Creating a Circular and Decarbonized Economy

Economic Impact Potential and Characterization of Municipal Solid Waste in Michigan

2024

Michigan Sustainable Business Forum

Grand Valley State University

EGLE
Michigan Department of Environment, Great Lakes, and Energy

Project Team

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Recommended Citation:

Schoonmaker D., Cruz C., Lowen A., Veldman C. (2024). Economic Impact Potential and Characterization of Municipal Solid Waste in Michigan. Michigan Sustainable Business Forum. misbf.org/msw.

Acknowledgments

The Michigan Municipal Solid Waste Valuation Project is based upon work funded by the Michigan Department of Environment, Great Lakes and Energy. Matching funds and in-kind support was provided by MiSBF members.

We would like to thank the following waste and recycling professionals for making this project possible:

WM
- Fred Sawyers
- Matt Roser
- Mike O'Rourke
- Keith Hayes
- Kathleen Klein
- Dave Rogers
- Tom Spees
- Jim Hamann

Kent County Department of Public Works
- Steve Faber
- Micah Herrboldt
- Keith King
- Dan Rose
- Riley Perrone
- Paul Smith
- JD Stencel

Republic Services
- Patrick Sullivan

Marquette County Solid Waste Management
- Bradley Austin
- Mike Stannard

We would also like to thank the following organizations for providing information and data to the research team for use in this study.

- Emmet County Recycling
- Glass Recyclers, Inc.
- Goodwill Industries of West Michigan
- Green Earth Recycling
- Kent County Department of Public Works
- PADNOS
- Resource Recovery and Recycling Authority of Southwest Oakland County
- Schupan
- Spurt Industries
- Valley City Electronic Recycling

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Executive Summary

Michigan is deeply invested in an economy-wide effort to achieve a 45 percent recycling rate. The state's circular economy decision makers need updated information to determine the value of potential new and expanded recycling streams, to assess the performance of programs, and define the environmental and economic costs of materials management. Sustainability professionals and recycling advocates need improved benchmarks to better communicate and support the value of landfill avoidance efforts.

The 2016 Michigan Municipal Solid Waste Characterization and Valuation Project created an important tool for the advancement of recycling, composting and the creation of a circular economy in the state. Through a series of sorting events at landfills and other disposal facilities, Michigan Sustainable Business Forum and its member collaborators worked to characterize economic and environmental opportunities available through sustainable materials management in Michigan. The ensuing report, *Economic Impact Potential and Characterization of Municipal Solid Waste in Michigan*, has been regularly cited by state and regional programs in the years since its publication. This project is intended to update that work.

Summary of Work

The 2024 Michigan Municipal Solid Waste Characterization and Valuation Study performed statistically significant waste sorts at sites across the state, and through this provided an economic valuation for diversion in terms of real material value, job creation, and other positive economic and environmental impacts.

The following report details the results of this initiative according to five objectives:

- Determine composition of Michigan MSW now being disposed of in landfills and incinerators.
- Compare the composition of Michigan's MSW to the MSW of other Midwest states.
- Compare the 2023 composition of Michigan's MSW to its composition in 2016.
- Complete an economic analysis of MSW composition.
- Create datasets to inform discussions on Michigan deposit containers, lithium-ion batteries, and food waste.

Summary of Findings

Material disposed of in Michigan's municipal solid waste each year has an estimated market value of $500 million to $676 million. If this material were collected for recycling, it would have an estimated economic impact of $609 million to $825 million per year, creating as many as 4,500 jobs. This is shown in the table below.

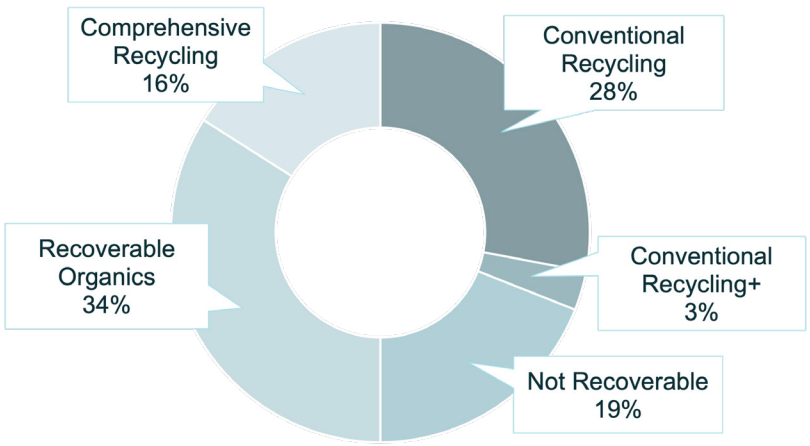
Value Reclaimed	Jobs Created	Total Effect Multiplier	Total Effect
$499,627,857	3,317	1.22	$609,764,673
$676,224,324	4,490	1.22	$825,289,659

Each year that Michigan does not make the investments in infrastructure, adopt new business practices, provide the necessary education to stakeholders, or advance and execute the public policy needed to increase the recycling rate, the state will lose at least a half billion dollars of potential feedstock for its manufacturers, farms and other end markets. The estimated lost value per year is detailed below.

	2023	2025	2030	2035
Population Projection*	10,033,757	10,202,350	10,424,510	10,569,985
MSW (tons)	8,993,502	9,154,045	9,353,377	9,483,904
Low Price (Adj) Total Value	$499,627,857	$508,546,694	$519,620,466	$526,871,805
High Price (Adj) Total Value	$676,224,324	$688,295,577	$703,283,441	$713,097,809

Most material currently being disposed of through landfills and incinerators could be recycled or composted in most metropolitan communities without great difficulty. Approximately one third of material could be recycled in any community that meets the recycling benchmarks specified in the new Part 115 materials management law, shown below as Conventional Recycling and Conventional Recycling+, which includes glass and other materials not universally accepted in Michigan.

Ease of Recycling for Materials in Michigan MSW (mean % by weight)



In comparison to the 2016 study, there is a statistically significant decrease in materials commonly targeted by recent investments in recycling collection and infrastructure, specifically plastic and mixed paper, suggesting that those improvements are working.

Composition Findings

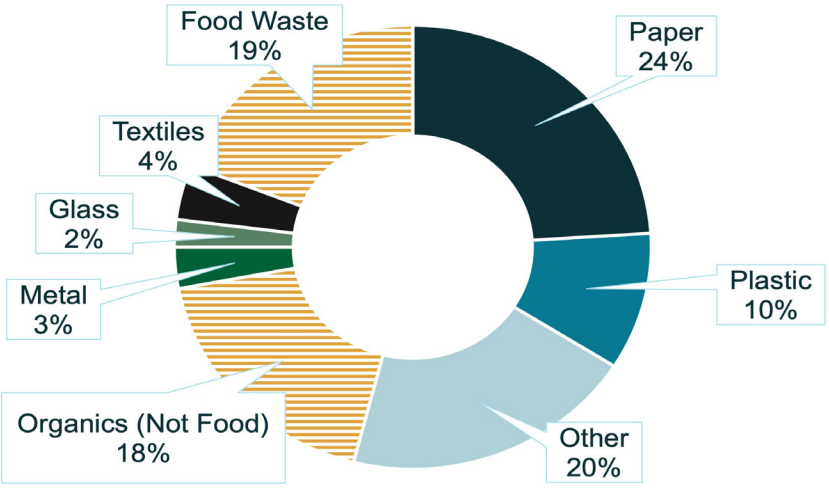
Total Michigan MSW Landfilled and Incinerate

Michigan landfills report received volume to the Michigan Department of Environment, Great Lakes and Energy on an annual basis. Based on these regulatory filings there were 8,810,390 tons of MSW landfilled during the 2021-2022 fiscal year that came from Michigan. In addition, the Kent County Waste-to-Energy Facility in Grand Rapids incinerated about 183,112 tons of MSW during 2022. Between these two sources we estimate the state generates 8,993,502 tons of MSW available for screening for recycling.

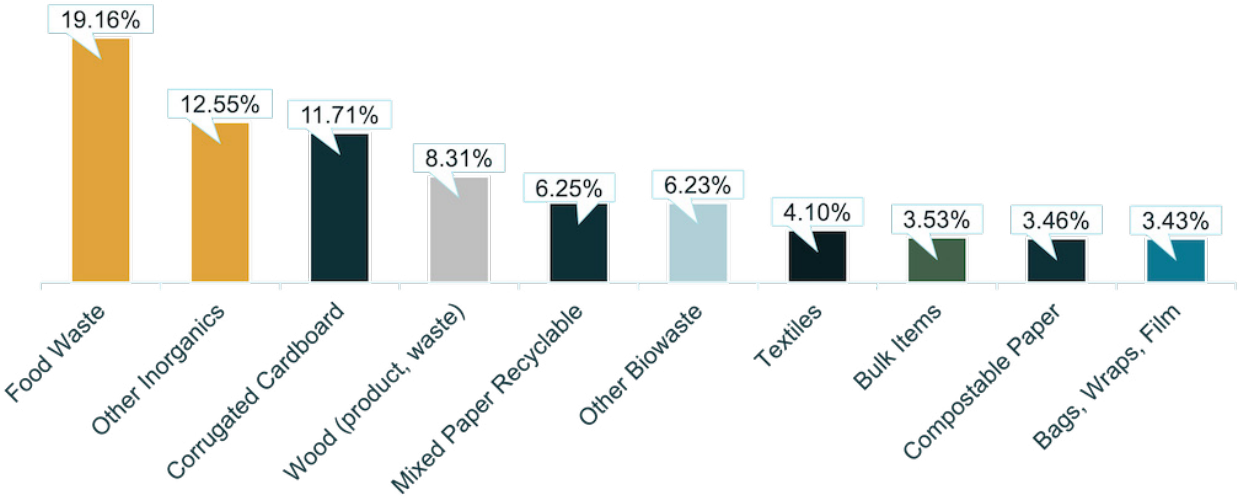
Composition Results

The first objective of this study was to provide an estimate of the statewide aggregate mixed municipal solid waste composition for Michigan. These results are detailed in the following figures and the table on page 13.

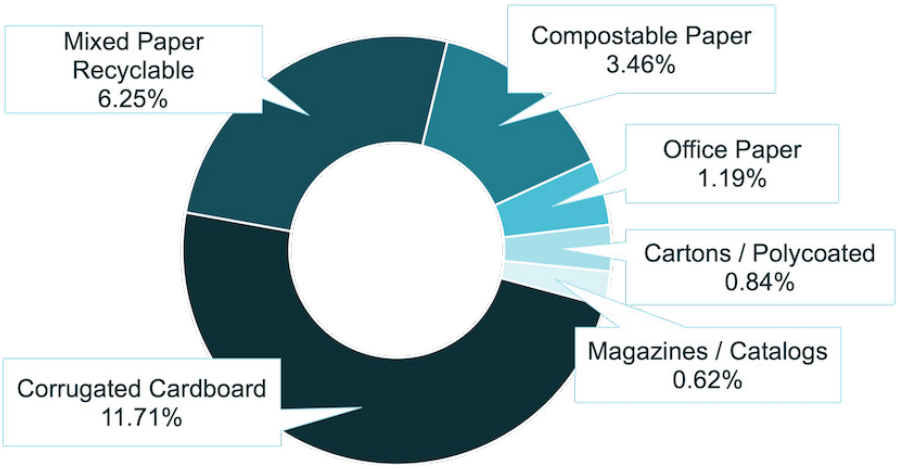
Michigan Municipal Solid Waste Composition (mean % by weight)



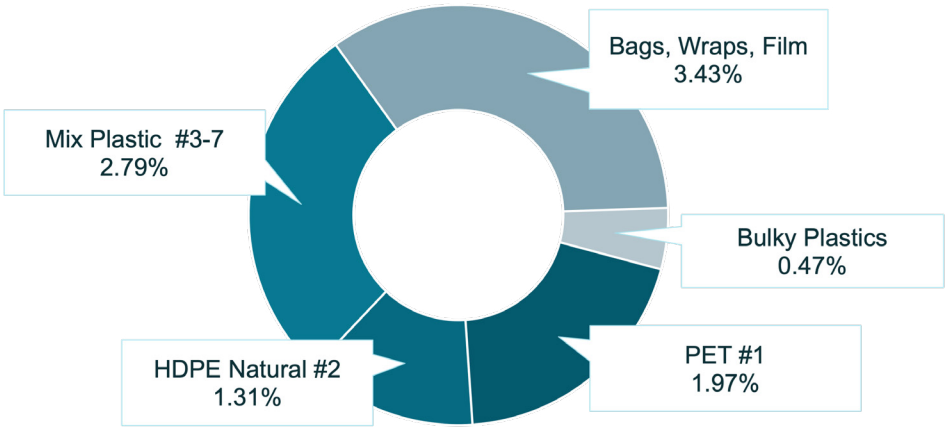
Top Materials in Michigan MSW Composition (mean % by weight)



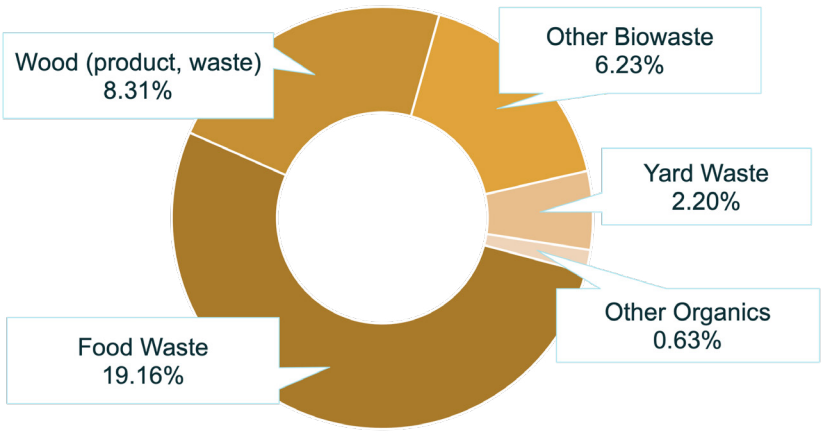
Paper in Michigan MSW Composition (mean % by weight)



Plastic in Michigan MSW Composition (mean % by weight)



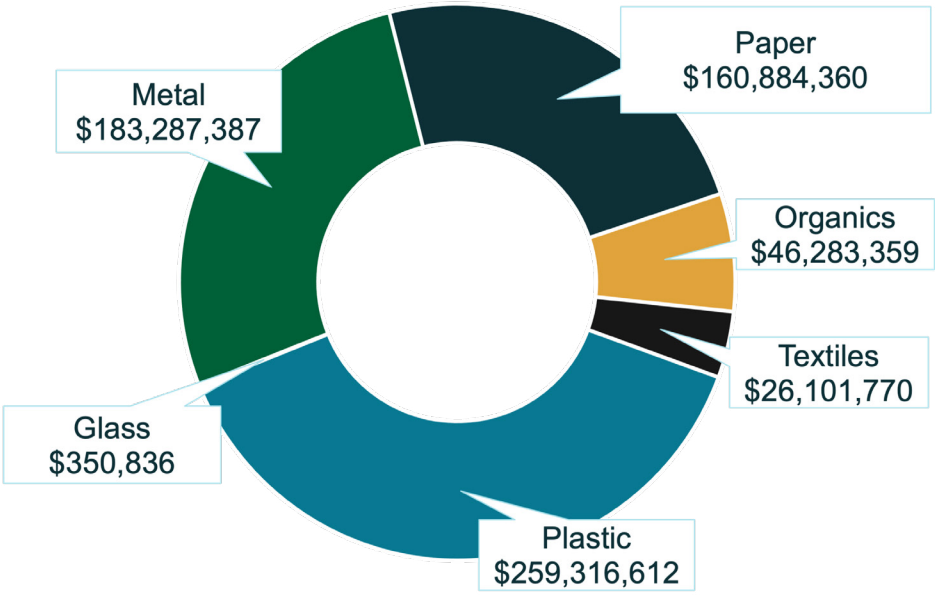
Organics in Michigan MSW Composition (mean % by weight)



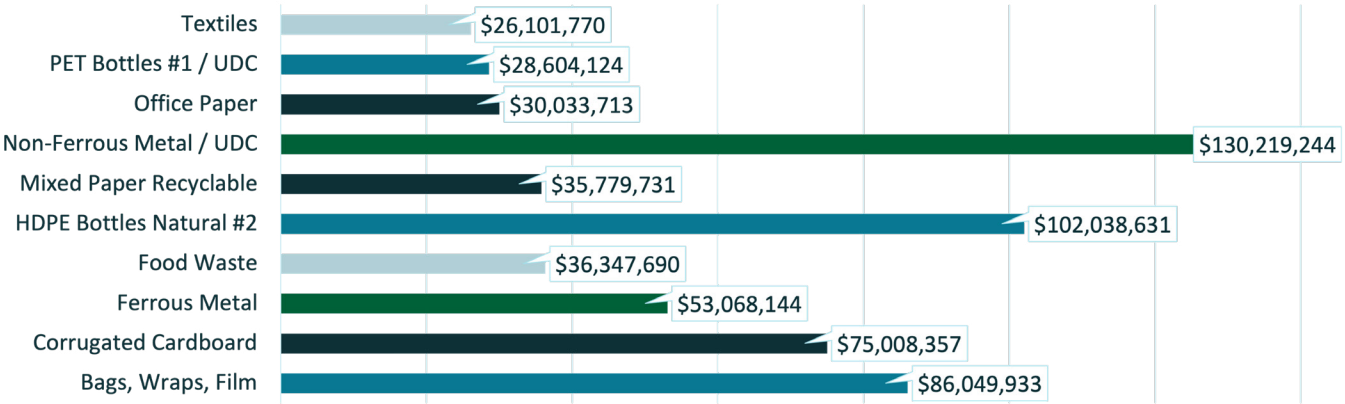
Economic Value

As described in the summary findings, material disposed of in Michigan's municipal solid waste each year has an estimated market value of $500 million to $676 million. This is detailed through the figures below and the table on the following page. In comparison, the 2016 Michigan MSW characterization study estimated the value of the state's 8.4 million tons of landfilled materials at between $293 million and $368 million. As infrastructure and demand for recycled materials grow, so does the lost opportunity for economic impact.

Total Value of Michigan MSW Material Disposed ($)



Top Commodities in Michigan MSW by Total Value



Michigan Statewide Composition (by weight), Available Material Valuation ($ in millions) and Net Recycling Value ($ per ton)

Material	Comp.	Value	Net	Material	Comp.	Value	Net
Paper				**Metals**			
Corrugated Cardboard	11.71%	$75.0	$340.47	Ferrous	2.20%	$53.1	$419.91
Mixed Paper Recyclable	6.25%	$35.8	$348.01	Non-Ferrous	0.69%	$105.4	$1,697.23
Compostable Paper	3.46%	$6.8	$302.60	UDC - Metal	0.22%	$24.8	$1,679.79
Office Paper - White & Color	1.19%	$30.0	$588.18	**Subtotal Metals**	**3.11%**	**$183.3**	**-**
Cartons / Polycoated	0.84%	$10.0	$397.26				
Magazines / Catalogs	0.62%	$3.3	$377.83	**Organic**			
Subtotal Paper	**24.07%**	**$160.9**	**-**	Food Waste	19.16%	$36.4	$307.18
				Wood (product, waste)	8.31%	$8.0	$259.59
Plastic				Other Biowaste	6.23%	-	-
PET Bottles #1	1.10%	$25.8	$476.52	Yard Waste	2.20%	$1.9	$259.59
UDC - Plastic	0.16%	$2.8	$199.59	Other Organics	0.63%	-	$199.59
PET Packaging / Containers	0.71%	$17.4	$467.31	**Subtotal Organic**	**36.54%**	**$46.3**	**-**
HDPE Natural #2	0.86%	$102.0	$1,527.31				
HDPE Color #2	0.45%	$8.7	$527.31	**Textiles**	4.10%	$26.1	$319.59
Expanded Polystyrene Foam	0.93%	-	$223.50				
Mix Plastic Containers #3-7	0.93%	$2.5	$244.06	**Other Wastes**			
Polypropylene #5	0.93%	$13.6	$372.89	C & D	1.15%	-	$199.60
Bags, Wraps, Film	3.43%	$86.1	$493.97	Electronics	1.52%	-	$199.60
Bulky Plastics	0.47%	$0.4	$224.06	Bulk Items	3.53%	-	$199.59
Subtotal Plastic	**9.98%**	**$259.3**	**-**	Other Inorganics	12.55%	-	$199.59
				Household Hazardous	1.42%	-	$199.59
Glass				**Subtotal Other Wastes**	**20.17%**	**-**	**-**
Glass	1.84%	-	$199.59				
UDC - Glass	0.19%	$0.4	$259.59				
Subtotal Glass	**2.03%**	**$0.4**	**-**				

Our findings are derived entirely from field studies, verifiable market prices for recycled commodities, and peer-reviewed academic studies. In the table above we have summarized our findings for material composition and valuation, as well as the net recycling value per ton after accounting for indirect benefits and processing costs. Together this data quantifies characterization of Michigan MSW disposed in landfills and incinerators by aggregate commodity value and as a net impact for recyclers and recycling communities.

