based fee rate (i.e., pay-as-you-throw)** that limited residential trash collection to one, 35-gallon container per week and charged for additional trash generation. Recyclable materials could be placed and collected curbside free of charge. The program helped to reduce waste by 30 percent and saved an estimated $70,000 in trash collection and disposal costs.[202]

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- **Banning materials at landfills** can lead to increases in material specific recycling rates. For instance, Vermont's landfill ban on food waste has led to an increase in composting at the Lamoille Regional Solid Waste District from 146 tons to 166 tons in six months.[203]
- A case study from Cambridge, MA states that **simplifying a permitting process** for new MRFs and vertical integration at existing MRFs can lead to increased ability to collect and process recyclable materials.[204]
- Charging an **advanced recovery fee (ARF) (i.e., a deposit)** has proven to be a successful tool for increased recycling. For example, bottle bills states in the U.S. that impose a $0.05 or $0.10 charge on the purchase of each bottled/canned product, recoverable upon return at deposit sites, have achieved an 80 percent recycling rate for deposit materials.[205]

In all, the case studies offer a window into on-the-ground facility improvements and unique initiatives that may be replicated on a national level. Where reports look to the future and consider what is needed for improvement, case studies provide insights into what has and has not been successful in the past.

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