Circularity Assessment Protocol
Ann Arbor, Michigan, USA

University of Georgia

Circularity Informatics Lab

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The Circularity Informatics Lab at the University of Georgia is committed to information sharing, data analytics, empowering communities, and systems change related to circular materials management.

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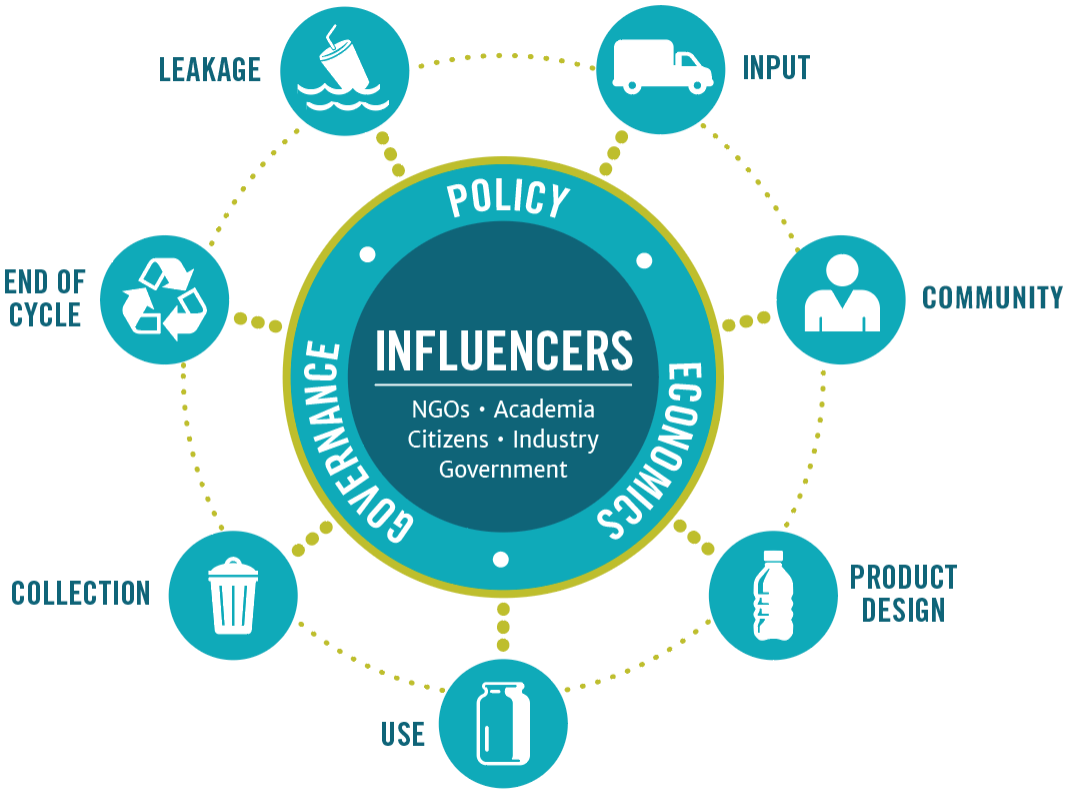
Executive Summary

Developed by the Circularity Informatics Lab at the University of Georgia, the Circularity Assessment Protocol (CAP) is a standardized assessment protocol to inform decision-makers through collecting community-level data on plastic usage. Grounded in materials flow and systems thinking concepts, the CAP uses a hub-and-spoke model to holistically characterize how consumer plastic flows into a community, is consumed, and flows out, either through waste management systems or leakage into the environment. The model, shown below, is comprised of seven spokes: input, community, material and product design, use, collection, end of cycle, and leakage. At the center, the system is driven by policy, economics and governance with key influencers including non-governmental organizations, industry, and government.



In May of 2023, a team from the Circularity Informatics Lab conducted fieldwork in the city of Ann Arbor, Michigan with support from United States Environmental Protection Agency (USEPA) Trash Free Seas program. Fieldwork was conducted in conjunction with Perpetual, Zero Waste Ann Arbor, and Recycle Ann Arbor.

Key Findings

INPUT

Findings: Findings: Based on store sampling, the most common products in the categories of Beverages, Candy, and Chips are as followed: Coca Cola, Gatorade, Mountain Dew, Monster, Red Bull; Reese's, M&Ms, Snickers, Hershey's, Kit Kat; Lays, Doritos, Cheetos, Popcorners, Ruffles. For tobacco, the top brands consisted of Marlboro, Newport, American Spirit, L&M, and Camel.

Opportunities:

- The significant overlap in parent company and manufacturing locations for products in Ann Arbor represent an opportunity for EPR. After the successful passage of a packaging EPR bill in Minnesota, Michigan introduced a bill in August 2024 (Michigan House Bill 5902) that would charge fees based upon type and quantity of packaging used by companies to fund waste collection and management. It would also phase our some chemicals for elimination of use (e.g., PFAS).
- The close minimum location of beverages and candy indicates that there could be opportunity for the city of Ann Arbor to have conversations with nearby cities that house parent companies and manufacturers to articulate a clear vision of what multiple areas and communities in Michigan want for EPR policy.
- Michigan's Electronic Waste Take Back Program has been in effect since 2008, proving that EPR can be done at the state level. EPR proponents in Ann Arbor can use this existing program to understand its strengths and weaknesses and to articulate similar or more robust EPR schemes for plastics.
- There may be an opportunity for Ann Arbor residents to begin considering alternatives to locally sold foam and plastic cups and lids, such as instituting a city-wide reuse system.

COMMUNITY

Findings: Our interviewees felt that the main barriers and challenges to promoting circularity in Ann Arbor included politics, transportation, and storage. Compostable plastics and the upcoming city-wide reuse system were also cited as points of concern, yet some interviewees felt that the recent changes to acceptable compostable materials presented an opportunity for reuse. Many interviewees noted that there is a lot of local interest in circularity, but it is sometimes difficult for people to figure out what they can do on an individual level.

Opportunities:

- Given that the local industrial composting facility recently stated they would no longer accept compostable plastic foodware, there is an opportunity to bolster existing interest in circularity within Ann Arbor by exploring city-wide initiatives such as a reusable foodware system, zero waste practices, and other initiatives that would continue to move away from single-use plastics.

- Concerns over what a city-wide reuse system would look like were shared by interviewees, proving that there is community interest. Further collaboration between Perpetual and community members could help address these concerns before a reuse system is implemented.

PRODUCT DESIGN

Findings: The most popular product materials in most stores are commonly multilayer film and PET. While major grocery stores and smaller, local grocery stores currently offer compostable alternatives to disposables, there is significantly less availability of plastic alternatives in gas stations and convenience stores. The majority of the candy, chips, and beverage products sampled in Ann Arbor were packed in single use plastic.

Opportunities:

- Candy and chips both had relatively low product and packaging mass, because of multilayer film's light weight; beverages had the highest product mass and packaging mass when compared to chips and candy.
- While compostable alternatives to cups, food containers, straws, and utensils could be found at restaurants, there could be an opportunity for more research and effort put into ensuring that compostable fiber containers offered do not contain PFAS or other toxic chemicals.

USE

Findings: Michigan's ban on plastic bag bans has complicated any efforts to institute bans, regulations, taxes, or fees on single-use plastic items. In the wake of this ban, paper bags with labeling denoting them as reusable, compostable, and recyclable have proliferated, presenting an opportunity for clearer labeling and education surrounding the best type of bags for each individual, as well as the accurate disposal methods unique to Ann Arbor's infrastructure.

Opportunities:

- One store in Ann Arbor offered discounts to customers who brought in reusable bags or the store's branded bags. While the statewide "plastic ban ban" inhibits policies to limit use, there are options to allow for positive incentives (such as discounts) to customers who bring in their own bags, tax breaks for local businesses who offer alternatives, or certificate programs for "green" restaurants or skip the SUP campaigns.
- Existing bulk water refill stations are in Ann Arbor grocery stores, representing a potential opportunity to expand refill infrastructure through partnering with this industry and brands.

Findings: Progressively, trash, recycling, and composting pickup services are all available curbside to Ann Arbor residents in single-family homes. Additionally, locals can bring hard-to-recycle materials to the local non-profit, Recycle Ann Arbor (RAA), who run a drop off station and a recovery yard.

COLLECTION

Opportunities:

- The current popularity of the non-profit Recycle Ann Arbor (RAA) proves the general public's interest in having spaces dedicated to hard-to-recycle materials; further data collection on where people may want similar services, what their barriers to participation may be, etc. could be necessary to expand infrastructure in Ann Arbor.
- There may be an opportunity to look at how to expand recycling and composting access to apartment dwellers, through strengthening relationships between apartment owners and service providers.
- Comprehensive monitoring of the different collection models (e.g., repeated litter transects or waste bin overflow assessments) would be useful to help evaluate what may or may not be effective for maximizing collection. Local organizations could collaborate to maximize efficient data collection and monitoring capabilities; this would also provide an opportunity to examine collection gaps and disparities in access across the community.

END OF CYCLE

Findings: Ann Arbor residents generate roughly 2.3 lbs of waste per day, which is less than half of the national average at 4.9 lbs per day. Contamination in recycling streams was mentioned as an issue, with residents potentially being confused about which plastics are recyclable. Additionally, recent composting regulations have caused a need to pivot, with compostable plastics no longer being accepted at the local industrial composting facility.

Opportunities:

- With landfill tipping fees being cheaper than recycling tipping fees, this presents an economic challenge to incentivizing recycling (outside of the container deposit scheme). The City Council has previously voted to increase statewide tipping fees, proving that there is existing interest and support related to this issue.
- Given the growing use of compostable and biodegradable items in various waste streams, there is a growing need to educate consumers about what these product designations mean, what product labels communicate, and how to appropriately manage different materials based on their disposal designations.

LEAKAGE

Findings: Cigarettes were the top littered item, followed by plastic fragments. The most common food plastics found in litter transects include plastic food wrappers, foam or plastic cups or lids, plastic bottle caps, straws, and plastic bottles.

Opportunities:

- Collecting data and monitoring trends over time can provide insight into waste patterns, community needs, and effectiveness of waste management programs. With continued litter monitoring in selected locations, the city may

be able to identify innovative ways to prevent and abate litter in the community.

- Cigarettes are the top litter item, which could be addressed through education campaigns, litter violation enforcement, and further implementation of cigarette collection receptacles in the city. There is currently no local recycling market for cigarettes in Ann Arbor.
- While it is typically difficult to control the packaging of items like food plastic wrappers that are being brought into Ann Arbor, the second most common food plastic litter item, foam or plastic cups or lids, likely originate in Ann Arbor. There may be an opportunity for Ann Arbor residents to begin considering alternatives to locally sold foam and plastic cups and lids, such as instituting a city-wide reuse system or applying for grants to build more robust refill infrastructure.

  The beverage container deposit-return system likely results in less bottles and cans in the litter. The deposit return scheme could potentially be expanded to other high leakage items.

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Introduction

As of 2023, the United States (US) is home to a population of 331 million people (US Census Bureau 2020) and has an average waste generation rate of 2.24 kilograms per person per day, more than twice that of the global rate of 0.74 kilograms per person per day (Kaza et al. 2018). As a high-income nation, waste management in the US is considered advanced due to its well-designed and regulated waste management infrastructure providing high coverage of the country's growing population waste needs. These advanced waste management capabilities are met with some of the highest rates of consumption in the world, with the US generating the largest mass of plastic waste (42 million metric tons in 2016) in the world (Law 2020). The waste in the US is 12% plastic, although the largest percentage of the waste stream is paper/paperboard (23%) and organic materials, like food waste, make up 21.6%. And while nearly 100% of waste is collected in the USA, plastic waste is generally disposed of via landfill (76% by mass), combustion (12%), or recycling (8.7%) (US EPA 2020). However, the US has gained attention in recent years for exporting some of the highest quantities of plastic scrap out of the country for management elsewhere, often to developing countries (Brooks et al. 2018, Law 2020). Further, an estimated 0.28 million metric tons of plastic waste are mismanaged in the USA, with an estimated 0.51–1.45 million metric tons lost to the coastal environments in the US (Law 2020). The focus of the CAP for this project was to look at both plastics and organic materials in the waste stream that could be managed through composting, compostable products, biodegradable products, and plastic packaging.