Food Waste

There is substantially more food waste in Michigan landfills than currently believed, and its contributions to greenhouse gas emissions are greater than previously known. This should be the largest priority in future efforts to divert materials from landfills.

- Michigan disposes of an estimated 1.5 to 2 million tons of food waste through its municipal solid waste each year. It was the most common material characterized at 19.16 percent of samples by weight.
- This was also the case in 2016 when it was 13.5 percent of samples by weight. At the time, we predicted that food waste would become more prevalent as a percentage of MSW as conventional recycling programs improve. This was proven true.
- If this material was used as feedstock for compost in Michigan, it would be worth an estimated $18 million to $36 million annually.
- Food waste was found disproportionately in residential loads: 23.8 percent by weight, compared to 9.1 percent for samples from commercial properties.

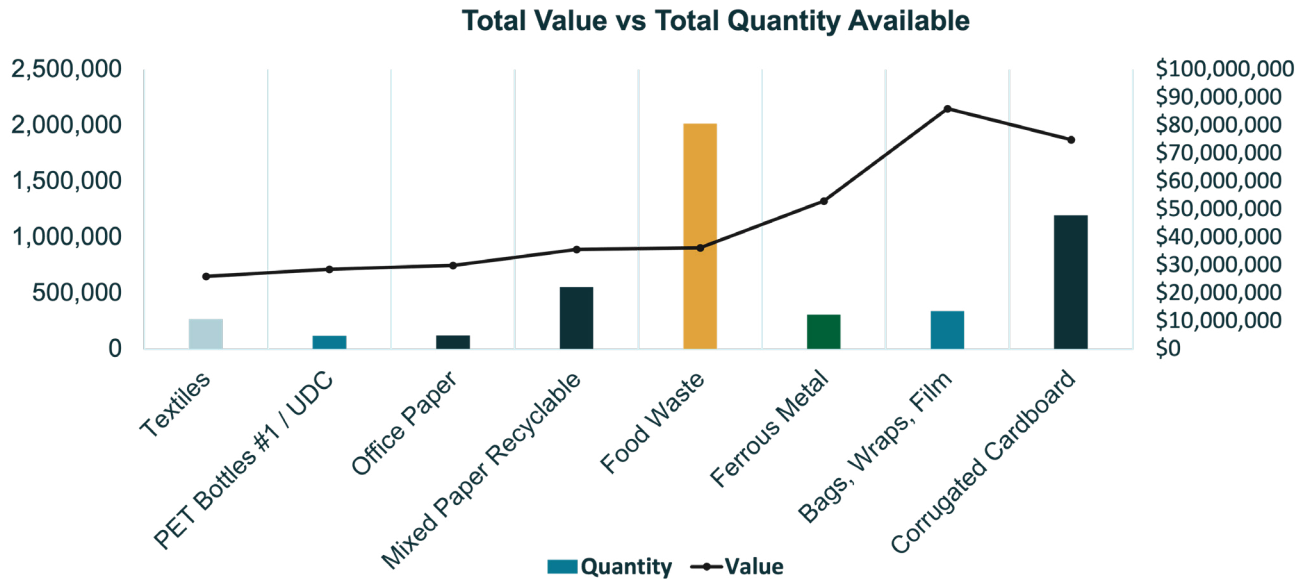
Our findings are consistent with characterization reports from peer states.

Paper and Corrugated Cardboard

Corrugated cardboard is a unique opportunity for the state. Arguably, it is the easiest material to recycle, universally accepted by residential programs and the material most commonly recycled by businesses. Yet it is 11.71 percent of MSW in Michigan by weight, a commodity value of $75 million during a depressed regional market for the material. At various points over the past five years it would have been worth two or three times more. Paper products are a combined 24 percent of MSW in Michigan. Although total paper is consistent with peer states, Michigan has more cardboard than any of its peers.

The material is disproportionately from business (16.5% to 8.6%). This may explain why cardboard is the only commonly accepted material that has not decreased in prevalence since 2016, as recent investments have favored residential waste streams.

The table below shows the quantity of available material in the state in comparison to the total value of the material. Cardboard is the one material with a large quantity of available material and a large total value.



Plastic and Metal

Metal is only three percent of MSW, but approximately a third of the commodity value ($183 million). When including environmental and social benefits, recycling a ton of non-ferrous metal has a net recycling value of $1,697 per ton, the most of any material.

Recoverable plastic is 10 percent of MSW in Michigan, with a total annual commodity value of $259 million disposed of each year in MSW. A majority of that value is from two categories: HDPE Natural (0.86%, $102 million) and Plastic Film (3.43%, $86 million).

- Although less than 1 percent of MSW, HDPE is a substantial opportunity. With a net recycling value of $1,527 per ton, there is an economic and environmental case for collection programs targeting that material specifically, similar to scrap programs for metal.

- The value of Plastic Bags, Wraps, Film may not accurately represent the investment opportunity. It increased from 2016, possibly due to a shift in recycling options for plastic bags from curbside recycling programs to retail drop-off locations. Bags tangle processing equipment and impair MRF operations - enough so that many facilities do not accept the material.

Other Findings

- There was a statistically significant increase in unclaimed bottle bill deposit containers in comparison to the previous study. There are now an estimated 1.3 billion unclaimed bottle bill containers in the municipal waste stream, three times more than in 2016.
- Non-food, non-fiber organic waste was 17.4 percent of total samples. Wood was the most prevalent material. Including food and non-food organic material, as much as 34 percent of MSW could be composted, although this may overstate the compostability of wood and paper products.
- The share of electronic waste has decreased by more than half since 2016. It is now approximately 1.5 percent of MSW. Although a characterization of electronic waste to precisely determine the presence of lithium-ion batteries was not possible, we can confidently estimate that there are no less than 30 million lithium-ion batteries in the state's municipal solid waste stream.
- There are an estimated 29 million "vape pens" in the municipal solid waste stream. These are a large, if not the largest, vector for lithium-ion batteries in the state's MSW, and could be a contributing factor to the increasing number of fires at solid waste management facilities in the state.
- There is a robust secondary and tertiary market for textile products, especially used clothing. However, industry stakeholders highlight that all textiles do eventually end up in the landfill, and it is difficult to determine where materials sampled in this study currently were in the product life cycle. We estimate that Michigan disposes of 271,893 tons of textile waste through MSW, a total commodity value of $26 million.
- Recycling facilities that process MSW universally indicate that glass has a negative value in their operations, meaning that they have to pay their customers to take it. However, glass that is processed through the deposit redemption program is sold to end markets in Michigan for $60 per ton.

This study demonstrates the economic and environmental benefits of recycling in its various forms. The economic opportunity is substantial and should be met with a sense of urgency. Likewise, in a vacuum, recycling provides a measurable environmental benefit over the landfill. But not all recycling (or composting) is mutually beneficial. As a general rule, prevention of waste through source reduction and reuse are beneficial to recycling, and should be prioritized.

1-1: Project Purpose

With a relatively small investment of stakeholder access and grant funds, the 2016 Michigan Municipal Solid Waste Characterization and Valuation Project created an important tool for the advancement of recycling, composting and the creation of a circular economy in the state. Michigan Sustainable Business Forum and its member collaborators worked to characterize economic and environmental opportunities available through sustainable materials management in Michigan. The ensuing report, *Economic Impact Potential and Characterization of Municipal Solid Waste in Michigan*,[1] has been regularly cited by state and regional programs in the seven years since its publication.

Much has changed since 2016. While Michigan was then in the beginning years of a goal to double the state's recycling rate, today it is deeply invested in an economy-wide effort to achieve a 45 percent recycling rate as part of the MI Healthy Climate Plan. International trade, transportation costs, infrastructure gaps and volatile end markets have created systemic challenges for the processing of certain materials, while accelerating or emerging end markets have created a growing need for other materials currently being sent to Michigan landfills. Led by the Michigan Department of Environment, Great Lakes and Energy and supported by the $15 million Renew Michigan Fund and other initiatives, there are now local, state and national programs working to create a circular economy to meet these challenges and opportunities.

Michigan's circular economy decision makers need updated information to determine the value of potential new and expanded recycling streams, to assess the performance of programs, and define the environmental and economic costs of materials management. Sustainability professionals and recycling advocates need improved benchmarks to better communicate and support the value of landfill avoidance efforts. Deposit containers, food waste, single-use plastics, embodied carbon and county materials management planning are key examples of concerns that will be informed by this new statewide characterization of municipal solid waste.

The 2024 Michigan Municipal Solid Waste Characterization and Valuation Study performed waste sorts at sites across the state, and through this provided an economic valuation for diversion in terms of real material value, job creation, and other positive economic and environmental impacts.

The following report details the results of this initiative according to five objectives:

- Determine composition of Michigan MSW now being disposed of in landfills and incinerators.
- Compare the composition of Michigan's MSW to the MSW of other Midwest states.
- Compare the 2023 composition of Michigan's MSW to its composition in 2016.
- Complete an economic analysis of MSW composition.
- Create datasets to inform discussions on Michigan deposit containers, lithium-ion batteries, and food waste.

This is the second in a series of *Creating a Circular and Decarbonized Economy* reports produced by Michigan Sustainable Business Forum.

1-2: Definitions

Confidence Intervals – The lower and upper confidence intervals indicate the likelihood that the population mean falls close to the sample mean as defined by the standard. For comparison with other studies, and in accordance with industry standards, the lower and upper bounds throughout this report have been calculated at a 90 percent level of confidence. The 90 percent confidence intervals define the upper and lower bounds for which we can be 90 percent confident that the particular material category's mean value will fall. If the confidence intervals are "wide" for a material category, it means there was greater variability of that material between samples. The confidence interval is used to define the "margin of error" for our statistical values.

End Market – End markets include processors such as plastic reclaimers, brokers, and manufacturers such as ferrous and non-ferrous foundries, paper and pulp mills, and glass container manufacturers.

Municipal Solid Waste – More commonly known as trash or garbage, consists of everyday items we use and then throw away, such as product packaging, yard waste, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses. In its annual solid waste report the Michigan Department of Environment, Great Lakes and Energy refers to this waste stream as Municipal and Commercial Waste. For purposes of this study, we will treat the two terms as synonyms.[2] Abbreviated as MSW.

Mean – The mean is calculated as the average composition of each material category (or primary material category) expressed as a percentage of the total amount of material within that sample set.

MSW Characterization – evaluation of the composition and quantity of material in MSW.

1-3: Michigan Municipal Solid Waste

Michigan landfills report received volume to the Michigan Department of Environment, Great Lakes and Energy on an annual basis. Based on these regulatory filings there were 8,810,390 tons of MSW landfilled during the October 2021 to September 2022 fiscal year that came from Michigan.[3] The Kent County Waste-to-Energy Facility in Grand Rapids incinerated an additional 183,112 tons of MSW in 2022.[4]

The landfill estimates omit incinerator ash (including it would double count that material as available for recycling), MSW imported from other states (it would be difficult to screen for recyclables and likely already has been), and MSW exported to other states (the number is not available). The incinerator does not process out-of-state MSW. Between these two sources we estimate the state generates 8,993,502 tons of MSW available for screening for recycling. This is shown in Table 1-1 and 1-2.

Table 1-1: Michigan Landfill Solid Waste Disposal Summary

Waste Type	Municipal Solid Waste	Incinerator Ash	Industrial Waste	Construction & Demolition	Total
By Volume in Cubic Yards	26,431,171	40,697	4,761,237	3,303,424	39,568,281
Est. by Weight in Tons	8,810,390	13,566	1,587,079	1,101,141	13,189,427
% of Total	66%	0.10%	23%	11%	100%

Source: EGLE Solid Waste Annual Report for FY 2022.

Michigan landfills report volumes received in cubic yards. The average density per cubic yard varies widely between material types. Glass or dirt can exceed 2,000 pounds per cubic yard, while single-stream recyclables may have as little as 50 pounds. EGLE and other stakeholders, including Michigan Sustainable Business Forum, have used a simple conversion of 3 cubic yards equals 1 ton of waste. For the purposes of simplicity and consistency with the 2016 report, we have followed this precedent except where indicated otherwise. The conversion rate does not impact the composition percentages reported in this report, only the total material available for recycling.

The most recent NextCycle Gap Analysis of Michigan[5] materials management needs prepared by RRS for the State of Michigan used a conversion of 3.3 cubic yards per ton to calculate available material, suggesting a slightly lower amount of total material available.

As the Detroit Renewable Power Facility included in the 2016 report is no longer operational, the percentage of Michigan's MSW processed through incineration is considerably lower than it was in 2016. Although a smaller amount, it still impacts projections for the amount of available material to be recycled, as ferrous metals are reclaimed from incinerator ash in significant volumes.

Table 1-2: Michigan Landfill Solid Waste Disposed Origin (by weight in tons)

Incinerator	Landfill	Total
183,112	8,810,390	8,993,502

MI Healthy Climate Plan: Increase Recycling Rate to 45 Percent

In September 2020, Governor Gretchen Whitmer signed Executive Directive 2020-10, which committed Michigan to a goal of achieving economy-wide carbon neutrality no later than 2050 and maintaining net negative greenhouse gas emissions thereafter. The MI Healthy Climate Plan was developed by EGLE with input from hundreds of Michigan residents. Six work groups met for a year to develop recommendations. An ad hoc internal group led by EGLE staff provided additional recommendations on decarbonization related to materials management. The Plan included six categories of recommendations in its Roadmap to 2030 section (abridged):

- **Commit to Environmental Justice and Pursue a Just Transition:** Ensure that at least 40 percent of state funding for climate-related and water infrastructure initiatives benefit Michigan's disadvantaged communities (in line with the federal government's Justice40 guidelines for federal funding); that Justice40 is developed in partnership with leaders in disadvantaged communities; and that Michigan emphasizes a just transition for all workers through proactive engagement, job training, and workforce development initiatives.
- **Clean the Electric Grid:** Generate 60 percent of the state's electricity from renewable resources and phase out remaining coal-fired power plants by 2030.
- **Electrify Vehicles and Increase Public Transit:** Build the infrastructure necessary to support 2 million electric vehicles on Michigan roads by 2030. Increase access to clean transportation options – including public transit – by 15 percent each year.
- **Repair and Decarbonize Homes and Businesses:** Reduce emissions related to heating Michigan homes and businesses by 17 percent by 2030. Increase investments in repairing and improving buildings to reduce costs for working families and small businesses.
- **Drive Clean Innovation in Industry:** Encourage clean innovation hubs where private enterprises strategically co-locate and collaborate to develop and deploy new, cleaner manufacturing technologies and conduct research and development to reduce emissions from hard to decarbonize industries. Triple Michigan's recycling rate to 45 percent and cut food waste in half by 2030.
- **Protect Michigan's Land and Water:** Protect 30 percent of Michigan's land and water by 2030 to naturally capture GHG emissions, maintain and improve access to recreational opportunities for all Michiganders, and protect biodiversity. Leverage innovative strategies to support climate-smart agriculture.

1-4: Study Design

The project consisted of two major research tasks: characterization and valuation. The characterization included waste sorts at 10 sites throughout Michigan, representing seven counties and five state planning regions. Sorting protocol and safety guidelines were adapted and updated from the 2016 study, based primarily on the methodology detailed in the professional standard ASTM D5231-92 (2008) Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste.[6] An advisory council, the Michigan Circular Economy Study Group, consulted on applicable regulations for municipal solid waste and provided guidance on various process decisions.

A limited number of amendments were made to the protocol in the field as questions and concerns emerged; most of these lessons were learned during the prior study. These amendments are documented in this section.

Sort Size and Selection

For the 2016 study, a governing component was used to determine the number of random samples necessary to achieve the desired precision level. This approach proved not to be relevant to the study findings or consistent with other state characterization studies. A comprehensive review suggests that the precision of each state characterization study is a function of budget, access and facility support. The 2023 study analyzed as many random samples as was possible during the time periods we were granted access to sites and host facility personnel to direct trucks and operate equipment.

At the beginning of each sorting day, compactor trucks were chosen via a random number generator. For instance, if the goal for the day was to sort three trucks and the number generator pulled 1, 7, and 15, then the first, seventh and fifteenth trucks would be sampled. One sorting sample of approximately 300 pounds was taken from each vehicle selected. Samples were taken via front loader or other heavy equipment, selected from a quadrant of the load pile by a coin-flip methodology that varied slightly as a function of load size. Average load weight varied between sites due to differences in the heavy equipment and density of the material.

Qualifying vehicles were compactor trucks serving residential or commercial route customers. Drivers were queried by research staff on the communities they served and the type of load. Site staff recorded truck weights.

Detailed truck and sample information has been retained and can be available upon request. Host sites were volunteered from representative operators and colleagues of operators among MiSBF members and collaborators.

Statistical Significance at Community/Site Scale

The characterization study was designed to determine the statewide composition of MSW. There were not enough samples taken at any specific site to reliably estimate composition for that facility or community. The statewide composition can be used as a downscaled estimate to approximate county or city composition. (County-specific estimates can be found at misbf.org/msw.)

We were able to create a statistically significant composition estimate for West Michigan in the 2016 study, as host facilities were heavily concentrated in that region. That is not the case for this study. Attempts were also made to collect data specific to disadvantaged communities in the regions served by sampled facilities, but it was not possible to do while maintaining randomization procedures.

Seasonality and Timing

Characterization studies of similar states have concluded that seasonal differences in the composition of the MSW stream are not statistically significant. Historically, the most seasonably variable material in the MSW stream is yard waste, and because Michigan has comprehensive yard waste collection and diversion programs in place, backed by a ban on certain yard wastes such as yard clippings, the extent of seasonal differences in the MSW composition is estimated to be minimal. As a result, all sampling and sorting was conducted in the summer of 2023, as opposed to collecting data at various times throughout the year.

In scheduling the sorting events, we were careful to avoid days in which waste composition or volume was likely to deviate from typical occurrence. All sorts were done on non-holiday weekdays.

The table below depicts the schedule and quantities of mixed municipal solid waste sorted at each of the host sites.