As one of the largest countries in the world, both in terms of population and land coverage, the US is known for substantial variation in infrastructure and development across regions, states, and cities. For example, the city of Seattle generates 0.95 kilograms per capita per day (Kaza et al. 2018) compared to 3.6 kilograms per person per day in Miami (Circularity Informatics Lab 2021). Substantial focus has been given to large cities and states with progressive waste management strategies, however, there is a lack of focus on regions that are in need of assessment in order to develop appropriate, context-sensitive solutions.

Ann Arbor has a population of about 123,800 people. Of that, 70.2% of the population are white, 6.7% are Black, 16.7% are Asian, 4.6% are Hispanic, 5.1% are two or more races, and 0.4% are Native American (US Census Bureau 2021). The Huron River runs through the northeast quadrant of Ann Arbor, feeding into Lake Erie and eventually ending up at the Atlantic Ocean. The main sectors of Ann Arbor's local economy are public education (most notably, the University of Michigan), the automotive industry, the healthcare industry, and software and technology industries. In Washtenaw County, where Ann Arbor is located, 3.7 million tourists visited in 2016, with a $1.1 billion total economic impact (Haynes 2018). Based on our interviews and various conversations with people who live in Ann Arbor, an increase in waste generation can be seen in Ann Arbor's downtown area during the weekends, during the fall and winter collegiate football and basketball season, as well as when students move out from the University of Michigan in the spring.

Some interviewees and community members that attended various workshops with Perpetual mentioned their frustration with the ban on bag bans in the state of Michigan. While some states, such as California, have banned the use of plastic bags, other states, including Michigan, have instituted a ban on any potential bag bans, including the banning of any regulations, taxes, or fees related to plastic bags. Michigan's "bag ban ban" also prohibits counties or cities from outlawing disposable plastic containers, cups, etc. (Daley 2017). The Michigan Restaurant Association was the main proponent of this bill, who were vocal about their belief that irregularities among bag regulations across cities and municipalities would prove to be difficult for widespread retailers and chain restaurants (Daley 2017).

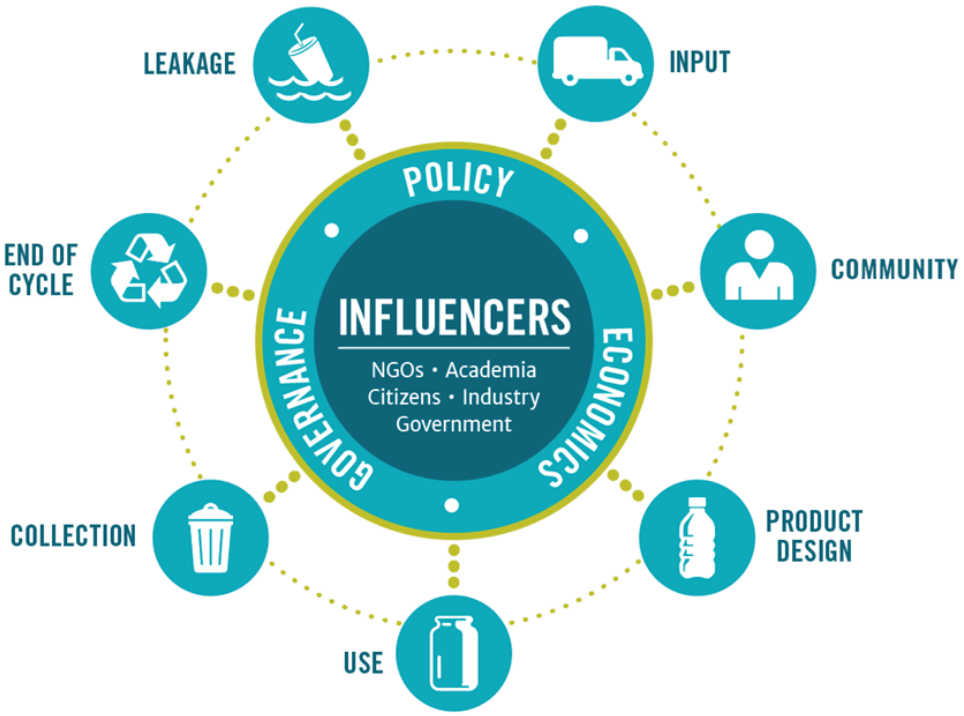
Michigan does have a container-deposit scheme with $0.10 charged for each beverage container (e.g., plastic bottles and aluminum cans) for soda, water, mineral water, etc. Following the successful passing of Extended Producer legislation in Minnesota. Michigan introduced a similar bill in August 2024 (Michigan House Bill 5902) that has not yet passed, but is still being considered. This bill would charge companies for

the type and quantity of packaging they use I order to raise money for waste management infrastructure. It would also phase out until elimination toxic chemicals in packaging (e.g., PFAS).

The Circularity Informatics Lab at the University of Georgia has developed a Circularity Assessment Protocol (CAP), which is a standardized assessment protocol used to collect community-level data to inform decision-makers (Figure 1). The CAP characterizes seven community components:

1. **Inputs** – What products are sold in the community and where do they originate?
2. **Community** - What conversations are happening and what are the stakeholders' attitudes and perceptions?
3. **Product design** - What materials, formats, and innovations are found in products, particularly packaging?
4. **Use** – What are the community trends around use and reuse of product types?
5. **Collection** – How much and what types of waste are generated? How much is collected and what infrastructure exists?
6. **End-of-cycle** – How is waste disposed? What is the fate of waste once it is properly discarded? How is it treated?
7. **Leakage** - What waste ends up in the environment? How and why is it getting there?

Figure 1; Circularity Assessment Protocol (CAP) hub-and-spoke model.

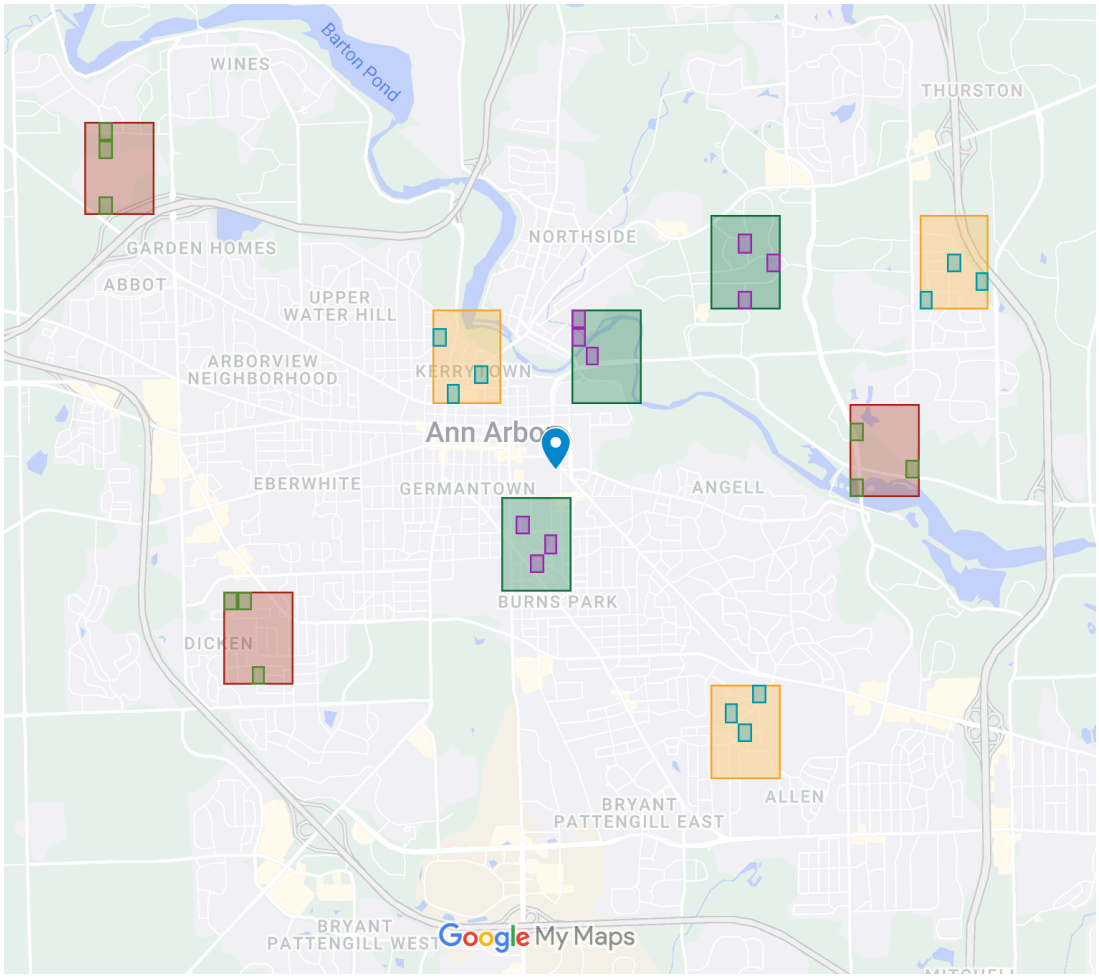


In May of 2023, a team from the Circularity Informatics Lab conducted fieldwork in the city of Ann Arbor, Michigan with support from United States Environmental Protection Agency (USEPA) Trash Free Seas program. Fieldwork was conducted in conjunction with Perpetual, Zero Waste Ann Arbor, and Recycle Ann Arbor. The CAP report is split into the following sections, which include results and discussion of each: Input, Community, Product Design, Use, Collection, End of Cycle, and Leakage, followed by Opportunities. The intent is for the data in this report to inform ongoing stakeholder engagement around solutions to strengthen the circular economy and waste management in Ann Arbor, Michigan.

Sampling Strategy

To randomly sample various locations in a city, the CAP typically identifies a 10km x 10km area over the city (with the center of the city in the center of the area). In this area, the ambient population is sectioned into three groups, or 'tertiles' (Figure 2). Ambient population count can be described as "where people go" and "societal activity" — it is not the population density of where people live. These three areas typically form samples of different land uses, etc. Typically, three 1 x 1 km areas for surveying are randomly selected within each population tertile using NOAA's Sampling Design Tool, resulting in a total of nine 1km2 areas for surveying. In total, 9 sites were surveyed, three in each of the high, mid and low population count tertiles.

Figure 2: Population tertiles and survey sites in Ann Arbor (green – high ambient population, yellow – medium ambient population, red – low ambient population).



Input

To get a snapshot of the characterization, scope, and source of common plastic packaged items that are entering Ann Arbor, the CIL team sampled common convenience items in three common product categories: candy, chips, and drinks. These items were recorded during transects held across nine 1 km2 survey areas in Ann Arbor — up to three within each tertile of the population count (Figure 2), a total of 25 stores in this case. The team selected three convenience or grocery shops to sample within each 1 km^2 transect area. In total, 415 convenience products were collected and sampled, including 163 beverages, 200 candies, 28 chips, and 24 tobacco products. Samples of identical brands were only collected once. For each of the top products documented, the team noted the type of packaging (including polymer, if possible), the brand, and the parent company. From there, the team tried to discern the manufacturing location from manufacturing locations listed on product packaging or desktop research, as well as the headquarters location for the parent company of the brand (largely determined by desktop research). The top brands in Ann Arbor are as followed:

- Beverage: Coca Cola, Gatorade, Mountain Dew, Monster, Red Bull
- Candy: Reese's, M&Ms, Snickers, Hershey's, Kit Kat
- Chips: Lays, Doritos, Cheetos, Popcorners, Ruffles

- Tobacco: Marlboro, Newport, American Spirit, L&M, Camel (top brands for tobacco were only identified, not purchased)

Manufacturing locations were challenging to identify, as there is no requirement in the US to identify manufacturing locations explicitly on packaging. It is likely that the manufacturing locations are closer than the parent company locations, but many were not able to be accurately located. As a result, the distances are defaulted to the parent companies. Tobacco products had the highest average distance to parent companies, while also having the lowest average distance to manufacturers (Table 1). A few products were manufactured and/or had a parent company location in the state of Michigan. These locations consisted of Petoskey, Traverse City, and Detroit. The minimum distance for candy in terms of parent company and manufacturer locations was approximately 14 km; the minimum distance for beverages was 27 km.