Table 1-3: Waste Sort Location Information, Schedule and Weight

Host Site	County	Operator	Urban/Rural	Sort Days	Weight Sorted (lbs)
Autumn Hills	Ottawa	WM	Mixed	6/6/2023	1,161
Westside RDF	St. Joseph	WM	Rural	6/8/2023	1,354
Northern Oaks	Clare	WM	Rural	6/13/2023	1,597
South Kent	Kent	Kent County	Mixed	6/20/2023	1,450
North Kent Transfer	Kent	Kent County	Mixed	6/27/2023 - 6/28/2023	2,826
Waste-to-Energy	Kent	Kent County	Urban	6/28/2023	2,209
Marquette County Solid Waste Management	Marquette	Marquette County	Mixed	7/26/2023 - 7/27/2023	1,456
Eagle Valley	Oakland	WM	Urban	8/1/2023	1,383
Woodland Meadows	Wayne	WM	Urban	8/2/2023	1,601
Sauk Hill Trails	Wayne	Republic	Urban	8/3/2023	1,221

Sorting Methodology

Sample loads were sorted by hand into 32 different categories (Table 1-4), weighed and returned to the waste stream. All sorting occurred within the tipping area of the landfill, incinerator or transfer station. Scavenging rules and impracticality prevented recycling of sampled materials.

Sorting categories were defined in the context of waste diversion potential through recycling and composting. There is a broad range in material categories and subcategories among state and local characterization studies and the U.S. Environmental Protection Agency. This study attempts to be as consistent to these studies as practical. These considerations are discussed at length in the sections that follow.

A limited number of adjustments were made to category definitions and the sorting process in the field as unanticipated situations emerged.

- A plastics category was eliminated as too little of the material was found to register on scales (HDPE Lids/Other #2), as well as a paper category that had no material at all (Newspaper).
- A category for Other Biowaste was created in the field, as this material would not provide the same diversion opportunities as the Other Organics category.
- Categories for Construction & Demolition waste and Bulky Plastics was created after the sort using a photographic journal of Bulk Items during data analysis.

Sorter Staffing

The waste sort team included three students or recent graduates from Michigan sustainability programs, and two veteran sustainability professionals. The research fellows were hired for a three-month period from May to August 2023. All sorters and supervisors received a safety orientation for the project protocol, and another orientation for each individual site, as well as extensive training to identify materials. No volunteers were used.

Table 1-4: Material Category Definitions

Material	Category Definitions
Office – White/colored Paper	Office / computer paper only.
Mixed Paper Recyclable	Newspaper, anything that would be included in residential "mixed mail", phone books, glossy paper, and boxboard (uncoated box board primarily used for boxes) such as cereal boxes.
Magazines/catalogs	Magazines and catalogs.
Corrugated Cardboard	Cardboard with a wavy core and not contaminated with other materials such as wax or plastic coating.
Cartons/Polycoated	Cartons, tetra-paks.
Compostable Paper	Paper towel, toilet paper, tissues, napkins.
PET Bottles #1	PET Beverage (#1) that are not returnable for Michigan deposit redemption. Clear and colored plastic beverage containers composed of polyethylene terephthalate. Key point: Look for the label "1" on the bottom.
PET Packaging / Containers #1	Clear and colored plastic containers and packaging composed of polyethylene terephthalate.
HDPE Natural #2	High Density Polyethylene containers with #2. Examples: white and milky white juice and milk jugs, shampoo bottles. After the first sort, this category was expanded to include lids and caps, or bottle crates of natural color.*

Table 1-4: Material Category Definitions (continued)

Material	Category Definitions
HDPE Color #2	High Density Polyethylene containers with #2. Examples: typically brightly colored detergent bottles, cleaners. After the first sort, this category was expanded to include lids and caps, or bottle crates.*
**HDPE Lids/Other #2*	High Density Polyethylene items with #2. Examples: lids and caps, bottle crates. **This category was not used after the first sort and combined with the bottle categories above.*
Bags, Wraps, Plastic Film	Plastic bags, grocery bags, garbage bags and other film plastic in bag form, stretch wrapping and shrink wrap.
PP #5	Polypropylene - should have #5 on bottom. Examples: yogurt containers, disposable cups and cutlery, margarine tubs.
EPS Foam	Expanded polystyrene foam products such as food service/transportation packaging.
Mix Plastic Containers #3-7	Plastics #3, 6, 7 or miscellaneous plastic that could not be excluded from the above categories on visual inspection. Not foam.
Glass	All clear and colored glass that is not returnable.
UDC - Glass	Glass containers returnable for deposit redemption in the state of Michigan - counted by unit and weight.
UDC - Metal	Cans returnable in the state of Michigan - counted by unit and weight.
UDC – Plastic	Bottle returnable in the state of Michigan - counted by unit and weight.
Ferrous Metal	All ferrous metals not containing aluminum such as iron or steel. Examples: clothes hangers, sheet metal products, pipes, metal scraps, cans.
Non-ferrous Metal	Any non-ferrous metal containing the element aluminum that does not include a Michigan deposit.
Food Waste	Food preparation waste, food scraps, spoiled food, kitchen wastes, liquid food wastes, waste parts from butchered animals.
Yard Waste	Non-woody plant material, plus loose dirt and gravel. Examples: grass, leaves, weeds, cut flowers, twigs, brush, fine mix, and branches.
Wood (product, waste)	Treated and untreated lumber and other wood products.
Soil and Bottom Fines	Loose dirt not including yard waste. As much of this material was deemed contamination from heavy equipment, it has been omitted from composition.
Other Organics	Any organic material not classified by any other category, including cotton balls, hair, paperboard egg cartons, compostable plastics, house plants, dead animals not killed for food, etc.
Textiles	Clothing, bedding, curtains, blankets, other cloth material.
Electronics	Products or appliances with electric cord or battery power source. Examples: Toasters, hairdryers, laptops, computer monitors, televisions, printers, cell phones, “white goods”.
HHW	Household Hazardous Products characterized as toxic, corrosive, flammable, ignitable, radioactive, poisonous, or reactive. (e.g. solvents, pesticides, antifreeze, batteries).
Bulk Items**	Large pieces of furniture, bed frames, fitness equipment, and mattresses.
Other Inorganics	Any other inorganic material that could not be placed into any other sort category.
Other Biowaste	Diapers, kitty litter and bags of feces.
***Bulky Plastics*	*Rigid plastics: Trash can lid, crates. This category was not used during the sort, but derived from photo review of “Bulk Waste” during analysis.*
***C & D Waste*	*Waste from construction and demolition activities. This category was not used during the sort, but derived from photo review of “Other Inorganic”, “Bulk Waste” and “Wood Waste” during analysis.*

Field Notes

Findings from each site were entered into a statistical model that calculates the mean and the 90% confidence intervals for individual material categories for each sorting event and in the aggregate.

The mean represents the mathematical average or average percent of material composing the MSW stream by weight. The confidence interval is an expression of accuracy. It provides the upper and lower limits of the "actual" mean for all the MSW received at the participating facility based upon the sorting and sampling observations of the sampled materials. For example, the 90% confidence interval represents that there is a 90 percent level of confidence that the true population mean falls within the upper and lower bounds of the confidence interval. The 90% confidence interval is the generally accepted industry standard for solid waste composition studies. In general, the more samples that are sorted, the narrower the confidence interval becomes for a given level of confidence. Given our sample sizes, narrower confidence intervals indicate less variability in the data.

Unless otherwise noted, adjustments were not made to manipulate the data according to demographic differences, such as weighting the sites by population or their percentage contributions to total Michigan MSW.

There are a number of factors that may influence the actual potential for diversion:

- By definition, all MSW is contaminated from a recycling perspective. We have assumed that all recyclable materials would be diverted in a clean and dry state. This was especially meaningful for textiles.
- Though we have tried to separate food waste from its packaging, and vice versa, this could not be done with precision in the field. There exists the possibility that weights for recyclable packaging may be overstated slightly by the presence of material that would be washed away if the product were recycled.
- Materials were sorted by their ability to be recycled in the state that they were disposed. Items containing recyclable material requiring significant disassembly to be recycled were classified as Inorganic Waste, or Bulk Items, whichever was appropriate. Some Bulk Items were moved into C&D and Bulky Plastics.
- The open face of landfills must be covered at the end of each work day. This is typically achieved with a layer of soil or mulch. This material contaminated several samples in a conspicuous way when unintentionally captured by front-loaders. This contamination overstated the share of Soil and Bottom Fines. To provide an accurate estimate of the material available for recycling, this category was omitted from the composition.

2-1: Composition Results

The first objective of this study was to provide an estimate of the statewide aggregate mixed municipal solid waste composition for Michigan. These results are detailed in Table 2-1 below and on the following page.

Table 2-1: Michigan Statewide Aggregate Composition (mean % by weight)

		Conf Int. (90%)	
Material	**Mean**	**Lower**	**Upper**
Paper			
Corrugated Cardboard	11.71%	8.39%	13.54%
Mixed Paper Recyclable	6.25%	5.30%	7.58%
Compostable Paper	3.46%	3.01%	4.05%
Office Paper - White and Color	1.19%	0.76%	1.61%
Cartons / Polycoated	0.84%	0.55%	1.33%
Magazines / Catalogs	0.62%	0.28%	0.71%
Subtotal Paper	**24.07%**	**18.29%**	**28.82%**
Plastic			
PET Bottles #1	1.10%	0.96%	1.38%
UDC - Plastic	0.16%	0.12%	0.21%
PET Packaging / Containers #1	0.71%	0.66%	0.98%
HDPE Natural #2	0.86%	0.72%	1.11%
HDPE Color #2	0.45%	0.35%	0.71%
Expanded Polystyrene Foam	0.93%	0.88%	1.20%
Mix Plastic Containers #3-7	0.93%	0.88%	1.20%
Polypropylene #5	0.93%	0.81%	1.10%
Bags, Wraps, Film	3.43%	3.15%	4.43%
Bulky Plastics	0.47%	0.11%	0.61%
Subtotal Plastic	**9.98%**	**9.75%**	**11.84%**

Note: Subtotals for the mean percentages may not equal the sum of the mean percentages due to rounding. Confidence intervals for primary categories and subcategories are calculated independently.

Table 2-1: Michigan Statewide Aggregate Composition (mean % by weight) - Continued

		Conf Int. (90%)	
Material	**Mean**	**Lower**	**Upper**
Metals			
Ferrous	2.20%	1.58%	2.75%
Non-Ferrous	0.69%	0.46%	0.83%
UDC - Metal	0.22%	0.18%	0.27%
Subtotal Metals	**3.11%**	**2.37%**	**3.69%**
Glass			
Glass	1.84%	1.40%	2.38%
UDC - Glass	0.19%	0.05%	0.27%
Subtotal Glass	**2.03%**	**1.55%**	**2.54%**
Organic			
Food Waste	19.16%	16.46%	21.80%
Wood (product, waste)	8.31%	4.36%	10.64%
Other Biowaste	6.23%	4.68%	8.01%
Yard Waste	2.20%	1.04%	3.54%
Other Organics	0.63%	0.32%	0.92%
Subtotal Organic	**36.54%**	**26.86%**	**44.91%**
Textiles	**4.10%**	**2.99%**	**4.60%**
Other Wastes			
Construction & Demolition	1.15%	0.19%	4.74%
Electronics	1.52%	0.95%	1.81%
Bulk Items	3.53%	1.60%	4.88%
Other Inorganics	12.55%	10.78%	14.27%
Household Hazardous	1.42%	0.97%	1.60%
Subtotal Other Wastes	**20.17%**	**14.49%**	**27.30%**

Note: Subtotals for the mean percentages may not equal the sum of the mean percentages due to rounding. Confidence intervals for primary categories and subcategories are calculated independently.

Figure 2-1: Michigan Municipal Solid Waste Composition (By Group)

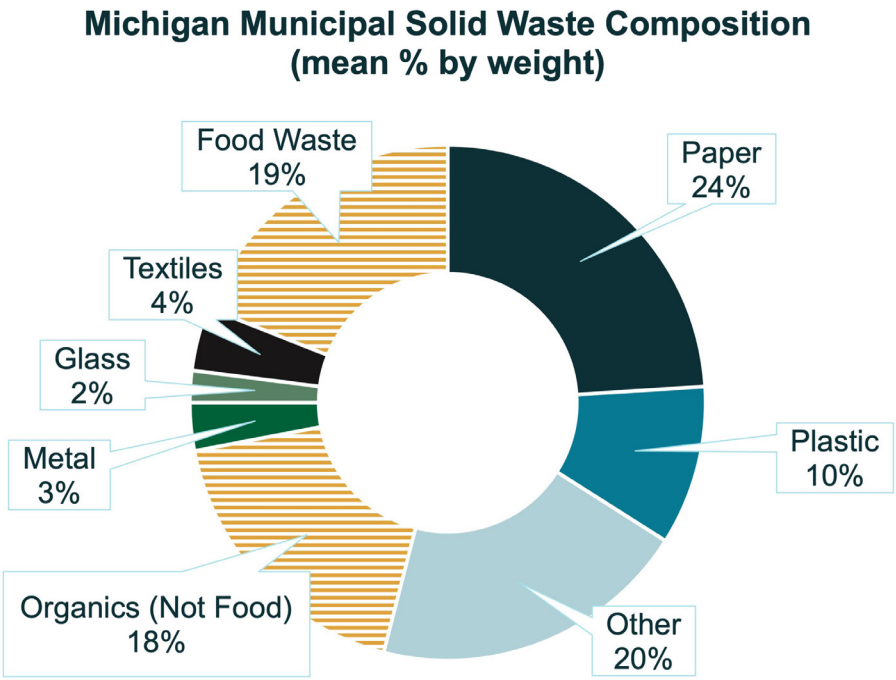


Figure 2-2: Michigan Municipal Solid Waste Composition Top Ten Materials

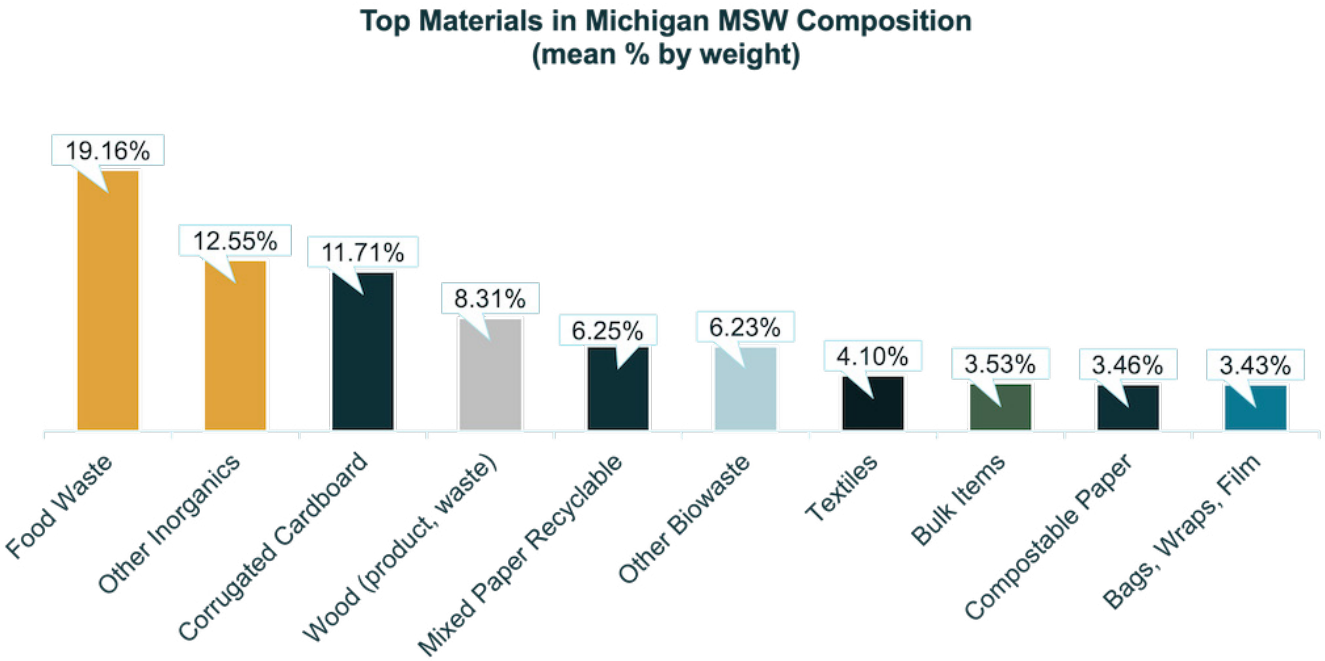
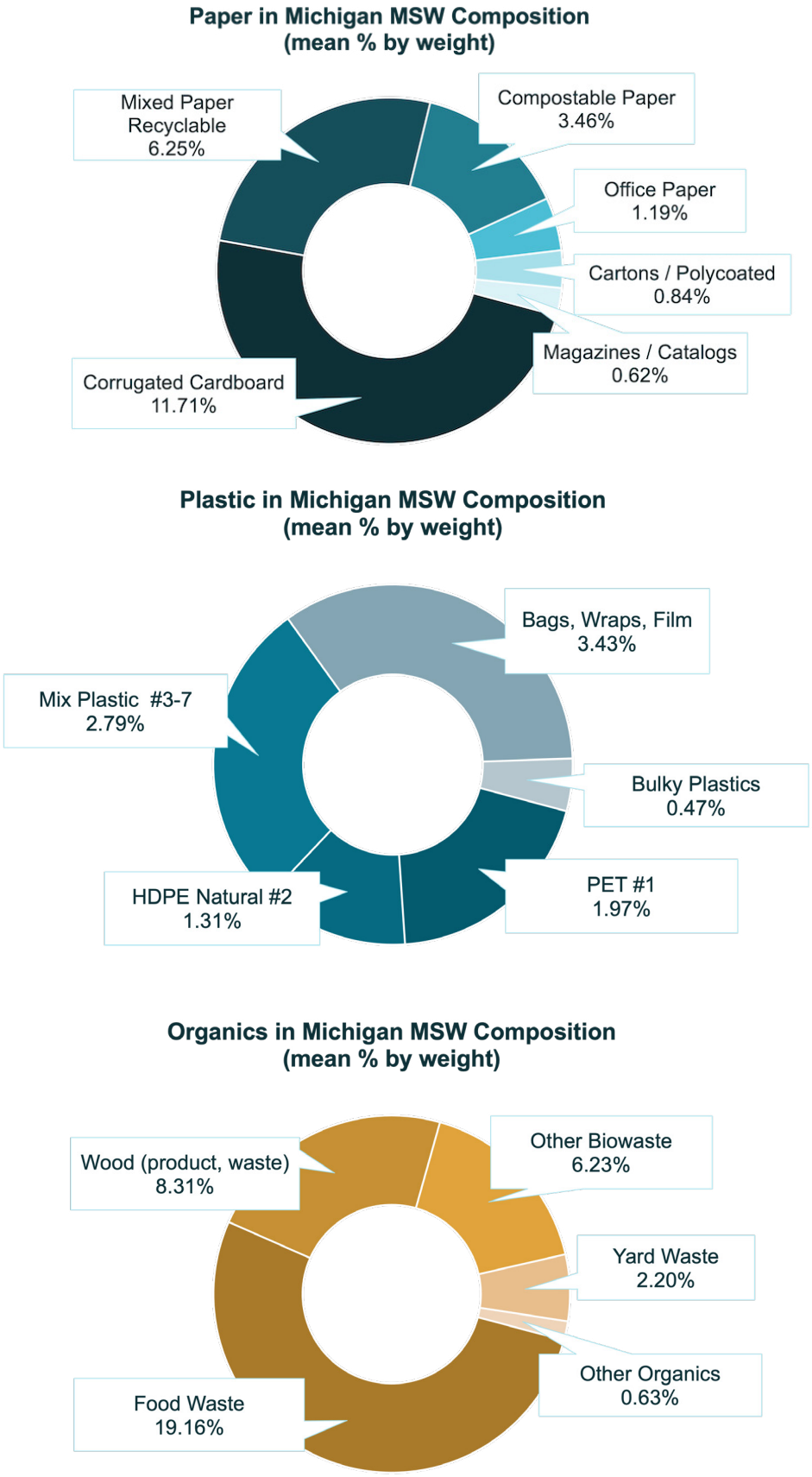


Figure 2-3: Michigan Municipal Solid Waste Composition Group Details



2-2: Commercial and Residential Composition

Table 2-2: Michigan Statewide Composition Commercial vs. Residential (mean % by weight)

Material	Statistically Significant Higher Value	Commercial				Residential			
		Rank	Mean	Conf Int. (90%) Lower	Conf Int. (90%) Upper	Rank	Mean	Conf Int. (90%) Lower	Conf Int. (90%) Upper
Paper									
Corrugated Cardboard	None	1	16.52%	9.88%	23.16%	3	8.60%	6.09%	11.10%
Mixed Paper Recyclable	None	5	6.48%	2.92%	10.05%	5	6.48%	5.59%	7.37%
Compostable Paper	None	12	2.56%	1.52%	3.59%	7	3.94%	3.33%	4.56%
Office Paper - White and Color	None	14	1.69%	0.49%	2.89%	22	0.83%	0.57%	1.10%
Cartons / Polycoated	None	15	1.35%	0.06%	2.63%	23	0.79%	0.52%	1.05%
Magazines / Catalogs	None	26	0.58%	0.07%	1.09%	26	0.46%	0.20%	0.72%
Subtotal Paper	**None**		**29.18%**	**14.94%**	**43.41%**		**21.10%**	**16.30%**	**25.90%**
Plastic									
PET Bottles #1	Residential	25	0.65%	0.43%	0.87%	16	1.48%	1.18%	1.78%
UDC - Plastic	Residential	30	0.09%	0.06%	0.12%	31	0.21%	0.15%	0.28%
PET Packaging / Containers #1	Residential	28	0.42%	0.21%	0.63%	21	0.95%	0.77%	1.12%
HDPE Natural #2	None	24	0.66%	0.38%	0.95%	19	1.04%	0.75%	1.33%
HDPE Color #2	None	23	0.68%	0.13%	1.23%	27	0.40%	0.28%	0.53%
Expanded Polystyrene Foam	None	20	0.86%	0.62%	1.10%	18	1.15%	0.93%	1.38%
Mix Plastic Containers #3-7	None	19	0.86%	0.62%	1.10%	17	1.15%	0.93%	1.38%
Polypropylene #5	None	21	0.84%	0.46%	1.22%	20	1.01%	0.86%	1.16%
Bags, Wraps, Film	None	9	3.94%	2.24%	5.63%	10	3.52%	3.02%	4.02%
Bulky Plastics	None	27	0.55%	0.00%	1.11%	28	0.34%	0.01%	0.67%
Subtotal Plastic	**None**		**9.55%**	**5.15%**	**13.96%**		**11.26%**	**8.88%**	**13.64%**
Glass									
Glass	Residential	22	0.83%	0.35%	1.32%	12	2.20%	1.51%	2.89%
UDC - Glass	None	31	0.05%	0.01%	0.09%	32	0.13%	0.04%	0.23%
Subtotal Glass	**Residential**		**0.88%**	**0.36%**	**1.41%**		**2.34%**	**1.56%**	**3.12%**
Metals									
Ferrous	None	13	1.70%	1.02%	2.38%	11	2.56%	1.66%	3.45%
Non-Ferrous	None	17	0.88%	0.30%	1.46%	25	0.59%	0.44%	0.73%
UDC - Metal	None	29	0.20%	0.13%	0.27%	30	0.25%	0.19%	0.30%
Subtotal Metals	**None**		**2.78%**	**1.45%**	**4.11%**		**3.39%**	**2.29%**	**4.49%**

Table 2-2 defines composition of statewide MSW disposed by commercial or residential generation. Study samples were split approximately evenly between commercial, residential and mixed route loads. As the sample size was much smaller for these populations than that of the statewide composition, the information should not be deemed as equally reliable. To ascertain statistically significant differences between the specific material types, we compared the confidence intervals to determine those where the difference between the sectors exceed the margin of error.

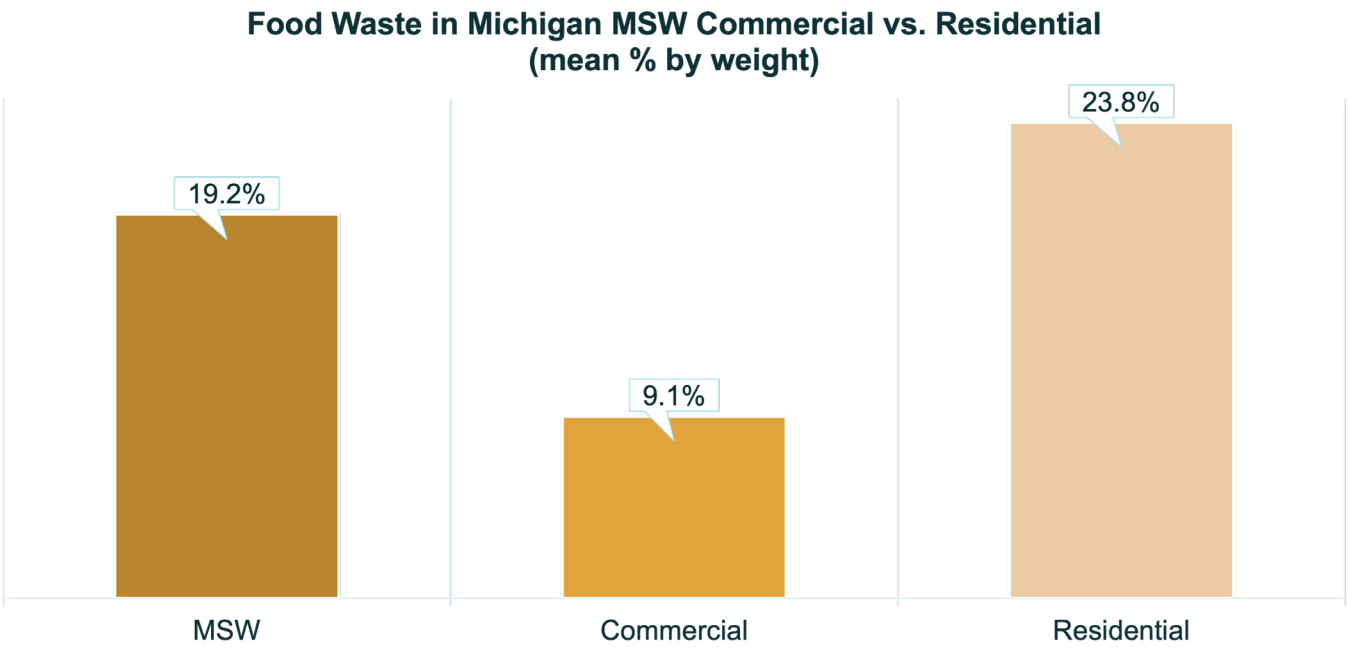
- PET Bottles, including unredeemed deposit containers, and PET Packaging were statistically higher in residential loads.
- Glass was statistically higher in residential loads.
- Food Waste was statistically higher in residential loads.
- Household Hazardous Waste was statistically higher in residential loads.
- C&D waste was statistically higher in commercial loads.
- Although not statistically significant, Corrugated Cardboard (17%) and Wood (16%) were both considerably more common in Commercial MSW.

Table 2-2: Michigan Statewide Composition Commercial vs. Residential (continued)

Material	Statistically Significant Higher Value		Commercial				Residential		
			Mean	Conf Int. (90%) Lower	Conf Int. (90%) Upper	Rank	Mean	Conf Int. (90%) Lower	Conf Int. (90%) Upper
Organic									
Food Waste	Residential	4	9.09%	5.19%	12.99%	1	23.80%	20.65%	26.95%
Wood (product, waste)	None	2	16.12%	6.25%	26.00%	6	4.67%	3.02%	6.31%
Other Biowaste	None	15	3.70%	0.90%	6.51%	4	6.86%	5.32%	8.41%
Yard Waste	None	10	3.47%	0.08%	7.02%	14	1.93%	0.69%	3.16%
Other Organics	None	18	0.87%	0.03%	1.71%	24	0.59%	0.28%	0.91%
Subtotal Organic	**None**		**33.25%**	**12.45%**	**54.23%**		**35.17%**	**27.92%**	**42.43%**
Textiles	None	8	3.96%	2.16%	5.75%	9	3.71%	2.67%	4.75%
Other Wastes									
Construction & Demolition	Commercial	6	4.99%	1.00%	11.25%	29	0.32%	0.00%	0.75%
Electronics	None	16	1.06%	0.27%	1.85%	15	1.61%	1.01%	2.22%
Bulk Items	None	11	3.19%	1.05%	5.32%	8	3.85%	1.33%	6.38%
Other Inorganics	None	3	10.12%	7.47%	12.76%	2	12.63%	10.42%	14.84%
Household Hazardous	Residential	7	1.05%	0.25%	1.00%	13	1.93%	1.50%	2.36%
Subtotal Other Wastes	**None**		**20.41%**	**10.04%**	**32.18%**		**20.35%**	**14.26%**	**26.56%**

Among these, Food Waste stands out as the most significant variance, representing 23 percent of residential MSW but only nine percent of commercial MSW. This is shown in Figure 2-4 below.

Figure 2-4: Food Waste in Michigan MSW Commercial vs. Residential



2-3: Ease of Recycling

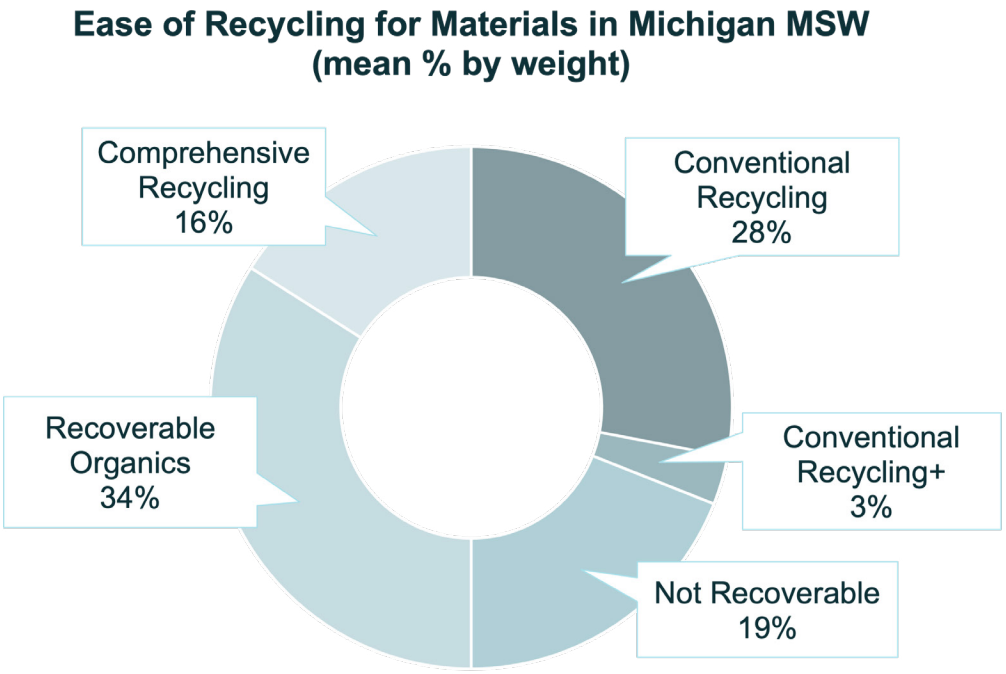
Several valuable insights were revealed through the composition analysis. Perhaps most importantly, it is clear that the MI Healthy Climate Plan goal of increasing the recycling rate to 45 percent is attainable if the state continues its current momentum. Most material currently being disposed of through landfills and incinerators could be recycled or composted in most metropolitan communities without great difficulty. Approximately one third of material could be recycled in any community that meets the recycling benchmarks specified in the new Part 115 materials management law, shown in Figure 2-5 as Conventional Recycling. Conventional Recycling+ refers to programs that include specific materials that are often but not always accepted by curbside recycling programs in Michigan, specifically glass and cartons.

An additional 34 percent could be composted, in theory, including compostable paper, food waste, soil, wood, and yard waste, although this will admittedly require a more permissive organics recycling ecosystem than presently exists, and may be overstating the compostability of wood and paper products.

With some effort, up to 81 percent of MSW could be recycled where facilities are also available for textiles, bulk items/furniture, electronics, foam, and household hazardous waste.

Approximately 19 percent of Michigan MSW is impractical or extremely difficult to recycle, including miscellaneous inorganic materials, certain plastic materials, and non-compostable organics. Some of this material could be processed through anaerobic digestion, pyrolysis, or other mechanical or chemical processes to increase the potential recycling rate further. An additional portion of inorganic waste could be recycled through extraordinary disassembly, or niche services such as Terracycle, which allows consumers to mail-in miscellaneous consumer products and packaging. Nevertheless, these materials have been characterized here as Not Recoverable.

Figure 2-5: Ease of Recycling of Materials in Michigan MSW

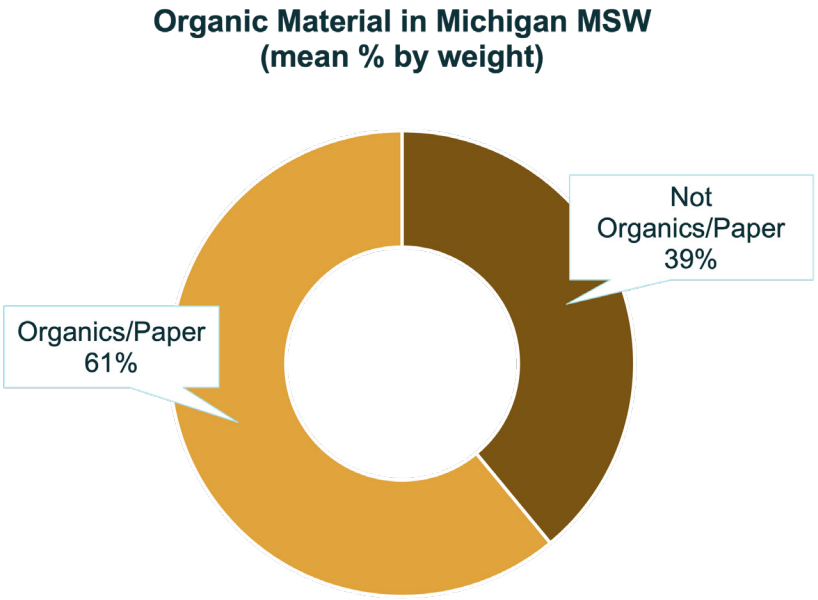


The Michigan Circular Economy Study Group that advised the development of this report offered mixed opinions on the compostability of certain materials that this study has indicated as compostable on the previous page. Wood products, for instance, may have coatings or treatments, or be of a size/shape that would be inconvenient for composters to process. Many paper products also include chemical or plastic coatings that impair compostability. Few composters wish to use human or pet waste as feedstock.

For the sake of simplicity, this study presumes all wood is compostable and all biowaste is not. To the best of our ability, we have characterized non-compostable wood building material as Construction & Demolition Waste.

The prevalence of organic material suggests there is value in anaerobic digestion or similar technologies that can process a wider array of organic material, with less consideration for contamination and feedstock value. A full 61 percent of MSW is organic material or paper, as shown in Figure 2-6 below.

Figure 2-6: All Organic Material in Michigan MSW



An unknown portion of textile waste is also organic material (e.g.: cotton, silk, wool), but this was impossible to characterize in the field. As such, the above figure may understate Organic Material in MSW by up to four percent.

2-4: Comparison With 2016 Study

A great deal has changed since the last state characterization study was published in 2016. China's "National Sword" policy impacted recycling markets considerably, forcing a systemic shift in domestics markets. In Michigan, the Renew Michigan Fund and related investments from local communities and private industry has propelled movement toward the creation of a circular economy. The COVID-19 pandemic impacted every facet of the economy, accelerating e-commerce and consumer behavior in retail and food service, including recycling.

Table 2-3 shows the estimated weight in tons disposed of in Michigan in 2022 and 2014 according to landfill regulatory fillings, the basis for the 2016 and 2024 studies. MSW increased considerably, while other solid waste types declined.

Table 2-3: Michigan Landfill Solid Waste Disposal vs. 2016 Study

Waste Type	Municipal Solid Waste	Incinerator Ash	Industrial Waste	Construction & Demolition	Total
2022 Est. by Weight in Tons	8,810,390	13,566	1,587,079	1,101,141	13,189,427
2014 Est. by Weight in Tons	7,475,259	14,942	3,137,819	1,503,421	12,131,441
% Change	18%	-9%	-49%	-27%	9%

Source: EGLE Solid Waste Annual Report for FY 2022 + MDEQ Solid Waste Annual Report for FY 2014

Table 2-4 compares the composition of MSW from the 2024 and 2016 studies. Categories and sub-categories have been adjusted for consistency. A statistically significant change was observed in the following:

- The share of unredeemed deposit containers increased. This is discussed further in Section 4.
- Mixed paper and mixed plastic decreased considerably, suggesting an impact from Michigan's investments in conventional recycling.
- Plastic bags increased, presumably due to a shift in recycling options for the material from curbside recycling programs to retail drop-off locations. Expanded polystyrene foam also increased, but from a small base.
- Yard waste decreased, potentially due to a sampling anomaly in the 2016 study that overstated the material, which was noted as a possibility in the prior study's data analysis.
- The 2016 report predicted a statistically significant increase in food waste would be observed as Michigan improved collection of conventional recyclables. Food waste was the most prevalent material at the time, but still increased considerably as a share of Michigan's MSW.

Table 2-4: Composition of Michigan MSW 2024 vs. 2016 (mean % by weight)

Material	Statistically Significant Increase / Decrease	2023 Results			2016 Results		
			Conf Int. (90%)			Conf Int. (90%)	
		Mean	Lower	Upper	Mean	Lower	Upper
Paper							
Mixed	Decrease	8.90%	6.89%	11.23%	13.29%	11.91%	14.66%
Corrugated	No Change	11.71%	8.39%	13.54%	8.42%	7.17%	9.67%
Subtotal Paper	No Change	20.61%	15.28%	24.77%	21.71%	19.08%	24.33%
Plastic							
Plastic Bags / Film / Wrap	Increase	3.43%	3.15%	4.43%	2.77%	2.45%	3.10%
PET Beverage (#1) No Deposit	No Change	1.10%	0.96%	1.38%	0.94%	0.82%	1.05%
EPS Foam	Increase	0.93%	0.88%	1.20%	0.71%	0.61%	0.81%
All Other Plastic	Decrease	4.37%	3.53%	5.72%	9.6%	8.36%	10.83%
Subtotal Plastic	No Change	9.83%	8.52%	12.73%	14.02%	12.24%	15.79%
Metals							
Ferrous	No Change	2.20%	1.58%	2.75%	3.32%	2.70%	3.94%
Non-Ferrous	No Change	0.69%	0.46%	0.83%	0.43%	0.34%	0.51%
Subtotal Metals	No Change	2.89%	2.04%	3.58%	3.75%	3.04%	4.45%
Glass							
Organic							
Food Waste	Increase	19.16%	16.46%	21.80%	13.57%	11.97%	15.17%
Yard Waste	Decrease	2.20%	1.04%	3.54%	5.00%	3.59%	6.41%
Wood	No Change	8.31%	4.36%	10.64%	5.19%	3.73%	6.65%
Other Organics	No Change	10.32%	8.01%	12.98%	9.05%	8.00%	10.11%
Subtotal Organic	No Change	39.99%	29.87%	48.96%	32.81%	27.29%	38.34%
MI Deposits - All	Increase	0.57%	0.38%	0.75%	0.29%	0.21%	0.37%
Other							
Textiles	No Change	4.10%	2.99%	4.60%	3.65%	2.98%	4.32%
Electronics	No Change	1.52%	0.95%	1.81%	2.49%	1.53%	3.46%
Household Hazardous	No Change	1.42%	0.97%	1.60%	0.93%	0.49%	1.36%
Bulk Items	No Change	3.53%	1.60%	4.88%	1.20%	0.33%	2.06%
Other Inorganics	No Change	13.70%	10.97%	19.01%	14.65%	12.64%	16.67%
Subtotal Other Wastes	No Change	24.27%	17.48%	31.90%	22.92%	17.97%	27.87%

Note: Categories and subcategories have been adjusted to provide a like-to-like comparison between the two studies. Subtotals for the mean percentages may not equal the sum of the mean percentages due to rounding. Confidence intervals for primary categories and subcategories are calculated independently.