Table 1. Distances between Ann Arbor and manufacturer and parent company locations for top FMCG convenience items

	Length Store to Parent Company (km)			Length Store to Manufacturer (km)		
	Minimum	*Maximum*	*Average*	*Minimum*	*Maximum*	*Average*
Beverages	27	15,882	1,975	27	15,882	2,112
Candy	14	13,666	2,305	14	13,768	1,505
Chips	58	6,763	1,346	58	3,155	1,476
Tobacco Products	753	6,100	3,325	724	2050	967

**Note: Distances were projected using an Azimuthal Equidistant projection. Values have been rounded to the nearest km.*

Based on the origins of the convenience categories, regional distribution of products in the United States was common among both manufacturers and producers. Domestic parent companies for beverages, chips, candy, and tobacco were mostly based out of the states of Georgia, Illinois, Texas, Pennsylvania, California, Virginia, and New York. Internationally located parent companies included but were not limited to the continent of Europe, as well as the countries of Australia, New Zealand, and Thailand. Domestic manufacturing locations of these same products included Georgia, Illinois, North Carolina, New Jersey, Pennsylvania, Texas, California, and New York. International manufacturing locations for sampled products included various countries in Europe, as well as China, Brazil, and Australia, among others. Maps of parent and manufacturing locations are in Figure 3 and 4.

With identifying parent companies and manufacturers (when possible), this can help with the current conversations around extended producer responsibility (EPR) models. A handful of states in the US have implemented EPR policy legislation that encourages producers of products to bear some responsibility for their end-of-life management, with Minnesota being the most recent to be successful (and also in the Midwest). EPR can take many forms, but common approaches throughout the world and the US include product-take-back and deposit-refund schemes as well as waste collection and take-back guarantees (UNEP 2018). They can also supply resources for current state or city-wide management systems as they currently are. The plastics industry in the US has historically opposed EPR schemes arguing that waste management relies on consumer practices and behaviors (Nash and Bosso 2013), and that the schemes can lead to increased costs, food waste, and life cycle impacts (ACC 2021). However, these attitudes toward EPR are changing in alignment with the United Nations plastics treaty negotiations. To date, the most prominent EPR program in Michigan has been the Michigan Electronic Waste Take Back Program, which includes electronic collectors, manufacturers, recyclers, retailers, and consumers (Department of Environment, Great

Lakes, and Energy 2024). EPR schemes are typically supported by state-level governance, suggesting that Ann Arbor state-level representatives could advocate for legislation targeting EPR efforts or engagement with packaging producers and consumer goods companies. EPR can be a requirement of the companies doing business in a state no matter where products are manufactured, or companies are located. The close minimum location of beverages and candy indicates that there could be opportunity for the city of Ann Arbor to have conversations with nearby cities that house parent companies and manufacturers to articulate a clear vision of what multiple areas and communities in Michigan want for EPR policy.

Figure 3: Manufacturer locations for top convenience items in Ann Arbor

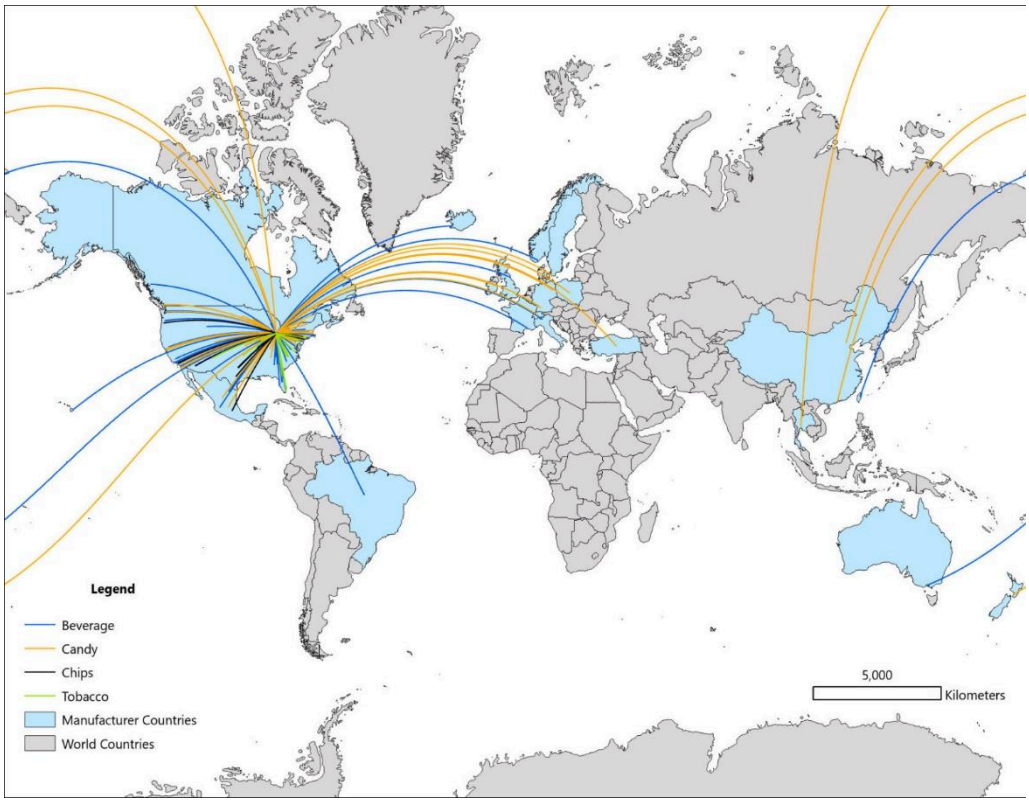
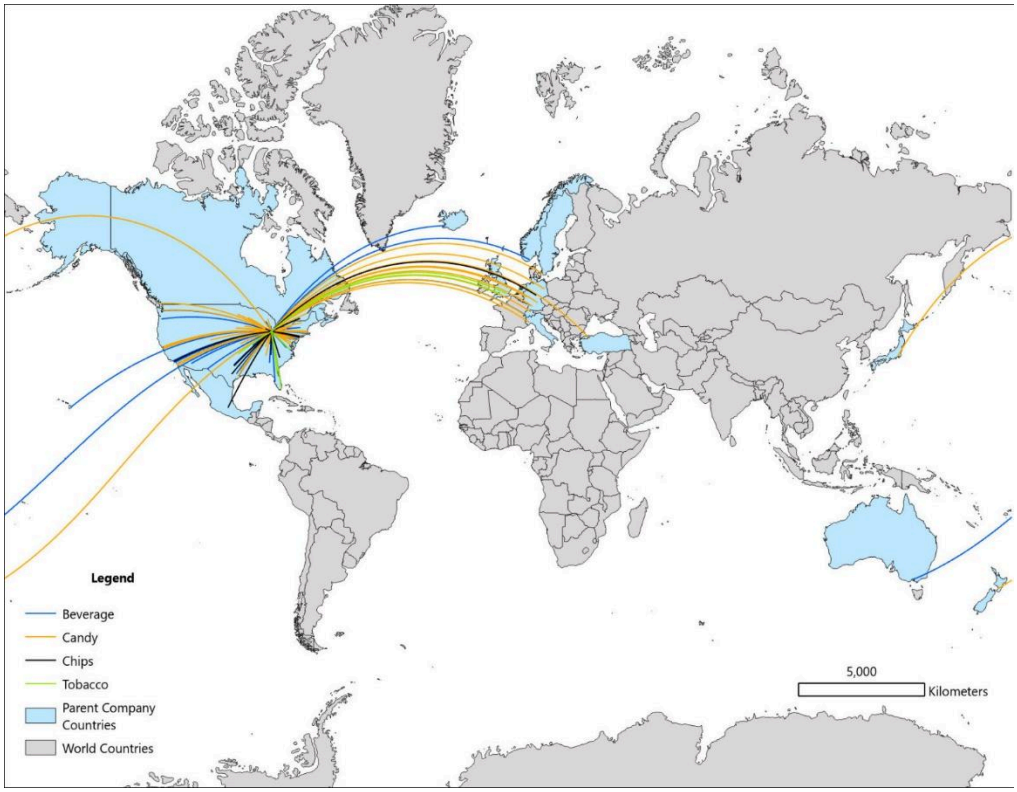


Figure 4: Parent company locations for top convenience items in Ann Arbor



There were some beverage, candy, and chip products that were produced and/or manufactured in states neighboring Ann Arbor, including products coming from Wisconsin, Illinois, Indiana, and Ohio (Table 2 below). These neighboring states could also potentially be involved in a cooperative EPR scheme that involves products being manufactured or sold in the Great Lakes Region.

Table 2: Domestic products and materials produced or manufactured in states neighboring Ann Arbor, Michigan

Neighboring state	Company Name	Product category	Packaging types
Wisconsin	Mayana Chocolate	Candy	Multilayer film
Illinois	The Coca-Cola Company	Beverage	PETE; hard plastic; film
	Kraft Heinz Company	Beverage	PETE; hard plastic; film
	PepsiCo	Beverage	PETE; hard plastic; film
	ConAgra Brands Inc	Chips	Multilayer film
Indiana	Albanese Confectionery Group	Candy	Multilayer film

	Endangered Species Chocolate LLC	Candy	Multilayer film
Ohio	Midwest Juicery	Beverage	PETE; hard plastic; film
	Garden of Flavor LLC	Beverage	PETE; hard plastic; film
	Spangler Candy Company	Candy	Multilayer film

Community

To understand current attitudes and perceptions of plastic waste, semi-structured interviews were conducted with 9 key stakeholders (Table 3). Among those interviewed,

4 were nonprofit representatives, 3 were city officials, 1 was a representative from a local restaurant, and 1 was a civil servant.

Table 3: Stakeholder Groups and Number of Interviews

Stakeholder Group	Interview Count
Nonprofit	4
City Officials	3
Local Restaurant	1
Civil Servant	1

In our semi-structured interviews, participants shared their thoughts on community attitudes and perceptions of plastic and organic materials, as well as their thoughts on circular economy activities. Barriers and challenges to promoting circularity in Ann Arbor included politics, transportation, and storage. Compostable plastics were frequently cited as a point of concern, given that the City of Ann Arbor and their compost site operator, Denali, recently announced the only compostable packaging they will continue to accept in 2024 will be fiber (Waste Today, 2023). Concerns over what a city-wide reuse system would look like were also shared; some of these related to encouraging city-wide participation, integrating the necessary tools and software into existing restaurant systems, and logistical concerns related to space and storage.

Regardless of the barriers and setbacks people in Ann Arbor are experiencing related to waste, recycling, zero waste, and circular economy efforts, interviewees spoke of many successful initiatives currently taking place, and had no shortage of suggestions for the types of changes they would like to see.

Attitudes and Perceptions

Interviewee views on the attitudes and perceptions of community members were mixed. Some interviewees felt like there is a high level if interest in circular economy activities in Ann Arbor:

"Last year, [the city] started recognizing there is a lot of public interest in circular economy work. There was a lot of momentum in that direction from the general public."