2-5: Comparison With Peer States in Great Lakes and Nationally

Michigan was the last of the Great Lakes states to conduct a field study on MSW disposal characterization when the 2016 study was completed. In order to quantify potential differences between the state's characterization and that of its neighboring states the 2016 study reviewed characterization studies for Illinois (2015), Minnesota (2013), Indiana (2012), Wisconsin (2009) and Ohio (2004). In the 2016 study, there were significant differences between the newer and older state MSW compositions, primarily driven by the increased digitization of media and documents during the decade between 2004 and 2014.

To account for this, we limited our 2024 review to studies performed since 2012, prioritizing more recent studies. However, only Wisconsin (2021) and Ohio (2019) have completed studies since 2016, with the Ohio study a "desktop" characterization written without sampling material in the field. To provide a more relevant comparison, we also reviewed studies from Midwest states Iowa and Missouri completed in 2017. We further hypothesized that the COVID-19 pandemic was a watershed event that permanently changed our nation's economy, and reviewed two additional studies from coastal states completed since 2021.

All of the statewide studies followed similar methodologies from a sorting standpoint, but differed slightly by category definition and significantly in scope. Care was taken to ensure standard definitions of material disposed, which resulted in reclassification of several materials in other reports. As such the values shown in the below tables will not precisely align with the category values found in the reports themselves. Table 2-5 and 2-6 show a comparison of MSW disposal composition by weight for eight Midwest states and four benchmark states post-COVID.[7]

Michigan's MSW composition is generally consistent with other Midwest states. Differences in material categories were within the margin of error, with one exception, and differences in specific materials can be attributed to inconsistencies between the characterization studies. This study characterized a much larger share of material as Other Inorganics and Wood than most Midwest states (except Ohio for Wood), with the balance coming from Bulky Plastics and Construction & Demolition, respectively.

Table 2-5: Between State Comparison MSW Disposed Categories - Midwest (Mean % by weight)
(continued on next page)

Material	Michigan	Wisconsin	Ohio	Iowa	Missouri	Illinois	Minnesota	Indiana
Year	2024	2021	2019	2017	2017	2015	2013	2012
Paper								
Corrugated Cardboard	11.71%	3.30%	4.87%	4.60%	8.50%	7.30%	3.70%	10.57%
Mixed Paper Recyclable	6.25%	10.10%	7.69%	10.30%	7.20%	6.20%	6.50%	5.95%
Compostable Paper	3.46%	5.30%	4.33%	7.60%	8.10%	4.80%	9.80%	4.49%
Office Paper - White /Color	1.19%	1.40%	3.39%	0.90%	1.30%	1.20%	1.10%	4.84%
Cartons / Polycoated	0.84%	0.40%	0.07%	0.60%	NA	NA	0.30%	1.09%
Magazines / Catalogs	0.62%	0.80%	1.00%	1.50%	0.90%	1.60%	0.70%	2.15%
Subtotal Paper	**24.07%**	**21.30%**	**21.35%**	**25.50%**	**26.00%**	**21.10%**	**22.10%**	**29.09%**

Note: Categories and subcategories have been adjusted to provide a like-to-like comparison between the two studies. Subtotals for the mean percentages may not equal the sum of the mean percentages due to rounding.

Material	Michigan	Wisconsin	Ohio	Iowa	Missouri	Illinois	Minnesota	Indiana
Year	2024	2021	2019	2017	2017	2015	2013	2012
Plastic								
PET Bottles #1 / UDC Plastic	1.26%	1.60%	0.63%	1.50%	1.40%	1.20%	0.80%	2.27%
PET Packaging / Containers #1	0.71%	0.40%	0.03%	0.50%	0.20%	0.50%	0.50%	0.78%
HDPE Natural #2	0.86%	0.30%	0.07%	0.50%	0.40%	0.50%	1.10%	1.66%
HDPE Color #2	0.45%	0.50%	0.37%	0.60%	0.50%	0.50%	NA	NA
EPS Foam	0.93%	0.80%	0.67%	0.80%	0.70%	1.00%	NA	0.76%
Mix Plastic Containers #3-7	1.86%	2.90%	0.17%	2.70%	1.00%	1.90%	1.70%	0.78%
Bags, Wraps, Film	3.43%	8.40%	4.00%	8.70%	6.90%	5.80%	6.60%	5.10%
Bulky/Other Plastics	0.47%*	2.30%	5.70%	3.10%	4.10%	5.00%	7.10%	5.35%
Subtotal Plastic	**9.97%***	**17.20%**	**11.64%**	**18.40%**	**15.20%**	**16.40%**	**17.80%**	**16.70%**
Glass / UDC - Glass	2.00%	2.20%	2.00%	2.10%	2.80%	4.20%	2.20%	2.87%
Metals								
Ferrous	2.20%	3.40%	4.27%	3.00%	2.80%	NA	3.40%	5.09%
Non-Ferrous / UDC - Metal	0.91%	1.30%	0.67%	0.90%	1.40%	NA	1.10%	0.77%
Subtotal Metals	**3.11%**	**4.70%**	**4.94%**	**3.90%**	**4.20%**	**4.30%**	**4.50%**	**5.86%**
Organic								
Food Waste	19.16%	19.60%	13.07%	20.0%	15.00%	20.20%	17.80%	9.86%
Wood (product, waste)	8.31%	0.70%	11.87%	2.30%	8.20%	NA	5.70%	6.77%
Other Biowaste	6.23%	5.90%	NA	3.50%	3.10%	3.20%	NA	3.18%
Yard Waste	2.20%	2.00%	6.06%	2.90%	2.60%	5.10%	2.80%	7.08%
Other Organics	0.63%	2.00%	4.76%	4.10%	3.50%	4.70%	4.70%	0.68%
Subtotal Organic	**36.54%**	**30.20%**	**35.76%**	**32.80%**	**32.40%**	**33.20%**	**31.00%**	**27.57%**
Miscellaneous								
Construction & Demolition	1.15%	6.10%	3.03%	2.90%	5.30%	11.00%	NA	5.41%
Electronics	1.52%	1.80%	2.50%	1.40%	1.20%	1.70%	1.20%	1.24%
Textiles	4.10%	5.50%	2.90%	4.10%	4.80%	5.10%	4.70%	5.65%
Bulk Items	3.53%	1.50%	3.30%	NA	4.60%	3.10%	5.70%	2.25%
Other Inorganics*	12.55%	4.30%	15.67%	6.30%	6.30%	NA	10.30%	2.73%
Household Hazardous	1.42%	1.30%	NA	0.90%	0.40%	0.90%	0.40%	0.60%
Subtotal Miscellaneous	**24.27%**	**20.50%**	**27.40%**	**15.60%**	**22.60%**	**21.80%**	**22.30%**	**17.88%**

*Michigan focused on recoverable plastics and included certain bulky or mixed material plastic items in "Other Inorganics" that would have been characterized as "Plastic" in other states.

Data sources: State characterization studies.

Table 2-6: Between State Comparison MSW Disposed Categories - Post COVID (Mean % by weight)
(continued on next page)

Material	Michigan	Pennsylvania	California	Wisconsin
Year	2024	2022	2021	2021
Paper				
Corrugated Cardboard	11.71%	7.30%	4.10%	3.30%
Mixed Paper Recyclable	6.25%	9.60%	4.70%	10.10%
Compostable Paper	3.46%	7.30%	5.60%	5.30%
Office Paper - White and Color	1.19%	0.50%	0.60%	1.40%
Cartons / Polycoated	0.84%	0.30%	0.20%	0.40%
Magazines / Catalogs	0.62%	0.80%	0.40%	0.80%
Subtotal Paper	**24.07%**	**25.80%**	**15.60%**	**21.30%**
Plastic				
PET Bottles #1 / UDC Plastic	1.26%	1.30%	0.60%	1.60%
PET Packaging / Containers #1	0.71%	0.20%	0.20%	0.40%
HDPE Natural #2	0.86%	0.40%	0.40%	0.30%
HDPE Color #2	0.45%	0.40%	0.10%	0.50%
EPS Foam	0.93%	0.90%	0.20%	0.80%
Mix Plastic Containers #3-7	1.86%	1.50%	3.30%	2.90%
Bags, Wraps, Film	3.43%	8.90%	4.00%	8.40%
Bulky/Other Plastics	0.47%	5.30%	4.90%	2.30%
Subtotal Plastic	**9.97%**	**18.90%**	**13.70%**	**17.20%**
Glass	2.03%	2.50%	2.40%	2.20%
Metals				
Ferrous	2.20%	2.50%	3.50%	3.40%
Non-Ferrous / UDC Metal	0.91%	1.40%	1.00%	1.30%
Subtotal Metals	**3.11%**	**3.90%**	**4.50%**	**4.70%**
Organic				
Food Waste	19.16%	17.00%	10.90%	19.60%
Wood (product, waste)	8.31%	6.00%	4.40%	0.70%
Other Biowaste	6.23%	5.60%	3.10%	5.90%
Yard Waste	2.20%	3.50%	6.00%	2.00%
Other Organics	0.63%	2.40%	NA	2.00%
Subtotal Organic	**36.54%**	**34.50%**	**24.40%**	**30.20%**

Note: Subtotals for the mean percentages may not equal the sum of the mean percentages due to rounding. Confidence intervals for primary categories and subcategories are calculated independently.

Table 2-6 Between State Comparison MSW Disposed Categories - Post COVID (Mean % by weight) (continued)

Material	Michigan	Pennsylvania	California	Wisconsin
Year	2024	2022	2021	2021
Miscellaneous				
Construction & Demolition	1.15%	4.20%	9.80%	6.10%
Electronics	1.52%	0.60%	0.90%	1.80%
Textiles	4.10%	4.00%	5.80%	5.50%
Bulk Items	3.53%	3.20%	5.60%	1.50%
Other Inorganics	12.55%	5.70%	17.10%	4.30%
Household Hazardous	1.42%	0.30%	0.20%	1.30%
Subtotal Miscellaneous	**24.27%**	**18.00%**	**39.40%**	**20.50%**

Our findings suggest that Michigan disposes of more corrugated cardboard than any of its peer states, beyond the margin of error for every benchmark except the decade-old Indiana study. When weighting the data to adjust for population size, the share of corrugated cardboard increases. Barring a chronic sampling error, cardboard was more prevalent in Michigan MSW during the summer of 2023 than would have been estimated from peer state benchmarks. The Ohio study included a graphic outlining an "evolving ton" that suggests cardboard is a material that is increasing in prevalence.[8]

Cartons were also more commonly found in Michigan MSW than in other states, beyond the margin of error. Although the advisory council has highlighted that 2023 was a particularly challenging year for end markets of cardboard and cartons, it seems unlikely that the disparity was the result of study timing.

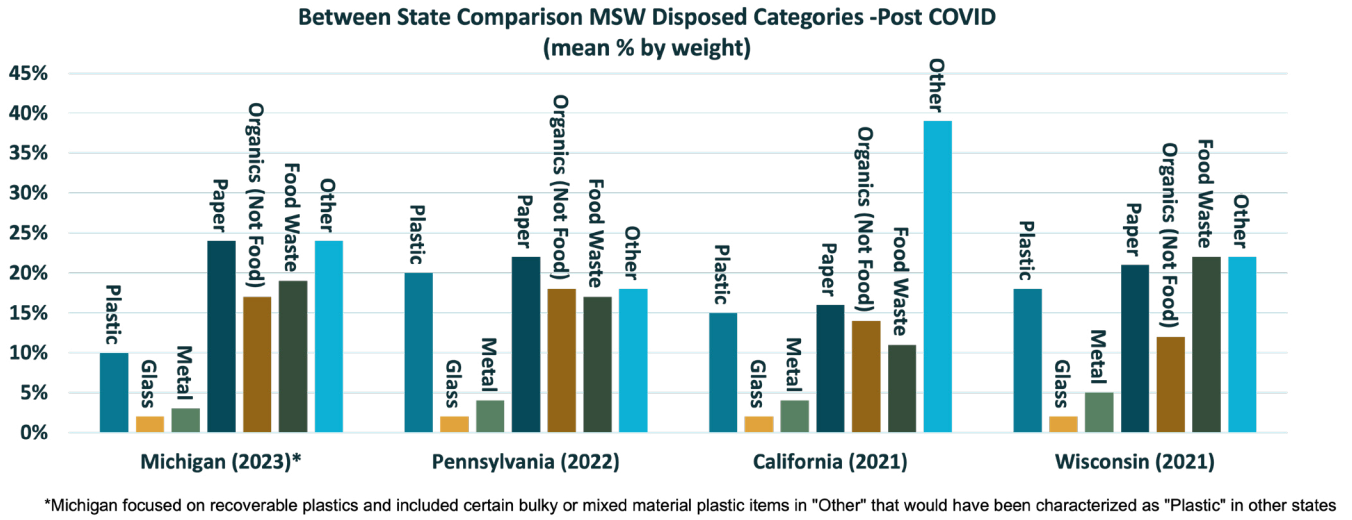
Michigan has a much lower concentration of plastic material in MSW than was found in peer state studies, some of which can be explained by differences in material definition and sorting methodology. This study was designed to identify recoverable materials, especially those with an economic value, and as a result we characterized a larger share of non-recyclable plastic as Other Inorganic.

There is also a statistically smaller share of plastic film in Michigan than Pennsylvania and Wisconsin. Upon review, these states and others appear to have a sizable amount of agricultural film, which was not found in any Michigan samples. This may be a sampling error, but is more likely the result of sampling protocol that included additional sectors in Pennsylvania, Wisconsin and Iowa. It could also speak to the success of Michigan's agricultural plastic recycling program.

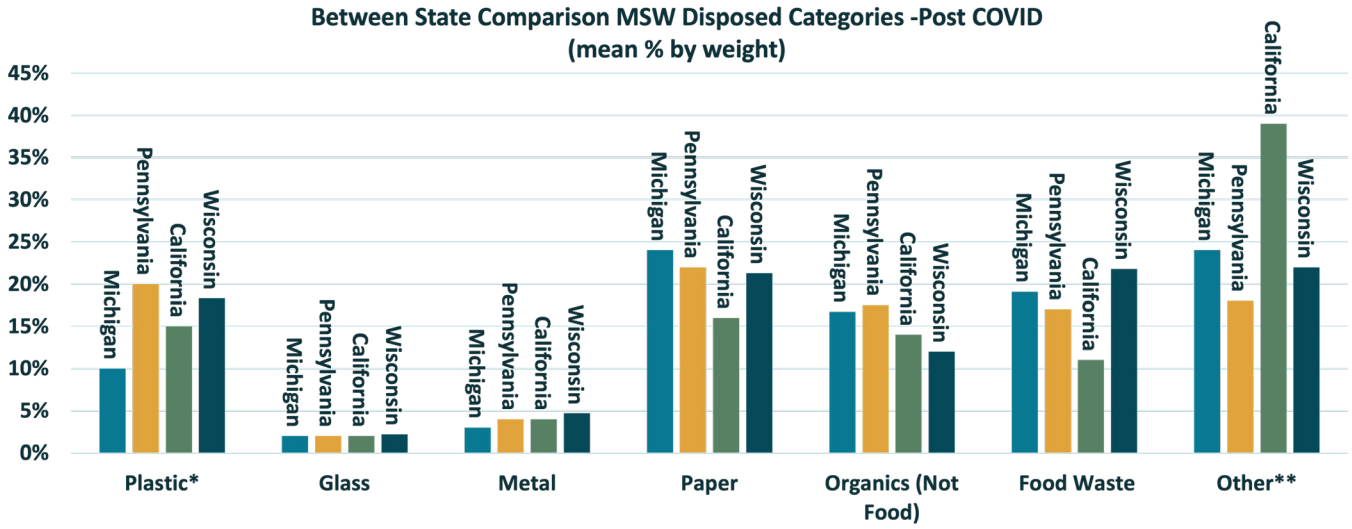
A comparison with post-COVID benchmark states is shown in Figure 2-7 on the following page.

Food waste was the most common material found in both Pennsylvania (17%) and Wisconsin (19.6%), within the margin of error for Michigan MSW (19.16%). In summary, when accounting for protocol inconsistency, and the exceptions highlighted above, Michigan MSW is similar to that of the two post-COVID benchmark states. In comparison to California, which currently has a 40 percent recycling rate, there are dramatic differences.

Figure 2-7: Between State Comparison MSW Disposed Categories - Post COVID



*Michigan focused on recoverable plastics and included certain bulky or mixed material plastic items in "Other" that would have been characterized as "Plastic" in other states



California MSW represents what Michigan MSW will most likely be when it achieves its 45 percent recycling rate.

- Most of California's MSW is difficult to recycle material, with considerably more Other Inorganics than other states.
- California had less paper products in its MSW than any other state, and is one of only two of the states reviewed where compostable paper is the most common paper material; the other is Minnesota, another state with a high-recycling rate.
- Food waste in California MSW is approximately half that of Michigan MSW, reinforcing the importance of the MI Healthy Climate Plan goal to reduce food waste by half.

3-1: Value and Available Quantity of Materials in Michigan MSW

Changing the rate of recycling in Michigan would have many economic effects, including changes in recycling markets and municipal budgets. Recycling rates also affect landfill capacity and real estate values and health outcomes for people living near landfills and incinerators. We consider each of these impacts in this and the following sections.

In Table 3-1 we use the results of the MSW Characterization sorts to estimate the volume of the different materials available for recycling.

A primary benefit of increased recycling is the economic value found from reclaiming these resources and selling them to the market. We have collected commodity prices for each of our composition categories and calculated the value of the material currently being disposed. Our process for defining material value is simple and straight-forward: What will the market pay for a ton of the material in Michigan when processed through conventional recycling or a comparable process?

This information can be found in Table 3-2 on the next page.

Recoverable Plastic and Paper

We collected data on prices from Kent County, Emmett County Recycling, Resource Recovery and Recycling Authority of Southwest Oakland County (RRRASOC) as well as from recycling companies such as PADNOS and Schupan. We observed a significant fluctuation in the prices of certain materials for the past 12 months, requiring us to estimate low price and high price values based on the distribution of the data. Representatives from Michigan recycling and processing firms confirmed the prices used were near competitive market rates for bulk recyclable materials. As required, additional research and analysis was conducted to ensure that data was representative of market conditions in Michigan and the Midwest.

Of note, expanded polystyrene foam can be sold as a recycled commodity if it can be collected and densified. EPS foam recycling resources suggest that densified foam is worth as much as $400 per ton.[9] However, no study group recycler was accepting the material when surveyed, and it would be insincere to suggest that recycling foam is a scalable opportunity at present. (Two of these facilities have since received grants to pilot drop-off programs.) If the practice were to expand considerably, it could be a sizable economic opportunity. This is further discussed on page 62.

Table 3-1: Available Weight by Material Type in Tons

Material	Estimate
Bulk Items	457,392
Bulky Plastics	45,239
Cartons / Polycoated	90,816
Compostable Paper	375,913
Construction & Demolition	166,540
Corrugated Cardboard	1,199,105
Electronics	125,026
Ferrous Metal	311,100
Food Waste	2,019,316
Glass	169,187
HDPE Color #2	30,246
HDPE Natural #2	85,891
Household Hazardous Waste	161,589
Magazines / Catalogs	51,378
Mix Plastic Containers #3, 6, 7	91,697
Mixed Paper Recyclable	558,454
Non-Ferrous Metal	81,365
Office Paper - White and Color	124,518
Other Biowaste	368,437
Other Inorganics	882,580
Other Organics	21,760
PET Bottles #1	111,271
PET Packaging / Containers #1	77,816
Plastics Bags / Wraps/ Film	341,585
Polypropylene #5	92,181
Polystyrene (EPS Foam)	91,697
Textiles	271,893
UDC - Glass	6,497
UDC - Metal	19,113
UDC – Plastic	11,917
Wood (product, waste)	446,987
Yard Waste	104,995

Compostable Organics

We assume that organic materials such as yard waste, food waste, wood waste, and compostable paper can be processed to produce compost. Upon consultation with industry experts, we find that the sellable material will yield 30 percent of the original volume, which can be sold at $10-$20 per yard or $30-$60 per ton. Although the 2016 study assumed no value for this material, after much conversation and debate it was determined that the several month time period required to process organic material into a marketable commodity was not meaningfully different than the time period conventionally recycled commodities stay on site awaiting a buyer, with similar costs for labor and processing. Other Biowaste and Other Organics are omitted, as many or most composters will not accept some or all of this material.

Textiles

The value of textiles in municipal solid waste is the subject of much debate. There is a robust secondary and tertiary market for textile products, especially used clothing. However, industry stakeholders highlight that all textiles do eventually end up in the landfill, and it is difficult to determine where materials sampled in this study currently were in the product life cycle. Optimistically, no more than one quarter of the material sampled was clothing that could have been diverted to a resale market if it were not disposed of in the landfill, with the balance rags or shredded material that was clearly beyond any further practical use prior to disposal.

Study group findings suggest that approximately 30 percent of donated clothing can be sold in local resale stores, the high-water mark for textile recovery. Clothing currently being disposed of in landfills are unlikely to meet those standards, and will instead be sold in bulk to developing countries (and eventually end up in a landfill or equivalent means of disposal). In this scenario, clean, "gently used" material can be sold for 4 cents to 36 cents per pound ($80 to $720 per ton).

Table 3-2: Estimated Material Prices and Data Sources

Material	Low Price	High Price
Bulk Items	$0.00	$0.00
Bulky Plastics	$10.00	$10.00
Cartons / Polycoated	$114.60	$122.40
Compostable Paper	$30.00	$60.00
Construction & Demolition	$0.00	$0.00
Corrugated Cardboard	$55.00	$69.50
Electronics	$0.00	$0.00
Ferrous Metal	$170.00	$189.54
Food Waste	$30.00	$60.00
Glass	$0.00	$0.00
HDPE Color #2	$260.00	$320.00
HDPE Natural #2	$1,031.00	$1,320.00
Household Hazardous Waste	$0.00	$0.00
Magazines / Catalogs	$33.76	$71.19
Mix Plastic Containers #3, 6, 7	$20.00	$30.00
Mixed Paper Recyclable	$33.76	$71.19
Non-Ferrous Metal	$1,360.00	$1,440.00
Office Paper - White and Color	$245.00	$268.00
Other Biowaste	$0.00	$0.00
Other Inorganics	$0.00	$0.00
Other Organics	$0.00	$0.00
PET Bottles #1	$227.67	$258.00
PET Packaging / Containers #1	$222.00	$248.80
Plastics Bags /Wraps / Film	$91.60	$279.90
Polypropylene #5	$148.00	$164.00
Polystyrene (EPS Foam)	$0.00	$0.00
Textiles	$80.00	$120.00
UDC - Glass	$60.00	$60.00
UDC - Metal	$1,360.00	$1,440.00
UDC – Plastic	$227.67	$258.00
Wood (product, waste)	$30.00	$60.00
Yard Waste	$30.00	$60.00

Data Sources: Kent County, Emmett County Recycling, Resource Recovery and Recycling Authority of Southwest Oakland County (RRRASOC), PADNOS, Schupan, Goodwill Industries of West Michigan, EGLE, Spurt Industries.

There is also a recycling market for source-separated textiles such as pure cotton and pure polyester, which can be sold near the top of the per-pound price range for international resale. Pure cotton and pure polyester clothing with no or limited mixed materials (e.g.: collars, buttons and tags) together represent approximately half of the material currently being donated to local resale stores. Rarer textiles such as wool and silk have higher salvage value: Wool can be sold for as much as $1 per pound, for instance, but represented just 0.04 percent of the resale clothing at a representative resale operation surveyed for this study.

Cleaning and processing this material for recycling by hand is estimated to cost as much as $4 per pound. There has been substantial investment in the development of more cost-efficient recycling approaches, and advanced recycling opportunities for other textile materials, mixed-material textiles, and definitively end-of-life products, but these remain unproven and hypothetical at scale.

Based on an estimate of 25 percent of material being salvageable for international clothing resale, we can estimate a reasonable range of $20 to $180 per ton, with a median range (40th to 60th percentile) of $80 to $120 per ton.

Glass and Unredeemed Deposit Containers

Plastic and aluminum beverage containers that could have been redeemed through Michigan's deposit law were given the same value as their composition material.

Recycling facilities that process MSW universally indicated that glass has a negative value in their operations, meaning that they have to pay their customers to take it. As such, we confidently list a $0 value for glass from MSW. There exists the potential for infrastructure improvements to over time increase the value of glass in the state, but that scenario is hypothetical.

However, glass that is processed through the deposit redemption program is sold to end markets in Michigan for $60 per ton. As such, a positive value is listed for unredeemed deposit containers composed of glass.

Electronics, C&D, HHW and Non-Recoverable Material

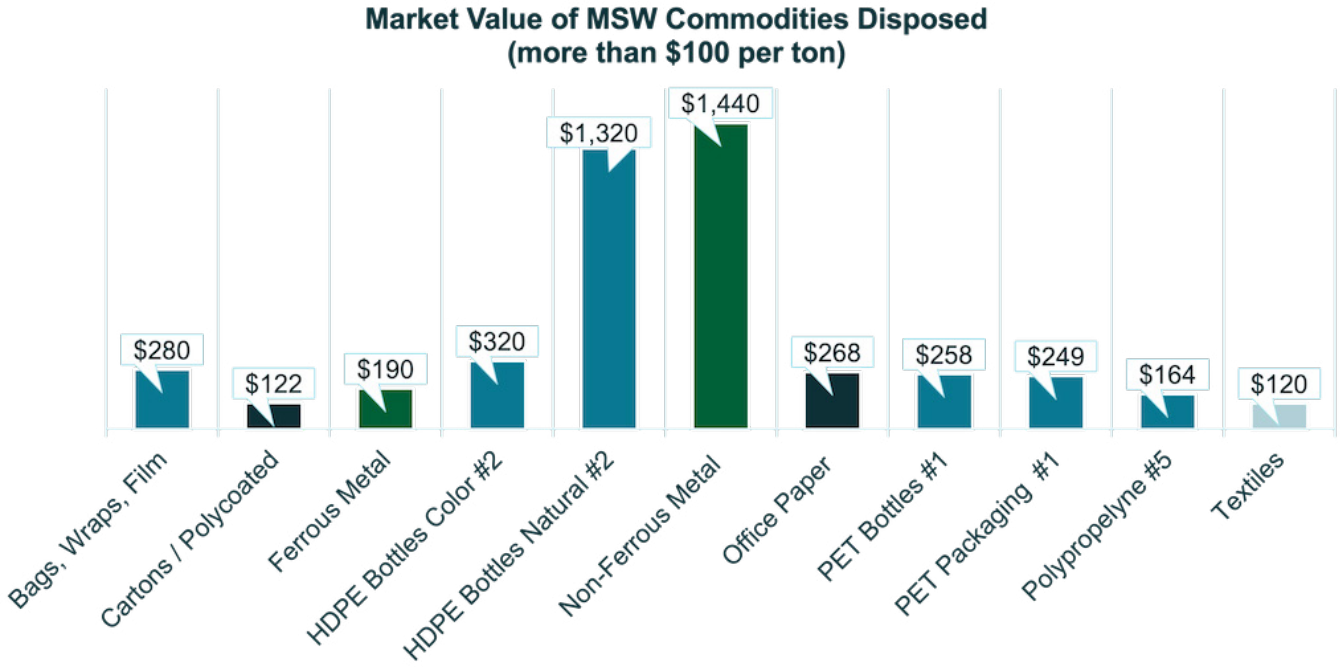
Electronics (including wires, cords, cell phones, and appliances) and inorganic/non-compostable materials were all valued at zero based on historical data and discussions with the representatives of relevant recycling facilities and companies.

We consulted with local electronics recyclers to analyze the complete list of electronics and appliances gathered by waste characterization staff. Some portion of the materials was recyclable, but had a sufficiently low market value that the recyclers indicated it would not be profitable to process them.

While electronics such as computers, monitors, and printers have value for e-waste recyclers, little of this material was found in this study. Further and most importantly for our protocol, processing electronic waste to recover materials is not an equivalent process in terms of labor or cost to conventional recycling. This result is consistent with previous findings in Michigan and other states.

Construction & demolition waste was given a zero value as no conventional recycling equivalent exists for recovering the material from MSW. Household hazardous waste and all non-recyclable material was also given a zero value.

Figure 3-1: Market Value of MSW Commodities Disposed (high price, $ per ton)



3-2: Value of Materials in Michigan MSW

We estimate the value of recyclables currently disposed of in Michigan landfills and incinerators by multiplying our estimate of the available MSW, the percent of each type in the waste stream, and the price of a ton of each material. To account for the contamination of recycled materials and handling in the materials processing facilities we multiply this number by 0.9 for all materials except textiles and organic waste. Textiles would presumably be collected as a separate stream with a greater potential for loss and uncertainty, and so we multiply it by 0.8. Meanwhile, we multiply the materials for composting by 0.3 to account for the volume reduction due to the composting process.

We compute the change in quantity comparing the maximum possible increase in recyclable materials in Michigan against the latest available national market size[10]. The market values of the available recyclables shown in Table 3-3 indicate that there is between $500 million and $676 million in available recyclable materials currently being disposed of in incinerators and landfills in Michigan. These estimates assume that the additional recyclable materials from Michigan will not significantly change market prices. Hence, these estimates can be argued to be the ceiling on the values given current market conditions.

However, it may be expected that an increase in recyclable materials would also increase the total amount of material available in the market. This increase in supply would likely push down the per-ton market price of these materials. We estimate the change in market price given a change in quantity using an "elasticity" estimate for this relationship defined by economist Karen Palmer and co.[11] After incorporating the decline in market prices, we estimate that the available recyclable materials in Michigan can be valued at between $432 million and $576 million. These estimates can be argued to be a floor of our value estimates. As more recyclable materials are collected without creating new markets, prices may be expected to move from the ceiling towards the floor.

For comparison, the 2016 Michigan MSW characterization study estimated the value of the state's 8.4 million tons of landfilled materials at between $293 million and $368 million. As infrastructure and demand for recycled materials grow, so does the lost opportunity for economic impact.

Table 3-3 Market Value of Available Recyclables

Material	Available Quantity	Quality Adjustment	Low Price	High Price	Low Price Total Value*	High Price Total Value*
Bulk Items	457,392	0.9	0.00	0.00	0	0
Bulky Plastics	45,239	0.9	$10.00	$10.00	$407,153	$407,153
Cartons / Polycoated	90,816	0.9	$114.60	$122.40	$9,366,811	$10,004,343
Compostable Paper	375,913	0.3	$30.00	$60.00	$3,383,219	$6,766,439
Construction & Demolition	166,540	0.9	0.00	0.00	0	0
Corrugated Cardboard	1,199,105	0.9	$55.00	$69.50	$59,355,715	$75,008,357
Electronics	125,026	0.9	0.00	0.00	0	0
Ferrous Metal	311,100	0.9	$170.00	$189.54	$47,598,263	$53,068,144
Food Waste	2,019,316	0.3	$30.00	$60.00	$18,173,845	$36,347,690
Glass	169,187	0.9	0.00	0.00	0	0
HDPE Bottles Color #2	30,246	0.9	$260.00	$320.00	$7,077,476	$8,710,740
HDPE Bottles Natural #2	85,891	0.9	$1,031.00	$1,320.00	$79,698,355	$102,038,631
Household Hazardous Waste	161,589	0.9	0.00	0.00	0	0
Magazines / Catalogs	51,378	0.9	$33.76	$71.19	$1,560,991	$3,291,778
Mix Plastic Containers #3, 6, 7	91,697	0.9	$20.00	$30.00	$1,650,538	$2,475,806
Mixed Paper Recyclable	558,454	0.9	$33.76	$71.19	$16,967,075	$35,779,731
Non-Ferrous Metal	81,365	0.9	$1,360.00	$1,440.00	$99,590,806	$105,449,089
Office Paper - White and Color	124,518	0.9	$245.00	$268.00	$27,456,193	$30,033,713
Other Biowaste	368,437	0.9	0.00	0.00	0	0
Other Inorganics	882,580	0.9	0.00	0.00	0	0
Other Organics	21,760	0.9	0.00	0.00	0	0
PET Bottles #1	111,271	0.9	$227.67	$258.00	$22,799,312	$25,837,071
PET Packaging / Containers #1	77,816	0.9	$222.00	$248.80	$15,547,648	$17,424,238
Plastic Bags/Wraps/Film	341,585	0.9	$91.60	$279.90	$28,160,276	$86,049,933
Polypropylene #5	92,181	0.9	$148.00	$164.00	$12,278,574	$13,605,987
Polystyrene	91,697	0.9	0.00	0.00	0	0
Textiles	271,893	0.8	$80.00	$120.00	$17,401,180	$26,101,770
UDC - Glass	6,497	0.9	$60.00	$60.00	$350,836	$350,836
UDC - Metal	19,113	0.9	$1,360.00	$1,440.00	$23,394,035	$24,770,155
UDC – Plastic	11,917	0.9	$227.67	$258.00	$2,441,720	$2,767,053
Wood (product, waste)	446,987	0.3	$30.00	$60.00	$4,022,882	$8,045,763
Yard Waste	104,995	0.3	$30.00	$60.00	$944,953	$1,889,906
TOTAL:	**8,993,502**				**$499,627,857**	**$676,224,324**

*A quality adjustment calculation has been made by the factor noted above to account for contamination, loss of mass in compost process, and other shrinkage. .

Figure 3-2: Total Value of Michigan MSW Disposed by High Price ($)

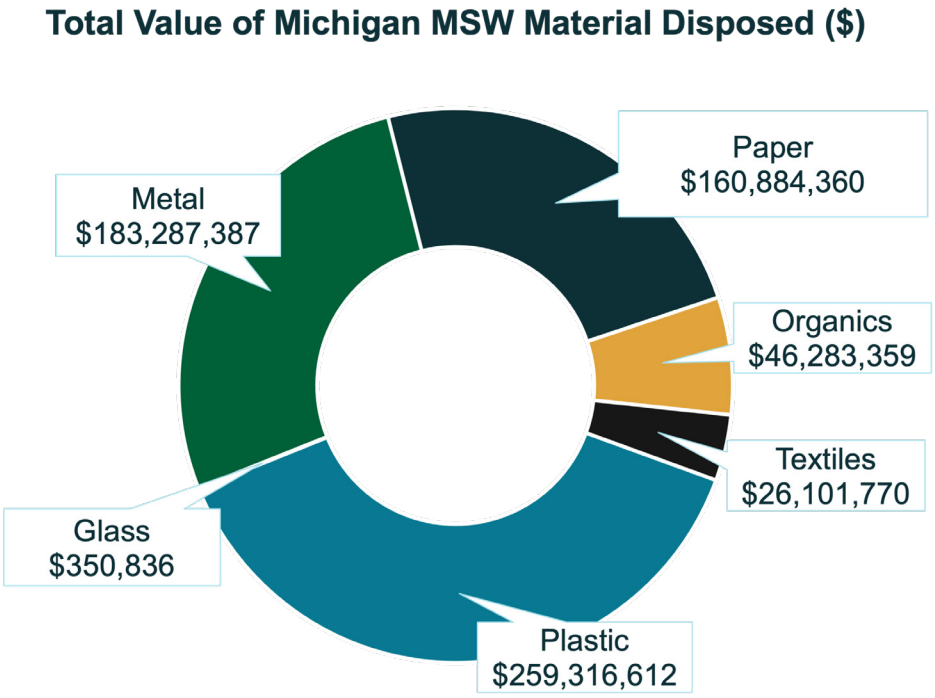
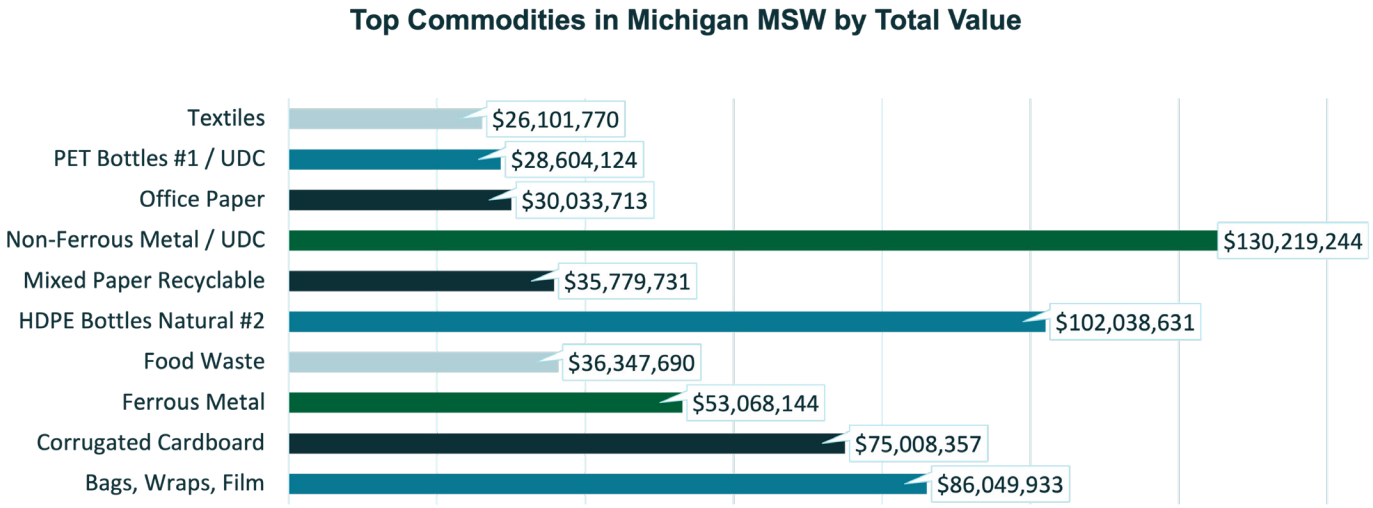


Figure 3-3: Top Commodities in Michigan MSW by Total Value (High Price)



Implications

First, we should note that the value of ferrous metals may be overstated. The ferrous metal reclaimed from incinerator ash in Kent County is by definition available to be reclaimed from MSW disposed through diversion efforts. However, the diversion of this material from MSW disposed would not be a net gain for recovered material in the state, as increases in diversion of this material would represent a corresponding decrease in its reclamation from incinerator ash.