– City Official

"Lots of folks in Ann Arbor care about the environment. Circular economy is easier for the everyday person to enact. It is easier for people who do not know as much about sustainability than getting solar power or switching to an electric stove. There's this idea of, 'there are very few things that I as an individual can do, but this is one thing I can do.'"

– City Official

However, one interviewee mentioned that they had a mixture of customer interest:

"We definitely have an educated audience that are paying attention and then others just don't care."

– Local Restaurant Representative

One interviewee mentioned the need to "bridge the gap" between people who really care about zero waste issues, and people who are unable to participate in curricular activities due to various inequalities:

"There are a lot of interpersonal barriers. More committed people in the circular economy want to work on systemic change, other people think individual zero waste is way too hard. It is difficult to bridge that gap. Really active people [in the circular economy/zero waste space] need to see the need to bring in more people. They need to help people who see it as hard for themselves."

– Nonprofit Representative

Other interviewees mentioned the tension between framing circularity as "personal responsibility" to alter smaller issues, while also needing to recognize how resources are allocated on a systemic level:

"For people who do get involved, they don't know what's next. They can fix their own life, but it creates an itch on the systemic level that they don't know how to scratch. [We are] building up public support and interest but for what?"

– Nonprofit Representative

"...People don't like doom and gloom and they want to celebrate small things, but they don't feel gratified in acceptance of small wins unless the standard is higher like zero waste."

– Nonprofit Representative

Barriers and Challenges

Interviewees mentioned several barriers to increasing circularity in Ann Arbor, including the politics of gaining and maintaining interest, logistical concerns, and the fast pace at which the sustainability field is accelerating within the face of wide-scale uncertainties:

Politics

"There is a lack of alternatives and a lack of significant political will. People are starting to get the idea that the circular economy is good but people are not always excited and mobilizing efforts."

– Nonprofit Representative

"There are a few people in this sphere, and they are not all on the same page...It's hard to come up with a strategy."

– City Official

"It is a constant struggle for operating units within municipal governments with small teams. There is an issue with trash on the ground, so we stop what we are doing and take a look at it. When you are in that reactive mode it is difficult to make more proactive decisions day-to-day."

– *City Official*

"You see how much value the circular economy allegedly is, but it's hard to translate it on the ground. What are we getting in AA? A Dunkin Donuts. No thank you."

– Civil Servant

Logistics

Interviewees mentioned how logistical concerns such as budget, storage space, and transportation impacts peoples' ability to participate in circular economy activities:

"Available resources and budget [are a challenge] -- education, outreach, program compliance -- mandatory recycling does not have all the resources they need to ensure that is being adhered to."

– City Official

"[We have] identified some gaps [in circular economy infrastructure]: storage space huge across the board."

– Civil Servant

"There are gaps in terms of transportation. Places that are more pivotal to recycling are on the edge of the city and are difficult to get to. Non-middle class people do not have the car to transfer, or the financial resources to hire the junk people where friends can split a truck every few years to clean out their basements…It would be great if on swap days, someone could offer pickups."

– Civil Servant

Broader Uncertainties

"Everything keeps changing very fast -- the environment, the climate, the weather, tech, people's ideas, fads, etc…"

– City Official

"The biggest roadblock is overconsumption…Since [the COVID-19 pandemic] we have had an explosion of boxes and more plastic, and we cannot stay on top of it. Our drivers have to get out of the truck and pick up the boxes overflowing out of the can. Our streets were not meant to fit this excess."

– City Official

Compostable Products

Compostable plastics were a topic of conversation frequently brought up by interviewees because of recent regulations on composting in Ann Arbor. On this topic, multiple interviewees mentioned that the local composting facility is no longer accepting single-use compostable plastics:

"When it comes to single use compostable things, people feel like it's a solution. The composting facility stopped accepting all single use compostable plastics, because it caused confusion in recycling and composting and resulted in litter at the composting site."

– City Official

"The composting facility said they would not accept [compostable plastics] anymore because there has been a lot of field research that these single-use compostable products don't break down as much as the food and other items that they want to get in their facilities. Compostable plastics look a lot like plastic and cause confusion and contamination. They are now only accepting food and fiber containers, no bamboo."

– City Official

Another interviewee spoke about how the new rule against accepting compostable plastics will likely affect their restaurant business:

"We did switch most materials to compostables, and the consumer perception [of that] is good. The rules banning PLA from compost will set us back. We pay a premium to offer compostable products even though the consumer generally does not understand the difference between plastics and compostable plastics."

– Local Restaurant Representative

On this topic, the interviewee added:

"It is difficult sourcing PLA while keeping the cost low. As a high volume restaurant, it makes it cheaper to purchase in high volume. The supply chain has been messed up, and the reliability of products that we need are not always there. There's been lots of times where we had to source a switch…The barriers [for us] include cost and sourcing the right container for the product; getting food in the right vehicle for its protection and the quality of the food. We still serve soup in plastic bowls because they have locking lids -- we find that it spills."

– Local Restaurant Representative

Reuse Program

Sentiments about Perpetual's partnership with City of Ann Arbor, Recycle Ann Arbor, and ZeroWaste.org to begin a city-wide reuse system in Ann Arbor naturally came up in interviews. One interviewee mentioned how a reuse system could help address the recent changes in composting regulations:

"[The change in allowing compostable plastics at the composting facility] indicates we need to be focusing on reusable/multi-use things, like a returnable container program…I would like to see the returnable containers program become city-wide."

– City Official

Other interviewees shared their concerns about a city-wide reuse system:

"We have a demand creation puzzle for reusable containers. Restaurants are on board but we are not seeing big demand from the consumer side."

– Nonprofit Representative

"Reusable containers are a very small piece of the puzzle, and I know that part of getting this setup is to expand to other reusables, but that seems like a lot of work for a small piece. Should we [instead] be focusing on lobbying for EPR?"

– City Official

"No matter what we do, we feel like we end up with two options…because our volume of out of town customers is so high, we have a hard time imagining how to do reusable containers, with visiting customers who are leaving and driving out of town. Another Impediment is the size of the menu and the size of containers to accommodate the menu. We have space constraints related to, "okay, these 2 containers for this product, how do you use one over another, where do you put them?'"

– Local Restaurant Representative

"If this [reuse system] is city wide and you experienced these containers everywhere you went, it would help us be motivated to change. It is hard to overcome those obstacles when nobody is using it, when there is no demand. When the demand changes it puts us in a position where it is worth it."

– Local Restaurant Representative

"Super curious [about the reuse system technology] with challenges we have had with overdoing things within our own systems. We have systems and data that don't talk to each other internally. It takes a lot of work for something simple like 'do you want napkins?' There's a lot of coding within that."

– Local Restaurant Representative

"Most recyclers are opposed to reuse because you are losing tipping fees. Is there a model for the amount of material we lose that we could make up as they move to reusables? For example, 'we lose x amount of clamshells but y amount moves through the reuse system now.'"

– Nonprofit Representative

Suggestions and Changes

Although interviewees felt there were multiple barriers and challenges to expanding circularity in Ann Arbor, they had no shortage of ideas on what changes they would like to see moving forward. Many of the barriers and challenges mentioned by interviewees were solved through the suggestions and changes suggested by the interviewees themselves; these proposed solutions included bans and policies, further research, equity and justice, and infrastructure.

Bans and Policies

Some interviewees were big proponents of enacting bans and policies both locally and at the state level:

"[I would want to] change the preemption ban at the state level."

– Nonprofit Representative

"Michigan has a ban on bans. I am hoping that will get overturned with the current administration. If that happens, I hope to ban single-use plastics at least at grocery stores and other things like that."

– City Official

"I wish they could ban red solo cups. They are huge contaminants in curbside recycling."

– Nonprofit Representative

"I would have the city adopt significantly different purchasing and maintenance policies. Start in the sphere of control with the city with city purchases."

– Nonprofit Representative

"In an ideal world, we would have returnable tonnage. No cardboard boxes."

– City Official

Further Research

Other interviewees felt that further research and understanding is needed to understand everyday barriers that people face:

"Deploy a fleet of people to learn what barriers are at an individual level to getting involved…The bag ban in New York has just turned into people buying reusable bags at the store every time."

– Nonprofit Representative

"Construction and demolition waste is one of the largest forms of waste here. Researching market capacity for dealing with that is needed."

– Civil Servant

Equity

Equity and justice were also topics that Ann Arbor interviewees cared about integrating into existing and future circular efforts:

"We are working toward this, but making everyone recognize that equity is a huge part of the circular economy and all sustainability work [is important]."

– City Official

"We are wanting to make sure that it is easy for underrepresented groups to participate in these programs as they roll them out."

– City Official

Necessary Infrastructure

Other interviewees mentioned wanting physical spaces to focus on reuse via consignment shops and university move in/move out:

"Though there are some places where you can get used goods, there aren't as many consignment shops as the city could support. There are few places that take or dispense furniture. A lot of people have stuff that they want to refresh periodically, but all of this happens through Facebook. We want a brick and mortar place because it supports the community."

– Civil Servant

"[We] also need space for [university] move in and move out to work, especially when they are leaving as seniors. We need an easy way for seniors to hand over things to freshmen."

– Civil Servant

One interviewee wanted to note how circular economy should be an income-generating sector that people can base their careers on:

"I would explicitly like to link job creation to the circular economy and have an incubator and investment fund for CE business fund. We want job creation and independent businesses; there is room and space. The circular economy space doesn't make money, and lots of places are staffed with retirees and volunteers. I would like people to make a proper living off of jobs related to the circular economy."

– Civil Servant

Interviewees generally felt that people in Ann Arbor were interested in circular economy activities, but there are critical differences between those who can currently participate and those who cannot, based on various identities and the availability of resources. Some common barriers and challenges to expanding circular economy activities included politics, logistical concerns, and broader uncertainties in the world. Composting, and more specifically compostable plastics, frequently were mentioned in interviews because of recent composting regulations, and interviewees' perceptions of compostables tended to be mixed. The solutions and ways forward provided by interviewees include enacting bans and policies, doing further research to understand barriers to circularity, and keeping equity and justice at the forefront of any and all changes.

Product Design

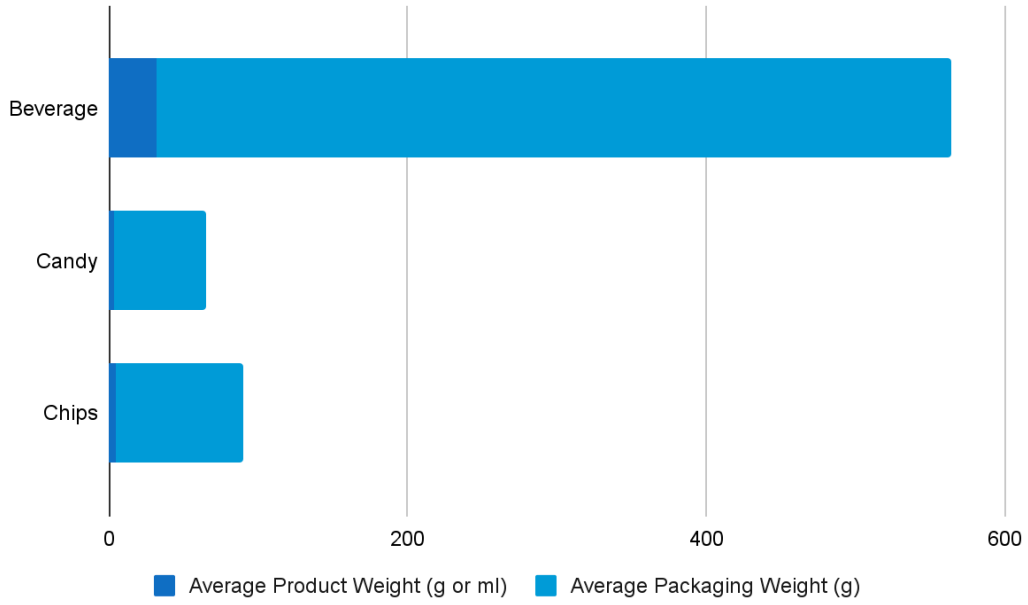
To characterize material types used in common consumer products, samples of common fast moving consumer goods (FMCG) convenience items were obtained as described in the Input section. The CIL team sampled stores in each of the nine 1 km^2 transect areas. Unique forms and brands were purchased to obtain packaging weights. The average weight of both the packaging and the product itself was collected for all samples (Table 4).