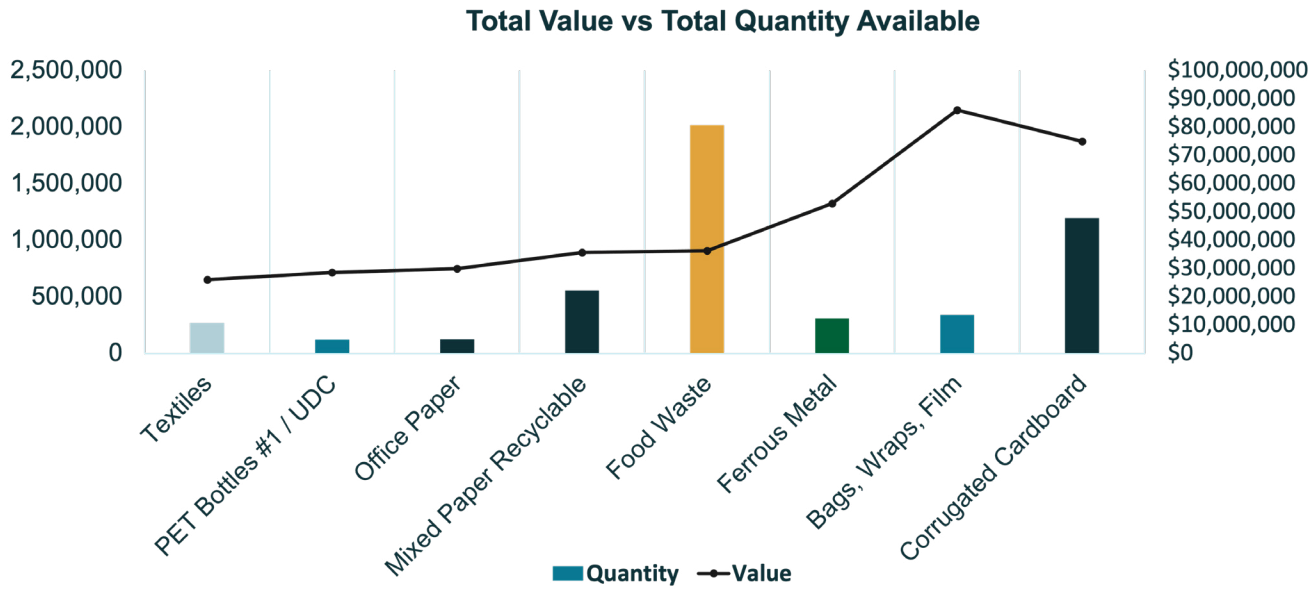
We have not made an adjustment to the available material value based on incinerator ash reclamation, or for that matter, other salvage or reclamation activities that may occur after materials arrive at a landfill, incinerator or transfer station that we may not be aware of. We do take this into consideration as part of the economic impact projection.

It should be highlighted that of the 32 categories we reported, only 23 categories analyzed in the characterization have any material value to the market, while the remaining nine have zero values. This is detailed in Table 3-2 and 3-3 in this section.

Due largely to the presence of HDPE plastic, plastic packaging would offer the most aggregate material value to the state. This is followed by metals (ferrous and non-ferrous), corrugated cardboard, compostable materials, paper, and textiles.

Total material value is not the best method to evaluate opportunity for diversion improvements. For instance, non-ferrous metal (i.e.: aluminum) represents the largest material valuation at 15.6 percent of the available material value with a high-price estimate of $105.4 million. Yet it is only 0.9 percent of the aggregate statewide composition of MSW disposed. The same can be said of other waste categories, including HDPE bottles, plastic bags, and ferrous metal. Figure 3-3 expresses these discrepancies below.

Figure 3-4: Highest Value Commodities in Michigan MSW by Available Quantity



Meanwhile, we see that one material exemplifies a relatively high-value, high-quantity scenario: corrugated cardboard. It accounts for about 11.1 percent of the high-price valuation while contributing 13.3 percent of the volume generated, when adjusted for population density.

3-3: Operating Costs and Externalities

To fully understand the potential economic impact of increased recycling we must also consider the cost savings inherent in diverting materials from the landfill or incinerator. Using our estimates of non-ash landfill and incinerator tonnage, the data show that almost all (98%) of Michigan MSW is landfilled while about two percent of Michigan MSW is incinerated each year. Each of these types of facilities has its own operating costs, and increased recycling would avoid these costs.

Landfills

Two approaches to valuing the financial costs of landfilling material are computing the marginal cost (adding tonnage to a currently operating facility) and computing the average cost of landfilling (the net present value of the average cost per ton added to a facility). People and companies dispose of MSW over time and across geography, so it is not possible to say any particular facility opened because of the failure to recycle materials. Regardless, this material fills facilities and causes the expansion of existing landfills and creation of new facilities over time. Given the ongoing cost of closing old facilities, opening new ones, and operating and expanding existing ones across the state, we use the average cost approach over computing the cost of adding additional tons to an existing landfill.

The cost of landfill construction and maintenance differs considerably across site characteristics.[12] We do not know the geography, regulatory environment, or features of future landfills, and so use multiple cost estimates. The literature provides multiple estimates of landfill construction costs. Scholarly research suggests an average price of $47.04 per ton over the lifetime of a landfill (adjusted from the 2002 value of $27.80 per ton to 2023 dollars using the Bureau of Labor Statistics' Consumer Price Index's (CPI-U) inflation adjustment of 1.692). Available literature also provides a thorough analysis of construction costs under different assumptions and estimates an average cost of $33.43 per ton (adjusted for 2023 prices from the $26.36 average estimate in 2016).

Similar with the 2016 study, we also use the tipping fee currently set by the Kent County Department of Public Works for its facilities. The tipping fee represents the cost of adding tons of MSW to an existing facility and is set at $46.10 per ton for general refuse in 2023.[13] The tipping fee for the Waste-to-Energy facility stood at $74 per ton while the fee for haulers delivering recycling to the Recycling and Education Center remained at $70 per ton for Kent County and $75 per ton for non-Kent County loads. It may be noted that this is lower than the national average of $53.72 per ton as estimated by the Environmental Research & Education Foundation for 2020.[14]

We estimate that the average cost of ton of MSW placed into a landfill is about $46.57 using data from prior research (adjusted for inflation) and the most recent numbers from Kent County. This estimate also omits the possible cost of an extreme outcome, such as when a closed landfill becomes a Superfund cleanup site.

Incinerator

After the demolition of the Detroit facility in June 2023, the only waste incinerator operating in Michigan is the Waste-to-Energy facility in Kent County. In 2022, the MSW incineration facility handled 183,112 tons of MSW and produced 96,624 MWh of electricity. Kent County entered into a new operating agreement in 2023 with Vicinity Energy for its Waste-to-Energy facility, which is expected to save about $1 million annually.

The Department of Public Works has committed $5,998,103 of net position related to waste-to-energy operations. While we did not have access to any recent documentation of the details of operating costs of the Waste-to-Energy facility, we previously estimated an operating cost of about $78.22 per ton of MSW in 2016, which translates to about $99.19 per ton in 2023 dollars. It may be noted that the tipping fee for the Waste-to-Energy facility in Kent County stood at $74 per ton. Given the lack of recent information on the details of operating cost of the facility as well as the transition

to a new management company, we estimate that the average operating cost of the facility to be about $86.60 per ton, which is the average of the tipping fee as well as the inflation-adjusted 2016 estimate.

Material Recovery Facilities

The material recovery facility in Kent County is a modern, single-stream facility that processes a wide variety of recyclable materials. In 2023, the fee for haulers delivering recycling to the Recycling and Education Center stood at $70 per ton for Kent County and $75 per ton for non-Kent County loads.

Indirect Effects

People differ in their willingness to value non-budgetary costs when valuing projects, and increasing recycling is no exception. In this section we examine a variety of other issues which may be of interest to policymakers and the public.

Landfill Capacity

Another benefit of increased recycling is that it would increase the lifespan of existing landfills. According to EGLE, Michigan used 23,185,592 cubic yards of capacity and only has 660,328,440 cubic yards of remaining, approved landfill capacity as of the end of the 2021-2022 fiscal year.[15] If MSW is created at the same rate as during that year, it is estimated that Michigan non-captive landfills have approximately 28 years of remaining disposal capacity left. EGLE notes that this estimate does not take into account possible changes in waste disposal rates, waste diversion programs, or waste import/export authorizations. Removing all recyclable materials of value would reduce MSW significantly, thus substantially extending the lifespan of existing, approved landfill capacity. This would also reduce the need to expand existing facilities and open new facilities over time.

Real Estate Values

A study analyzing housing prices near landfills showed that high-volume landfills (500 tons per day or more) reduce adjacent housing values by 12.9 percent and that rate decreases 5.9 percent per mile, while lower volume landfills decrease adjacent housing values by 2.5 percent on average, decreasing at 1.2 percent per mile.[16] A more recent article[17] presents a meta-analysis of 727 estimates from 83 hedonic pricing studies and finds that property values increase by about 1.5 percent to 2.9 percent per mile of increased distance from a waste site.

Given the uncertain nature of future landfills, we take the average of these numbers: 7.7 percent for adjacent houses decreasing at 2.9 percent per mile. To simplify the analysis we assume the effect ends after two miles and that the effect radiates from a single point. We note that this set of assumptions biases the estimate of damages toward zero.

Landfills are likely to be built in rural areas rather than urban areas. According to the US Census, there are about 178 people per square mile in Michigan or about 103 people per square mile in rural areas in 2020. This is adjusted from the previous estimate of Citizens Research Council of Michigan. Moreover, the state has an average house size of 2.45 people (for 2018-2022) and median house listing price of $278,415. (This represents the average median listing price in Michigan from January[18]). This results in about $11,704,794 in house values for every square mile of rural Michigan property.

A one-mile radius circle around a point contains 3.14 square miles of property (about $36,753,053 in value) while the second mile-wide ring around that contains an additional 9.43 square miles (about $110,376,206 in value). If we estimate the loss in value of homes in the first ring at the average of the adjacent value and the one mile ring (7.7% and 4.8%; 6.3%), and homes in the second mile ring at

the average of those two values (4.8% and 1.9%; 3.4%) the total decrease in housing values would be about $2,297,066 and $3,697,603 for a total of $5,994,669.

According to EGLE solid waste reports, the median landfill in Michigan disposed of 290,785 cubic yards (59,756 tons) during 2021-2022.[19] Assuming the construction of a single landfill of moderate size handling the additional MSW caused by non-recycling would result in a real estate loss of about $100.32 per ton of MSW processed.

We estimate the benefit of increased recycling on real estate near an incinerator at zero, as the Kent county facility may be expected to stay in business even if there is a reduction in waste volumes, and a decrease in volume will have little impact on the visual impact, odor, or psychological effects of living near the facility.

When weighting the real estate loss of $100.32 per ton for landfills by the 97.96 percent of materials sent to landfills (as opposed to incineration), this adds an additional social cost of $98.28 per ton.

Environmental Effects: Greenhouse Gases

The EPA's Waste Reduction Model (WaRM) calculates the outcomes of various waste management techniques in terms of their carbon dioxide equivalent (MTCO2E) across many common materials.[20] The most recent WaRM tool (Version 15) provided the net effect of landfilling or incineration of materials against recycling, with results listed in Table 3-4. We use the baseline assumptions from the calculator, including use of the national average for landfill-gas extraction (since landfills differ across the state).

The table on the next page computes the carbon dioxide improvement from recycling versus landfilling or incinerating for each type of material. We then weigh the improvements in tons of carbon dioxide by type of disposal, assuming two percent of materials are incinerated rather than landfilled, and multiply by the December 2023 auction price in the Regional Greenhouse Gas Initiative of $17.88 per ton.[21]

Environmental Effects and Health Effects

Tables 3-5 and 3-6 contain a variety of estimates of the environmental and health impacts of MSW (adjusted for 2023 dollars). These results vary widely by the pollutants included and the specific setting of the facility. We do not know the conditions of a particular new facility and so use the average of the high and low estimates from each study cited. Note that in each case some value has been given to carbon dioxide so they would not be added to the damage estimates from Table 3-4.

The average values from these two sources are $16.94 per ton of MSW in landfilling and $41.88 per ton of MSW in incinerators or, net of other energy sources, $14.01 per ton of MSW in landfilling and $17.14 per ton of MSW in incinerators; weighted by the percent of MSW that is landfilled or recycled this yields an average environmental impact of $14.08. Given our goal of assessing total social cost we use Method 2, which accounts for the other energy sources displaced.

Table 3-4: Value of MTCO2E, Recycling and Composting Against Landfill Incineration

Material	EPA Category	Emissions Vs Landfill	Emissions Vs Incinerator	Cost per Ton CO2	Cost Savings per Ton
Bulk Items	Mixed Recyclables	-2.887	-2.429	$14.88	$42.83
Bulky Plastics	Mixed Plastics	-0.946	-2.185	$14.88	$14.45
Cartons / Polycoated	Mixed Paper (primarily residential)	-3.561	-3.057	$14.88	$52.83
Compostable Paper	Newspaper	-1.862	-2.150	$14.88	$27.80
Construction & Demolition	Mixed MSW	N/A	N/A	$14.88	N/A
Corrugated Cardboard	Corrugated Containers	-3.317	-2.646	$14.88	$49.15
Electronics	Mixed Electronics	-0.806	-1.172	$14.88	$12.10
Ferrous Metal	Steel Cans	-1.852	-0.241	$14.88	$27.07
Food Waste	Food Waste	N/A	N/A	$14.88	N/A
Glass	Glass	-0.296	-0.303	$14.88	$4.41
HDPE Bottles Color #2	HDPE	-0.779	-2.044	$14.88	$11.97
HDPE Bottles Natural #2	HDPE	-0.779	-2.044	$14.88	$11.97
Household Hazardous Waste	Mixed MSW	N/A	N/A	$14.88	N/A
Magazines / Catalogs	Magazines/third-class mail	-2.643	-2.716	$14.88	$39.35
Mix Plastic Containers #3, 6, 7	Mixed Plastics	-0.946	-2.185	$14.88	$14.45
Mixed Paper Recyclable	Mixed Paper (general)	-3.620	-3.054	$14.88	$53.70
Non-Ferrous Metal	Aluminum Cans	-9.148	-9.162	$14.88	$136.12
Office Paper - White and Color	Office Paper	-3.998	-2.393	$14.88	$59.00
Other Biowaste	Mixed MSW	N/A	N/A	$14.88	N/A
Other Inorganics	Mixed MSW	N/A	N/A	$14.88	N/A
Other Organics	Mixed Organics	N/A	N/A	$14.88	N/A
PET Bottles #1	PET	-1.056	-2.277	$14.88	$16.08
PET Packaging / Containers #1	PET	-1.056	-2.277	$14.88	$16.08
Plastic Bags / Wraps / Film	Mixed Plastics	-0.946	-2.185	$14.88	$14.45
Polypropylene #5	PP	-0.814	-2.082	$14.88	$12.50
Polystyrene	PS	N/A	N/A	$14.88	N/A
Textiles	Mixed Recyclables	-2.887	-2.429	$14.88	$42.83
UDC - Glass	Glass	-0.296	-0.303	$14.88	$4.41
UDC - Metal	Mixed Metals	-4.411	-3.370	$14.88	$65.33
UDC – Plastic	Mixed Plastics	-0.946	-2.185	$14.88	$14.45
Wood (product, waste)	Branches	N/A	N/A	$14.88	N/A
Yard Waste	Yard Trimmings	N/A	N/A	$14.88	N/A

Table 3-5: Total Environmental and Health Effects, 2023 Dollars (Method 1)[22]

Facility	Author	Year	Low	High	Avg of High and Low
Landfill	Schall	1992	$4.00	$23.39	$13.69
	CSERGE	1993	$1.50	$24.22	$12.86
	Powell and Brisson	1994	$2.65	$10.58	$6.61
	Enosh	1996	$10.75	N/A	$10.75
	EMC	1996	$4.96	N/A	$4.96
	Miranda and Hale	1997	$4.00	$21.77	$12.88
	EU	2000	$9.93	$72.78	$41.35
	ENOMIA	2002	$12.42	$16.85	$14.64
	Dijkgraaf	2003	$34.74	N/A	$34.74
	Average				**$16.94**
Incinerated	Tellus	1992	$1.66	$8.27	$4.96
	CSERGE	1993	$9.54	$32.75	$21.14
	Powell and Brisson	1994	-$3.15	$10.43	$3.64
	ECON	1995	$46.32	$282.86	$164.59
	ECON	1996e	$2.15	N/A	$2.15
	Enosh	1996	$16.69	N/A	$16.69
	EMC	1996	$2.73	N/A	$2.73
	Miranda and Hale	1997	$8.55	$52.11	$30.33
	Rabl et al.	1998a	$20.35	N/A	$20.35
	ExternE	1998	$24.81	$152.18	$88.50
	EU	2000	-$9.01	$205.11	$98.05
	EUNOMIA	2002	$48.61	$75.84	$62.23
	Dijkgraaf	2003	$29.07	N/A	$29.07
	Average				**$41.88**

Table 3-6: Total Environmental and Health Effects, 2023 Dollars (Method 2)

Facility	Type	Damages per US ton of MSW
Landfill	No energy recovery	$15.13
	Electricity recovery replacing coal and oil	$12.90
Incinerator	Electricity recovery replacing coal and oil	$18.80
	Electricity and heat recovery replacing coal and oil	$15.49

3-4: Total Impact of Recycling

The impact of increasing recycling varies depending on the materials diverted from the MSW stream, where it is sent for processing, and what non-budgetary impacts are included.

The budgetary costs of one ton of recyclables placed in the MSW stream for landfilling or recycling is:

$$Cost_{Landfill} * ProportionMSW_{Landfill} + Cost_{Incinerate} * ProportionMSW_{Incinerate}$$

Or

$$\$46.57/ton * 0.9796 + \$86.60/ton * 0.0204$$

This yields an average operating cost for disposing of MSW of $47.39 per ton of MSW.

The real estate loss of $100.32 per ton for landfills (weighted by the 97.96 percent of materials sent to landfills) adds an additional social cost of $98.27 per ton, for a total processing cost of $145.66. Adding in environmental and health effects, weighted by the percent of materials sent to landfills versus incinerators yields an additional average cost of $14.08 per ton of MSW. Adding together the operations cost of landfills and incinerators, the impact on property values, and other environmental and health effects yields a total social cost of $159.74 per ton of MSW.

While recycling materials saves on these costs, it must be processed. The total cost of sending the materials to a MRF is the gross cost of processing net of the revenues from selling the recycled materials. Due to lack of information on the operating costs of Kent County's MRF, we use the tipping fee as proxy for the cost of sending materials to MRFs. According to the Kent County Department of Public Works, in 2023, the fee for haulers delivering recycling to the Recycling and Education Center remained at $70 per ton for Kent County and $75 per ton for non-Kent County loads, or an average of $72.50 per ton.

This total benefit is measured against the cost of MRF sorting in table 3-7. Here we see a per-ton metric for the net impact of recycling each type of material. For the case of PET plastic, diverting one ton of material out of the MSW stream into recycling yields a gain between $427.26 and $476.52 in total social benefits per ton. For office paper, the values range from $444.59 to $588.18 in total social benefits per ton.