Table 4: Average weight of products and their plastic packaging for common convenience items.

Product Type	Number of Samples	Average Weight of Plastic Packaging (g)	Average Quantity of Product (g or mL)
Beverages	103	532.20	31.78
Candy	133	61.95	3.3
Chips	25	86.00	4.13

A total of 25 grocery and convenience stores were sampled across the nine transects. 13 stores consisted of convenience stores and pharmacy chains like Marathon and Circle K, and Walgreens and CVS, respectively. 10 of the stores included large grocery chains such as Target and Meijer; local grocery stores and co-ops were also sampled. The team also sampled a chain discount store and a local bulk store. 261 items were sampled in total. Candy and chips both had relatively low product and packaging mass, probably due to multilayer film's light weight (Figure 5). A majority of packaging for both candy and chips are multilayer film, with the exception of chip multi-material canisters (such as Pringles cans) and candy packaged in paper, wax paper, and hard plastic (Table 5). Although multilayer films are useful for their ability to preserve and protect food products, their combination of materials makes it difficult to isolate in traditional recycling processes, ensuring that the material has little value in recycling markets.

Figure 5: Convenience items packaging to product weight ratio, shown in grams (not including unknown products or tobacco as there is no weight data for tobacco)



Beverages had the highest product mass and packaging mass when compared to chips and candy (Figure 5). This difference could be attributed to both the high density of polyethylene terephthalate (PET) commonly used in plastic beverage bottles, as well as the high density of liquid found in beverage products. Both candy and chips had a packaging to product ratio of 0.05, while beverages had a packaging to product ratio of 0.06. Beverages therefore generate the most packaging waste per unit of product out of the three categories, even if by a small margin. Reducing the ratio of plastic packaging to product through minimal packaging design and/or increasing quantities of products can make product delivery more efficient (Youngblood et al. 2022). For each convenience item surveyed, the CIL team also documented the polymer/packaging type (Table 5 and Figure 6).

For comparison, samples taken in several cities in India showed that the average product weight for candy items was around 3.8g and the average packaging weight was around 0.15g — those found in Santiago, Chile, were around 10 times larger for both product and packaging weight. Smaller product sizes may lead to more frequent, less individually expensive purchases compared to larger product sizes, although there is often a "poverty tax" associated with these small packets compared to the price per quantity in larger sizes, in addition to the generation of more packaging weight in summation.

Cigarettes were excluded from our purchasing of samples in this case, but they are typically a standard size and we have previously found an average of about 10g of plastic packaging to about 15g of product. This relatively high product-to-packaging ratio is likely driven by the cellulose acetate filters in cigarette butts, which typically weigh about a gram each. A majority of the candy sampled was packaged in multilayer film plastic (85%), while the remaining materials consisted of paper (9%), wax paper (3%), and hard plastic (3%). Chips were overwhelmingly packaged in multilayer film (99%) with a small percentage (1%) being multi-material canisters. Over half of all beverages sampled were packaged in PET (62%) followed by aluminum (30%) and glass (8%) (Figure 6).

Table 5: Overall material Characterization of chip, candy, and beverage convenience items.

	Candy	Chips	Beverages
Glass	-	-	8%

Aluminum	-	-	30%
PET	-	-	62%
Aseptic Carton	-	-	-
Film/ Multilayer film	85%	99%	-
Paper	9%	-	-
Wax Paper	3%	-	-
Hard plastic	3%	-	-
Multi-Material Canister	-	1%	-

Figure 6: Overall material Characterization of chip, candy, and beverage convenience items.

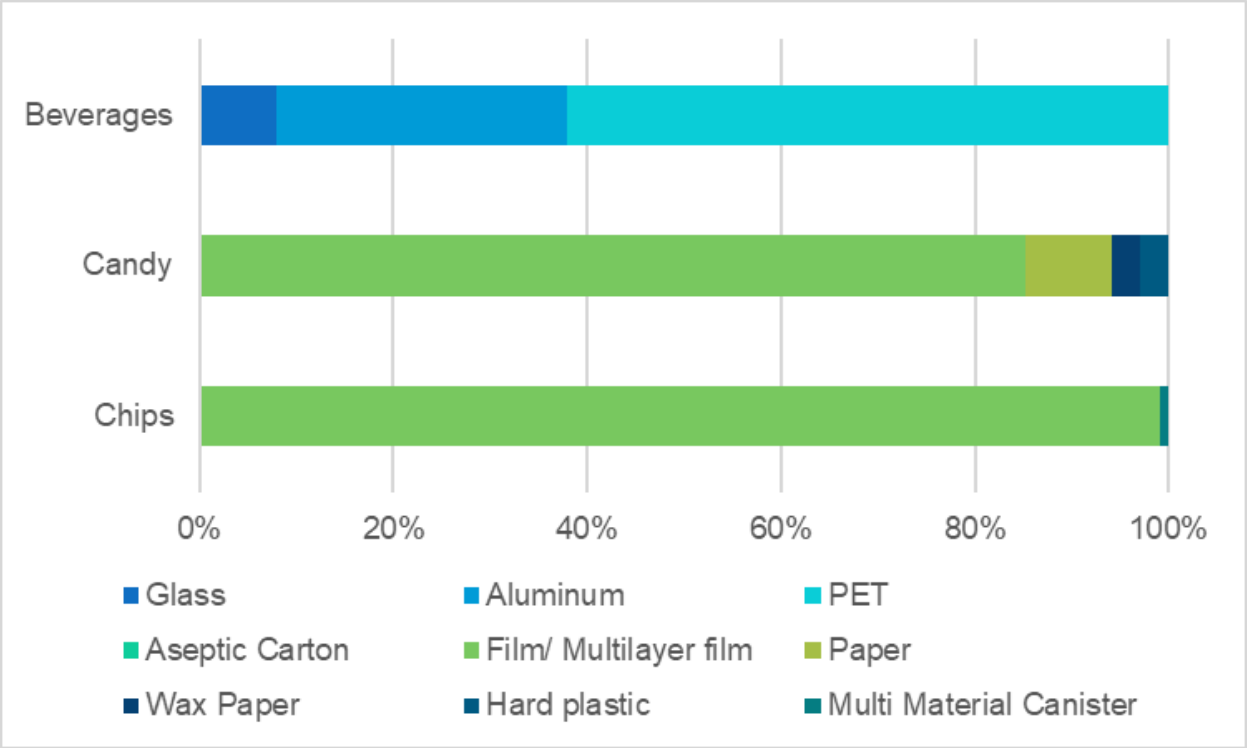
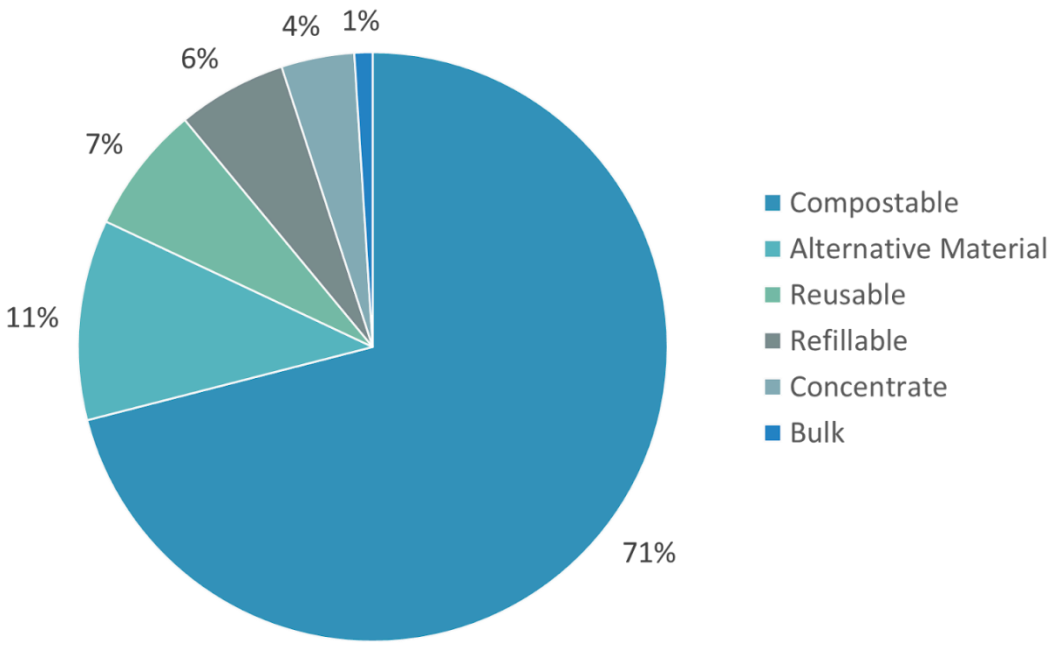


Table 6: SUPs Characterization of chip, candy, and beverage convenience items

	Single-Use Plastic	Other Materials
Candy	85%	15%
Chips	99%	1%
Beverages	62%	38%

The CAP team also sampled a variety of products to determine the availability of potential plastic alternatives in product packaging within the sampled stores, including items found in the picnic, personal care, and cleaning sections. The team collected samples that included compostable, reusable, and refillable products, among others (Figure X).

Figure 7: Material Characterization of 167 plastic alternatives.



In addition to surveying convenience and grocery stores, the CIL team surveyed restaurants in each of the nine 1 km2 transects areas. Through visual assessments and discussions with restaurant owners, we assessed the material type for to-go food items, including cold cups, food containers (including lids, if applicable), straws and utensils. 31 food vendors were sampled in total, including local and chain restaurants. This included sampling 16 sit down restaurants, 8 fast food restaurants, 5 coffee shops, 1 grocery store deli, and 1 gas station that served to-go food. Although compostable offerings were found across each of the four categories, plastic tended to be the most prominent material used (Table 7). While cups and food containers were offered in a wide variety of materials, straws and utensils tended to be either plastic or some type of compostable material.

Some stakeholders in Ann Arbor mentioned concern over the prevalence of PFAS (Per- and polyfluoroalkyl substances) which is a classification of chemicals used in various everyday products, ranging from nonstick cookware to rain resistant jackets. PFAS can also be found as a contaminant in groundwater, and has recently been identified within the neighboring city of Detroit's water system (Allnutt, 2020). While data is still coming out about the prevalence of PFAS contamination, there could be an opportunity for the community of Ann Arbor to spearhead research into ensuring that the compostable fiber containers provided locally do not include PFAS chemicals.

Table 7: Restaurant material types of cup, food containers, straws, and utensils

Material Type	Cups	Food Container	Straws	Utensils
Compostable	22%	10%	12%	7%

Plastic	48%	41%	88%	93%
Paper	–	15%	–	–
Foam	15%	13%	–	–
Plastic-Lined Paper	11%	10%	–	–
Bioplastic	4%	–	–	–
Aluminum	–	3%	–	–
Cardboard	–	8%	–	–

Use

In the same survey of 25 stores in Ann Arbor, roughly 66% provided plastic bags, 25% provided paper bags, and 9% provided both paper and plastic bags. Additionally, some stores offered reusable canvas or woven plastic bags that could be purchased for a dollar or two, while other stores reused excess plastic bags that were brought in by customers. One store even offered discounts to customers who brought in reusable bags or the store's branded bags.

A couple stores that provided paper bags for free had similar labeling, (shown below) including the 3 arrow recycling symbol stating that the paper bag is 40% PCW, and a label qualifying the bags as Sustainable Forestry Initiative certified. Additionally, the bags are labeled as "Reusable. Compostable. Recyclable." This form of paper bag has also been provided in other CAP cities, yet interviewees in other cities have expressed concern over the actual compostability of these paper bags, sharing their concerns about the actual compostability and harmlessness of the dyes used to decorate the bags.

Figure 8: Example of paper bags found in stores

In one grocery store, there was a water refill station, enabling customers to fill their own water for 49 cents per gallon. This partnership with Glacier Water represents an opportunity for more robust refilling opportunities that incentivize customers with discounts for bringing their containers back to the store to refill.

Figure 9: Water refill station in Ann Arbor grocery store

In addition to plastic bags, other common plastic items and their respective alternatives were examined by price, material, and disposability. Reusable items were generally much more expensive than disposable and recyclable items. For example, stainless steel reusable straws were $1.57 each compared to single-use

polypropylene straws that cost $0.03 or compostable straws at $0.08 each. Similarly, items labeled as compostable were a typically more expensive alternative to disposable and recyclable items. For example, compostable plates were nearly 215% more expensive than their cheapest single-use traditional plastic alternative. Of all the item types, reusable plastic storage bags (e.g., zipper sandwich bags) were the most expensive in comparison to their single-use items largely due to the use of more expensive synthetic materials (e.g., silicone). The least expensive items were polypropylene straws, expanded polystyrene plates, and cutlery (Table 8), all of which are generally not accepted in recycling waste streams due to their size, shape, and lightweight characteristics.

It is worth noting that misleading nomenclature and public information can cause confusion due to labeling on different types of plastic, particularly when it comes to 'compostable' items. Based on the CAP survey, plastic items labeled as compostable were typically designated as made of natural and organic material like bamboo, plant material, fiber, and sugar cane. Plastics marketed as biodegradable do not necessarily degrade in the natural environment as they do in laboratory conditions, with many biodegradable items requiring specific conditions provided in industrial composting facilities. Bio-based plastics can be chemically identical to fossil-fuel-based plastics but can be confused for compostable or biodegradable. These items can also be mistaken as recyclable (Moss 2017). These subtleties can lead to consumer confusion due to uncertainty around material types and categories as well as ambiguity around appropriate management. Recent studies highlight the challenges associated with bio-based and biodegradable plastics driven by the combination of inadequate legal provisions for effective collection and treatment, unharmonized waste collection infrastructure, and social attitudes and awareness around consuming, sorting, and managing these materials (Stasiškienė et al. 2022).

Table 8: Cost comparison of alternatives

Product	Plastic Alternative	Avg. Cost of Alternative (per unit)	Avg. Cost of Plastic or Similar	Min. Cost of Alternative	Min. Cost of Plastic or Similar	Avg. Cost Difference for Alternative (percentage)
Bowls	Compostable	$0.26	$0.45	$0.13	$0.17	-34%
Cups	Compostable	$0.34	$0.46	$0.05	$0.13	33%
	Reusable	$11.42		$4.99		2555%
Plates	Compostable	$0.29	$0.09	$0.11	$0.08	215%
Utensils	Compostable	$0.16	$0.05	$0.11	$0.05	214%
Straws	Compostable	$0.08	$0.03	$0.04	$0.02	156%
	Reusable	$1.57		$1.57		3851%

Tall Trash Bags	Compostable	$0.90 / 13-gallon bag	$0.26	$0.50	$0.25	255%
Small Trash Bags	Compostable	$0.24 / 3-gallon bag	$0.14	$0.20	$0.09	75%
Sandwich Bags	Compostable	$0.17	$0.07	$0.12	$0.04	189%
	Reusable	$13.49		$12.99		30,629%
Snack Bags	Compostable	$0.19	$0.02	$0.14	$0.02	654%
	Reusable	$10.49		$9.99		42029%
Gallon Bags	Compostable	$0.49	$0.23	$0.35	$0.23	115.76%
	Reusable	$15.99		$15.99		6982%
Shampoo	Concentrated	$0.24	$0.03	$0.24	$0.008	598%
	Bar	$0.09		$0.04		233%
Conditioner	Concentrated	$0.24	$0.03	$0.20	$0.03	598%
	Bar	$0.18		$0.18		428%
Body Wash	Bulk	$0.01	$0.02	$0.01	$0.02	-8%
Laundry Detergent	Concentrated	$0.23	$0.18	$0.22	$0.12	45%
Dish Soap	Bulk	$0.004	$0.006	$0.002	$0.003	-34%
Wet Wipes	Compostable	$0.09	$0.09	$0.09	$0.09	8%

Collection

The City of Ann Arbor provides weekly curbside trash cart collection to all single-family homes and duplexes. Multi-family locations, such as apartments, have dumpsters that are purchased and maintained by the location's owner, while the city provides a weekly service. Large items like mattresses and appliances are

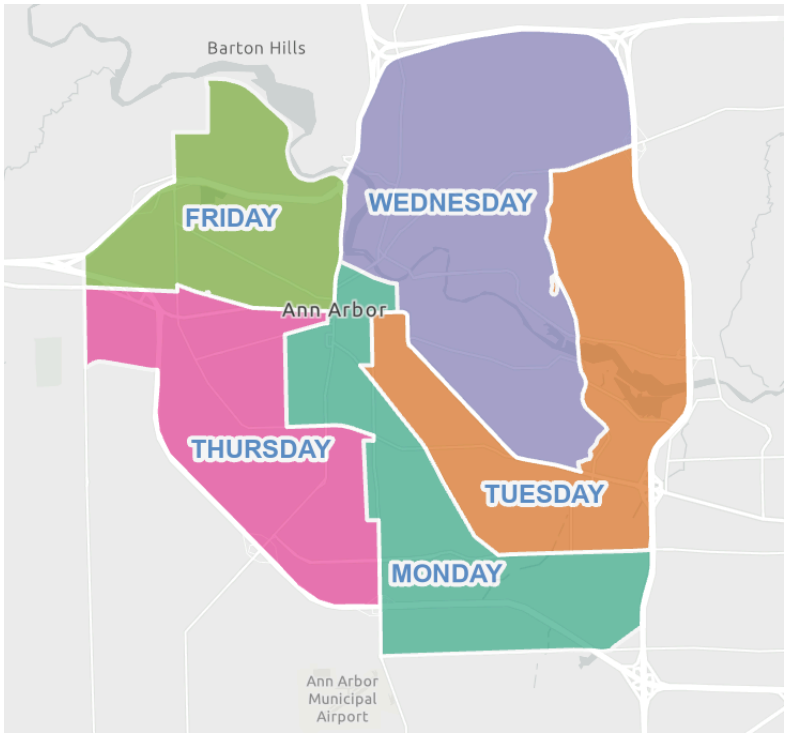
not accepted through the city's curbside recycling program, but residents can take their large items to the local nonprofit Recycle Ann Arbor (RAA), which operates a drop off station and recovery yard (Recycle Ann Arbor 2024). Curbside collection of trash, recycling and compost is quite progressive for a relatively smaller city like Ann Arbor.

One interviewee mentioned that multifamily housing recycling options could be improved:

"People in single family housing have high recycling and composting rates, but those rates are not as good for apartment housing which is half of the housing in Ann Arbor."

- Civil Servant

Figure 10: Residential Solid Waste Collection Schedule for Ann Arbor



Recycling carts are city managed and are required unless the location is using an approved recycling dumpster. RAA also works with the city to provide recycling resources and education, including but not limited to their user-friendly A-Z recycling guide, where residents can enter the item or substance they wish to dispose of and find out if and where RAA can accept the materials in question.

Figure 11: List of acceptable and unacceptable recyclable materials in curbside recycling (Courtesy: www.recycleannarbor.org)

Compost carts at 64 or 96-gallons are offered to residents for free. Food waste is accepted through Ann Arbor's curbside composting program, while yard trimmings are accepted through curbside composting, or at RAA's drop-off station or recovery yard.

High-traffic areas where there is likely to be more waste generated include the downtown area and the University of Michigan stadium area, specifically during football season. Interviewees also mentioned a large amount of trash and recycling materials accumulating around student move in and move out. The City of Ann Arbor has recently instituted measures to curb the generation of waste in these areas by allowing

businesses who have Saturday trash pickup to also receive it on Sunday on graduation weekends, and having 7 day/week trash pickup in the downtown area beginning in the spring season (City of Ann Arbor Downtown Initiatives, 2023).

End of Cycle

Using the City of Ann Arbor's Solid Waste data, the team was able to determine approximate per capita waste generation rates (City of Ann Arbor SW Metadata). During the calendar year of 2023, the average per capita waste generation rates for residents in Ann Arbor ranged from 0.5 lbs of recycling per day to 2.3 lbs of trash generated (Table 9).

Table 9: Per capita waste generation rates for residents in Ann Arbor

Material Stream	Monthly Per Capita Waste Generation Rate (lbs)	Daily Per Capita Waste Generation Rate (lbs)
Composting	18	1.4
Recycling	15	0.5
Trash	70	2.3

In 2018, per capita MSW generation for Americans was 4.9 lbs per person per day, which is about 147 lbs per month; Ann Arbor residents generate less than half of the national average (EPA 2020). With landfill tipping fees less than recycling tipping fees, there is not an economic incentive for supporting recycling. In 2018, the City Council previously voted to increase statewide tipping fees from $0.36 per ton to $4.44 per ton (Waste 360). More recently, there was a proposal within Michigan's governor's 2025 fiscal budget that will increase the landfill tipping fee to $5.00, yet it did not end up being included in the budget approved by the Michigan House (Huron River Watershed Council, 2024). This $0.36/ton fee is incredibly low compared to nearby states, Ohio charges $4.75 per ton and Wisconsin charges $6 to $13 per ton (Huron River Watershed Council, 2024). While these attempts at raising the tipping fee prove that there is existing interest and support locally, some interviewees expressed frustration with the broader trend of other Midwest states in the region having similarly low landfilling tipping fees, which disincentives recycling. Contamination of recycling streams is also a common issue in cities. Some interviewees specifically mentioned recycling contamination as an issue:

"Contamination [in the recycling stream] is at 12%, and it has gone up in recent years. People are confused about what plastic to put in."

– Nonprofit Representative

"I hate those red solo cups. It doesn't matter that there is a recycling symbol on them. They aren't recyclable here."

– Nonprofit Representative

Contamination in compost streams was also mentioned by various stakeholders. Effective January 1st, 2024, the City of Ann Arbor and its compost facility operator, Denali WeCare, no longer accept BPI-certified material at the city's compost facility or in compost carts. Instead, only selected products identified as being certified "CMA-W" (Compost Manufacturing Alliance - Windrow) and made of fiber material are accepted. Additionally, bamboo and palm leaf products are excluded as they do not easily biodegrade in the composting process (City of Ann Arbor, 2024). The city has provided a searchable spreadsheet of certified

CMA-W, fiber-only products to aid residents in this transition. This change in Ann Arbor's acceptable compostable materials mirrors a challenging shift in materials that interviewees in multiple CAP projects have spoken about: compostable plastics often look like plastics, and as such, end up contaminating composting streams. Additionally, interviewees across multiple CAP projects have shared their frustrations with the multitude of allegedly compostable materials not being properly field tested, which the City of Ann Arbor and Denali have been trying to mitigate through the CMA-W certification of acceptable materials (See Community Section: Compostable Products for more information about what interviewees thought of this change).