Table 3-7: MRF Cost Net of Recycling Benefits ($)

	Benefit Measures		Material Price		Lowest Benefit	Highest Benefit	Recycling Value, Net MRF	
	Ops+RE +RSZ	Ops+RE +RSZ	Low	High	Low	High	Low	High
Bulk Items	$272.09	$258.01	$0.00	$0.00	$258.01	$272.09	$185.51	$199.59
Bulky Plastics	$272.09	$286.56	$10.00	$10.00	$282.09	$296.56	$209.59	$224.06
Cartons / Polycoated	$272.09	$347.36	$114.60	$122.40	$386.69	$469.76	$314.19	$397.26
Compostable Paper	$272.09	$315.10	$30.00	$60.00	$302.09	$375.10	$229.59	$302.60
Construction & Demolition	$272.09	$258.01	$0.00	$0.00	$258.01	$272.09	$185.51	$199.59
Corrugated Cardboard	$272.09	$343.47	$55.00	$69.50	$327.09	$412.97	$254.59	$340.47
Electronics	$272.09	$258.01	$0.00	$0.00	$258.01	$272.09	$185.51	$199.59
Ferrous Metal	$272.09	$302.87	$170.00	$189.54	$442.09	$492.41	$369.59	$419.91
Food Waste	$272.09	$319.68	$30.00	$60.00	$302.09	$379.68	$229.59	$307.18
Glass	$272.09	$266.21	$0.00	$0.00	$266.21	$272.09	$193.71	$199.59
HDPE Color #2	$272.09	$279.81	$260.00	$320.00	$532.09	$599.81	$459.59	$527.31
HDPE Natural #2	$272.09	$279.81	$1,031.00	$1,320.00	$1,303.09	$1,599.81	$1,230.59	$1,527.31
Household Hazardous Waste	$272.09	$258.01	$0.00	$0.00	$258.01	$272.09	$185.51	$199.59
Magazines / Catalogs	$272.09	$379.15	$33.76	$71.19	$305.85	$450.33	$233.35	$377.83
Mix Plastic Containers #3, 6, 7	$272.09	$286.56	$20.00	$30.00	$292.09	$316.56	$219.59	$244.06
Mixed Paper Recyclable	$272.09	$349.33	$33.76	$71.19	$305.85	$420.51	$233.35	$348.01
Non-Ferrous Metal	$272.09	$329.73	$1,360.00	$1,440.00	$1,632.09	$1,769.73	$1,559.59	$1,697.23
Office Paper - White and Color	$272.09	$392.68	$245.00	$268.00	$517.09	$660.68	$444.59	$588.18
Other Biowaste	$272.09	$258.01	$0.00	$0.00	$258.01	$272.09	$258.01	$272.09
Other Inorganics	$272.09	$258.01	$0.00	$0.00	$258.01	$272.09	$185.51	$199.59
Other Organics	$272.09	$258.01	$0.00	$0.00	$258.01	$272.09	$185.51	$199.59
PET Bottles #1	$272.09	$291.02	$227.67	$258.00	$499.76	$549.02	$427.26	$476.52
PET Packaging / Containers #1	$272.09	$291.02	$222.00	$248.80	$494.09	$539.81	$421.59	$467.31
Plastic Bags / Wraps / Film	$272.09	$286.56	$91.60	$279.90	$363.69	$566.47	$291.19	$493.97
Polypropylene #5	$272.09	$281.39	$148.00	$164.00	$420.09	$445.39	$347.59	$372.89
Polystyrene Foam	$272.09	$296.00	$0.00	$0.00	$272.09	$296.00	$199.59	$223.50
Textiles	$272.09	$258.01	$80.00	$120.00	$338.01	$392.09	$265.51	$319.59
UDC - Glass	$272.09	$266.21	$60.00	$60.00	$326.21	$332.09	$253.71	$259.59
UDC - Metal	$272.09	$312.29	$1,360.00	$1,440.00	$1,632.09	$1,752.29	$1,559.59	$1,679.79
UDC – Plastic	$272.09	$286.56	$227.67	$258.00	$499.76	$544.56	$427.26	$472.06
Wood (product, waste)	$272.09	$258.01	$30.00	$60.00	$288.01	$332.09	$215.51	$259.59
Yard Waste	$272.09	$258.01	$30.00	$60.00	$288.01	$332.09	$215.51	$259.59

3-5: Employment Impact

Increasing recycling will create jobs in Michigan. The value of recyclable materials diverted from landfills and incinerators to markets will eventually end up with households through increased employment and profits by waste haulers and recycling processors, and also through purchases of goods and services to support these businesses.

Since very little virgin material (particularly plastics and metals) is extracted in Michigan, we assume all of the revenues from the sale of recyclables can be counted as new household spending. Using RIMS multipliers[23] for the state of Michigan from 2022, we find extracting recycling from the MSW stream would create between 3,317 and 4,490 full time equivalent jobs in Michigan with a total effect of between $610 and $825 million dollars, as shown in Table 3-8 below.

Values were computed using current market prices, not adjusted for elasticity.

Table 3-8: Employment and Total Financial Effect of Increased Recycling

Value Reclaimed	Jobs Created	Total Effect Multiplier	Total Effect
$499,627,857	3,317	1.22	$609,764,673
$676,224,324	4,490	1.22	$825,289,659

4-1: Findings and Conclusions

In the preceding sections, we have accomplished the primary objectives of this study, which was to provide information and analysis on the composition of municipal solid waste currently landfilled and incinerated in Michigan, and the economic value of this material. Its findings are derived entirely from field studies, verifiable market prices for recycled commodities, and peer-reviewed academic studies.

As detailed in Section 3, we estimate total material value of Michigan MSW disposed in landfills and incinerators of as much as $676 million. If all of this material was recovered and sold to the market, it would have an estimated total economic impact of up to $825 million.

In Table 4-2 on the following page we have summarized our findings for material composition and valuation, as well as the net recycling value per ton after accounting for indirect benefits and processing costs. Together this data quantifies characterization of Michigan MSW disposed in landfills and incinerators by aggregate commodity value and as a net impact for recyclers and recycling communities.

In the following section, we will provide additional analysis on topics of unique interest to the advisory committee, MiSBF members, and the public.

But first, it should be noted that if the solid waste generated per capita is maintained, we expect Michigan's solid waste generation to follow the population growth rate. Assuming no significant changes in material prices, we anticipate that the value of recyclable materials will grow from $500-$676 million in 2022 to $527-$713 million by 2035, as shown in Table 4-1 below.

Table 4-1: Michigan Material Valuation Projection

	2023	2025	2030	2035
Population Projection*	10,033,757	10,202,350	10,424,510	10,569,985
MSW (tons)	8,993,502	9,154,045	9,353,377	9,483,904
Low Price (Adj) Total Value	$499,627,857	$508,546,694	$519,620,466	$526,871,805
High Price (Adj) Total Value	$676,224,324	$688,295,577	$703,283,441	$713,097,809

Source: Population data from 2022 from State of Michigan. Population projection from Michigan Dept of Technology, Management and Budget.

Each year that Michigan does not make the investments in infrastructure, adopt the new business practices, provide the necessary education to stakeholders, or advance and execute the public policy needed to increase the recycling rate the state will lose at least a half billion dollars of potential feedstock for its manufacturers, farms and other end markets.

Michigan will dispose of $6.2 billion to $8.3 billion of marketable material through its municipal solid waste stream by 2035, reinforcing the need to prioritize recycling and composting as part of the MI Healthy Climate Plan.

Table 4-2: Michigan Statewide Composition (by weight), Available Material Valuation ($ in millions) and Net Recycling Value ($ per ton)

Material	Comp.	Value	Net	Material	Comp.	Value	Net
Paper				**Metals**			
Corrugated Cardboard	11.71%	$75.0	$340.47	Ferrous	2.20%	$53.1	$419.91
Mixed Paper Recyclable	6.25%	$35.8	$348.01	Non-Ferrous	0.69%	$105.5	$1,697.23
Compostable Paper	3.46%	$6.8	$302.60	UDC - Metal	0.22%	$24.8	$1,679.79
Office Paper - White & Color	1.19%	$30.0	$588.18	**Subtotal Metals**	**3.11%**	**$183.3**	**-**
Cartons / Polycoated	0.84%	$10.0	$397.26				
Magazines / Catalogs	0.62%	$3.3	$377.83	**Organic**			
Subtotal Paper	**24.07%**	**$160.9**	**-**	Food Waste	19.16%	$36.4	$307.18
				Wood (product, waste)	8.31%	$8.0	$259.59
Plastic				Other Biowaste	6.23%	-	-
PET Bottles #1	1.10%	$25.8	$476.52	Yard Waste	2.20%	$1.9	$259.59
UDC - Plastic	0.16%	$2.8	$199.59	Other Organics	0.63%	-	$199.59
PET Packaging / Containers	0.71%	$17.4	$467.31	**Subtotal Organic**	**36.54%**	**$46.3**	**-**
HDPE Natural #2	0.86%	$102.0	$1,527.31				
HDPE Color #2	0.45%	$8.7	$527.31	**Textiles**	4.10%	$26.1	$319.59
Expanded Polystyrene Foam	0.93%	-	$223.50				
Mix Plastic Containers #3-7	0.93%	$2.5	$244.06	**Other Wastes**			
Polypropylene #5	0.93%	$13.6	$372.89	C & D	1.15%	-	$199.60
Bags, Wraps, Film	3.43%	$86.1	$493.97	Electronics	1.52%	-	$199.60
Bulky Plastics	0.47%	$0.4	$224.06	Bulk Items	3.53%	-	$199.59
Subtotal Plastic	**9.98%**	**$259.3**	**-**	Other Inorganics	12.55%	-	$199.59
				Household Hazardous	1.42%	-	$199.59
Glass				**Subtotal Other Wastes**	**20.17%**	**-**	**-**
Glass	1.84%	-	$199.59				
UDC - Glass	0.19%	$0.4	$259.59				
Subtotal Glass	**2.03%**	**$0.4**	**-**				

Note: Subtotals for the mean percentages may not equal the sum of the mean percentages due to rounding.

4-2: Food Waste

Food waste is the most common material currently disposed of in Michigan's landfills and its one remaining waste-to-energy facility. ReFED, an organization that serves as a national clearinghouse for the food loss and waste reduction movement, estimates that between 2016 and 2021 approximately 950,000 to 1.5 million tons of food waste was disposed of through landfills or incineration each year.[24] This study suggests that there is more food waste in Michigan's waste stream than expected, with approximately 1.5 million tons being disposed of through its MSW alone. When our data is adjusted for population density, that estimate grows to 2 million tons, as it was more prevalent in samples from larger communities.

Beyond its prominence, food waste is uniquely impactful if disposed of in Michigan landfills. Last year, the U.S. EPA attempted to quantify methane emissions into the atmosphere from degrading food waste in MSW landfills for the first time.[25] It found that an estimated 58 percent of the fugitive methane emissions that are released to the atmosphere from MSW landfills are from landfilled food waste. Further, an estimated 61 percent of methane generated by landfilled food waste is not captured by landfill gas collection systems and is released to the atmosphere: Because food waste decays relatively quickly, its emissions often occur before landfill gas collection systems are installed or expanded.

- While total methane emissions from MSW landfills are decreasing due to improvements in landfill gas collection systems, methane emissions from landfilled food waste are increasing.
- For every 1,000 tons (907 metric tons) of food waste landfilled, an estimated 34 metric tons of fugitive methane emissions (838 MT CO2e) are released.
- Nationally, reducing landfilled food waste by 50 percent in 2015 could have decreased cumulative fugitive landfill methane emissions by approximately 77 million metric tons of CO2 equivalents by 2020, compared to business as usual.

To further this dialogue in Michigan, our study highlights the following points specific to food waste:

- Food waste has increased as a percentage of MSW since the last Michigan characterization study in 2015.
- Food waste is more common in residential MSW, where it is 23 percent of material disposed, compared to nine percent in commercial streams.
- California has half as much food waste by percentage as Michigan, a key driver for its high-recycling rate.
- If collected and processed as compost, the food waste in Michigan MSW is worth as much $36 million per year.
- When accounting for social and environmental benefits, including emissions reductions, food waste collected for recycling provides a net value of $307 per ton.
- Further research is necessary to quantify the amount of uneaten food in MSW, as opposed to inedible food scraps (e.g.: carrot top), and donatable food.

4-3: Unclaimed Bottle Deposits

Michigan's deposit return system was enacted by a 1976 citizen initiative and went into effect in December of 1978. It currently covers all soft drink, beer, mixed wine or spirit, or kombucha beverage containers of any material type under one-gallon with a 10-cent consumer deposit eligible for redemption at retail locations selling the same container.

Historically, Michigan's deposit redemption rate has averaged around 95 percent, ranking as one of the highest in the world. However, this redemption rate has seen a steady decline over the past 10 years and dropped by more than 15 percent in 2020 when container returns were halted during the pandemic. Since then, the annual redemption rate has since averaged around 75 percent. These numbers equate to approximately 1 billion unredeemed containers with a deposit value of approximately $100 million foregone each year.

As expected, there was a substantial and statistically significant increase in unclaimed bottle bill containers in comparison to the 2016 study. There are now an estimated 1.3 billion unclaimed bottle bill containers in the municipal waste stream, nearly three times more than in 2016.

When adjusted to align with fiscal year reporting, there is a $22.1 million difference between the estimated containers and the Bottle Bill Escheat, a moderately larger variance than was observed in 2016, but not proportionate to the variance in 2016, perhaps due to the post-pandemic increase in the portion of unclaimed deposits that are now being processed through conventional recycling streams (curbside residential and commercial). To understand this phenomenon, additional data on the usage of conventional recycling is necessary, and potentially estimates for container hoarding, litter and miscellaneous shrinkage. It could also be a sampling error.

However, it is suspicious that the variance remained reasonably consistent with the 2016 study. An unknown amount of fraudulent containers may be entering the system through illegal distribution practices or consumer practices; these fraudulent containers can potentially skew the redemption numbers to appear higher than in reality. Prior reports have estimated there are about 100 million fraudulently returned containers or $10 million in deposits each year.[26] That estimate is consistent with our findings.

Table 4-3: Calculated Deposit Beverage Containers in Michigan MSW

Escheat Basis Year	2020	2013
Est. Containers per Ton MSW	156.9	50.6
Total MSW Basis Year	8,293,390	7,378,758
Total Containers	1,301,272,748	373,365,155
Deposit Value	$130,127,275	$37,336,515
Expected Deposit Value (Escheat)	$108,000,000	$21,500,000
Variance	$22,127,275	$15,836,515

4-4: Electronic Waste, Vapes and Lithium-Ion Batteries

Electronic waste, or e-waste, is one of the most complex streams in MSW, as it is immensely diverse and contains both hazardous and valuable materials. We have defined e-waste as electronic items that are nearing or have reached the end of their usable life, and which have been discarded by a consumer or business. Electronic items are any product requiring a power source, which may or may not include circuitry. Examples include, but are not limited to, computers and computer accessories, televisions, hard copy devices, mobile units, and entertainment systems.

The 2016 Study prioritized data collection for e-waste and analyzed the value and prevalence of the material at length. At the time, we were surprised to find few examples of products commonly associated with the issue, such as cathode ray televisions. We hypothesized that consumers and businesses were unlikely to dispose of computer equipment and TVs through MSW, and will instead dispose of it through a donation center, an electronic recycling event or drop-off. The mean share of electronic waste in Michigan MSW has decreased by more than half since 2015 to approximately one percent of MSW.

Table 4-4: Electronic Waste Sampled

Item	Total Count
Vapes	24
Wires	22
Lights and fans	15
Cords and power strips	14
Phones and accessories	12
Home AV	11
Toys	10
Computers, calculators and accessories	7
Tools	6
Smoke Detector	6
Kitchen/bathroom appliances	5
Personal AV (not phones)	3
Motors	3
Christmas lights	2

Table 4-6 is an inventory of e-waste discovered in samples. Sorters were astonished by the number of electronic cigarette vape pens found in samples. There are an estimated 29 million “vape pens” in the municipal solid waste stream. These are a large, if not the largest, vector for lithium-ion batteries in the state’s MSW, and could be a contributing factor to the increasing number of fires at solid waste management facilities in the state.

Although a characterization of electronic waste to precisely determine the presence of lithium-ion batteries was not practical to accomplish in the field, we can estimate that there are more than 30 million, given the number of vapes, most likely substantially more.

Table 4-5: Estimated Vape Pens in Michigan MSW

Vapes	22
Tons Sampled	6.787555
Est. Containers per Ton MSW	3.241226038
Total MSW (Tons)	8,995,390
Total Vapes in MSW	29,156,092

4-5: A Case for Source Reduction

This study is intended to demonstrate the economic and environmental benefits of recycling in its various forms. We have done so. The economic opportunity is substantial and should be met with a sense of urgency. Likewise, in a vacuum, recycling provides a measurable environmental benefit over the landfill.

But not all recycling (or composting) is mutually beneficial. Some recycling pathways actually have the potential to increase greenhouse gas emissions. For example, modeling by the Oregon DEQ found that drop-off recycling that requires users to transport low-value materials long distances may result in more emissions from personal vehicle use than are offset by the recycling process.[27]

Moreover, even in the case of food waste, which is responsible for enormous amounts of methane emissions from the landfill, the vast majority of emissions occur prior to disposal. Most emissions actually occur during manufacture or production, upstream of the consumer, and cannot be reduced through recycling alone.[28]

Prevention of waste through source reduction and reuse should be prioritized.

- Approximately 59 percent of Michigan MSW are single-use products, and the vast majority of those are low-value materials: 47 percent of Michigan MSW are single-use products with an adjusted high price of less than $72 per ton.*

- There are well-documented operational costs that may prevent the recovery of certain materials at scale. For instance, this study would suggest that the increased collection of plastic bags is a substantial economic opportunity. Bags and film were second only to cardboard as a material with both high value and high supply. But bags tangle processing equipment and impair MRF operations - enough so that many facilities do not accept the material. Enough Michigan communities have attempted to ban their use entirely that the legislature passed along preventing them from doing so.

- Just 17 percent of Michigan MSW are materials with an adjusted high price of more than $72 per ton.*

- Substitution for reusable products could have a substantial impact on the recycling rate, especially for packaging and utensils, as well as napkins and diapers.

- Food loss and waste reduction is a particularly impactful opportunity. Reducing food loss and waste by 50 percent would increase the recycling rate by an equivalent amount.

*Adjusted high price is an estimate based on the 60th percentile of 12 months of data. It is not the highest price paid for the material.

4-6: Value of Recycled Expanded Polystyrene Foam

As discussed in Section 3 and in the 2016 report, expanded polystyrene foam is a controversial material from a recycling perspective. Sustainability programs often prioritize the elimination of EPS foam, especially from food service applications, primarily because of how difficult it is to recycle. In 2016, we argued that EPS foam did not merit the widespread attention it received as an environmental threat at the time, given that it was less than 1 percent of MSW by weight or volume, and had no measurable economic value. We noted that efforts to reduce or divert food waste, paper or other plastic products would have a greater return on investment.

Since that time, the availability of EPS foam recycling has improved, and it is now understood that it can be sold as a recycled commodity wherever it can be collected and densified. EPS foam recycling resources suggest that densified foam is worth as much as $400 per ton. No study group recycler was accepting the material when surveyed, and though a number have made recent investments to begin doing so, it would be insincere to suggest that recycling foam is a scalable opportunity at present.

The Foodservice Packaging Institute has made 32 grants for foam recycling infrastructure since 2015. In 2022 those programs collectively recycled just 700 tons of densified material. If the practice were to expand considerably, it could be a sizable economic opportunity. As such, to fully inform decision-makers in the state, we have conducted a separate analysis below in Table 4-6.

The first row is the value of material based on the range of available prices, based on the estimated available quantity of material and an adjustment for contamination and shrinkage. The second row is an estimate for the price of a ton of densified EPS foam in Michigan if the supply were to increase at scale.

Based on this, in the event that it were possible to scale the collection of EPS foam in Michigan, it would be worth an additional $14 million to $33 million to the value of materials currently being disposed of in the state's MSW. In this scenario, it would be one of the most valuable commodities currently being disposed of in Michigan MSW. Note that price quotes are from industry resources, not Michigan recyclers, and may be an overly optimistic representation of the market.

Table 4-6: Estimated Market Value of EPS Foam in Michigan MSW ($ per Densified Ton)

	Available Quantity	Quality Adjustment	Low Price	High Price	Low Price Total Value	High Price Total Value
No price adjustment	91,697	0.9	$240.00	$400.00	$19,806,451	$33,010,752
Price adjustment	91,697	0.9	$171.53	$285.88	$14,155,618	$23,592,697

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