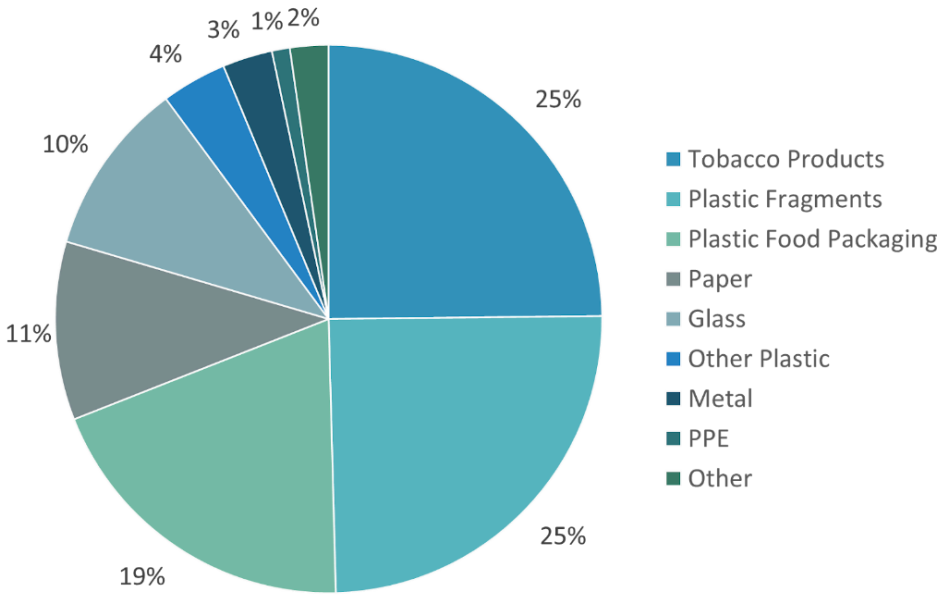
There are a few waste management models that could be applied to Ann Arbor's waste management system. Ambitious models include striving for a circular economy or zero waste model. The circular economy is an alternative approach to traditional linear models ('take-make-waste') that encompasses an industrial economy that is designed to be restorative and regenerative (Ellen MacArthur Foundation 2017) through '4Rs' framework that prioritizes reduction, reuse, recycling, and recovery (Kirchherr et al. 2018). Zero-waste models aim to eliminate waste entirely through volume reduction driven by product design and management processes that recover and conserve all materials and resources and reduce demand on natural resources (Anshassi et al. 2019). These advanced systems like zero waste goals can be challenging to adopt in cities due to the need for harmonized and coordinated efforts, sustainable behavior and consumption patterns, product stewardship, supportive legislation, and near perfect recovery of items (Zaman 2011). Further, zero-waste models encourage complete avoidance of landfill disposal. Given the economic disparity with tipping fees versus recycling in Michigan, one feasible model to focus current sustainable plastic waste management efforts could be through the sustainable materials management model which focuses on use/reuse of resources and minimization of material consumption through decisions based on overall material impacts to environment, society, and the economy (Allen et al. 2009), and which emphasizes a net environmental outcome rather than elimination of landfill disposal practices entirely (Silva et al. 2017).

Leakage

A spatially stratified random sampling method generated survey areas for conducting transects, which were selected within nine 1-square kilometer areas and were distributed across three groups of ambient population (i.e., societal activity) (upper, middle, lower) across Ann Arbor. These ambient population activities were based on the Oak Ridge National Laboratory's LandScan global ambient population data for 2021 (Sims et al. 2022). Litter items were recorded using the open-source Debris Tracker mobile application ('app') (Jambeck and Johnsen 2015). A full list of items available in the app and their associated material categories can be found in the Appendix. Litter was examined based on abundance, proportion of material and product types, and product densities across all transects and aggregated across the three population groupings.

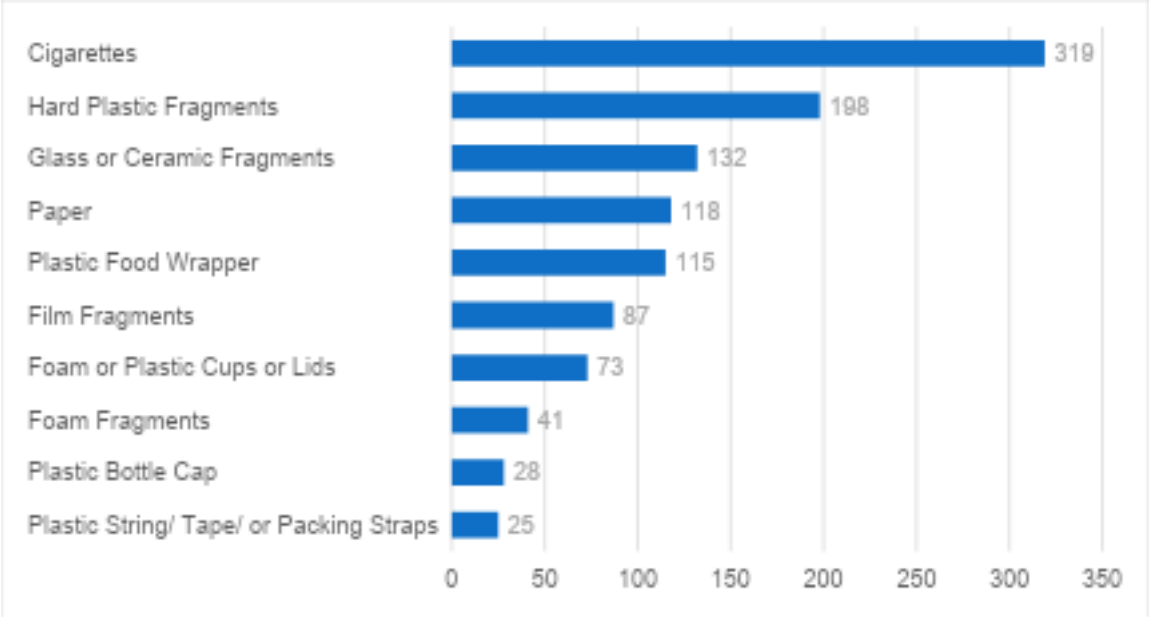
In total, 1,321 litter items were recorded across twenty-seven 100 m^2 transects in nine different square kilometer areas sampled in May 2023. Across all surveyed transects, tobacco products and plastic fragments were the most prevalent litter item by item type, together representing 50% of all items recorded. The second largest category was plastic food packaging (19%) followed by paper (11%), glass (10%), other plastics (4%), and metal (3%). The remaining categories represented 3% or less of all litter items (Figure 12). Total plastic category (tobacco, fragments, food wrappers, other plastic and PPE) percentages equal 74% of the items, which is in the range (65% – 85%) often observed for the leakage component of the CAP. In addition, since COVD, PPE has been consistently observed at 1-2% of litter items.

Figure 12: Litter survey material characterization



The top 10 litter items (Figure 13) ranked include cigarettes at the top. Cigarettes are often misconstrued as 100% paper, but the filters are plastic (cellulose acetate). Hard plastic fragments were also prevalent. Fragments are larger items that have fragmented from weathering and the item they once were can no longer be determined. Without identification, the intervention for fragments is to prevent the plastic items they come from from getting into the environment. Glass fragments were also observed, suggesting that these materials are not being captured in current waste management and recycling systems. The other top 10 litter items consisted mainly of various SUP food packaging, ranging from wrappers and fragments to cups, lids, and bottle caps.

Figure 13: Litter survey top 10 litter items

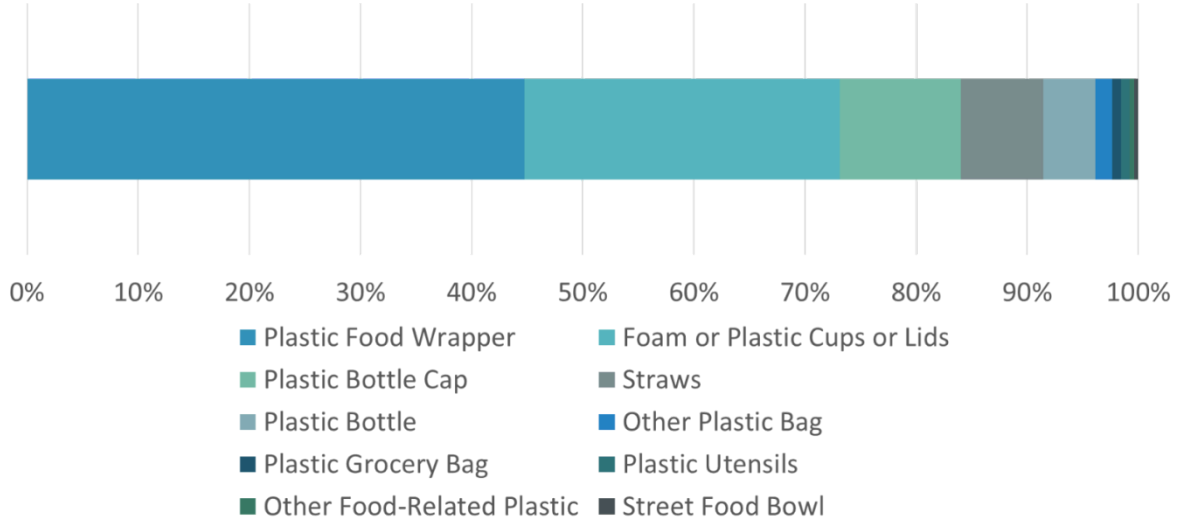


Sometimes plastic beverage bottles and aluminum cans are in the top 10 items found, but this is not the case in Ann Arbor; these items are being managed properly, likely through recycling since MI has one of the higher

deposit amounts at $0.10 per container. It also indicates this policy is effective since they are not observed in large quantities in the litter. Aluminum cans were ranked 11th (21 of them found) and plastic bottles were 15th (12 of them found).

When looking only at food-related plastics, the most common food plastics found in litter transects include plastic food wrappers, foam or plastic cups or lids, plastic bottle caps, straws, and plastic bottles. Common food packaging like candy and chip wrappers have low packaging-to-product ratios, which are generally less valuable for recycling compared to plastic bottles made of PET (especially when PET bottles have a deposit). Plastic food wrappers were the most common food plastic litter item; this packaging type tends to be most common for goods that originate outside of the community. While it is typically difficult to control the packaging of items that are being brought into Ann Arbor, the second most common food plastic litter item, foam or plastic cups or lids, likely originate in Ann Arbor. There may be an opportunity for Ann Arbor residents to begin considering alternatives to locally sold foam and plastic cups and lids, such as instituting a city-wide reuse system. It is also interesting that plastic bottle CAPs are more frequently found compared to bottles, this is also observed elsewhere indicating that caps can more easily be lost than the bottles and caps don't have an incentive to manage properly like the deposit for bottles. Recent policies in the UK require bottle caps to be attached to the bottles so they cannot be lost easily.

Figure 14: Litter survey food plastics Characterization



When looking at the leakage data for each ambient population category (high, medium and low), the litter characterization is relatively similar with a few differences. There is a higher percentage of paper items found in the low ambient population areas, and a higher percentage of fragments in the high ambient population areas (Figure 15). Cigarettes are the number one item in the mid- and low-ambient population areas, which fragments were highest in the high ambient population area. The litter density (number of items per square meter) is highest in these areas as well, which could be the result of the larger items fragmenting over time. The next highest litter density is the low ambient population area, although it is not too much higher than the mid-population area, which is the lowest litter density. The highest population area is where the most people are in their daily lives (over a 24-hr period), so the higher concentration makes sense, although there is not

always a correlation between numbers of people and litter since infrastructure is often more developed in areas of high people traffic and there also can be more establish maintenance activities.

Figure 15: Proportion of most common plastic items in low (inner), mid (middle), and high (outer) population count areas in Ann Arbor

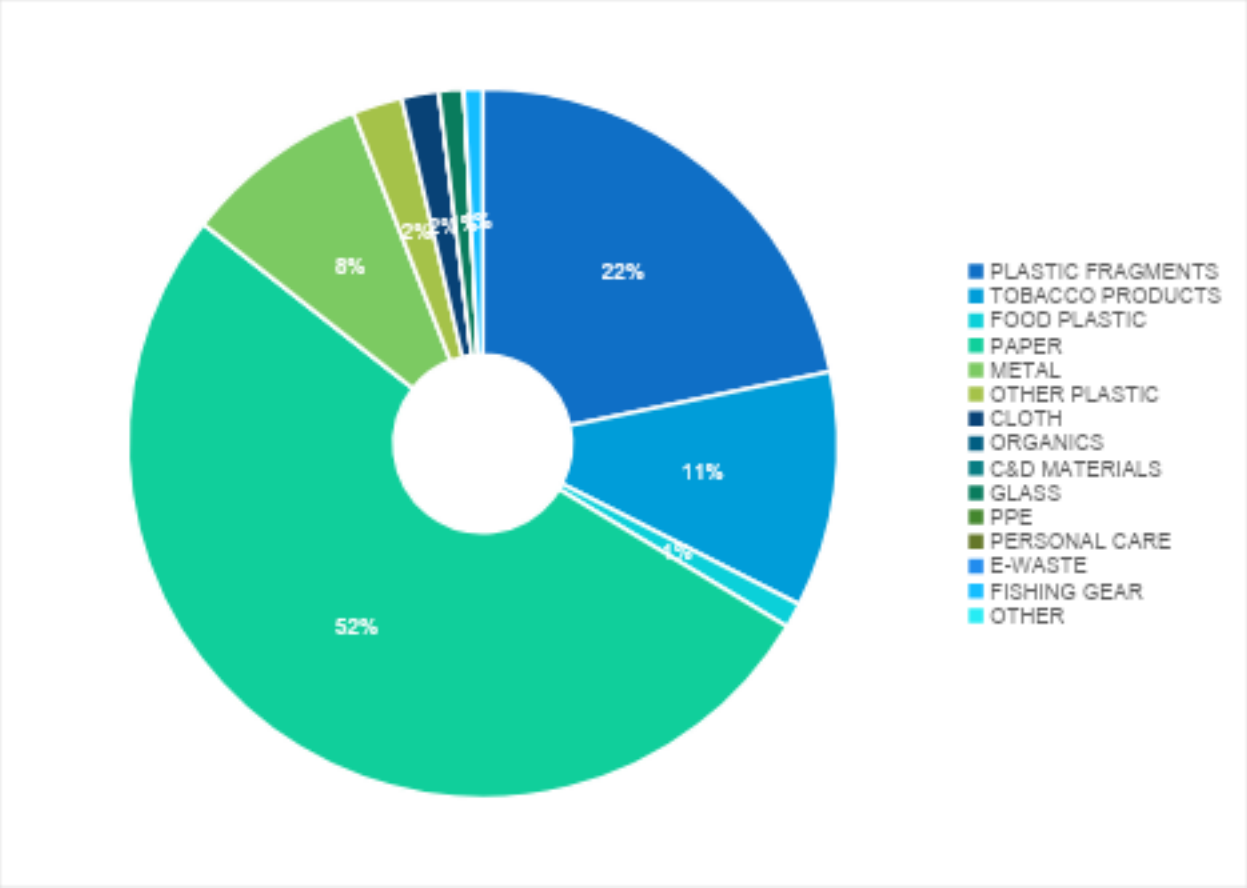


Table 10: Litter Density and Top Litter Items for Each Area of Societal Activity (Ambient Population)

Population Tertile	Top 5 Litter Items	Litter Density (count/m^2)
Upper	1) Glass or Ceramic Fragments, 2) Hard Plastic Fragments, 3) Cigarettes, 4) Food or Plastic Cups or Lids, 5) Paper	0.84
Middle	1) Cigarettes, 2) Paper, 3) Hard Plastic Fragments, 4) Plastic Food Wrappers, 5) Film Fragments	0.24
Lower	1) Cigarettes, 2) Hard Plastic Fragments, 3) Paper, 4) Film Fragments, 5) Foam Fragments	0.39

Opportunities

CIL found the following opportunities to expand and enhance circularity in Ann Arbor based on the findings of this report. These opportunities are categorized based on the seven spokes of the CAP model. Stakeholder engagement with the partners of this project should take place to further expand, refine and prioritize these opportunities based on local context, impact, feasibility, and cost. It is important to note that the opportunities listed below are individualized based on the findings, but solutions cannot happen in a vacuum and are most impactful when strategically combined within a holistic system framework.

Input

- The significant overlap in parent company and manufacturing locations for products in Ann Arbor represent an opportunity for EPR. After the successful passage of a packaging EPR bill in Minnesota, Michigan introduced a bill in August 2024 (Michigan House Bill 5902) that would charge fees based upon type and quantity of packaging used by companies to fund waste collection and management. It would also phase our some chemicals for elimination of use (e.g., PFAS).
- The close minimum location of beverages and candy indicates that there could be opportunity for the city of Ann Arbor to have conversations with nearby cities that house parent companies and manufacturers to articulate a clear vision of what multiple areas and communities in Michigan want for EPR policy.
- Michigan's Electronic Waste Take Back Program has been in effect since 2008, proving that EPR can be done at the state level. EPR proponents in Ann Arbor can use this existing program to understand its strengths and weaknesses and to articulate similar or more robust EPR schemes for plastics.
- There may be an opportunity for Ann Arbor residents to begin considering alternatives to locally sold foam and plastic cups and lids, such as instituting a city-wide reuse system.

Community

- Given that the local industrial composting facility recently stated they would no longer accept compostable plastic foodware, there is an opportunity to bolster existing interest in circularity within Ann Arbor by exploring city-wide initiatives such as a reusable foodware system, zero waste practices, and other initiatives that would continue to move away from single-use plastics.
- Concerns over what a city-wide reuse system would look like were shared by interviewees, proving that there is community interest. Further collaboration between Perpetual and community members could help address these concerns before a reuse system is implemented.

Product Design

- Candy and chips both had relatively low product and packaging mass, because of multilayer film's light weight; beverages had the highest product mass and packaging mass when compared to chips and candy.
- While compostable alternatives to cups, food containers, straws, and utensils could be found at restaurants, there could be an opportunity for more research and effort put into ensuring that compostable fiber containers offered do not contain PFAS or other toxic chemicals.

Use

- One store in Ann Arbor offered discounts to customers who brought in reusable bags or the store's branded bags. While the statewide "plastic ban ban" inhibits policies to limit use, there are options to allow for positive incentives (such as discounts) to customers who bring in their own bags, tax breaks for local businesses who offer alternatives, or certificate programs for "green" restaurants or skip the SUP campaigns.
- Existing bulk water refill stations are in Ann Arbor grocery stores, representing a potential opportunity to expand refill infrastructure through partnering with this industry and brands.

Collection

- The current popularity of the non-profit Recycle Ann Arbor (RAA) proves the general public's interest in having spaces dedicated to hard-to-recycle materials; further data collection on where people may want similar services, what their barriers to participation may be, etc. could be necessary to expand infrastructure in Ann Arbor.
- There may be an opportunity to look at how to expand recycling and composting access to apartment dwellers, through strengthening relationships between apartment owners and service providers.
- Comprehensive monitoring of the different collection models (e.g., repeated litter transects or waste bin overflow assessments) would be useful to help evaluate what may or may not be effective for maximizing collection. Local organizations could collaborate to maximize efficient data collection and monitoring capabilities; this would also provide an opportunity to examine collection gaps and disparities in access across the community.

End of Cycle

- With landfill tipping fees being cheaper than recycling tipping fees, this presents an economic challenge to incentivizing recycling (outside of the container deposit scheme). The City Council

has previously voted to increase statewide tipping fees, proving that there is existing interest and support related to this issue.
- Given the growing use of compostable and biodegradable items in various waste streams, there is a growing need to educate consumers about what these product designations mean, what product labels communicate, and how to appropriately manage different materials based on their disposal designations.

Leakage

- Collecting data and monitoring trends over time can provide insight into waste patterns, community needs, and effectiveness of waste management programs. With continued litter monitoring in selected locations, the city may be able to identify innovative ways to prevent and abate litter in the community.
- Cigarettes are the top litter item, which could be addressed through education campaigns, litter violation enforcement, and further implementation of cigarette collection receptacles in the city. There is currently no local recycling market for cigarettes in Ann Arbor.
- While it is typically difficult to control the packaging of items like food plastic wrappers that are being brought into Ann Arbor, the second most common food plastic litter item, foam or plastic cups or lids, likely originate in Ann Arbor. There may be an opportunity for Ann Arbor residents to begin considering alternatives to locally sold foam and plastic cups and lids, such as instituting a city-wide reuse system or applying for grants to build more robust refill infrastructure.
- The beverage container deposit-return system likely results in less bottles and cans in the litter. The deposit return scheme could potentially be expanded to other high leakage items.

Glossary

CAP: Circularity Assessment Protocol

CIL: Circularity Informatics Lab

EPR: Extended Producer Responsibility

EPS: Expanded polystyrene

FMCG: Fast moving consumer goods

HDPE: high density polyethylene

MSW: municipal solid waste

PET: polyethylene terephthalate

PP: polypropylene

RAA: Recycle Ann Arbor

SUP: single-use plastic

UGA: University of Georgia

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Appendix

Table A1:

Product Type	Number of Samples	Average Weight of Plastic Packaging (g)	Average Quantity of Product (g)	Ratio of Packaging to Product
Candy	133	3.3	61.9	.05
Chips	25	4.1	86	.05
Beverages	103	31.8	532.2	.06

Table A2: Full List of Debris Tracker Litter Items and Associated Material Categories

Material	Items
C&D Materials	Aggregate & Brick Bolts, Nails, and Screws Building Materials Lumber Other C&D
Cloth	Clothing Towels or rags Fabric Pieces Other Cloth
E-Waste	Batteries E-Waste Fragments Wire Other E-Waste
Fishing Gear	Buoys and Floats Fishing Line Other Fishing Gear Plastic Net or Net Pieces Plastic Rope
Glass	Glass Bottle Glass or Ceramic Fragments

	Other Glass
Metal	Aluminum Foil Aluminum or Tin Cans Foil to-go container Metal Bottle Caps or Tabs Metal Fragments Other Metal
Organic Waste	Food Waste Other Organic Waste
Other	Other Popsicle or lollipop Stick
Other Plastic Products	Bulk Bags Flip Flops or shoes Plastic String, Tape, or Packing Straps Rubber Bands Trash bag Tires Balloons Plastic toys or balls Car Parts Hard plastic jugs or containers Other Plastic
Food-Related Paper	Paper cups Paper food box or container Paper plates or bowls Compostable paper cups Paper food wrapper Compostable food box or container Napkins Other Food-Related paper

Paper	Office paper and newspaper Tags, tickets, and receipts Corrugated Cardboard Paper fragments Other Paper
Personal Care Products	Blister Pack or other pill packaging Cotton Buds Ear plugs Personal Care Product Sachet or packet Toothbrushes Toothpaste or Other Product Tube Flossers Feminine products Needles and syringes Other Personal Care Product
Food-related plastic	Foam cups Plastic cups Compostable plastic cups Cup Lids Plastic Bottle Aseptic cartons Mini alcohol bottles Plastic Bottle Cap Plastic Food Wrapper Condiment packet or container Plastic Grocery Bag Sandwich or snack bags Plastic Utensils Straws Foam to-go container or clamshell Plastic to-go container or clamshell Compostable plastic container or clamshell

	Other Food-Related Plastic
Plastic Fragments	Film Fragments Foam Fragments Hard Plastic Fragments Rubber/ tire fragments Other Fragments
PPE	Disinfectant Wipes Disposable Gloves Face Masks Other PPE
Tobacco Products	Cigarette Packaging Cigarettes Tobacco Sachets or packets E-cigarettes and vaping Plastic cigar/cigarillo tips Lighters Cannabis-related waste Other Tobacco Product

Figure AXX: Litter densities in transects and sites surveyed in [city name].

Include an interactive web map such as in the example below.

An interactive web map version of this map is available at:
https://usg.maps.arcgis.com/apps/mapviewer/index.html?webmap=92d84e3251fa40f2a5a04c041ec718a7